Revised Feasibility Study

STERICYCLE WASHOUGAL SITE

WASHOUGAL, WASHINGTON

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EXECUTIVE SUMMARY

Dalton, Olmsted, & Fuglevand, Inc. (DOF), has prepared this Revised Feasibility Study (FS) Report on behalf of Burlington Environmental, LLC, (referred to as Stericycle in this document)[1] for the Stericycle Washougal facility located at 632 South 32nd Street in Washougal, Washington (the Facility or Site). The purpose of a FS is to develop and evaluate cleanup action alternatives to enable a cleanup action to be selected for the Site [WAC 173-340-350(8)(a)]. To develop cleanup action alternatives, preliminary cleanup levels, generally established in the Remedial Investigation (RI) were reviewed and updated. Data collected since the RI were reviewed to update the current areas and media requiring cleanup. Screening of remedial technologies was performed to identify a subset of technologies to potentially be used in remedial alternative development to protect human health and the environment.

Hydrogeology at the Site is characterized by a Shallow Groundwater Zone and Lower Aquifer, separated by a Silt Layer that acts as a somewhat leaky aquitard between these two groundwater-bearing zones. High organic carbon content in the Silt Layer also adsorbs and retards the migration of organic materials, including many of the constituents of concern (COCs) at the Site. The vadose zone exists entirely within a sandy unit present above the Silt Layer, with a depth to groundwater varying from 1 to 4 feet below ground surface (bgs) during the wet season. The Silt Layer and the sand/gravel unit below are fully saturated and below the water table year-round.

The former tank farm area had known releases of chlorinated solvents to the subsurface. Previous interim measures removed significant contamination from this primary contaminant source area, provided information for future designs, and addressed immediate threats to indoor air quality at the Site. However remaining contamination has contributed to groundwater impacts in and beyond the former tank farm area. Full contaminant removal was not performed during the interim measures in order to maintain the Silt Layer separation layer from the Lower Aquifer, and due to overlying adjacent buildings. Additional areas of contamination were identified in the RI in the vicinity of former container storage areas at Building 2 and Building 3, an area west of the waste oil tank system, the area in the immediate vicinity of monitoring well MC-14, and downgradient at well MC-15D.

Overall groundwater quality has improved since the primary interim measure, indicating natural degradation of chlorinated ethenes. Biodegradation appears to be a very important process affecting the fate and transport of chlorinated organic compounds in groundwater at the Site. Levels of dissolved oxygen in groundwater at the Site are likely suppressed by the biological oxygen demand resulting from the naturally occurring organic matter in aquifer materials associated with the current and former wetland environment. Patterns observed in both contaminant and geochemical data for groundwater at the Site indicate that microbial degradation of contaminants is likely occurring.

Current concentrations of COCs in groundwater at the Site are typically in the low parts per billion (ppb) range. Recent data indicate that the residual contamination in the Silt Layer at the Site has

[1] Burlington Environmental, LLC, is a wholly owned subsidiary of PSC Environmental Services, LLC (PSC), which is wholly owned subsidiary of Stericycle Environmental Solutions, Inc., which is now part of Clean Earth, owned by Harsco.

allowed for dispersion of the COCs into the deeper areas of the Silt Layer and into the shallow portion of the Lower Aquifer and this is the primary remaining COC source warranting treatment.

Multiple technologies were reviewed for applicability to Site conditions and narrowed to 7 separate technological combinations forming remedial alternatives established for the Site. They included consideration of:

- Monitored natural attenuation (MNA),
- In-Situ bioremediation (ISB) via carbohydrate and/or emulsified Zero Valent Iron (ZVI) injection,
- In-Situ remediation via chemical oxidation (ISCO),
- Deep soil mixing,
- Electrical resistive heating,
- Permeable reactive barriers,
- Hydraulic control,
- Long-term maintenance of soil covers,
- Compliance and long-term confirmational monitoring (LTM),
- Inhalation pathway interim measure (IPIM) operation already implemented at the Site, and
- Grouting of a utility bed that may be acting as a potential contaminant migration pathway.

Seven alternatives were developed:

- Alternative A-1- Capping and MNA;
- Alternative A-2- Capping, ISB, ISCO, and Monitored Attenuation (MA);
- Alternative A-3- Capping, Deep Soil Mixing, ISCO, ISB and MA;
- Alternative A-4- Capping, Electrical Resistive Heating, ISB and MA;
- Alternative A-5- Capping, Permeable Reactive Barrier with ZVI, ISCO, and MA;
- Alternative A-6- Capping, ISB, ISCO, Hydraulic Control, and MA; and
- Alternative A-7- Capping, Full Scale ISCO, ISB, and MA.

The alternatives were evaluated relative to the following criteria specified under the Washington Model Toxics Control Act (MTCA): protectiveness, permanence, cost, long-term effectiveness, management of short-term risks, technical and administrative implementability, public concern, and restoration time frame. The alternatives were scored for each criterion on a scale of 1 to 10, where 1 is the worst possible score and 10 is the best possible score. Total scores were used to evaluate the relative benefit of each alternative. The benefits were then compared to the costs for each alternative using a disproportionate cost analysis (DCA).

All of the alternatives developed in this FS are anticipated to be permanent, with Alternative A-4 being the most permanent. However, Alternative A-4 has the highest cost and scored second lowest for technical and administrative implementability, which combine to give it the highest Cost per Benefit of any of the alternatives. As a result, Alternative A-4 is one of the least practicable alternatives. Therefore, Alternative A-2 has been designated the "baseline alternative" because it has the highest Cost to Benefit ratio and is therefore the most practicable permanent solution.

Alternative A-2 includes the following elements:

- Grouting the utility trench under the stormwater piping to the east of the Stericycle property;
- Continued operation of the existing IPIM under Building 1;
- Augmenting the existing surface cover by paving select areas of the Site;
- Long-term monitoring and maintenance of the pavement cover;
- ISCO treatment near well MC-14 to treat 1,4-dioxane and volatile organic compounds (VOCs) in the Shallow Groundwater Zone;
- ISB treatment in the former tank farm area and near the north fence line (near MC-118D) - targeting chlorinated VOCs remaining in the Silt Layer and the upper portion of the Lower Aquifer;
- ISB treatment in the Lower Aquifer upgradient of and near MC-15D to reduce risk of off-site migration of chlorinated VOCs in the upper portion of the Lower Aquifer;
- MA of the groundwater downgradient of the remediation areas;
- Groundwater monitoring to evaluate ISB/ISCO effectiveness for the duration of the restoration time frame (15 years based on vendor experience and the extrapolation of groundwater monitoring data trends once source area remediation is complete). Once groundwater monitoring indicates ISB/ISCO and MA has permanently destroyed COCs to below cleanup levels, remediation would be considered complete; and
- Institutional controls.

All of the alternatives under consideration are expected to significantly reduce risks and be protective of human health and the environment. Overall, all of the active alternatives, including baseline Alternative A-2, scored well, while Alternative A-1 (MNA) scored poorly.

All of the alternatives incorporate MA, resulting in the permanent removal of COCs. All of the alternatives would result in reduction in total mass of COCs. Overall, most of the active alternatives scored well, while Alternative A-1 (MNA) scored poorly. Alternatives A-3 (DSM) and A-4 (ERH) scored highest since they were the most aggressive technologies in addressing all of the COCs.

Net Present Value (NPV) cost estimates were prepared for all alternatives to allow alternatives to be compared on an equal basis. Some implementation costs would occur in the future, after initial remediation or planning tasks are completed. The NPV costs are based on the implementation and operation period for each of the alternatives. Once treatment area remediation is complete, natural degradation rates were assumed to be on the same approximate time scale as observed at existing wells that have declining COC trends. For the FS, that means for technologies that are predicted to destroy almost all COCs during implementation, the timeline is much shorter than alternatives expected to take several years to destroy COCs. The baseline Alternative A-2 (ISB) and Alternative A-5 (PRB) are ranked 1 and 2 for Cost per Benefit and are almost 50% more cost effective than the 3rd ranked Alternative A-7 (ISCO). The lowest Cost per Benefit ranking is for Alternative A-4 (ERH) which has more than double the Cost per Benefit than the highest ranked alternatives.

Most of the active alternatives scored well for long-term effectiveness of alternatives, while Alternative A-1 (MNA) scored poorly. Alternatives A-3 (DSM) and A-4 (ERH) scored highest since they were the most aggressive technologies with the least amount of uncertainty in effectiveness for treating all of the COCs.

The highest scoring alternative for short-term risk to human health and the environment during implementation of an alternative was the only completely passive alternative, Alternative A-1 (MNA) and Alternative A-4 (ERH) was the lowest scoring alternative since it was the most aggressive alternative with multiple waste streams and the highest number of hazards during implementation. The baseline alternative A-2 (ISB) and alternative A-5 (PRB) scored well due to being mostly in-situ (fewer wastes) with relatively low risk chemical use for the bulk of the treatment.

Alternative A-1 (MNA) was rated highest for technical and administrative implementability of all the alternatives because it would rely on installing a paved cover, simple minor construction (grouting), groundwater monitoring, and the existing IPIM. The baseline Alternative A-2 (ISB) is rated the highest for active remedies, since it would be relatively manageable to implement around ongoing operations at the Facility and provides more certainty with a longer lasting treatment technology. Alternative A-3 (DSM) and Alternative A-4 (ERH) scored poorly due to the difficulties in implementing in an actively operating Facility and ERH treatment would include air and condensate discharges to manage.

General public concerns could be raised based on restoration time frames or active construction nuisance. The period of active implementation of the various alternatives could range from as little as a few months for MNA to as much as 2 or 3 years for the injection technologies. Alternative A-1 (MNA) received the lowest rating for this criterion, because it would likely have the longest restoration time frame although there is limited risk to receptors given the relatively low concentrations of COCs and mostly shrinking groundwater plumes. The baseline Alternative A-2 (ISB) received the highest rating with very little waste disposal or off-site impacts and immediate reductions of COCs at implementation. The other alternatives scored lower primarily because they would create noticeable and prolonged nuisances such as noise, traffic, and air emissions.

Based on the current trends in groundwater concentrations, Alternatives, A-3, A-4, A-5, and A-7 would meet the preliminary cleanup levels within 10 years with Alternatives A-2 and A-6 predicted to take 15 years. This 5 year difference would result in a slightly higher risk to terrestrial or human receptors onsite that could be controlled via institutional controls, but is unlikely to change risk for off-site receptors, as each of the active groundwater remedies employed will intercept the downgradient plume during the first year of implementation. The alternatives also have different time frames for active remediation, with the more aggressive technologies completing active remediation in the faster. The longer time frames for active remediation generally trigger an overall longer restoration time frame, but they also provide for a longer period of treatment for COCs desorbing from the lower permeability units onsite. Thus, while Alternative A-2 and A-6 have a 50% longer remedial time frame, the risk to off-site receptors is reduced in a similar time frame to the other alternatives, while Alternatives A-2 and A-6 provide additional time to treat desorbing COCs from the low permeability units.

Downgradient monitoring already indicates that ongoing biodegradation and attenuation are showing decreasing concentrations in shallow groundwater monitoring wells. Groundwater monitoring well trends in the Lower Aquifer are increasing in some areas onsite, but current trends (without treatment) indicate that Lower Aquifer COCs are unlikely to reach receptors before degrading to below preliminary cleanup levels off-site: i.e. before reaching the river or shallow groundwater. Given the relatively low concentrations of COCs onsite, the ongoing industrial use of the facility, and the institutional controls (ICs) employed, the difference of 5 years in reasonable restoration time frame is considered marginal.

The preferred remedial alternative for the Site is Alternative A-2. The Preferred Alternative is expected to fully attain remediation objectives, provides a permanent solution to the maximum extent practicable, with a reasonable restoration time frame, and considers public concerns. Results of a sensitivity analysis performed as part of this FS further support this selection. Specifically, the preferred alternative would:

- Prevent direct contact with soils and inhalation of dust within the Site and be protective of industrial workers;
- Address both chlorinated VOCs and 1,4-dioxane and thereby reduce the restoration time frame to approximately 15 years to meet cleanup levels at the point of compliance;
- Reduce current risks due to inhalation of vapors prior to when cleanup levels are attained by incorporating ICs;
- Require vapor intrusion provisions until soil and groundwater are remediated to eliminate this pathway;
- Protect potential off-site human and ecological receptors in the Steigerwald Marsh by destroying groundwater COCs and limiting the further release of COCs by removal/treatment of Site soils; and
- Support current and future industrial use of the Stericycle property.

In addition, the Preferred Alternative would provide:

- A reliable remediation approach using proven, robust technologies with low long-term maintenance requirements; and
- An approach that would create moderate short-term risks and have minimal potential for causing public concern about exposure to Site constituents during construction.

This alternative would introduce a microbial culture capable of breaking down chlorinated COCs and migrating within the subsurface, providing continuous treatment of residual COCs as concentrations decline towards remedial objectives. Under this alternative the majority of groundwater remediation required is achieved within 1 year and the remainder is expected within 3 to 5 years, without the use of chemicals hazardous to human health, i.e. strong oxidizers. Institutional controls protect for other possible exposure routes during the restoration time frame.

The preferred alternative (A-2) would fully comply with MTCA, the Dangerous Waste Regulations (WAC 173-303), and the RCRA regulations. The preferred alternative would comply with the requirements of the Permit and achieve the environmental indicator standards for controlling potential exposure to both soil and groundwater for affected media located at and near the Site.

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ACRONYMS & ABBREVIATIONS

µg/L	micrograms per liter
AMEC	AMEC Geomatrix, Inc.
APPL	Agriculture & Priority Pollutants Laboratories, Inc.
ARAR	applicable, relevant and appropriate requirements
bgs	below the ground surface
BTEX	benzene, toluene, ethylbenzene, and xylenes
ºC	degrees Celsius
CAP	cleanup action plan
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CLARC	Ecology's Cleanup Levels and Risk Calculation
COCs	constituents of concern
CPOC	conditional point of compliance
CSM	conceptual site model
CUL	preliminary cleanup level
CY	Cubic Yard
DCE	dichloroethene
1,2-DCE	*cis*- and trans-1,2-dichloroethene
cis-1,2-DCE	*cis*-1,2-dichloroethene
DNAPL	dense nonaqueous phase liquids
DSM	deep soil mixing
DUS	dynamic underground stripping
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
ERH	electrical resistive heating
EZVI	emulsified zero-valent iron
ºF	degrees Fahrenheit
Facility	area of operations of the Stericycle RCRA facility located at 632 South 32nd Street in Washougal, Washington
FS	Feasibility Study
GAC	granular activated carbon
GCRC	Gibbons Creek remnant channel
Geomatrix	Geomatrix Consultants, Inc.
gpm	gallons per minute
HRC	hydrogen-releasing compound
HVAC	heating, ventilation, and air conditioning
ICs	institutional controls
IPIM	inhalation pathway interim measure
ISB	in-situ bioremediation
ISCO	in situ chemical oxidation
iSOC™	in situ oxygen curtain
LNAPL	Light nonaqueous-phase liquid
MA	monitored attenuation
MCL	maximum contaminant level

MDL	method detection limit
MTCA	model Toxics control Act
NAPL	Nonaqueous phase liquid
NPDES	National Pollutant Discharge Elimination System
NPV	net present value
NRWQC	National Recommended Water Quality Criteria
NTR	National Toxics Rule
O&M	operation and maintenance
O.C.	on-center
ORC	oxygen release compound
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PCE	tetrachloroethene
Permit	Resource Conservation and Recovery Act Part B Permit No. WADO92300250
POC	point of compliance
POTW	publicly owned treatment works
ppb	parts per billion
PQL	practical quantitation limit
PRB	permeable reactive barrier
PSC	PSC Environmental Services, LLC
RCRA	Resource Conservation and Recovery Act
redox	Reduction/oxidation
RFI	RCRA Facility Investigation
RI	Remedial Investigation
RI/FS	Remedial Investigation and Feasibility Study
RSL	Regional Screening Level
SEAR	solvent-enhanced aquifer remediation
SEE	Sweet-Edwards/EMCON
SITE	Area affected by releases from historic operations of the RCRA dangerous waste Facility operations
SLNWR	Steigerwald Lake National Wildlife Refuge
SPOC	standard point of compliance
SVE	soil vapor extraction
SVOC	semivolatile organic compounds
TCE	trichloroethene
TPH	total petroleum hydrocarbon
VC	vinyl chloride
VOC	volatile organic compound
WAC	Washington Administrative Code
WDOH	Washington State Department of Health
ZVI	zero-valent iron

Final Feasibility Study

Stericycle Washougal Site

Washougal Washington

August 25, 2020

This report was prepared by the staff of Dalton, Olmsted, & Fuglevand, Inc., under the supervision of the engineer whose seal and signature appears hereon.

The findings, recommendations, specifications, or professional opinions have been prepared in are presented within the limits described by the client, in accordance with generally accepted professional engineering and geologic practices in Western Washington for the client at the time the services were provided. No warranty is expressed or implied.

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Patrick Hsieh, P.E.
Senior Engineer

1.0 INTRODUCTION

Dalton, Olmsted, and Fuglevand (DOF) prepared this Feasibility Study (FS) Report on behalf of Burlington Environmental, LLC, a wholly owned subsidiary of PSC Environmental Services, LLC, which is a wholly owned subsidiary of Stericycle Environmental Solutions, Inc. Stericycle Environmental Solutions, Inc. was purchased by CleanEarth, Harsco company, in 2020. The name Stericycle is used in this FS to refer to these companies. This FS was prepared pursuant to requirements of the Resource Conservation and Recovery Act (RCRA) and the Model Toxics Control Act (MTCA) for the Stericycle Washougal Site located at 632 South 32nd Street in Washougal, Washington (Figure 1-1). The Facility operates under RCRA Part B Permit No. WADO92300250 (the Permit).

Stericycle conducted a RCRA facility investigation (RFI) at the Site in 1991 (SEE, 1991) and completed various investigations and interim measures at the Site since then under the RCRA permit. In 2010, Stericycle completed a draft Remedial Investigation/Feasibility Study (RI/FS) Report (AMEC Geomatrix, 2010), which was submitted to the Washington State Department of Ecology (Ecology). Based on comments from Ecology received in May 2011 (Ecology, 2011), Stericycle split the RI/FS into separate RI and FS reports. Separate revised RI and FS reports, addressing Ecology's 2011 comments, were submitted in 2013. Ecology issued additional comments on the 2013 RI and FS Reports in May 2019. Since receipt of the comments, Ecology and Stericycle met multiple times and worked through comments to produce this FS that addresses remaining comments on the 2013 RI, as well as the 2013 FS. The interim 2019 and 2020 submittals that are incorporated in this FS are summarized below:

- **RI/FS Comments –** In May 2019 Ecology provided comment letters from Ridolfi Environmental regarding the 2011 RI and 2013 FS reports. The RI letter recommended that the RI comments could be addressed during revision of the FS.
- **Point of Compliance and Preliminary Cleanup Level Assessment –** In August 2019 Stericycle submitted a Technical Memorandum: Feasibility Study – Point of Compliance and Preliminary Cleanup Level Assessment to Ecology to address comments on these topics. Ecology provided comments in September 2019. The Technical Memorandum was revised to address these comments in November 2019 (Appendix A).
- **Nature and Extent of Contamination –** In September 2019 Stericycle submitted a Technical Memorandum: Feasibility Study – Nature and Extent of Contamination Update to Ecology (Appendix B) to provide an updated current Site conceptual model of contamination at the Site and address comments on this topic. Ecology provided comments in October 2019 and Stericycle and Ecology met and discussed these comments over the next few months. Additional information was developed regarding the nature and extent of contamination to include in subsequent Technical Memorandum and this FS.
- **Technology Screening –** In October 2019 Stericycle submitted a Technical Memorandum: Feasibility Study – Technology Screening, to Ecology to address comments on this topic and screen additional technologies not considered in the 2013 FS. Ecology provided comments

later in October and the memorandum was revised in November 2019 (Appendix C). Ecology provided additional comments in December 2019 that were incorporated in development of revised remedial alternatives and this FS.

- **Remedial Alternatives –** In January 2020 Stericycle submitted a Technical Memorandum: Feasibility Study – Remedial Alternatives to Ecology to provide revised remedial alternatives for consideration in the FS (Appendix D). Ecology provided comments in late January and met with Stericycle in February to further refine the alternatives for inclusion in this FS. Additional comments to be addressed in this FS were provided by Ecology in March 2020.

1.1 Purpose of this Report

This FS Report has been prepared to update the 2013 FS and achieve the following objectives:

- Identify potential remedial alternatives appropriate to address the risks to human health and/or the environment posed at the Site, as identified in RI Report;
- Evaluate potential remediation alternatives; and
- Recommend a preferred remedial alternative for the Site.

1.2 Organization and Scope

Information is provided in the following sections of this FS report:

- Section 2 – Site Setting
- Section 3 – Cleanup Standards
- Section 4 – Remediation Considerations and Objectives
- Section 5 – Potentially Applicable Remedial Technologies
- Section 6 – Remedial Alternative Evaluation Criteria
- Section 7 – Development and Evaluation of Remedial Alternatives
- Section 8 – References

1.3 Terminology

The RCRA Facility's dangerous waste permit, issued by Ecology in 1992 under the Washington Dangerous Waste Regulations (Chapter 173-303 of the Washington Administrative Code [WAC]), requires Stericycle to perform corrective action (cleanup) within and beyond the property boundaries of the permitted RCRA Facility to address releases of hazardous substances. Chapter 173-303 WAC requires that cleanup actions be implemented consistent with the Washington State MTCA regulations (Chapter 173-340 WAC). MTCA requires Stericycle to perform cleanup actions to address releases "where a hazardous substance has been deposited, stored, disposed of, placed, or otherwise come to be located." Under Washington State MTCA regulations, this area of contamination is referred to as the "Site".

In this FS Report, the term *Site* will be used to refer to the area affected by releases from operations of the RCRA dangerous waste Facility operations, which includes both the Stericycle former RCRA operational Facility and other areas that have been affected by releases that occurred at, or through, RCRA operations.

2.0 SITE SETTING

This section summarizes information provided in and updated from the 2013 RI report about the setting of the Site, including Facility layout, geology and hydrogeology, constituents of concern (COCs), previous interim remedial measures, the nature and extent of contamination, and the conceptual site model (CSM) of potential exposure pathways. A more detailed description of the Site setting and background is provided in the RI Report (AMEC, 2013).

2.1 Location and Layout

The Stericycle property is located at 632 South 32nd Street, Washougal, Clark County, Washington, near the Columbia River (Figure 1-1). The 5.2-acre property is situated within a diked portion of the Columbia River floodplain in the Camas/Washougal Industrial Park. Prior to development of the industrial park, the area was part of low marshlands in the Columbia River floodplain.

The Stericycle property currently operates as a hazardous waste transfer facility. Figure 2-1 shows the current layout of the Stericycle operations. A small portion of the south end of the property is leased to a neighboring property owner, TrueGuard, LLC, for vehicle parking. Approximately 40% of the Stericycle property is an unpaved open gravel area and is not used for Facility operations (Figure 2-1). The property currently houses five existing buildings, one of which is a temporary office trailer (not slab on grade) constructed in 2006. Land use in the vicinity of the Site is industrial, with the exception of the Steigerwald Marsh, which is part of the Steigerwald Lake National Wildlife Refuge (SLNWR) to the east (downgradient) of the Stericycle property. Neighboring property owners are shown on Figure 2-2.

The property has been used for industrial operations since at least 1978. Operations have included activities related to the paper industry, as well as waste oil and solvent recovery, drum storage, and oil storage and blending. Figure 2-1 shows the historical layout of the Facility. A detailed operational history of the property was presented in the RI.

2.2 Land Use

The Stericycle property is zoned for industrial land use and is expected to continue to be used for either industrial or commercial use in the foreseeable future; however, the Stericycle property is bordered to the east by SLNWR. Land use in the vicinity of the Stericycle property is also industrial, with the exception of Steigerwald Marsh to the east.

2.3 Physiography, Geology, and Hydrogeology

The Site is located within a diked portion of the Columbia River floodplain at an elevation of approximately 20 feet above mean sea level. The immediate area has little topographic relief but slopes gently downward toward the Steigerwald Marsh complex. The immediate area was constructed by the U.S. Army Corps of Engineers by building up dredge sands on top of native marshy silts in the floodplain surrounding Steigerwald Marsh to elevate the land for development. Surface water bodies nearest the Site are the Steigerwald Marsh complex to the east and the Gibbons Creek remnant channel to the north (Figure 1-1). The Columbia River flows generally east to west approximately 0.4 mile south-southwest of the Site.

2.3.1 Geology

The near-surface geology at the Site is characterized by the following four lithologic units listed in order of increasing depth:

- Sand Fill – The uppermost stratum consists of poorly graded, fine- to coarse-grained sands, with occasional fine gravel that were dredged from the Columbia River and emplaced hydraulically over Columbia River floodplain silts. The Sand Fill extends vertically from the ground surface to as much as 12 feet below ground surface (bgs) and is present across the entire area of the Stericycle property.
- Silt Layer – The Silt Layer consists of native floodplain and marsh deposits that were present at the location of the Stericycle property and the rest of the Industrial Park prior to site development, which entailed the emplacement of hydraulic dredge fill (the Sand Fill). The Silt Layer consists of dark greenish-grey to black, well-sorted silt and clay, with some sand. The upper surface of the Silt Layer ranges from approximately 3.5 to 12.0 feet bgs and the Silt Layer appears to be continuous in the industrial park. The thickness of the Silt Layer at the Site ranges from approximately 5 feet to 20 feet.
- Gravel – Poorly graded, fine to coarse gravel intermixed with silt and sand (silt decreasing with depth) underlie the Silt Layer. Large gravel and boulders are present within this unit. The upper surface of the Gravel Unit lies at depths of between approximately 14 and 22 feet bgs, and the thickness of this layer has been ranged from 0.5 foot to 24 feet.
- Deeper Silty Sand: Moderately sorted, fine to coarse sand and silt underlie the gravel deposits. The top of the Deeper Silty Sand unit was encountered at depths of between 24 and 36 feet bgs.

A representative cross section of geologic units is presented on Figure 2-3.

2.3.2 Hydrogeology

Three primary hydrogeologic units have been delineated beneath the Site based on analysis of the geologic and hydrogeologic data collected during previous investigations:

- Sand Fill Shallow Groundwater Zone: This unit includes portions of both the Sand Fill and the underlying Silt Layer. Depth to water ranges from approximately 4 to 6 feet bgs in the dry season to approximately 1 to 4 feet bgs in the wet season. Groundwater within the Shallow Groundwater Zone consistently flows to the east toward Steigerwald Marsh.
- Silt Layer or Upper Confining Unit (Silt Aquitard): The low-permeability Silt Layer underlies the Shallow Groundwater Zone and acts as a confining unit for the Shallow Groundwater Zone above. This layer directly overlies and hydraulically confines the Lower Aquifer. The Upper Confining Unit is laterally continuous, but the thickness of the unit varies across the Site.

- Lower Aquifer: The Lower Aquifer corresponds to the Gravel and Deeper Silty Sand geologic units. Groundwater elevations in the Lower Aquifer are influenced by changes in the tidally influenced surface water stage in the Columbia River, and as a result the flow direction varies greatly and can be to the north/northeast or south/southeast.

The vadose zone exists entirely within the upper Sand Fill Unit. The depth of the vadose zone in the Sand Fill unit varies from 4 to 6 feet bgs during the dry season and from 1 to 4 feet bgs during the wet season. The Silt Layer and the sand/gravel unit are fully saturated and below the water table year-round.

A representative groundwater elevation map for the Shallow Groundwater Zone is presented on Figure 2-4. The Hydrogeologic Conceptual Model for the Site places the uppermost groundwater at the Site primarily within the Sand Fill. Shallow Groundwater consistently flows to the east toward Steigerwald Marsh, with downward and upward vertical flow components that vary both spatially and temporally. Near Steigerwald Marsh, the Sand Fill becomes thinner, and the phreatic water table is located within the Silt Layer. This observation suggests that the shallow groundwater within the Sand Fill drains into the Silt Layer at the eastern boundary of the Stericycle property and ultimately discharges into the Marsh. Observed horizontal flow gradients suggest that groundwater in the Lower Aquifer generally flows toward the south and east (Figure 2-5), ultimately discharging to the Columbia River. However, flow direction in the Lower Aquifer can vary significantly based on hydraulic control measures for surface waters in the area, specifically the water elevation in the nearby Columbia River, which varies in response to both seasonal variability in runoff, dam releases, and diurnal tidal cycles. Figure 2-5 and Figure 2-6 reflect typical variation in flow direction observed.

In general, vertical hydraulic gradients show seasonal variability. Since the water table within the shallow Sand Fill is recharged during the wet winter months, groundwater vertical gradients are primarily downward for most of the Site during the winter and early spring. During the drier months, when the water table in the Sand Fill drops, recharge decreases and the downward vertical gradients tend to weaken or reverse to upward in portions of the Site and/or in especially dry years. The storm sewer utility line located along the west side of South 32nd Street is recognized as a possible preferential groundwater flow pathway that could result in northward contaminant transport.

The observed vertical hydraulic gradients at the Site suggest the Silt Layer acts as a somewhat leaky aquitard. The high organic carbon content in the Silt Layer also adsorbs and retards the migration of organic materials, including many of the COCs at the Site. Decomposition of organic matter in the fill and the Silt Layer produce reducing conditions within the Shallow Groundwater Zone during the drier months.

2.4 Constituents of Concern

COCs for the Site were identified in the RI and are presented in Table 2-1 for soil and Table 2-2 for groundwater. As described in the RI, the extensive list of COCs established for the Site resulted from a conservative screening process.

2.4.1 Historical Site Characterization

The Site has been investigated extensively since 1985, but many of the older data may not be representative of current conditions or meet the data quality objectives (DQOs) for the project. Thus, the process to identify COCs in the RI involved two main steps:

- Assess existing data to identify those analytical data that met project-specific DQOs; and
- Evaluating the relevant and appropriate data in relation to potential CULs.

The data set selected for use in the RI included soil data collected since 1996 and groundwater data collected since 2000. These data were selected based on the data's age, distribution, quality, and appropriateness for meeting the project DQOs. An upper confidence limit was calculated for each constituent tested at the Site and compared to preliminary CULs. Non-detects with elevated reporting limits were carried through as COSs as well. In practical terms, if a constituent was ever detected at a concentration greater than the screening level, it was included as a COC and due to elevated reporting limits, many constituents that were largely undetected were identified as COCs in the RI (Amec, 2013).

Figures 11-2 and 11-3 in the RI (provided in this FS as Appendix G) showed the soil analytical results for detected concentrations that exceeded preliminary CULs for volatile organic compounds (VOCs) and inorganic constituents, the two most frequently detected COC analyte groups. Other analyte groups, including total petroleum hydrocarbons (TPH), pesticides, and Semi-VOCs (SVOCs), were occasionally detected in soil at concentrations above the respective preliminary CUL (RI Figure 11-4). However, as is evident in Figure 11-4, these occasional detections above the CUL occurred in samples collected in areas where VOCs and metals were also found at elevated concentrations. Because VOCs and metals were more widespread around the property and tended to occur in the same locations where elevated levels of other COC groups were found, these groups were designated as indicators of areas of contamination for a broad range of constituents at the facility and to highlight the spatial distribution of COCs (AMEC, 2013).

The RI noted that concentrations of COCs in soil must be evaluated in light of the shallow depth to groundwater and considered in combination with the comprehensive analytical data available for groundwater. In addition, for the purposes of developing remedial alternatives, it is notable that the soil concentrations present at the Site are below the direct contact/ingestion MTCA Method C CULs and only exceeded CULs for inhalation or groundwater protection (including surface water protection). RI Table 11-1 summarized this comparison and is included in Appendix G). As a result, these exceedances represent a much lower real risk than the elevated concentrations present prior to the 1997 interim measure described below in Section 2.5, and remediation should consider this fact.

The RI summarized that in groundwater the Lower Aquifer is most heavily affected in the area of the former tank farm, and this is likely the result of residual contamination in the Silt Layer migrating downward. The Shallow Groundwater Zone still showed some impact, but the magnitude is much lower. The higher concentrations observed in the Shallow Groundwater Zone were farther east of the former tank farm and likely more affected by the residual shallow soil contamination present underneath Building 1, leaching COCs that migrate east in the Shallow Groundwater Zone (AMEC, 2013).

The review of Site data in the RI showed that the primary COCs detected above CULs was a subset of the extensive COC list. In soil, primary soil COCs included trichloroethene (TCE) and tetrachloroethene (PCE), and their breakdown component, vinyl chloride (VC); limited areas of benzene, toluene, ethylbenzene, and xylenes (BTEX); and inorganics including cyanide, arsenic, copper, silver, zinc, and barium. There are very few areas of soil concentrations exceeding preliminary CULs for TPH, pesticides, or SVOCs, and no instances of polychlorinated biphenyls (PCBs) being detected above preliminary CULs. In groundwater, the primary COCs are similar to soil with the same VOCs consistently present, along with 1,4-dioxane, arsenic, and a few other inorganic COCs. The review of nature and extent of COCs in the RI confirmed that the extensive lists of COCs established in the RI resulted from a conservative screening process for the Site.

2.4.2 Recent Site Characterization Data

Review of the RI data and more recent data, and revised preliminary CULs, reveal that in soil, the primary COCs remain:

- TCE and PCE, and their breakdown component VC;
- Limited areas of BTEX; and
- Inorganics, including, cyanide, arsenic, copper, silver, zinc, and barium.

Among COC analyte groups listed in Table 2-1, VOCs and inorganic constituents are detected in soil most frequently at concentrations above preliminary CULs. Other analyte groups, including petroleum hydrocarbon fractions, pesticides, inorganics, and SVOCs, have also occasionally been detected in soil at concentrations above the respective preliminary CUL.

In groundwater, the primary COCs are similar to soil with the same VOCs consistently present, along with 1,4-dioxane, arsenic, and a few other inorganic COCs. Chlorinated ethenes are the primary VOCs detected above preliminary CULs in groundwater and are considered indicators of contamination at the Site, as discussed in Section 2.6.

As discussed in the RI, cyanide has been detected in soil at concentrations below CULs developed for all pathways except groundwater protection, which drives the CUL. To assess potential impacts of cyanide to groundwater, cyanide was included in the list of analytes at wells MC-15, MC-16, and MC-17 as part of quarterly groundwater monitoring during the fourth quarter 2013 and first quarter 2014. The results of the investigation indicated cyanide was not present in groundwater, as cyanide was not detected in any of the samples. Additional discussion related to cyanide, including tabulation of cyanide results was presented in the September 24, 2019 technical memorandum: Feasibility Study – Nature and Extent of Contamination Update (Appendix B) prepared during the revision process of this document. Cyanide was therefore not carried forward for consideration in this FS.

2.5 Previous Interim Measures

Previous interim measures have removed much of the contamination from the former tank farm source area, provided information for future designs, and addressed immediate threats to indoor air quality at Building 1. Previous interim measures at the Site were detailed in the RI and are summarized in this section (AMEC, 2013).

2.5.1 Recovery Well MC-R

A recovery well (MC-R) operated beginning in 1987 to recover dense nonaqueous-phase liquid (DNAPL) in the area of the former solvent distillation processing area of the tank farm (PSC, 1998). During the DNAPL recovery interim measure, 60 gallons of solvent and 18,000 gallons of contaminated groundwater were removed from a screened interval of 1.5 to 8 feet bgs, which placed the bottom of the well approximately two feet into the Silt Layer. The recovery well was abandoned and removed during soil excavation in 1997.

2.5.2 Tank Farm Soil Excavation

An interim action soil excavation was conducted in September and October 1997 in the former tank farm area. Soil investigation of multiple depths above the Silt Layer indicated that the highest concentrations of contaminants were present at approximately four feet bgs, a few feet above the top of the Silt Layer. These findings prompted the interim action soil excavation project. The excavation led to removal of most of the contaminated soil in the source area. Soil was excavated to the Silt Layer, approximately six feet bgs. A potential “dry well” was discovered within a few feet of the recovery well MC R during the excavation. Complete source area removal was not possible due to the proximity of Building 1 and the Silt Layer (see Figure 2-1). COC-impacted silt was left in place below the water table, and soils were not removed immediately adjacent to and underneath Building 1 (AMEC, 2013). Work was summarized in a 1998 Final Interim Action Report (PSC, 1998).

2.5.3 Enhanced Bioremediation Pilot Test

A pilot test to assess the effectiveness of using hydrogen-releasing compound (HRC) for enhanced bioremediation of groundwater was conducted in shallow groundwater downgradient of Building 1, near MC-14, in the early 2000s. Monitoring well MC 14 had consistently shown the highest concentrations of various constituents in the Shallow Groundwater Zone. The Silt Layer near MC 14 was investigated to determine if a depression in the Silt Layer was present there, causing contaminants to pool in this area. No obvious depression was found (Geomatrix, 2008b). MC 14's one distinction from other Shallow Groundwater Zone wells at the facility is its construction. Its screen was set directly above the Silt Layer, but eight feet of sand pack were used to backfill the boring below the bottom of the well. In essence, this well is completed into the Silt Layer.

The pilot test included 12 direct-push borings injected with HRC near MC-14 to assist in reductive dechlorination of chlorinated solvent contaminants in the Shallow Groundwater Zone. The 2 inch-diameter borings were drilled to the top of the Silt Layer (approximately 7.5 feet bgs). The HRC was heated to approximately 270 degrees Fahrenheit (°F), then approximately 50 to 55 pounds of HRC was pumped into each boring, filling them to the ground surface.

The pilot test was monitored after installation to evaluate its effectiveness. The long term trends in groundwater concentrations showed the most obvious decreases in concentrations occurred after the 1997 tank farm area soil removal interim measure and before the HRC Pilot Test. Natural degradation is also documented based on the presence of degradation products, including VC, in groundwater samples collected prior to the HRC pilot test. Ethane and total organic carbon, concentrations initially increased after the pilot test, and oxidation/reduction (redox) potential (ORP) initially decreased. Concentrations of chlorinated solvents fluctuated but are consistently lower since the pilot test, suggesting that contamination migrating away from the former tank farm source area decreased over time. However, it is unclear whether the decreases in chlorinated solvent concentrations are partially due to the HRC injection or solely the result of the source removal and subsequent natural degradation. Overall, the pilot results indicated HRC had some benefit but not as significant as the interim action in the tank farm performed several years earlier (AMEC, 2013).

2.5.4 Indoor Air Inhalation Pathway Interim Measure

Soil gas sampling performed beneath Building 1 in October 2001 and February 2002 indicated that soil gas concentrations beneath the building might be adversely impacting indoor air in Building 1. In June 2005, indoor air, soil gas, and ambient air samples were collected at or adjacent to Building 1 to evaluate whether indoor air concentrations, associated with potential vapor intrusion from soil gas, exceeded levels of concern to human health. Results were not conclusive enough to rule out risk from soil gas, so a mitigation system was installed in Building 1 in lieu of resampling and conducting routine air monitoring.

The indoor air inhalation pathway interim measure (IPIM) was implemented in October 2005 to prevent the risk of exposure for workers in Building 1 to VOCs. The IPIM decreases the pressure below the building slab such that pressure inside the building is higher than the pressure in the subsurface. Air flow between the building and the slab is forced downward out of the building and into the slab, thereby preventing volatile constituents that may be present in soil from migrating into the building. A fan pulls gases from the subsurface and vents them to the ambient air. It continues to operate.

2.6 Nature and Extent of Contamination

This section summarizes the nature and extent of contamination at the Site. This summary combined with the conceptual site model presented in Section 2.7 and the remediation considerations discussion in Section 4.1 form the basis for evaluating alternative technologies for remediation at the Site. The nature and extent of contamination was reviewed and updated to incorporate recent data collected since the 2013 FS as part of the 2019 technical memorandum titled *Feasibility Study – Nature and Extent of Contamination Update* (Appendix B), the January 15, 2020 technical memorandum titled *Feasibility Study – Remedial Alternative* (Appendix D), and over the course of 2019 and 2020 meetings with Ecology in preparation of this FS.

Since the submittal of the 2013 FS additional groundwater monitoring has been performed in the Shallow Groundwater Zone and Lower Aquifer groundwater. The nature and extent of COCs has changed over time with trends in COCs now better defined.

2.6.1 Contaminant Sources

As noted in the previous section, the primary contaminant source areas at the Site were previously remediated as part of interim actions. The main source area contributing to groundwater impacts is the former tank farm area (Figure 2-1). This was an area of known releases of chlorinated solvents to the subsurface and has been the focus of considerable investigation and a major soil excavation interim action in 1997. The interim action removed contaminated soil from the area of the Site where the most significant contamination was found, but as noted above, the presence of Building 1 made excavation east of the former tank farm infeasible at that time and a building-specific interim measure (the IPIM) was installed instead.

Data from groundwater directly above, in, and below the Silt Layer at the Stericycle property indicate that the Silt Layer beneath the former tank farm is serving as an ongoing secondary source of COCs to groundwater, primarily to the Lower Aquifer. For sites such as this with old releases, back- diffusion of contaminants from low-permeability units present in the aquifer can adversely affect attainment of preliminary CULs. Back-diffusion could cause residual concentrations to exceed preliminary CULs within the source area for years after removal of almost all constituent mass from the source area. The residual contamination in the Silt Layer at the Site has allowed for dispersion of the COCs into the deeper areas of the Silt Layer and into the Lower Aquifer. The COCs adsorbed within the Silt Layer are likely to continue to migrate through the Silt Layer and into the Lower Aquifer over time.

2.6.2 Soil

As discussed above in Section 2.4 the RI evaluated the broad list of COCs and concluded that the former tank farm area had areas of soil contamination that could not be fully removed during the 1997 interim action. The locations of historical soil sampling investigation are shown on Figure 2-9. The 2013 RI evaluated the risk posed by soil concentrations with regards to the site conceptual model, particularly risk to contaminating groundwater and human/ecological receptors. Beyond the former tank farm area only two other smaller source areas were identified at the Site where soil contamination is the primary concern: the former container storage areas at Building 2 and Building 3, and the area west of the waste oil tank system. Soil immediately underneath Buildings 2 and 3 exceeded the preliminary CULs for cyanide, PCE, and TCE, but the absence of exceedances for these COCs in groundwater nearby indicates a limited extent of affected soil. These soil data collected for the RI (AMEC, 2013) are also useful in identifying sources of contamination and areas where it may be suspected that contaminants may remain for some time. However, for remedy design purposes, additional information to inform current concentrations of COCs, particularly VOCs that have been demonstrated to be naturally degrading at the Site, would be beneficial. To meet this objective, Stericycle has agreed to collecting additional soil gas data from beneath Building 1 via the existing soil gas monitoring ports installed during the RI as part of investigation and implementation of the IPIM following discussion with Ecology. Stericycle plans to conduct this sampling in late 2020 to allow for use in the draft cleanup action plan. Shallow groundwater results from around Building 1 indicate the threat to groundwater from COCs present in soil under this building is limited.

2.6.3 Groundwater

As presented in the RI, in groundwater, the primary COCs are similar to soil with the same VOCs consistently present, along with 1,4-dioxane, arsenic, and a few other inorganic COCs. Chlorinated ethenes are the primary VOCs detected above preliminary CULs in groundwater and are considered indicators of contamination at the Site.

Evidence for the degradation of chlorinated organic compounds was presented in the RI (AMEC, 2013). Biodegradation appears to be a very important process affecting the fate and transport of chlorinated organic compounds in groundwater at the Site. Levels of dissolved oxygen in groundwater at the Site are likely suppressed by the biological oxygen demand resulting from the naturally occurring organic matter in aquifer materials associated with the current and former wetland environment. Consequently, anaerobic degradation processes, such as fermentation and reductive dechlorination, are likely to be the most important biodegradation processes occurring at the Site. Patterns observed in both contaminant and geochemical data for groundwater at the Site indicate that microbial degradation of contaminants is likely occurring.

As part of preparing the FS, groundwater trends for the primary COCs were updated to include more recent data and revised preliminary CULs. These trends are included in Appendix E for the wells routinely monitored at the Site in both the Shallow Groundwater Zone and the Lower Aquifer. Appendix E also includes meeting presentation slides used in discussion of the FS with Ecology over the course of development of this FS to evaluate extent of contamination and determine appropriate treatment areas. Trends and recent concentration show:

Shallow Groundwater

- The 1997 excavation removed the bulk of the COC mass above the Silt Layer, but presumably left contamination remaining under Building 1. As a result of this interim action, groundwater quality in the Shallow Groundwater Zone has improved dramatically, indicating that residual contamination left beneath Building 1 may have attenuated over time. Groundwater monitoring data in shallow wells around Building 1 indicate predominantly decreasing concentration trends. The decreasing trends coupled with seasonally high groundwater that is only a few feet from the surface leaves uncertainty as to how much VOC contaminant mass may remain underlying Building 1. Additional testing will be completed in preparation for the cleanup action plan, as described above. Concentrations of all COCs except arsenic and 1,4-Dioxane are trending downward.
- Seasonal changes in redox conditions affect subsurface geochemistry and lead to seasonal changes in concentrations of inorganic constituents and chlorinated VOCs. In the winter, recharge with oxygenated rainwater changes redox conditions to a more oxidizing state, causing arsenic concentrations to decrease and chlorinated VOC concentrations to increase (see the RI for further details). Thus, arsenic concentrations in groundwater are generally highest during the summer period when groundwater levels are lowest, dissolved oxygen concentration in groundwater is lowest, and reducing conditions are present within the organic-rich Silt Layer. Conversely arsenic concentrations throughout the Site are generally lowest in the winter months when water levels are highest and fresh rainwater is oxygenating the Shallow Groundwater Zone. At the same time, chlorinated VOC concentrations increase during winter months when rates of reductive dechlorination are lowest.
- VOCs concentrations are generally below preliminary CULs or are at low concentrations and trending down (Appendix E), with data indicating ongoing natural attenuation. VC is the main VOC of concern with the highest concentration detected at well MC-14 (approximately 0.9 micrograms per liter (µg/L)).
- Virtually no trace of 1,4-dioxane remains in the Shallow Groundwater Zone in the vicinity of the former tank farm area. 1,4-dioxane concentrations are highest at well MC-14 (approximately 320 µg/L), and concentrations downgradient of this area (MC-20, MC-123) have declined to levels near or below the preliminary CUL (Appendix E). Based on trend analysis, the source appears to be primarily present in the shallow sand fill unit, not in the Silt Layer. Higher concentration wells show concentrations in the Shallow Groundwater Zone go up when the water table is highest, during periods when more of the sandy unit above the Silt Layer is saturated, making it more readily accessible for treatment.
- Arsenic concentrations are generally below the preliminary CUL, with the highest concentrations at MC-14 and MC-31 and strong seasonality (Appendix E). Anaerobic

conditions likely existed in the former marsh prior to industrial activities owing to the high organic content of native sediments. Aerobic microbial breakdown of the released organic constituents further depleted the groundwater of dissolved oxygen. The organic Silt Layer is likely to still be creating reducing conditions in groundwater with the strongest reducing conditions occurring during the drier summer season, as is evidenced by the low dissolved oxygen content in wells and correlating higher arsenic levels that do not appear to be related to a release from Facility operations

Lower Aquifer

- The highest concentrations of VOCs remaining onsite are detected at wells in the former tank farm area. Trends in concentrations of chlorinated ethenes over time indicate that the Silt Layer is retaining contamination that continues to leach to groundwater in the shallower portions of the Lower Aquifer. Lower aquifer wells screened immediately below the Silt Layer have higher concentrations than wells screened deeper, indicating the silt is acting as a probable secondary source of COCs.
- Additional areas where VOCs have recently been detected above preliminary CULs are located along the northern property line, near MC-118D, and southeast of the former tank farm, near well MC-15D (Appendix E). However, the concentrations in these areas are at least an order of magnitude lower than those in the former tank farm area. Shallow wells in these areas do not show elevated concentrations, indicating the source is upgradient.
- 1,4-dioxane concentrations detected in the Lower Aquifer are much lower than in the Shallow Groundwater Zone, with the highest concentrations (approximately 5 to 15 µg/L) detected in the former tank farm area and along the northern property line (near MC-118D) (Appendix E).
- Trends in concentrations of COCs in the Lower Aquifer show degradation in and north of the area of the former tank farm, and are increasing in the area of MC-15D, downgradient of the former tank farm (Appendix E). This well has shown low levels of PCE and TCE (less than 1 ug/L) but an increase in degradation compounds *cis*-1,2-dichlorethene (*cis*-1,2-DCE) and VC. The low levels of parent compound VOCs and the lack of historical concentrations of elevated VOCs in the paired shallow well MC-15 indicate the source of contamination detected at MC-15D is likely the upgradient residual former tank farm contamination.

Additional detail is provided in the Nature and Extent of Contamination Technical Memorandum (Appendix B).

Recent concentrations of primary COCs in groundwater are shown on Figure 2-7 for the Shallow Groundwater Zone and on Figure 2-8 for the Lower Aquifer. The intent of these figures is to visually show recent concentrations of primary COCs above preliminary CULs and the direction of concentration trends in different areas. Additional figures showing isoconcentration contour maps for key COCs and detailed investigation results are provided in the RI (AMEC, 2013) and in Appendix E. A critical step in completion of this updated FS was to assess the current groundwater COC concentrations in the context of contaminant degradation and migration. Part 2 of Appendix E presents the areas where individual COCs remain at concentrations above preliminary CULs, along with the long-term trends at those locations to show where concentrations are steady, declining, or increasing. This information is used in the FS to develop treatment areas. This information is also useful in evaluating the potential for off-site migration prior to cleanup, as shown in several of the slides.

Current concentrations of COCs in groundwater at the Site are typically in the low parts per billion (ppb) range. Even the maximum concentrations don't exceed a few thousand ppb for VOCs and 400 ppb for 1,4-dioxane, which is well below solubility limits (Appendix E). These concentrations indicate there is not a high concentration source like DNAPL in the subsurface. In addition, DNAPL was not encountered during the 1997 excavation interim measure or subsequent investigations in the source area in the former tank farm area. Residual chlorinated and nonchlorinated organic COCs are present in groundwater and adsorbed in the Silt Layer. These COCs adsorbed to the Silt Layer represent a long-term, low concentration continuing secondary source of COCs to groundwater, but appear to no longer be heavily affecting the Shallow Groundwater Zone.

2.7 Conceptual Site Model of Exposure Pathways

The conceptual site model (CSM) was initially developed in the RI and generally remains the same, however, the nature and extent of COCs has changed as described in the previous section, and building, paved areas, and utility locations have also been modified over time. A block diagram visually depicting the CSM is presented in Figure 2-10. The block diagram illustrates the current understanding of the potential sources and releases of constituents, and constituent distribution and transport at the Site.

Contaminant transport must account for site-specific details including:

- Sandy fill from ground surface to a depth of approximately 10 feet below ground surface (bgs), with an underlying Silt Layer from approximately 10 to 20 feet bgs, and below that a silty gravel material containing larger cobbles.
- The water table is typically quite shallow - approximately four feet bgs (plus or minus two feet), but the vadose zone can be flooded entirely in wet winter periods.
- Shallow groundwater consistently flows to the east, towards the neighboring marsh.
- Lower Aquifer groundwater generally flows to the southeast, towards the neighboring marsh, but occasionally flows to the northeast, also towards the marsh, with eventual connection to the Columbia River, which is the nearest larger surface water body, located south of the Site.
- As part of updating the FS, recent COC trends were reviewed and used to evaluate the rate of COC migration across the Site and potential risk to off-site receptors in the marsh or river. As shown in several slides included in Appendix E, the anticipated point off-site at which groundwater would be at concentrations below preliminary CULs (without treatment) is between 40 and 200 feet away from the Stericycle property, well before reaching the Columbia River, based on current concentrations and the extensive monitoring record available for trend analysis at the Site.

- Vertical gradients can be upwards from the Lower Aquifer to the Shallow Groundwater Zone or down from the Shallow Groundwater Zone to the Lower Aquifer, depending on seasonal water level fluctuations in the Shallow Groundwater Zone.
- The Site is situated within an active industrial park, constructed on non-native fill sands placed over a native marshy silt. The sandy fill thins out towards the edges of the industrial park, with the native Silt Layer encountered closer to ground surface. The industrial park neighbors the SLNWR, a wildlife refuge located east of the Site.

The CSM recognizes the following complete or potentially complete pathways for human health receptors.[2]

- Office workers, working primarily indoors;
- Industrial workers, working primarily outdoors;
- Temporary workers, working primarily outdoors; and
- Site visitors present at the Stericycle property for short durations.

Other future receptor pathways, including well installation for drinking water use and site development for residential use, are considered unlikely since institutional controls will forbid commercial and residential use of the property and forbid the use of groundwater at the Site for drinking water.

Ecological receptors were also considered as part of the RI and screening contaminant levels against criteria protective of those receptors. On the Stericycle property itself, soil (where exposed) is considered a potentially complete pathway for small birds, rodents, and rabbits. Concentrations of COCs in soil were compared to MTCA screening levels protective of this exposure pathway. Results showed only barium concentrations in the upper 6 feet of soil exceed these screening levels. However, barium concentrations on the Stericycle property itself are below state and regional background values.

Based on the CSM and the RI, Figure 2-11 provides a summary of remedial areas to address complete or potentially complete pathways for Site receptors.

[2] Receptors could become exposed to contaminated groundwater, other media, or organisms impacted currently or potentially impacted in the future due to contamination already in groundwater or from future migration of contaminants from soil to groundwater.

3.0 CLEANUP STANDARDS

This section outlines the approach used to develop preliminary CULs for the Site. The preliminary CULs must be established for affected media and must be appropriate for the land use and relevant exposure pathways identified in the conceptual site model. Affected media identified through previous investigations include soil in the area of the former tank farm, including areas outside the tank farm footprint, and groundwater beneath the Stericycle property that is migrating beyond the Stericycle property boundary.

MTCA regulations require that remedial action alternatives achieve cleanup standards. MTCA regulations establish three primary components for cleanup standards:

- CULs for constituents of concern;
- The point of compliance (POC) where these CULs must be met; and
- Other regulatory requirements that apply.

MTCA regulations define three basic methods of determining CULs for soil and groundwater.

- Method A – applies to “routine” sites or where few hazardous substances are involved. Method A CULs have been established for unrestricted and industrial land uses.
- Method B – the “universal” method that can be applied to all media at all sites (unrestricted and industrial use). Two types of Method B CULs can be used: standard (or default) CULs based on standard assumptions, and modified CULs that incorporate chemical-specific or site-specific information.
- Method C – a conditional CUL that can be used where more rigorous CULs cannot be achieved. Similar to Method B, Method C comprises two types: standard and modified. Use of Method C CULs requires institutional controls to ensure future protection of human health and the environment and is generally applicable only to industrial sites.

For carcinogenic constituents of concern, MTCA Method B and Method C CULs are generally defined by the upper bound of the estimated lifetime cancer risk, which cannot exceed 1×10^{-6} and 1×10^{-5}, respectively, for each method, for individual carcinogens. Hazard indices for both Methods B and C cannot exceed 1.0, and the total risk for COCs under each method cannot exceed 1×10^{-5}.

Cleanup standards in MTCA Methods A, B, and C are required by RCW 70.105D.030 (2)(d) to be “*at least as stringent as all applicable state and federal laws*.” These requirements are similar to the applicable, relevant and appropriate requirements (ARAR) approach of the federal Superfund law, and are described in entirety in WAC 173-340-710. In addition, the Stericycle property meets criteria established in WAC 173-340-200 and 173-340-745 for a site to be defined as an industrial property, as described in the RI. Although there is a potential for the property to be used sometime in the future for residential use (and therefore residential exposure was considered in the conceptual site model as a potentially complete exposure pathway), the property and surrounding industrial park are industrial and are expected to remain industrial for the foreseeable future, and institutional controls are anticipated to be established at the Site as part of the cleanup action, restricting use of the property to industrial uses. As noted in the RI, groundwater from the Stericycle property discharges to the Steigerwald Lake National Wildlife Refuge, and since Steigerwald Marsh is not zoned as industrial, the entire "facility" or "Site" cannot be viewed as industrial and CULs must reflect this distinction for areas outside the industrial park.

Preliminary site-specific CULs must be protective of the pathways established in the conceptual site model, including the following media exposure pathways:

- Groundwater – the groundwater-to-surface water pathway (the Shallow Groundwater Zone groundwater discharges to the Steigerwald Marsh and Gibbons Creek Remnant Channel, and the Lower Aquifer groundwater discharges to the Columbia River);
- Groundwater – indoor vapor inhalation pathway;
- Soil – industrial direct human exposure pathways (ingestion, inhalation, dermal absorption);
- Soil – indoor vapor inhalation pathway; and
- Soil – groundwater pathway (protective of a groundwater level that accounts for all groundwater-related pathways including drinking water, surface water, and vapor pathways).

Since groundwater in the Lower Aquifer is also considered a potential drinking water source, and the Shallow Aquifer appears to have some connectivity to the Lower Aquifer, these aquifers must also be considered for direct ingestion of groundwater (levels protective of drinking water).

3.1 Groundwater Preliminary Cleanup Levels

Preliminary groundwater CULs are based on a general analysis of groundwater use and the MTCA methodology for establishing CULs. Final CULs will be established in the Cleanup Action Plan (CAP) for use in designing the final remedy for the facility. For groundwater in the Shallow Groundwater Zone (above or in the Silt Layer) as well as for groundwater in the Lower Aquifer (in or below the Silt Layer), the preliminary CUL for each constituent of concern is a MTCA Method B CUL selected by choosing the minimum of the following:

- **MTCA Groundwater Table Values (from CLARC [Ecology, 2019])**
  - MTCA Method A levels for constituents that do not have a Method B level available;
  - MTCA standard Method B levels based on drinking water beneficial use, which include Federal Maximum Contaminant Levels (MCLs);
- **Surface Water ARARs**

  Several surface water criteria have changed since the RI and draft FS due to updates in the Environmental Protection Agency's (EPA's) National Recommended Water Quality Criteria (304[a]) in 2015 and 2016, Ecology's Water Quality Standards (WAC 173-201A) in 2016, and the

Environmental Protection Agency (EPA)'s 2016 "Revision of Certain Federal Water Quality Criteria Applicable to Washington" (40 CFR 131.45; formerly the Washington criteria were in 40 CFR 131.36, referred to as the National Toxics Rule, or NTR).

  - Water Quality Standards for Surface Waters of the State of Washington (WAC 173-201A) – Acute and Chronic effects, Aquatic Life, Human Health (water and organism), Human Health (organism only), Freshwater;
  - National Recommended Water Quality Criteria (NRWQC) (Clean Water Act §304) – Freshwater, Acute and Chronic effects, Aquatic Life and for the Protection of Human Health;
  - National Toxics Rule (40 CFR 131) – Freshwater, Human Health, Consumption of Water and Organisms;

- **MTCA Surface Water Table Values (from CLARC)**
  - MTCA Method B Surface Water levels from Ecology's Cleanup Levels and Risk Calculation (CLARC) tables if a federal or local surface water value is not found in the above references (Ecology, 2019); and
- **Values Protective of Indoor Air**
  - For the Shallow Groundwater Zone only, MTCA Method B groundwater CULs protective of vapor intrusion, obtained from CLARC (Ecology, 2019).

After selecting the minimum value from the MTCA Method B levels and the ARARs, preliminary CULs were established for use in the FS. For some constituents, the preliminary Method B CULs were revised upward in accordance with the MTCA regulations [WAC 173-340-705(6)] so that the screening levels were not lower than the practical quantitation limits (PQLs) obtained by the project laboratory. The preliminary CULs established by this process are modified MTCA Method B CULs. In reviewing the modified Method B CULs based on analytical considerations, Ecology may consider the availability of improved analytical techniques and require their use. In accordance with WAC 173-340-707, if the PQL for a constituent was higher than the preliminary groundwater CUL, the CUL was raised to the PQL level if:

- The PQL is no greater than 10 times the method detection limit (MDL); and
- The laboratory PQL is not higher than the PQL established by the EPA.

The PQLs were obtained from the current project laboratory, Agriculture & Priority Pollutants Laboratories, Inc. (APPL) of Clovis, California, which is certified by the state of Washington. APPL performs low-level and selective ion monitoring (SIM) for VOCs and SVOCs, and analyses for PCBs, to attain PQLs below typical reporting limits. For some constituents, the APPL PQL was slightly higher than 10 times the MDL. In these cases, the value of 10 times the MDL was used as the PQL.

The preliminary groundwater CULs are summarized in 3-1. Additional adjustments for background were considered for arsenic in accordance with WAC 173-340-705 and -706, which establish the applicability of Method B and C to determine CULs for this constituent (further discussed in the RI).

Both area and natural background were considered in developing preliminary CULs for arsenic. Background values were calculated using upgradient Site data outside of contaminated source areas as described in the RI. These calculated values are 22.84 µg/L for the Shallow Groundwater Zone and 1.42 µg/L for the Lower Aquifer. It is difficult to ascertain if these background values should be categorized strictly as natural background values or area background values given that the Site has both natural and anthropogenic (area) influences:

- Natural - The Site and surrounding industrial park are built over a large marsh, resulting in naturally reducing conditions. These naturally reducing conditions are directly impacting concentrations of arsenic on the Site. The arsenic concentrations show a clear and consistent trend of higher concentrations in the Shallow Groundwater Zone during the summer months (when the groundwater elevation is lowest and we observe the strongest reducing conditions) and lower concentrations in the winter months when recharge of oxygenated rainwater occurs. The natural conditions (high organic content and peat layers that promote reducing conditions) would encourage mobility of arsenic.
- Area - The Site is located within a man-made industrial park, constructed on imported fill. The shallow aquifer is actually within this fill zone, but the geochemistry of this unit is strongly influenced by the methanogenic conditions produced by the underlying marsh deposits.

In 2010, the MTCA Science Advisory Board reviewed a statewide dataset of groundwater data for arsenic (San Juan, 2010). For this background study, arsenic study data were obtained from the Washington Department of Health Drinking Water Program. A total of 18,238 groundwater sample results, collected over a 10-year period (2000-2010) from 6,776 drinking water wells (depths of 10 to 2,200 feet.), were evaluated. Ecology used the “MTCAStat” statistical software to estimate background arsenic concentrations using the procedures specified in WAC 173-340-709. The review produced the following key results:

- On a statewide basis, Ecology estimated that arsenic concentrations of 10.7 µg/L represent the 90th percentile of the sampling distribution for groundwater in the State.
- High arsenic concentrations (greater than 25 µg/L) were detected in 12 western Washington counties (Clark, Cowlitz, Island, Jefferson, King, Lewis, Mason, Skagit, Skamania, Snohomish, Thurston, and Whatcom). The PSC Washougal facility is located in Clark County.

Stericycle’s site-specific background calculation yielded results consistent with Ecology’s study that indicates high arsenic concentrations are present in Clark County. Stericycle set the preliminary CUL for arsenic at 22.84 µg/L for the Shallow Groundwater Zone and 1.42 µg/L for the Lower Aquifer.

The arsenic assessment and background calculation were described in Appendix O of the RI.

3.1.1 Beneficial Use of Groundwater

The designation of the highest beneficial use of groundwater in an area governs potential exposure to groundwater in that area. The designation of the highest beneficial use of groundwater in a particular area is regulated by several different agencies, including Ecology, the Washington State Department of Health (WDOH), and county and city governments. The requirements, rules, and guidance of each of these agencies are considered in the determination of the highest beneficial use of groundwater under MTCA (WAC 173-340-720). According to WAC 173-340-720, groundwater CULs must be based on the highest beneficial use of groundwater, which is human ingestion, unless the criteria outlined in WAC 173-340-720(2) subsections (a) through (c) are met. Unless all of the criteria can be demonstrated, WAC 173-340-720(2) defines all groundwater as potable.

Since groundwater in the Lower Aquifer is considered a potential drinking water source, CULs must be developed based on an exposure pathway that includes direct ingestion of groundwater (levels protective of drinking water). Groundwater in the Shallow Groundwater Zone of the Site is not a current source of drinking water, and has a very low yield; however, the Shallow Groundwater Zone is partially connected to the Lower Aquifer groundwater, which could potentially be used as a drinking water source, and therefore drinking water is a potential exposure mechanism for both the Shallow Groundwater Zone and the Lower Aquifer.

3.2 Soil Preliminary Cleanup Levels

The Stericycle property is located in an area zoned for heavy industrial use; therefore, MTCA Method C soil CULs are appropriate for use at the Stericycle property. In addition, the Stericycle property meets criteria established in WAC 173-340-200 and 173-340-745 for a site to be defined as an industrial property, as described in the RI. However, portions of the Site that are east of the property, outside the industrial park, do not meet this definition since a national wildlife refuge exists in this area. Areas of the Site outside the industrial park require development of more stringent CULs, which would apply in these areas. MTCA Method C industrial soil CULs are based on adult occupational exposures and assume that current and future land use will be restricted to industrial purposes.

Preliminary CULs for soil on the property are selected by choosing the minimum of the following MTCA CULs:

- MTCA Method C - Industrial CUL based on direct contact/ingestion obtained from the CLARC website (Ecology, 2019);
- For those constituents with no available Method C CULs, MTCA Method A Industrial Soil CULs (MTCA Table 745-1);
- Soil CULs protective of the preliminary groundwater CULs described in Section 2.1 [WAC 173-340-747(4)];
- EPA Regional Screening Levels (RSLs); and

- Ecological Indicator Soil Concentrations for Protective of Terrestrial Plants and Animals (MTCA Table 749-3).

Additionally, areas of the Site outside the Industrial Park will be considered with regard to MTCA Method A and B – Unrestricted Cleanup Levels (and residential EPA RSLs), based on direct contact/ingestion obtained from the CLARC website. After selecting the minimum value from the levels described above, the preliminary cleanup levels are established below. For some constituents, the preliminary cleanup levels were revised upward when compared to natural background levels and PQLs in accordance with the MTCA regulations [WAC 173-340-709 and WAC 173-340-705(6)]. The modified preliminary cleanup levels were established as follows.

- The risk-based soil cleanup level selected for each constituent was compared to the natural background concentration. If the risk-based cleanup level was less than the natural background concentration, the natural background concentration was selected for comparison to the PQL.
- If natural background concentrations were lower than the risk-based soil cleanup level, the risk-based soil cleanup level was selected for comparison to the PQL.
- If the selected natural background concentration or risk-based soil CUL was less than the PQL, the PQL was selected as the CUL.

Natural background levels for metals were defined by Ecology (1994) for the Clark County area. The Clark County natural background values were calculated as the 90th percentile value using Ecology's MTCA STAT program on a sample set of n = 45. Screening levels that were below the defined Clark County natural background levels were adjusted up to the applicable natural background level in accordance with the limitations set forth in WAC 173-340-706(6).

Applicable PQLs were established for soil in the same manner described in Section 3.1 for groundwater. The preliminary CULs for on-property soils and for off-property soils in Table 3-2.

3.3 Points of Compliance

To develop and evaluate a reasonable range of cleanup alternatives in the FS, a POC must be defined for contaminated sites. As defined in the MTCA regulations, the POC is the point or points at which CULs must be attained. The POC, CULs, and other applicable standards taken together define the cleanup standard. Sites that achieve the cleanup standards at the point of compliance and comply with applicable state and federal laws are presumed to be protective of human health and the environment, as approved by Ecology. The POC or multiple POCs will be used in the FS for design and evaluation of potential remedial alternatives. After approval of the FS, the proposed final POC(s) will be incorporated into the CAP and final design for the cleanup alternative selected in the FS. The final POC(s) to be used for implementing the cleanup action will be determined after Ecology approval of the CAP and after completing the requirements specified in the MTCA regulations for approval by other agencies, other property owners, and the public. POC was updated as part of the *Revised Feasibility Study – Point of Compliance and Preliminary Cleanup Level Assessment* (Appendix A).

The MTCA regulations specify POCs for various media that may become contaminated. MTCA defines both the standard POC (SPOC) and the less stringent conditional POC (CPOC). The SPOC applies to all soil, groundwater, air, or surface water at or adjacent to any location where releases of hazardous substances have occurred or that has been impacted by releases from the location. A CPOC is usually defined only for groundwater, air, or surface water. A CPOC typically applies to a specific location as near as possible to the source of the release. Site-specific conditions determine whether the SPOC or CPOC would be appropriate for a site. Several requirements are specified in the MTCA regulations for establishing a CPOC, as discussed in more detail below. The most important criterion for approval of a CPOC is the practicality of attaining CULs within a reasonable time frame throughout the plume. A common situation for use of a CPOC is migration of contaminated groundwater beyond the property boundary. In this case, a CPOC is most frequently established at the property boundary beyond which contaminated groundwater has migrated. However, in certain instances a CPOC may be established beyond the property boundary if Ecology and any landowners located between the source area and the CPOC approve the CPOC before it can be incorporated into a final cleanup action.

As described in the RI Report, affected media at the facility include soil and groundwater. POCs for soil and groundwater are established separately and may be different due to different regulatory requirements and potential exposure pathways associated with the two media.

3.3.1 Soil Point of Compliance

The regulatory requirements for the soil POC are presented in the MTCA regulations, WAC 173-340-740(6). The requirements for the soil POC depend on the relevant exposure pathway. Therefore, MTCA may require different soil POCs for different COCs. The requirements specified by MTCA are as follows.

- For soil COCs whose CUL is based on protection of groundwater, the POC shall be in soils throughout the Site.
- For soil COCs whose CUL is based on the vapor/inhalation pathway, the POC must be the soils throughout the Site (from the ground surface to the uppermost water table).
- For soil COCs whose CUL is based on human exposure (i.e., the Commercial Cleanup Level defined in the RI Report), the POC must include the soils throughout the Site from the ground surface to a depth of 15 feet bgs.
- For soil COCs whose CUL is based on ecological exposure, additional specific requirements that must be addressed are presented in WAC 173 370 7490(4).

The soil POCs defined above by MTCA would apply to soil at the surface and beneath the surface affected by releases from the Stericycle operations. However, for cleanup actions that involve containment of contamination, WAC 173-340-740(6)(f) establishes the following provisions for the cleanup to comply with the cleanup standards:

> *For those cleanup actions selected under this chapter that involve containment of hazardous substances, the soil CULs will typically not be met at the points of compliance specified in (b) through (e) of this subsection. In these cases, the cleanup action may be determined to comply with cleanup standards, provided:*
>
> *(i) The selected remedy is permanent to the maximum extent practicable.*
>
> *(ii) The cleanup is protective of human health.*
>
> *(iii) The cleanup action is demonstrated to be protective of terrestrial ecological receptors.*
>
> *(iv) Institutional controls are put in place … that prohibit or limit activities that could interfere with the long-term integrity of the containment system.*
>
> *(v) Compliance monitoring and periodic reviews are designed to ensure the long-term integrity of the containment system.*
>
> *(vi) The types, levels and amounts of hazardous substances remaining on-site and the measures that will be used to prevent migration and contact with those substances are specified in the cleanup action plan.*

3.3.2 Groundwater Point of Compliance

The groundwater SPOC, as described in WAC 173-340-720(8)(b), would include all groundwater within the saturated zone beneath the Stericycle property and in any area affected by releases from the Stericycle operations. Under WAC 173-340-720(8)(c), Ecology may approve use of a CPOC if the responsible person demonstrates that it is not practicable to attain the SPOC within a reasonable restoration time frame and that all practicable methods of treatment have been used. A CPOC is essentially a vertical surface extending downward from the water table and laterally so that it spans the vertical area affected by the release (e.g., the contaminated groundwater extending beyond the boundary of the Stericycle property). Groundwater CULs would apply everywhere downgradient from the CPOC; groundwater CULs could be exceeded upgradient from the CPOC. Under WAC 173-340-720(8)(c), a CPOC must be as close as practicable to the source of hazardous substances and not exceed the property boundary.

The MTCA regulations favor a permanent solution for groundwater cleanup at the SPOC. If a permanent cleanup action (e.g., a cleanup action capable of attaining CULs of all COCs in groundwater at the SPOC) is not selected for a site, then MTCA imposes additional requirements as described in WAC 173 340 360(2)(c)(ii). Under this section, MTCA requires treatment or removal of the sources of the release for liquid wastes, high concentration COC areas, highly mobile COCs, or COCs that cannot be reliably contained. This may include removal of light non-aqueous phase liquids through generally accepted remedial technologies. MTCA states containment may be appropriate for dense non-aqueous phase liquids after generally accepted remedial technologies have been exhausted. Groundwater containment measures are required to the maximum extent practicable to avoid lateral and vertical migration of COCs in groundwater. During development of the remedy these requirements will be addressed if a non-permanent remedy is proposed.

Under MTCA, additional requirements apply for establishing a groundwater CPOC beyond the property boundary for facilities such as the Stericycle Washougal facility that are near, but not abutting, surface water are set forth in WAC 173-340-720(8)(d)(ii).

- The CPOC must be located as close as practicable to the source of the release.
- The CPOC must not be located beyond the point or points where groundwater flows into surface water.
- The conditions specified in WAC 173-340-720(8)(d)(i) must be met.
- All affected property owners between the source of contamination and the CPOC agree in writing to the CPOC location.
- The CPOC cannot be located beyond the extent of groundwater contamination exceeding CULs when Ecology approves the CPOC.

A CPOC at the property boundary may be selected for groundwater. The specific regulatory requirements that will apply for establishing a groundwater CPOC for the facility include the following.

- It is not practicable to attain the SPOC within a reasonable restoration time frame [WAC 173-340-720(8)(c)].
- The CPOC shall be as close as practicable to the source of the release [WAC 173 340-720(8)(c)].
- All practicable methods of treatment are used in the Site cleanup [WAC 173 340 720(8)(c)].

The regulatory requirements in the bullet list above must be met in order to specify a groundwater CPOC for the facility.

3.3.3 Proposed Points of Compliance

As defined in the MTCA regulations, the POC is the point or points at which CULs must be attained. Given the nature and extent of contamination in the source area within the Site and in the groundwater downgradient from the source area, some cleanup alternatives incorporate a CPOC for groundwater. The POCs proposed for consideration in completing the FS are described in Sections 3.3.3.1 and 3.3.3.2.

3.3.3.1 Soil

The soil POC includes soil throughout the Site, as required under WAC 173-340-740(6). For remedial alternatives to be considered in the FS that rely on containment and will not meet the soil CUL at the

POC, the requirements specified in the MTCA rules under WAC 173-340-740(6)(f) to demonstrate compliance with the soil POC are addressed.

Based on the Site conditions presented in the RI, the FS assumes that preliminary soil CULs will not be met at the POC and that the provisions of WAC 173-340-740(6)(f) will apply. It is not practicable to attain the preliminary CULs at the POC for soil because buildings on the property limit the accessibility to some portions of the subsurface, and the presence of shallow groundwater limits the practicable depth of many technologies, including excavation. PSC conducted an interim measure to remove shallow impacted soils from the former tank farm area. This excavation was successful at removing Shallow Groundwater Zone soils that were a significant source of COCs to soil and groundwater. However, it is not practicable to remove the impacted Silt Layer below the water table. In addition, the Silt Layer provides some protection from migration of shallow impacted groundwater to deeper, less impacted water-bearing zones. Therefore, removal of the Silt Layer may not be desirable.

3.3.3.2 Groundwater

For groundwater, a standard POC is throughout the Site from the uppermost level of the saturated zone extending vertically to the lowest most depth which could potentially be affected by the Site.

If a CPOC is necessary, a CPOC near the property boundary will be evaluated for areas where the effectiveness of a particular remedial alternative is uncertain. As noted above, the CPOC must be located as close to the source area as practicable.

The practicability of attaining a standard POC are discussed in relation to the remedial alternatives considered in this FS. Additional background on POC is provided in the 2019 Technical Memorandum (Appendix A).

4.0 REMEDIATION CONSIDERATIONS AND OBJECTIVES

This section presents the remediation objectives for the cleanup action at the Site and an analysis of Site characteristics that will affect the development of remediation alternatives.

The overall objective of this FS is to identify the preferred remediation alternative to reduce the risks to human health and the environment resulting from COCs in soil and groundwater at the Site to acceptable levels. All remedial alternatives must address the CSM and the Site migration and exposure pathways of concern described in Section 2.7. The remediation considerations and remediation objectives established for the Site (Sections 4.1 and 4.2) will provide the framework for development of remedial alternatives.

4.1 Remediation Considerations

This section presents a discussion of Site characteristics and other issues to be considered in developing and analyzing cleanup alternatives. These considerations include the physical and land-use characteristics of the Site, previous interim measures that have been conducted, regulatory issues, cost, and the point(s) of compliance.

4.1.1 Physical, Chemical, and Land Use Characteristics

Many remediation technologies are better suited for specific soil types and groundwater flow characteristics. This section presents a discussion of the key elements of the CSM and the nature and extent of contamination that form the basis for identifying remediation technologies applicable to the Site.

The Site presents site-specific conditions that will influence the performance of remedial measures. In particular, the contaminant trends and transport mechanisms described in Section 2 must be considered. The Silt Layer adsorbs and retards migration of many Site COCs and produces reducing conditions within the Shallow Groundwater Zone during the drier months. The Silt Layer holds contaminants and slowly releases them into the underlying groundwater units. Due to the long history of industrial activities at the Stericycle property, constituents in groundwater have diffused/dispersed into the Silt Layer over many decades. Releases to groundwater combined with natural reducing conditions of the organic-rich Silt Layer have caused localized alteration of geochemistry, resulting in dissolution of naturally occurring metals present in the saturated zone.

Since the majority of contamination in the source area remains below the water table within the Silt Unit, technologies that are more effective at addressing COCs remaining in the low-permeability silt and the upper portion of the Lower Aquifer will be preferable.

The high organic content in native sediments at the Site (former marsh) places a high demand for oxygen, leading to naturally occurring reducing conditions in the marsh sediments at the Site. Aerobic degradation of organic constituents released at the Site has further increased oxygen demand, creating even more anoxic and reducing conditions conducive to anaerobic degradation. Metals, such as arsenic, iron, and manganese, exhibit higher solubility under reducing conditions than under oxidizing conditions. These metals are present in the naturally occurring minerals present within the saturated zone. While the reducing conditions caused by biodegradation of the released organic constituents has contributed to the observed concentrations of several metals in a couple of the wells on Stericycle property, it is clear that elevated background levels for many of these metals existed prior to these releases.

It is expected that remediation focused on the organic COC releases from the Site will indirectly reduce concentrations of soluble metals that were mobilized as a result of those releases. Remediation efforts will be focused on reducing concentrations of organic COCs in the plume that are the result of industrial activities and not on inorganic constituents that are the result of naturally occurring conditions at the Site. Given that higher arsenic concentrations are primarily the result of naturally reducing conditions occurring in the marsh that existed prior to site development, it is assumed that after treatment of the organic COCs, arsenic levels will return to background levels.

Remediation technologies to be considered in the FS must be able to address the multiple COCs on the Site. Some technologies allow concurrent treatment of multiple COCs. Others are not compatible for concurrent use, but would instead require phased use to treat all COCs at the Site. In order to screen remedial technologies a smaller set of COCs were identified as the major drivers of cleanup due to the extent of their distribution and the difficulty of remediation. These selected COCs included VOCs (PCE, TCE, *cis*-1,2-DCE, and VC), and SVOCs (1,4-dioxane).

Analytical results and the analysis presented in the RI demonstrated that several VOCs detected at the Site, such as VC and *cis*-1,2-DCE, are daughter products of PCE and TCE and were not released in the source area (AMEC, 2013). As described in the RI report, biodegradation appears to be a very important process affecting chlorinated organic compounds in groundwater at the Site. Patterns observed in both contaminant and geochemical data for groundwater at the Site indicate that microbial degradation of contaminants is occurring. The RI report provides extensive data demonstrating that natural attenuation is active and ongoing, and these natural processes will be considered in developing remedial alternatives for the Site. COC trends and degradation patterns used to evaluate the rate of COC migration across the Site indicate groundwater is unlikely to reach off-site receptors at concentrations above preliminary CULs (Appendix E).

Given the long history of industrial use within and immediately adjacent to the Stericycle property, future land uses considered in the FS will be limited to industrial activities.

4.1.2 Regulatory Consideration

The MTCA regulations (WAC 173-340-360) present the general requirements for selecting cleanup actions for a contaminated site. The minimum requirements applicable to all cleanup actions include specific threshold requirements and other requirements that must be met by all cleanup actions.

The threshold requirements specify that the cleanup action should:

- Protect human health and the environment (WAC 173-340-360(2)(a)(i));
- Comply with cleanup standards specified in WAC 173-340-700 through WAC 173-340-760 (WAC 173-340-360(2)(a)(ii));
- Comply with applicable state and federal laws (WAC 173-340-360(2)(a)(iii)); and
- Provide for compliance monitoring (WAC 173-340-360(2)(a)(iv)).

The other requirements cited in the MTCA regulations (WAC 173-340-360(2)(b)) specify that the cleanup action should:

- Use permanent solutions to the maximum extent practicable (WAC 173-340-360(2)(b)(i)), as determined by the requirements of WAC 173-340-173-340-360(3);
- Provide for a reasonable restoration time (WAC 173-340-360(2)(b)(ii)), as determined by the requirements of WAC 173- 340-360(4); and
- Consider public concerns (WAC 173-340-360(2)(b)(iii)).

For remediation of impacted groundwater, MTCA requires that, if practicable, a permanent cleanup action must be implemented to achieve CULs at the standard POC. If it is not practicable to implement a permanent groundwater cleanup action, the following requirements are specified by the MTCA regulations (WAC 173-340-360(2)(c)(ii)(A) and WAC 173-340-360(2)(c)(ii)(B)):

- Treatment or removal of the source area must be conducted for liquid wastes, highly impacted areas, highly mobile constituents, or hazardous constituents that cannot be reliably contained.
- Light nonaqueous-phase liquid (LNAPL) must be removed using normally accepted practice.
- If DNAPL is present, source containment may be appropriate if the DNAPL cannot be recovered.
- Groundwater containment shall be implemented to the maximum extent practicable to control lateral and vertical expansion of the affected groundwater volume.

Cleanup actions that rely on engineering controls to achieve remedial objectives must also incorporate appropriate institutional controls developed and implemented in accordance with WAC 173-340-440. Additionally, cleanup actions must prevent or minimize present and future constituent releases and shall not rely primarily on dilution and dispersion to attain the cleanup standard unless the incremental costs of active remedial measures over the costs of dilution and dispersion grossly exceed incremental benefits achieved by active remediation [WAC 173-340-360(2)(g)]. If remediation levels are used in a cleanup action, the regulations require that it be demonstrated that more permanent actions are not practicable and that the action using remediation levels meets all regulatory requirements and is protective of human health and the environment. The use of remediation levels has not been proposed for this Site.

The preferred remedial alternative identified by this FS must be capable of meeting the above regulatory requirements.

Permanent solutions are defined as solutions "… in which cleanup standards of WAC 173-340-700 through 173-340-760 can be met without further action." Ecology's goal in obtaining a permanent solution is to reduce potential risks that may be posed by hazardous substances present at a site, either by destroying, immobilizing, or by otherwise rendering the substances nontoxic. As noted in the regulations, Ecology recognizes that permanent solutions are not always practicable; the MTCA regulations have provided for implementation of nonpermanent remedies provided that applicable regulatory requirements are met and the solution is approved by Ecology.

The MTCA regulations outline the identification of permanent solutions and provide a framework for accepting nonpermanent solutions, including conducting a disproportionate cost analysis, as described at WAC 173-340-360(3)(e).

Restoration time frame is the time required to achieve the cleanup standard. The regulatory requirements for assessing the reasonableness of the restoration time for a cleanup action are described at WAC 173-340-360(4). In determining a reasonable restoration time frame, the following factors must be considered:

- Potential risks to human health and the environment and the toxicity of Site constituents (WAC 173-340-360(4)(b)(i));
- Practicability of achieving a shorter restoration time (WAC 173-340-360(4)(b)(ii));
- Current and future land use for the Site and surrounding area (WAC 173-340-360(4)(b)(iii) and (WAC 173-340-360(4)(b)(iv));
- Availability of alternative water supplies (WAC 173-340-360(4)(b)(v));
- The effectiveness and reliability of institutional controls (WAC 173-340-360(4)(b)(vi));
- The ability to control and monitor the migration of hazardous substances from the Site (WAC 173-340-360(4)(b)(vii));
- The toxicity of the hazardous substances at the Site (WAC 173-340-360(4)(b)(viii)); and
- Proven natural processes that reduce concentrations of Site constituents (WAC 173-

340-360(4)(b)(ix)).

In assessing the restoration time for this FS, it is necessary to assess the technical capability of achieving restoration. The remediation alternatives considered in this FS and presumptive remedies established by the U.S. Environmental Protection Agency (EPA) will be reviewed to assess the capability to fully restore the Site. As noted in WAC 173-340-360(4)(d), any remedial action that cannot achieve Site CULs is considered an interim measure.

In addition to the regulatory issues related to the MTCA regulations, corrective actions at the Site must be performed in accordance with the Facility RCRA Permit and applicable RCRA regulations.

4.1.3 Disproportionate Cost Analysis

The MTCA regulations will be followed to determine whether certain types of remediation are warranted at the Site following a disproportionate cost analysis 173-340-360(3)(e). A frequently cited example of a disproportionate cost is a landfill where the large volumes of refuse, typically with a wide variety of contaminants, could be cleaned up only by excavating and moving the refuse to another engineered landfill. The costs to remove all refuse to a different landfill are disproportionate to the reduction of risk. The landfill case has been adopted by EPA as a presumptive remedy, in that the model remedy assumes that the landfill would be left in place and the appropriate remedy is capping. Ecology follows the EPA presumptive remedy approach for landfills.

MTCA's disproportionate cost analysis can be performed quantitatively or qualitatively. For this FS, the qualitative approach to disproportionate cost analysis is appropriate and further described in Sections 6 and 7.

4.1.4 Points of Compliance

POCs for soil and groundwater are discussed in Section 3.2. Permanent alternatives capable of attaining CULs at the point of compliance are preferred.

4.1.5 Source Area Characteristics

Complete removal of the source area would require treatment of the entire Silt Layer underneath the former tank farm in the central area of the Site and would require major site-disturbing activities, such as excavation (see Section 5 for limitations of in situ remediation technologies). As a result, the remediation alternatives proposed in Section 7 assume CULs for groundwater would be met in 1 to 30 years, depending on the alternative. Since the risk to receptors is limited (given the shrinking COC plume in the Shallow Groundwater Zone and long distance for natural degradation of COCs in the Lower Aquifer with little chance to expose potential receptors) the alternatives proposed meet the MTCA requirements of a reasonable restoration time frame [173-340-360 (4)].

4.2 Remediation Objectives

The remediation objectives presented in the FS and approved by Ecology can be applied to the entire Site. General remediation objectives applicable to the Site are summarized as follows:

- Prevent direct contact with surface or subsurface soil and inhalation of dust from surface soil affected with COCs at concentrations that exceed industrial CULs (not groundwater protection standards) or reduce the risks associated with these exposure pathways to acceptable levels.
- Reduce subsurface VOC concentrations to levels that will not pose a threat to industrial indoor air quality or reduce risks associated with inhalation of vapors from affected soil or groundwater to acceptable levels established in accordance with MTCA regulations.
- Reduce, as practicable, COC mass.
- Protect human and ecological receptors by reducing COC concentrations in affected soil and by meeting groundwater CULs at the CPOC within a reasonable time frame.
- Support current and future industrial use of the property.
- Attain remedial objectives as soon as possible and cleanup standards within a reasonable time frame.
- Use all practicable methods of treatment in the Site cleanup.

5.0 POTENTIALLY APPLICABLE REMEDIAL TECHNOLOGIES

This section presents the potentially applicable remediation technologies considered in the revised FS. Technologies were re-evaluated based on updated state of practice since the 2013 FS was submitted. Several technologies are now included that had not been previously evaluated in the 2013 FS. Because the revised FS is intended to be a focused FS, only those technologies that show the greatest potential to satisfy the Site remediation objectives were retained for development of remedial alternatives.

Potentially applicable remediation technologies are considered in the revised FS to address the exposure pathways associated with concentrations of COCs in soil and groundwater. A wide range of potentially applicable technologies were selected for evaluation relative to the specific remediation considerations for the Site. A summary of the remediation technologies considered for the revised FS for soil and groundwater are provided in Tables 5-1 and 5-3, respectively. The results of the technology screening are presented in Table 5-2 for soil and in Table 5-4 for groundwater. A list of the retained technologies for both soil and groundwater is presented in Table 5-5.

Often a disproportionate cost analysis is conducted as part of an FS to aid in evaluating permanence of a potential clean action. WAC 173-340-360(f) outlines evaluation criteria to be used in such an analysis. These criteria provide a helpful framework for evaluating technologies against site-specific conditions and have therefore been incorporated in the screening. Cost is one of the seven criteria under the DCA framework, but was not used as a basis for retention or rejection of a technology in Tables 5-2 and 5-4.

5.1 Technology Screening Criteria

The technologies described in Tables 5-1, 5-2, 5-3, and 5-4 were screened to identify those technologies best suited for potential use in developing remedial alternatives for the Site. The applicability of each technology was considered in light of:

- Remediation objectives presented in Section 4.2;
- Updated data on technology performance (with heavier weight given to peer reviewed and government agency provided literature, as well as data regarding implementation of technologies performed under similar geologic and hydrologic conditions); and
- Physical Site characteristics.

Potential remediation technologies were screened based on the following four screening criteria:

1. **Technology Development Status (bench, pilot, or full scale):** This criterion refers to the level of development for the technology in addressing the COCs observed at the Site. Technologies with full-scale implementation are favored over less developed technologies, such as those that have shown limited effectiveness at treating the COCs observed at the Site or that are still in early stages of development (such as technologies only tested in

bench-scale or pilot studies).

2. **Performance Record:** This criterion refers to the technology's record of successfully attaining the remediation objectives established for the technology in prior implementations for projects with similar site conditions. Factors to evaluate include ability to achieve CULs, the time required to meet the CULs, and the ability to meet the CULs without the potential for future re-contamination (i.e., mobilization of contaminants). Technologies successfully implemented in a variety of environmental and geologic settings (especially environments similar to the Site) are favored over technologies with a more restricted application record.
3. **Contaminants Addressed:** This criterion refers to the constituents the technology is capable of addressing. Only technologies demonstrated capable of addressing the specific constituents in the specific media of interest (soil or groundwater) are retained for the FS.
4. **Implementability within the Constraints of the Site:** This criterion refers to the ability to be implemented including consideration of whether the alternative is technically possible, availability of necessary off-site facilities, services and materials, administrative and regulatory requirements, scheduling, size, complexity. Monitoring requirements, access for construction operations and monitoring, and integration with existing Facility operations and other current and potential remedial actions. Technologies requiring minimal access and simpler permitting are favored over technologies requiring extensive permitting or access to numerous locations. Technologies that require significant infrastructure (permanent wells, extensive piping runs, public and private easements, and access agreements) might be difficult to implement due to the associated logistical and administrative challenges; it is possible that in select cases some of these technologies might not be practicably implementable. Technologies that support and build on the documented natural degradation of VOCs are favored over those technologies that arrest or interrupt this natural degradation. However, technologies that arrest or interrupt natural degradation are not discounted if they achieve CULs.

5.2 Soil Remediation Technologies

Several proven remediation technologies have been considered as appropriate candidates for remediation of soils at the Site (Table 5-1). Soils requiring treatment at the Site are primarily within the Silt Layer underlying the shallow sand fill since the 1997 interim action removed the majority of the shallower contaminated soils in the former tank farm area. Table 5-1 summarizes the results of technology screening including technology development status, performance record, and contaminants addressed and lists the areas at the Site that would be addressed using each technology. Table 5-2 summarizes the results of technology screening for implementability within the constraints of the Site and includes the results of screening (retain or reject) for each technology.

The technologies addressed by the screening process summarized in Table 5-1 and Table 5-2 include both in situ and ex situ biological, chemical, and physical processes that would result in destruction, removal, or containment of contaminants. In situ remediation technologies for soil are described in Section 5.2.1, and ex situ technologies are described in Section 5.2.2. Technologies are grouped into general response actions in the tables depending on the category of treatment each technology encompasses. General response action categories separate treatment methods into technologies that may be implemented in situ versus ex situ and whether the technology employs physical (i.e., excavation or containment), chemical, or biological techniques.

5.2.1 In Situ Remediation Technologies

In situ technologies for remediation of soil are implemented without excavation and removal of soils and with minimal disturbance to soil. These technologies rely upon techniques to alter subsurface conditions and promote remediation of COCs present in the subsurface. In situ technologies are generally better suited for remediation in highly developed areas, active production facilities, and areas with deep or widely distributed contaminants.

5.2.1.1 Bioventing

Bioventing stimulates the natural biodegradation of aerobically degradable compounds in soil by providing oxygen to existing soil microorganisms. Bioventing uses low air flow rates to provide only enough oxygen to sustain microbial activity. Oxygen is most commonly supplied through direct air injection into areas of residual contamination in soil, frequently through a system of small-diameter wells or permanent injection points.

Soil permeability to air must be adequate to permit the flow of air throughout the contaminated soil mass. Excess soil moisture or a high water table can inhibit movement of air. Soil must also contain the basic nutrients necessary to sustain an active microbial culture capable of degrading contaminants. Bioventing is most effective on fuel hydrocarbons and nonhalogenated VOCs. Its applicability to inorganics is very limited. This technology would potentially target VC in the Shallow Groundwater Zone. Monitoring for soil vapors must be conducted while implementing bioventing to assess potential migration of volatile compounds into indoor air. Vapor monitoring requirements on the Stericycle property would not need to be protective of all areas regularly occupied by workers. Vapor monitoring would potentially be required in the lab/warehouse building and possibly in the temporary buildings at the Stericycle property. Due to the shallow depth to groundwater, the volume of vadose zone soils at the Site to implement bioventing is very limited, and implementation of this technology would be further complicated by seasonal fluctuations in groundwater elevation.

For these reasons this technology was rejected for use in the FS.

5.2.1.2 Enhanced Bioremediation

Enhanced bioremediation is an in situ process in which indigenous microorganisms (e.g., existing soil fungi, bacteria, and other microbes) degrade organic contaminants found in Site soil, converting them to innocuous end products. Nutrients, electron donors or acceptors, or other amendments may be used to enhance bioremediation and contaminant desorption from subsurface materials. In the presence of sufficient oxygen (aerobic conditions) and other nutrient elements, microorganisms will ultimately convert many organic contaminants, such as VC, to carbon dioxide, water, and microbial cell mass.

To create optimal conditions for aerobic degradation to progress, oxygen is added to the subsurface in the form of oxygen-releasing compounds (ORC). With sufficient carbon sources to act as electron donors (such as existing organics in soil or added carbohydrates) and reducing conditions, anaerobic microorganisms will dechlorinate halogenated VOCs. To be successful, biodegradation must degrade COCs and yield end products of low toxicity.

Enhanced bioremediation of soil typically involves the percolation or injection of water mixed with nutrients and saturated with dissolved oxygen or reducing agents (such as zero-valent iron [ZVI] or electron-donor compounds) into the subsurface. Enhancements to the approach can include addition of acclimated microorganisms (bioaugmentation) and/or alternative oxygen sources, such as hydrogen peroxide or aboveground aeration chambers. An infiltration gallery or spray irrigation is typically used to address shallow impacted soils, and injection wells are frequently used for deeper contaminated soils. This technology would be considered for use to address all soils impacted by chlorinated VOCs beneath the former tank farm area.

Enhanced bioremediation is a long-term technology that may require a number of years to accomplish remedial goals. In some cases, bioremediation rates diminish before remediation goals are met, leaving residual COCs in place at lower concentrations, but potentially at concentrations that still exceed CULs. Enhanced bioremediation has been demonstrated effective for nonhalogenated VOCs and the lighter, nonhalogenated SVOCs as well as fuel hydrocarbons. It has not been proven effective on inorganics in soil and only moderately effective for halogenated VOCs. Frequently, groundwater capture systems are required to capture infiltrating aqueous solutions that are applied to stimulate biological activity.

On the basis of these limitations, this technology is not considered applicable and has been rejected for use in the FS.

5.2.1.3 Phytoremediation

Phytoremediation is a set of processes that uses plants to destroy or remove contamination in groundwater. Plants can be used for phytoremediation in several ways, including enhanced rhizosphere biodegradation, phyto-degradation, and phyto-volatilization. Enhanced rhizosphere biodegradation utilizes natural substances released by plant roots to supply nutrients to microorganisms, which enhances their ability to biodegrade organic contaminants. Phyto-degradation is the metabolism of contaminants within plant tissues, and phyto-volatilization occurs as plants take up water containing organic contaminants and release the contaminants through transpiration. Some

COCs, such as metals, may be immobilized by adsorbing to the root zone of plants. This technology relies primarily upon biodegradation to achieve remediation objectives with some limited plant uptake and transpiration. Recalcitrant and mobile COCs (such as 1,4-dioxane) would not be effectively remediated using this approach.

Phytoremediation can address organic contaminants including petroleum hydrocarbons, halogenated compounds, and pesticides. The technology can also address some inorganic compounds, such as metals.

Phytoremediation is not as effective at remediating areas with high contaminant concentrations, and the success depends on several environmental factors, including weather, maintenance of the plants, and a large enough distribution of plants to cover the target areas. Given that the Site is an active industrial property, limited areas could be treated, as the number of plants and areas requiring treatment would interfere with current and future Facility operations (the former tank farm and east of Building 1). In addition, plants would require harvesting and potentially special disposal depending on the plants' uptake of the COCs. During the cold seasons, plants are less effective at removing COCs from the groundwater, especially where transpiration is the primary treatment method. Phytoremediation is a long-term technology that may require a number of years to accomplish remedial goals. Therefore, this technology is retained for potential use as a contingent remedy to remove residual COCs in soil.

5.2.1.4 Chemical Oxidation

In situ chemical oxidation (ISCO) involves application of a chemical oxidant, such as permanganate, ozone, persulfate, Fenton's Reagent, hydrogen peroxide, or a proprietary formulation of these agents[3], into the subsurface to react with organic contaminants. By-products of the ISCO reaction are nonhazardous compounds that are more stable, less mobile, and/or inert (Siegrist, 2000). ISCO results in rapid and complete chemical destruction of many toxic organic chemicals and some inorganic constituents; other organic species are amenable to partial degradation as an aid to subsequent bioremediation. In general, the oxidants have been capable of achieving high treatment efficiencies (e.g., > 90 percent) for unsaturated aliphatic (e.g., TCE) and aromatic (e.g., benzene) compounds, with rapid reaction rates under ideal conditions and in homogeneous soils. Although typically applied to impacted groundwater, chemical oxidants may also be applied to vadose zone soils through the use of infiltration galleries, vertical or horizontal injection wells, mechanical mixing, or direct-push injection points with forced advection to rapidly move the oxidant into the subsurface.

[3] One such proprietary formulation is RegenOx, which involves combining slow-release hydrogen peroxide and Fenton's Reagent to form radicals that serve to oxidize the COCs.

The rate and extent of oxidation of a targeted COC are dictated by several factors: (1) the properties of the COC itself; (2) susceptibility of the COC to oxidative degradation; and (3) the matrix conditions, most notably the concentration of organic carbon and of other oxidant-consuming substances (including natural organic matter, such as the organic Silt Layer, reduced minerals, carbonate, and other free radical scavengers). Given the relatively indiscriminate and rapid rate of reaction of the oxidants with reduced substances, the method of delivery and distribution throughout a subsurface region is of paramount importance. Subsurface heterogeneities and preferential flow paths may result in inefficient treatment. Dispersion and groundwater advection assist groundwater ISCO treatment systems in achieving oxidant contact with contaminants. In the vadose zone, however, distribution of the oxidant relies solely on injection under pressure and vertical migration, resulting in the need for more closely spaced injection points.

Oxidation reactions can decrease the soil pH if the system is not adequately buffered. Other potential oxidation-induced effects include mobilization of redox-sensitive and exchangeable sorbed metals, possible formation of toxic by-products, evolution of heat and gas, and interference with biological activity.

This technology would be applied to impacted vadose zone soils in the areas located beneath the former tank farm and east of Building 1. ISCO would target all Site COCs with the exception of metals. The limited depth of the vadose zone (less than about 6 feet) would limit the cost effectiveness of this technology; an extensive distribution network would be needed to distribute reactant, and the limited depth would result in a high cost for treating a small soil volume. For most of the Site, access would be readily available, and the significant safety concerns that arise from handling the hazardous chemicals needed for chemical oxidation could be addressed. However, safety issues from handling hazardous oxidation chemicals would be significant in areas that are actively used for industrial purposes, such as around Building 1.

Chemical oxidation may result in generation of oxygen in the subsurface, reduction in pH of the soil, and the oxidation of electron donors in the subsurface. In addition, the temporary increase in redox potential of the soil may shift conditions from methanogenic conditions, which are associated with reductive dehalogenation. Reductive dehalogenation of chlorinated VOCs has already been documented at the Site and is contributing to decreasing COC concentrations.

Despite these limitations, this technology was retained for soil remediation because it is one of the few technologies capable of treating the majority of Site COCs simultaneously.

5.2.1.5 Soil Flushing

In situ soil flushing induces the extraction of contaminants from the soil matrix by water or other aqueous solutions, depending on the contaminants being targeted. Soil flushing is accomplished by passing the extraction fluid through in-place soils using injection wells, an injection gallery, or other infiltration process in conjunction with extraction wells to prevent off-site migration of the extracted COCs. The extraction fluids must be recovered from the underlying aquifer and treated, recycled, or disposed as waste. Flushing can be accomplished using water mixed with a variety or extraction fluids, such as surfactants, organic solvents, or chelating agents.

A groundwater recovery system to capture the extraction fluid and the desorbed contaminants must be operated in conjunction with the soil flushing operation. This technology has been shown to be effective for inorganics, VOCs, and SVOCs. Soil flushing has been successfully applied on only a few sites at full scale and is not generally commercially available.

Recovered groundwater and flushing fluids with the desorbed contaminants would need to be treated to meet appropriate pretreatment standards prior to discharge to the City of Washougal publicly owned treatment works (POTW). To the maximum extent practicable, recovered fluids used in the soil flushing process are typically reused. The separation of the flushing agents from recovered flushing fluid for reuse in the process is a major factor in the cost of soil flushing. Treatment of the recovered fluids results in process sludge and residual solids, such as spent carbon and spent ion-exchange resin, which must be appropriately treated before disposal. Air emissions of volatile contaminants from recovered flushing fluids may need to be collected and treated, as appropriate, to meet applicable regulatory standards. Residual flushing additives in the soil may also be a concern.

Implementation of this technology at the Site would have varying degrees of success, depending on the contaminants being targeted and the soils being treated. To cover the full range of COCs at the Site, different flushing agents would be required in varying quantities to effectively remove COCs. To remove metals, a combination of a pH reduction solution and a chelating agent would be required to desorb and transport the metals to the extraction wells. To treat organics, a co-solvent or a surfactant would be required, depending on the hydrophilic/hydrophobic properties of the COC.

The success of soil flushing is a function of underlying soil characteristics, including organic carbon content and permeability, which determine the degree to which the flushing agent is transported throughout the contaminated areas. Given that a large percentage of the mass of COCs are present in the confining Silt Layer at the Site (a highly impervious layer), this technology would only address a small percentage of the COCs present, as the most active source to ongoing groundwater contamination is located in the Silt Layer (AMEC, 2013). As noted above for chemical oxidation, an extensive distribution and collection system would be required to distribute the soil-washing reagent throughout the vadose zone and the Lower Aquifer and collect it for treatment or disposal.

This technology would be applied at the Site in the vadose zone soils underneath the former tank farm area and east of Building 1.

Due to the limited effectiveness of this technology for the soil characteristics at the Site, the COC locations, and the extensive infrastructure requirements for implementation, this technology has been rejected from further consideration.

5.2.1.6 Soil Vapor Extraction

The use of in situ soil vapor extraction (SVE) has a long and successful history for remediation of source area VOC-impacted soils within the vadose zone. SVE has been proven to reduce levels of volatile constituents in the subsurface by desorption of VOCs from soil and nonaqueous-phase liquid (NAPL), volatilization of constituents from groundwater, and removal of soil gas. Systems for implementing SVE typically consist of several vapor extraction wells installed in the source area vadose zone to collect soil gas. The soil gas is usually drawn from the vapor extraction wells to a manifold using a blower, with the blower discharge typically treated by carbon adsorption or thermal oxidation.

In the Site soil, SVE would target the residual vadose zone source area to remove both halogenated and nonhalogenated VOCs, which may contribute to ongoing groundwater contamination. These vadose zone areas on Site are assumed for the areas around the former tank farm and east of Building 1. Removal of VOCs from the vadose zone can be rapid, usually being complete within 1 to 2 years for a properly designed SVE system. Implementation of SVE is intrusive in that many wells and a gas collection manifold are typically required. Treatment of the extracted soil gas is typically included to limit emissions and reduce potential exposure of onsite workers and off-site receptors to COCs in the extracted vapors. An air emissions permit may be required to install and operate an SVE system. The vadose zone at the Site is generally less than 6 feet thick, which limits the spatial/lateral extent of the effectiveness of individual vapor extraction wells.

This technology could address and remediate the key volatile COCs in the vadose zone at the Site, including chlorinated ethenes, TPH constituents, and chlorinated propanes. However, it would not be effective for metals or SVOCs. The limited depth of the vadose zone within all soil remediation areas would limit the radius of influence of individual SVE wells, thereby necessitating more wells to achieve effective treatment.

For better effectiveness, SVE in the vadose zone would likely be combined with air sparging to remediate contaminants in the smear zone, but sparging would likely disrupt ongoing anaerobic reductive dehalogenation in groundwater. Addition of excess oxygen into the anaerobic zones in the groundwater may temporarily reduce the degradation of halogenated VOCs through reductive dehalogenation as the facultative aerobic bacteria tend to out-compete the obligate anaerobic bacteria for nutrients in the presence of sufficient oxygen (it is typically more energetically favorable to use oxygen as the terminal electron acceptor rather than the chlorinated compound) (Madigan et al., 2012).

The primary source of ongoing contamination at the Site is the Silt Layer, which would not be treated through the use of a stand-alone SVE system. Moreover, concentrations of chlorinated VOCs in shallow groundwater at the Site have generally been declining, which suggests that the smear zone is no longer acting as a major source to the Shallow Groundwater Zone.

Due to the limited vadose zone, the declining concentrations of chlorinated VOCs in the Shallow Groundwater Zone, the possible disruption of ongoing anaerobic biodegradation, and the limited effectiveness of this technology for some Site COCs, SVE as a stand-alone technology has limited, if any, application for this Site and has been rejected from further consideration. However, SVE in combination with other treatment methods to volatilize VOCs will be retained and is discussed below under the relevant headings.

5.2.1.7 Solidification/Stabilization

In situ stabilization involves promoting chemical reactions/environmental conditions that may chemically immobilize COCs, reduce the solubility of COCs, or convert COCs into a less toxic form (primarily through oxidation/reduction reactions). In situ solidification involves encapsulation of COCs in the soil by decreasing the conductivity of the contaminated soil through mechanical or chemical treatment. Chemical treatment may include the addition of solidifying reagents, such as cement, kiln dust, or fly ash, or addition of a reductant, such as ZVI, to address chlorinated organics. The chemical agents can be introduced into the subsurface by injection or by mechanically mixing the agent into the soil (i.e., in situ soil mixing).

Encapsulation or immobilization would primarily be effective for metals and not for organic compounds. In order for the technology to be effective, the reactants must be uniformly and completely distributed throughout the matrix and brought into direct contact with the inorganic and/or organic COCs. Stabilized metals in the subsurface can be effectively immobilized with a very long effective treatment life. Although this technology does not destroy COCs or remove contaminants from the soil matrix, chemicals (typically oxidizing or reducing agents) can be added to the mixture to destroy COCs.

The volume of affected soil at the Site would require an extensive distribution of fixation chemicals to effectively immobilize metals in Site soil. For in situ soil mixing, this would require demolition of several surface and subsurface structures within the affected areas. The addition of cement or other stabilization additives may also cause a 20 percent to 25 percent increase in soil volume, create significant volumes of waste to manage or resulting in substantial changes in Site topography.

In situ soil mixing at the Site would be used to target metals and organics in the vadose zone and silts in and around the former tank farm area and Building 1. However, soil cleanup standards for the source areas would not be met with this technology because metals would remain in Site soils and be subject to erosion. In situ soil mixing with chemical treatment is discussed further in Section 5.3.23 as a technology to address groundwater.

Although difficult and expensive to implement, in situ soil stabilization could be effective in immobilizing metals and reducing organic constituents

5.2.1.8 High-Temperature Volatilization

High-temperature volatilization remediation technologies consist of heating contaminated soil in order to volatilize organic contaminants. Heating can be achieved by injection of steam or hot air, by radio-frequency heating, or by electrical resistance heating. Heating enhances the release of contaminants from the soil matrix. Some VOCs and SVOCs are stripped from the contaminated zone and brought to the surface through SVE. The extracted soil vapor may in turn be treated using granular activated carbon (GAC) or another treatment method.

High-temperature volatilization can be effective for VOCs and many SVOCs; however, it has little to no effect on inorganic constituents. High soil moisture content (e.g., within the capillary fringe) tends to hinder this process, requiring significantly more energy to achieve the desired soil temperatures. Because the technology requires SVE for off-gas collection and treatment, an air emissions permit would be required to govern the off-gas treatment process. Treatment residuals include accumulated liquid (soil moisture and contaminants) and spent GAC, if used to manage SVE emissions. Depending on the exact technology used, some soil contaminants would likely remain in the subsurface due to non-uniform heating or strong sorption.

Implementation of this technology in areas occupied by industrial workers could create unacceptable inhalation risks if mobilized vapors are not completely collected and controlled. Careful selection of specific technologies would be necessary to avoid creating adverse impacts on underground utilities, such as fiber optic cables, gas lines, sanitary sewers, or any plastics sensitive to heating that may be used in underground utilities. However, this technology has been shown to be very effective for use in silt or clay, especially in source areas with high concentrations of COCs.

For the Site, this technology would be implemented in and around the former tank farm area and underneath and around Building 1 to target organics.

This technology is most cost effective for very high source area concentrations, when soils would otherwise require treatment or off-site disposal. This technology is less cost effective when concentrations are lower and the contaminants are more diffuse. While the vadose zone lies entirely within the Sand Fill unit, this technology is being retained for treatment of the Silt Layer and the Lower Aquifer. As part of a combined system for simultaneous soil and groundwater remediation this technology is much more cost effective. Implementation of this technology would cause major disruption to Facility operations during installation, but operational disruption would be minimal as it could address COCs under Building 1 while industrial activities continue at the Facility. For these reasons, this technology has been retained for use in the FS.

5.2.1.9 Cap/Surface Cover

Various caps and surface covers can be used to minimize exposure at the surface to waste materials, to reduce vertical infiltration of surface water into wastes that could generate contaminated leachate, and to control gas emissions from waste containing VOCs. Caps can also provide a useful surface for various land uses, such as golf courses, parking areas, and warehouses. For many sites, a cap/surface cover is combined with subsurface barrier walls to provide a comprehensive engineered barrier to effectively contain affected soil.

Typical cover designs for industrial facilities include Portland cement concrete or asphalt pavement. These cover systems effectively convey surface water to collection systems and definitively reduce contact with soils, encourage runoff to reduce infiltration, and prevent human exposure to underlying soil or waste. These rigid or semi-rigid caps allow the Site to be maintained in productive use by allowing for structures to be constructed and vehicles and equipment to be operated. Flexible membrane liners and compacted clay or bentonite liners are more conventionally applied to landfill caps, where large areas prone to differential settlement must be graded, sloped, covered, vegetated, and managed over the long term with limited use of the area after capping. A variety of subsurface barriers can be combined with caps, including slurry walls, sheet-pile walls, grout curtains, cement-bentonite walls, soil-cement walls, or barrier walls constructed of proprietary materials such as Impermix®.

The Stericycle property consists of a patchwork of concrete, gravel, and asphalt covering. A cap/cover system would minimize human exposure to underlying waste materials, limit erosion and runoff of impacted soil, and reduce (but not eliminate) infiltration of surface water (thereby reducing the potential for soil COCs to leach into groundwater). Either a new cover or restoration of existing cover at the Site could be installed to cover areas around the former tank farm area, Building 2, and Building 3, and west of the waste oil tank system. Installing a more impermeable cover in areas currently covered only with soil may improve the overall effectiveness of the current cover system. Capping/surface cover has been retained as a potential technology for the FS.

5.2.2 Ex Situ Remediation Technologies

Remediation of soil using ex situ technologies requires excavation of affected soil for treatment using above grade techniques. These technologies are typically used only for remediation of shallow hotspots rather than for widely distributed or deep contamination.

5.2.2.1 Biopiles

Biopile treatment is a full-scale technology in which excavated soils are mixed with soil amendments and placed on a treatment area that includes leachate collection systems and some form of aeration. It is primarily used to reduce concentrations of petroleum constituents in excavated soils via biodegradation. Moisture, heat, nutrients, oxygen, and pH can be controlled to enhance biodegradation.

The treatment area would generally be covered or contained with an impermeable liner to minimize the risk of contaminants leaching into uncontaminated soil. Runoff from the biopile is collected and may itself be treated in a bioreactor before recycling. Vendors have developed proprietary nutrient and additive formulations and methods for incorporating the formulation into the soil to stimulate biodegradation. The formulations are usually modified for site-specific conditions.

Biopile treatment has been applied to treatment of nonhalogenated VOCs and fuel hydrocarbons. Halogenated VOCs, SVOCs, and pesticides also can be treated, but the effectiveness of the process varies, and biopiles may be applicable only to some compounds within these constituent groups. Biopile treatment requires excavation of affected soil and a sufficiently large open area to hold the piles for treatment. The limited area available to conduct biopile treatment at the Stericycle property would make implementation of this technology difficult. Additionally, biopile treatment of soil would cause VOCs to volatilize, creating significant short-term risks of vapor exposure. Biopile treatment would primarily remediate BTEX, leaving the halogenated VOCs and metals untreated.

This treatment technology would be used to treat BTEX in soils within the vadose zone around the former tank farm area and east of Building 1. Soils treated using biopiles would require appropriate engineering controls if the soils were returned to the excavations. If the treated soil is not returned to the excavations, it would be necessary to dispose of the material in a secure landfill. Biopiles would provide only incomplete treatment of soil at the Site, and therefore the highly invasive excavation needed to implement this technology is not justified, since other more effective and cost-effective technologies are evaluated. This technique has therefore been rejected for use as a soil remediation technology.

5.2.2.2 Soil Washing

In soil washing, contaminants sorbed onto fine soil particles are separated from bulk soil on the basis of particle size in an aqueous-based system. The wash water may be augmented with a basic leaching agent, surfactant, pH adjustment, or chelating agent to help remove organics and heavy metals. The process removes contaminants from soils in one of two ways:

- By dissolving or suspending contaminants in the wash solution, or

- By concentrating contaminants into a smaller volume of soil through particle size separation, gravity separation, and attrition scrubbing (similar to techniques used in sand and gravel operations).

A complex mixture of contaminants in the soil and heterogeneous contaminant compositions throughout the soil mixture make it difficult to formulate a single suitable washing solution that can consistently and reliably remove all of the different types of contaminants. Soil washing is generally considered a media transfer/volume reduction technology. The contaminated water generated from soil washing must be ultimately treated and disposed. This process may also create concentrated treatment residuals that require land disposal.

For the Site, this technology would address vadose zone soil areas in and around the former tank farm and east of Building 1. Site COCs that would be targeted with this technology would be halogenated VOCs, non-halogenated VOCs, and some metals.

As noted above, in situ soil flushing was rejected as a potential technology (Section 5.2.1.4). Ex situ soil washing would provide only partial remediation of soils in the Site and would require invasive and expensive excavation. Although the constituents treated by this technology are different from those that would be treated by bioremediation in biopiles, the degree of remediation achieved would be similar (i.e., many COCs would remain in soils, requiring appropriate post-treatment management). For these reasons, this technology has been rejected as a soil remediation technology.

5.2.2.3 Solidification/Stabilization

Similar to in situ solidification/stabilization, with ex situ solidification/stabilization contaminants are physically bound or enclosed within a stabilized mass (solidification), or chemical reactions are induced between the stabilizing agent and contaminants to reduce their mobility. Some of the most successful and commonly used stabilization agents are pozzolans (primarily composed of silicates from pozzolanic-based materials, such as fly ash, cement kiln dust, pumice, or blast furnace slag) and Portland cement. These materials chemically react with water to form a solid matrix that improves the handling and physical characteristics of the waste. They also raise the pH of the water, which may help precipitate and immobilize some heavy metal contaminants. Pozzolanic and cement-based binding agents are typically appropriate for inorganic contaminants. These binding agents have limited effectiveness with organic contaminants, especially VOCs. Nuisance conditions (dust, noise, odors) and loss of VOCs to air may occur during implementation of this technology.

Ex situ solidification/stabilization would be implemented for the vadose zone and Silt Layer soils in and around the former tank farm area. Ex situ solidification/ stabilization would target the inorganic metals.

Ex situ solidification/stabilization would require large site disturbances to remove and stabilize soils in the source areas and in some cases would require deep excavations to remove the source soils as they are predominately in the Silt Layer at depths of greater than 6 feet bgs. In addition, ex situ solidification/stabilization would require large quantities of stabilized soil to be disposed of offsite, as soil volumes typically increase between 20 and 30 percent. Removal of the soil would likely require dewatering and contaminant water treatment operations, and this process would have the potential to release VOCs into the air at potentially hazardous levels. Because in situ soil mixing is more cost effective and creates less disturbance, in addition to the issues described above, ex situ solidification/stabilization is not considered feasible to treat contaminated soils at the Site. Ex situ solidification/stabilization has been rejected as a potential remediation technology in the FS.

5.2.2.4 Thermal Desorption

Thermal desorption is a physical separation process designed to volatilize water and organic contaminants by heating the excavated soil, and thereby remove contaminants from the adsorbed phase in the soil. In this process, wastes (excavated soil) are heated, and a carrier gas or vacuum system transports the volatilized water and organics to a gas treatment system. The bed temperatures and residence times designed into thermal desorption systems volatilize selected contaminants, but typically do not oxidize them. Higher temperatures are required to volatilize SVOCs than VOCs. Thermal desorption alone is not intended to destroy organic contaminants, although the secondary vapor treatment may include incineration of the organic vapors to create carbon dioxide and water vapor.

Two common thermal desorption designs are the rotary dryer and the thermal screw. Rotary dryers are horizontal cylinders that can be either indirect or direct fired. The dryer is normally inclined and rotated. For the thermal screw units, screw conveyors or hollow augers are used to transport the medium through an enclosed trough. Hot oil or steam circulates through the auger to indirectly heat the medium. Depending on air emissions, thermal desorption systems may require treatment of the off-gas to control emissions of particulates and the volatilized contaminants. Particulates are removed by conventional particulate removal equipment, such as wet scrubbers or fabric filters. Contaminants can be removed through condensation followed by carbon adsorption, or they can be destroyed in a secondary combustion chamber or catalytic oxidizer. Most thermal desorption units are transportable. This technology can be operated as either low- or high-temperature thermal desorption (depending on the COCs).

The target contaminant groups for low-temperature thermal desorption systems are usually nonhalogenated VOCs and fuels, although chlorinated VOCs can also be treated. The technology can be used to treat SVOCs and pesticides at reduced effectiveness or at higher temperatures. Volatile metals, such as arsenic or mercury, may be removed by high-temperature thermal desorption systems, but these metals complicate emission control. The presence of chloride can affect the volatilization of some metals, such as lead.

This technology could successfully address chlorinated VOCs if operated at higher temperatures (600-1000 degrees Fahrenheit [ºF]). Unless thermal desorption is operated at very high temperatures, this technology would likely not achieve cleanup standards for the non-volatile inorganics, such as most metals.

Thermal desorption would be used at the Site to address contaminated soils in the vadose zone and Silt Layer in and around the former tank farm and east of Building 1.

Thermal desorption is a very costly alternative that requires large amounts of energy to achieve high temperatures and an external vapor collection and treatment system. It also does not remove most metals in contrast to other alternative physical treatment methods (such as excavation and off-site disposal). Given the high cost compared to other technologies and the difficulty in implementation, this technology has been rejected for use in the FS as a soil remediation technology alone, but is considered for groundwater and the Silt Layer (see Section 5.3.11).

5.2.2.5 Excavation and Off-Site Disposal

Excavation and off-site disposal involve excavation of either all or selected hotspot areas of soil that exceed preliminary CULs. Excavation could potentially include removal of soil to target all COCs. The excavated soil would be stockpiled, characterized, and transported and disposed off-site. New clean fill would be placed in the excavation and compacted to restore the Site to pre-existing grade. Dewatering would be required to remove the full extent of impacted soils, and a rock ballast layer with geotextile fabric may need to be installed to stabilize the soft, wet bottom of the excavation prior to backfilling. Excavation of the contaminated soil beneath the water table would require extensive dewatering of the area and an associated water treatment system. In addition, excavation of portions of the Site would be impossible due to the existing buildings on the Stericycle property, which are expected to remain staffed during remediation activities.

Unlike many of the other ex situ remediation methods, excavation with off-site landfill disposal would comprehensively address all soil COCs.; however, excavation is limited to hotspots that are not located immediately adjacent to or underneath buildings. For example, further excavation in the former tank farm area has been ruled out from all alternatives as it would require demolition of the existing Building 1, shutdown of the Facility, excavation below the water table, and associated water treatment. Thus, excavation of remaining source area soils is only feasible for areas not occupied by existing buildings.

Excavation requires the disposal of excavation spoils off-site. The costs associated with the disposal of dangerous waste can be extremely high. In addition, significant short-term risks would be created due to dust generation, volatilization of COCs, and transportation of impacted soils. Nevertheless, this technology would address all COCs in the excavated areas and may be utilized in isolated areas, and therefore has been retained for the FS.

5.3 Groundwater Remediation Technologies

Several general technologies have been considered to address groundwater impacts within the Shallow Groundwater Zone and Lower Aquifer (Table 5-3). Table 5-3 summarizes the results of the technology screening as discussed in Section 5.1 and lists the areas at the Site that would be addressed using each technology. Table 5-4 provides detailed discussion of site-specific issues affecting the remedial technology and implementability for the Site, including the screening results (retain or reject) for each technology.

Technologies are categorized in the tables by the method of treatment they encompass (chemical, biological, physical, etc.), under a heading called general response actions. General response actions group the treatment methods into technologies that may be implemented in situ or ex situ and technologies that employ physical (i.e., excavation or containment), chemical, or biological techniques. Ancillary or support technologies as outlined in Tables 5-3 and 5-4 are technologies used in conjunction with another primary treatment technology as a support measure. A list of the retained groundwater remediation technologies is presented in Table 5-5.

5.3.1 Enhanced Biodegradation by Biosparging

Enhanced biodegradation by biosparging involves injection of air into groundwater to provide oxygen and increase the aerobic biological activity of the indigenous microorganisms. Compressed air is supplied to groundwater using vertical or horizontal wells screened below the depth of affected groundwater. The injected air forms bubbles in the groundwater, which then rise to the unsaturated zone, effectively delivering oxygen to the entire column of groundwater above the injection depth. This technology can be implemented either as a biobarrier to provide a reactive zone within the groundwater flow path, or as a distributed system addressing source areas and the aerial extent of impacted groundwater. Horizontal wells are best suited for implementation as a biobarrier, while vertical wells could be used for a biobarrier or for a distributed approach. Both horizontal and vertical wells must be placed appropriately to span the target area for affected groundwater. Placement of vertical wells is typically determined by the aeration radius observed during pilot testing.

This technology performs well for organic compounds that can be readily degraded aerobically, including VC. The technology does not work well for most halogenated VOCs that degrade via anaerobic degradation pathways. It also is ineffective for 1,4-dioxane. Potential problems associated with biosparging include possible volatilization of constituents that may affect air quality in surrounding buildings, the potential for chemical fouling of biosparge wells due to high iron concentrations in groundwater that may precipitate upon oxidation, and/or fouling by excessive biological growth adjacent to the aeration well(s). The presence of natural iron in Site groundwater would create an oxygen demand that would increase the amount of air that must be supplied to the groundwater to successfully degrade VC. Aerobic biodegradation is not known to be effective for TCE without the addition of a co-metabolic inducer; aerobic conditions may actually slow the degradation rate for TCE, which is currently being actively biodegraded at the Site by reductive dechlorination.

This technology would be implemented at the Site around the former tank farm area and east of Building 1 in both the Shallow Groundwater Zone and the Lower Aquifer where VC is a COCs. At the request of Ecology, this technology has been retained for consideration in the FS for the treatment of VC. However, technologies that provide more complete treatment are generally more cost-effective, and therefore are preferred over this technology.

5.3.2 Oxygen Enhancement with Hydrogen Peroxide or ORC®

Oxygen to support aerobic degradation of VC and other COCs amenable to aerobic biodegradation can be delivered to impacted groundwater using chemicals, such as Oxygen Release Compound (ORC®) or hydrogen peroxide. As noted above, aerobic biodegradation is not effective for 1,4-dioxane and halogenated VOCs.

ORC is a proprietary chemical developed and sold by Regenesis, Inc.; similar products are offered by other vendors. ORC is a peroxide compound that slowly degrades in water, thereby releasing oxygen. Hydrogen peroxide is a highly reactive, oxidizing compound that rapidly decomposes in water, releasing oxygen. Chemical oxygenation technology differs from the other aerobic bioremediation technologies only in the means for delivery of oxygen to the groundwater. Chemical oxygenation requires storage of the chemical to be introduced to groundwater, a means to feed the chemical at the proper rate, and a means to distribute the chemical to the impacted groundwater.

Chemical oxygenation using hydrogen peroxide requires injection of the chemical into groundwater. This can be done by slowly feeding the chemical into vertical wells and relying on passive diffusion to deliver oxygen to the aquifer or by withdrawing groundwater, adding peroxide or ozone, and re-injecting the groundwater. The passive method would have similar advantages and disadvantages to other passive oxygenation methods.

The most widely used approach for oxygenation by ORC is to suspend a bag containing the ORC in a vertical well. The ORC slowly dissolves, delivering oxygen to the groundwater near the well by passive diffusion. The ORC must be replaced periodically to maintain a continuous source of oxygen. This would result in a limited radius of influence for each well, both laterally and vertically. The technology is not typically implemented in horizontal wells due to the need to periodically replace the ORC pouch and the limited vertical radius of influence that would be created by passive diffusion.

Implementation of this technology for the Site would require a high density of vertical wells with placement of ORC at multiple depths in each well. Regular access would be required to each of the oxygenation wells to replenish the ORC. No mechanical equipment other than the wells would be needed for this approach to oxygenation.

Hydrogen peroxide is a strong oxidant and is classified as a hazardous, reactive chemical. Hydrogen peroxide is sold as a liquid; its use would require storage at the injection point(s) and periodic transport to deliver fresh chemical for injection. It is corrosive and can react spontaneously with organic materials or reduced compounds. Hydrogen peroxide can spontaneously react when in concentrated form.

As mentioned above, oxygenation of groundwater will only aid in the biological remediation of nonhalogenated VOCs. Furthermore, the addition of excess oxygen into the anaerobic zones in the groundwater may temporarily reduce the rate of degradation of chlorinated VOCs through reductive dehalogenation as the facultative aerobic bacteria tend to out-compete the obligate anaerobic bacteria for nutrients in the presence of sufficient concentrations of oxygen (it is typically more energetically favorable to use oxygen as the terminal electron acceptor compared to the chlorinated compound) (Madigan et al., 2012). The magnitude and duration of this interference would depend on the quantities, durations, and frequency of injections of oxygen into the target areas, the concentrations of the oxygen-demanding substrates, and the ability of the bacterial population to rebound from the disturbance.

Although this technology is not preferred because of its limited application at the Site, it has some potential for use in isolated areas and has been retained. Oxygenation of groundwater could potentially be applied in the Shallow Groundwater Zone and the Lower Aquifer around the former tank farm area and east of Building 1, where VC has been identified as a COC.

5.3.3 Co-Metabolic Treatment

Chlorinated solvents have been biologically degraded under aerobic conditions using in situ co-metabolic processes. Co-metabolic aerobic degradation can be accomplished by injecting a hydrocarbon substrate, such as ethane, along with oxygen into the subsurface. The co-metabolic process has been demonstrated through passive diffusion using the in Situ Oxygen Curtain (iSOC^{TM}) process or through groundwater recirculation systems using the Super-Ox^{TM} technology.

These technologies have been shown to promote the degradation of PCE, TCE, *cis*-1,2-DCE, and VC, but are generally less effective for nonhalogenated VOCs and 1,4-Dioxane and ineffective for metals. Drawbacks of the technology include the potential for biological or chemical fouling of wells and equipment and the potentially explosive conditions created when combining oxygen and a flammable hydrocarbon substrate.

Co-metabolic treatment would be implemented at the Site in both the Shallow Groundwater Zone and the Lower Aquifer around the former tank farm area and east of Building 1, where chlorinated VOCs are COCs.

This technology creates significant safety hazards due to the need for simultaneous handling of a fuel gas and pure oxygen. In addition, given the source area in the silts beneath Building 1, it would be difficult and costly to implement this technology to address the source area. This technology would also require a complex injection and distribution system to inject the two gases and distribute them throughout the subsurface. The gases would be difficult to distribute into the Silt Layer given the much lower permeability of the Silt Layer compared to the Shallow Groundwater Zone and the Lower Aquifer. As discussed in Section 5.3.2 for injection of ORC or other oxygen-releasing compounds, injections of oxygen gas would oxygenate the subsurface and likely temporarily disrupt the anaerobic biodegradation process currently occurring for the chlorinated VOCs. While safety precautions can be taken, significant potential for fire or explosion would remain under any conditions.

Because of these shortcomings, this technology is rejected for use in both the Shallow Groundwater Zone and the Lower Aquifer.

5.3.4 Biostimulation of Reductive Dechlorination (Anaerobic)

Biostimulation of reductive dechlorination involves injecting a carbohydrate electron donor (e.g., molasses, sodium lactate, or vegetable oil) into the affected groundwater to create reducing conditions and enhance naturally occurring reductive dechlorination processes. This is a proven technology with a substantial history of success in a variety of applications. The carbohydrate could be injected with wells, direct-push probes, or groundwater recirculation systems. Groundwater recirculation systems could use vertical or horizontal wells. This approach could be implemented as either a reactive zone to treat a source area or as a biobarrier to intercept and treat groundwater as it moves downgradient.

This technology would likely address PCE, TCE, *cis*-1,2-DCE, and VC. It would also contribute to the degradation of many nonhalogenated VOCs, as they may be used as electron donors under reducing conditions, but anaerobic degradation for these constituents is slow. Reductive dechlorination would not address inorganics (metals) or 1,4-dioxane in groundwater. In addition, mobilization of metals due to reducing conditions created by anaerobic biostimulation may temporarily increase the concentrations of metals in groundwater. However, since groundwater conditions are already strongly reducing at and downgradient from the Stericycle property, it is not expected that biostimulation of reductive dechlorination would substantially affect the concentrations of metals in groundwater.

Natural bioattenuation of VOCs is already occurring at the Site as is evidenced by the strong downward trend in concentrations of VOCs in the Shallow Groundwater Zone. This trend also indicates that indigenous organisms can support reductive dechlorination of chlorinated organic COCs. However, in a pilot test performed near MC-14 (Section 2.5), using HRC as an electron donor was not clearly effective, indicating some other limiting factor may be inhibiting further biodegradation activity. Further sampling to assess the possible limiting nutrients should be completed prior to any further attempts to enhance anaerobic biodegradation at the Site. Injection of other amendments into the impacted groundwater could potentially be needed to maintain conditions favorable for enhanced reductive dechlorination. This technology could be applied alone or in conjunction with aerobic bioremediation to comprehensively address groundwater constituents that biodegrade under both aerobic and anaerobic conditions.

Enhanced anaerobic bioremediation through biostimulation has been retained for consideration in the FS. This technology addresses the chlorinated VOCs and is compatible with ongoing natural biological processes in affected groundwater in both the Shallow Groundwater Zone and the Lower Aquifer. This technology will be considered for areas around the former tank farm, underneath Building 1, and east of Building 1.

5.3.5 Bioaugmentation

Bioaugmentation is an in situ remedial technology in which a biological seed culture, specifically adapted for degradation of the constituents of interest, is introduced to the impacted groundwater. Bioaugmentation could be conducted using anaerobic or aerobic biological seeds.

Under anaerobic conditions, the microorganism *Dehalococcoides ethogenes* must be present for dechlorination of VC to ethene. For bioaugmentation technology, a microbial culture containing *Dehalococcoides ethogenes* would be added to the impacted groundwater to promote full reductive dechlorination. Injection wells are typically used for injecting the microorganisms. The culture added to the subsurface would then compete with indigenous organisms for nutrients and substrate. For many bioaugmentation applications, the added organisms do not compete successfully with indigenous organisms. Due to the ongoing natural attenuation occurring within both the Shallow Groundwater Zone and the Lower Aquifer, it is expected that indigenous organisms are present that effectively degrade COCs at the Site and that bioaugmentation could enhance biodegradation in these zones.

Due to the use of oxygen and injection wells, aerobic bioaugmentation technology would encounter the same issues of iron fouling and biofouling as discussed in Section 5.3.1. For either anaerobic or aerobic bioaugmentation technologies, permitting to allow injection would be required and may be complex due to introduction of a nonnative biological organism if they are not currently present. The bacterial strain introduced by bioaugmentation processes is typically not fully adapted to the local environment; therefore, the bioaugmentation seed may require periodic or continual addition in order to maintain a viable population and effective bioremediation.

This technology would be considered for areas around the former tank farm, underneath Building 1, and east of Building 1 to address PCE, TCE, *cis*-1,2-DC, and VC.

Aerobic bioaugmentation has been rejected for the use as a groundwater remediation technology in the Shallow Groundwater Zone due to its potential to interfere with anaerobic processes that are actively degrading halogenated VOCs in affected groundwater. Although biodegradation is active at the Site, anaerobic bioaugmentation has been retained for possible use should future testing confirm that the degradation of COCs is stalling.

5.3.6 Monitored Natural Attenuation

Monitored natural attenuation is a proven technology that has been effective in reducing contaminant concentrations in groundwater when appropriate conditions are present. This process relies on the attenuation of groundwater constituents by natural processes, including biodegradation, abiotic degradation, adsorption, and dilution. This technology is combined with a long-term monitoring program designed to be sufficiently robust to monitor the progress of natural attenuation toward meeting cleanup objectives. Due to the passive nature of this remedial technology, it can be readily implemented with a minimum of institutional issues, such as permitting or arranging for access permissions, and also would have minimal potential for implementation problems, such as fouling.

The potential drawbacks of sole reliance on this technology include potentially longer remediation periods when compared to active groundwater remediation technologies. Selected COCs, including metals and 1,4-dioxane, present within the Site may not be amenable to natural attenuation.

Biodegradation of chlorinated solvents present at the Site is currently observed and accounts for the presence of VC in groundwater. Natural attenuation, including substantial biodegradation, is currently occurring throughout the Site as is evidenced by degraded VOC concentrations observed during long-term monitoring in the Shallow Groundwater Zone wells coupled with the evidence of the key attenuation parameters, such as daughter compounds. Monitored natural attenuation may be used either in conjunction with or following implementation of more active groundwater remediation technologies at a site. When implemented following more active remedial technologies, it is often referred to as monitored attenuation (MA). Selection of a remedial strategy for the Site will include consideration of processes that have limited negative impact on the natural attenuation process.

Natural attenuation may also serve as one component of a comprehensive remedial alternative considered for this FS that includes active treatment.

Monitored natural attenuation has been retained as a technology for both the Shallow Groundwater Zone and the Lower Aquifer for all areas of the Site with organic or chlorinated COCs. Natural attenuation is currently active at the Site, and for many of the most significant COCs, natural attenuation provides a permanent approach for remediation.

5.3.7 Phytoremediation

Phytoremediation is a set of processes that uses plants to destroy or remove contamination in groundwater. Plants can be used for phytoremediation in several ways, including enhanced rhizosphere biodegradation, phyto-degradation, and phyto-volatilization. Enhanced rhizosphere biodegradation utilizes natural substances released by plant roots to supply nutrients to microorganisms, which enhances their ability to biodegrade organic contaminants. Phyto-degradation is the metabolism of contaminants within plant tissues, and phyto-volatilization occurs as plants take up water containing organic contaminants and release the contaminants through transpiration. Some COCs, such as metals, may be immobilized by adsorbing to the root zone of plants. This technology relies primarily upon biodegradation to achieve remediation objectives with some limited plant uptake and transpiration. Recalcitrant and mobile COCs (such as 1,4-dioxane) would not be effectively remediated using this approach.

For the Site, phytoremediation would be implemented for the Shallow Groundwater Zone along the north and east sides of the property and along the east side of the property for the Lower Aquifer. Phytoremediation at the Site would primarily target metals and VOCs in the Shallow Groundwater Zone and Lower Aquifer. Use of the technology in the Lower Aquifer would require the installation of conductor casing to allow groundwater to contact the root zone of the plants.

Phytoremediation is not as effective at remediating areas with high contaminant concentrations, and the success depends on several environmental factors, including weather, maintenance of the plants, and a large enough distribution of plants to cover the target areas. Given that the Site is an active industrial property, limited areas could be treated, as the number of plants and areas requiring treatment would interfere with current and future Facility operations (the former tank farm and east of Building 1). In addition, plants would require harvesting and potentially special disposal depending on the plants' uptake of the COCs. During the cold seasons, plants are less effective at removing COCs from the groundwater, especially where transpiration is the primary treatment method. Given that the Stericycle property is an active industrial facility, with seasonal weather variations that will affect plant performance, and the large and disperse contaminant distribution at the Site, other technologies are expected to achieve CULs at the POC faster and be a more permanent solution. Therefore, this technology has been retained for use as a contingent remedy for remediation of the Shallow Groundwater Zone and Lower Aquifer.

5.3.8 Carbon Augmentation

Carbon augmentation is an in situ technology and has been successfully used for treatment of chlorinated solvents, and other VOCs. The technology reduced COC mass by sequestering contaminants with an affinity for carbon, but relies on contact with constituents and good distribution within the subsurface to be effective. This technology is based on injection of nano-carbon into the impacted groundwater or addition to excavations (at or below the water table) before backfill. Injection of the carbon can be accomplished using direct-push techniques, injection wells, or recirculation wells and can migrate within the subsurface for further disbursement.

This technology is ineffective for treatment of 1,4-dioxane and may exacerbate release of metals with the addition of a carbon source to the subsurface. Delivery of the carbon within the Silt Layer would be difficult and might limit the potential use of this technology. Dependent on groundwater COC concentrations and other competing compounds (iron), the carbon augmentation may have a short active period before the adsorptive capacity of the product is depleted.

Based on the limited effectiveness and potential for exacerbating metals concentrations, this technology has been rejected for potential application.

5.3.9 Air Sparging

Air sparging is an in situ technology in which air is injected through a contaminated aquifer. The injected air traverses horizontally and vertically in channels through the soil column, creating an in situ air stripper that removes contaminants by volatilization. This injected air helps to flush (bubble) the contaminants up into the unsaturated zone, where a vapor extraction system is usually implemented in conjunction with air sparging to remove the generated vapor-phase contamination. Oxygen added to contaminated groundwater and vadose zone soils can also enhance aerobic biodegradation of contaminants below and above the water table.

Implementation of an air sparging system at the Site would require installation of numerous air sparging wells and vapor extraction systems to recover VOCs. As noted above, the Site has a limited vadose zone to attempt capture. VOCs that are not captured could potentially result in a vapor intrusion threat to occupants of Building 2 or Building 3 and workers located above or near the air sparging and collection system. Additionally, this technology will not treat the groundwater for 1,4-dioxane. As discussed above for other technologies that involve the addition of air or oxygen to the subsurface, the oxygen added to the water could have adverse effects on the natural anaerobic degradation process that has been documented to be occurring within areas containing elevated levels of VOCs (specifically chlorinated ethenes). The addition of air may not only inhibit the anaerobic degradation pathway of the chlorinated VOCs, but may also transport some of the VOCs downgradient through condensation of the soil gas.

Despite the limitations of this technology, it has been retained for consideration in the FS to address VOCs (but not 1,4-dioxane) in the Shallow Groundwater Zone in the areas around the former tank farm and east of Building 1.

5.3.10 Chemical Oxidation

Chemical oxidation has the potential to treat various COCs in groundwater across the Site and can be implemented as active chemical oxidation or passive chemical oxidation. These methods are discussed in section 5.3.10.1 and 5.3.10.2, respectively.

5.3.10.1 Chemical Oxidation – Active

Active chemical oxidation has been successfully used for in situ treatment of chlorinated solvents, and other VOCs. Oxidants that have been used include potassium permanganate, hydrogen peroxide, ozone, persulfate, and Fenton's reagent. This technology is based on injection of the chemical oxidant into the impacted groundwater or addition to excavations (at or below the water table) before backfill. Injection of the chemicals can be accomplished using direct-push techniques, injection wells, or recirculation wells. This technology is typically considered only for treatment of highly impacted source areas; the technology is not well suited for use in dilute groundwater plumes. High doses of reactant chemical would be required, and low utilization efficiencies would be achieved for dilute plumes, thereby resulting in high remediation costs.

Hydrogen peroxide, ferrous sulfate, and permanganate (potassium or sodium) are generally purchased and stored as a liquid, which must be metered into the groundwater. However, ferrous sulfate, sodium persulfate, and potassium permanganate can be purchased as a solid and dissolved onsite prior to injection into the groundwater. Ozone can be generated onsite using specialized equipment. In addition, proprietary chemicals, such as Regenox (manufactured by Regenesis, Inc.), can be purchased. These chemical oxidants are all reactive, hazardous chemicals that require proper design and management to be used safely.

Although chemical oxidation may effectively degrade chlorinated solvents in groundwater, it would alter existing subsurface conditions that are necessary for natural biodegradation processes in all areas affected by the oxidant, temporarily suppressing the natural anaerobic biodegradation processes currently occurring in impacted groundwater. In addition, the technology is effective only when the oxidant is directly in contact with COCs. Delivery of the oxidant within the Silt Layer would be difficult and might limit the potential use of this technology. The organics and peat within the Silt Layer would also react with the oxidant, reducing the treatment effectiveness or potentially releasing metals.

Some COCs are recalcitrant to chemical oxidation. However, all of the key COCs, including

1,4-dioxane, can be effectively remediated using this technology. 1,4-Dioxane concentrations at concentrations similar to those observed at the Site were reduced in pilot studies by 90 percent through the use of sodium persulfate (Houston et al., 2009). The use of hydrogen peroxide in conjunction with ozone was able to reduce 1,4-dioxane concentrations by varying percentages, in a study performed by the EPA (Yunker, 2007).

Based on its effectiveness in pilot trials at sites with 1,4-dioxane concentrations similar to those observed at the Site, this technology has been retained for potential application. Chemical oxidation would be implemented to address VOCs and SVOCs (including 1,4-dioxane) at the Site in both the Shallow Groundwater Zone and the Lower Aquifer in the areas around the former tank farm and east of Building 1.

5.3.10.2 Chemical Oxidation – Passive

Passive chemical oxidation is similar to active chemical oxidation in treatment of COCs with the primary difference being implementation. The oxidizing chemical is suspended in a monitoring well on an inert media to passively diffuse oxidizer for treatment of contaminants. This technology is typically considered only for treatment of dilute groundwater plumes.

The inert media is generally purchased with the selected oxidizer already impregnated and ready for deployment into a well. Passive media is available with many of the same oxidizing chemicals available under active chemical oxidation. These chemical oxidant-impregnated membranes are all reactive and hazardous and require proper management to be used safely.

Diffusion of oxidant into the groundwater by the passive media would follow preferential pathways and treatment of COCs within the silt is unlikely. The oxidant would preferentially treat dilute groundwater concentrations due to back diffusion from the silt within the Shallow Groundwater Zone and Lower Aquifer and require multiple applications to maintain oxidant presence for continuous treatment.

Based on the Site groundwater flow conditions, challenges to addressing remaining COC source, and effectiveness in pilot trials at sites with 1,4-dioxane and chlorinated VOC concentrations similar to those observed at the Site, this technology has been rejected for potential application.

5.3.11 Thermal Treatment

Thermal treatment involves heating the saturated zone to volatilize contaminants, which would be collected from the vadose zone using SVE. Methods to heat the saturated zone include adding steam through injection wells, direct soil heating, electrical resistive heating (ERH), or a combination of these technologies, known as dynamic underground stripping (DUS). All of these methods heat the aquifer to vaporize volatile and some semivolatile contaminants in groundwater that are sorbed to soil.

Direct soil heating involves installation of thermal wells that are heated and conduct heat into the surrounding soil to vaporize contaminants. ERH involves application of a current from subsurface electrodes and relies on the natural resistance of the aquifer to create heat to vaporize contaminants. Vaporized components rise to the vadose zone, where they are removed by SVE and then treated. The process can be used to remove large portions of oily waste accumulations and to retard downward and lateral migration of organic contaminants.

High-molecular-weight constituents (e.g., polycyclic aromatic hydrocarbons [PAHs]) and nonvolatile constituents (e.g., inorganics) are not effectively remediated by this technology. Depending on the amount of heat added to the subsurface, 1,4-dioxane can be volatilized and then collected and treated in the SVE system through the use of thermal oxidation. The process is potentially applicable to shallow and deep contaminated areas.

Thermal treatment can be implemented at a site using readily available mobile equipment. Some versions of this technology that employ higher temperatures applied to the subsurface may interfere, at least temporarily, with ongoing biodegradation processes occurring at the Site. However, lower temperature versions have been shown to actually speed up biodegradation processes, once the active heating has been stopped. Treated soils and aquifer materials remain at elevated temperatures for years following cessation of active heating. This elevated temperature may initially impede biodegradation, but as the subsurface cools, biodegradation may actually increase substantially compared to previously existing conditions. In follow-up to a pilot-scale implementation of DUS at a Lawrence Livermore National Laboratory site, groundwater temperature within the treatment area was found to be approximately 100º F when measured 10 years after the last DUS treatment.

Implementation of this technology is generally difficult in active facilities due to operational disturbances during installation and system operations. Use within the Former Tank Farm Area of the Site would be further complicated due to the existing structures. Due to the high permeability of the Shallow Groundwater Zone and Lower Aquifer and the low permeability Silt Layer, thermal heating would be further complicated due to the need to slowly heat the Silt Layer to prevent drying around the heating elements, increasing operation run times and water generation from the more permeable units. Thermal treatment is most effective in highly impacted source areas and would be a somewhat effective in situ treatment for key COCs, including VOCs and the less volatile 1,4-dioxane. Since the source area in the former tank farm area has already been excavated, the remaining COCs are at lower concentrations, for which thermal methods are less cost effective. Although implementation would be difficult, it could be used under existing structures.

This technology would likely be used at the Site by heating the subsurface to approximately 100 degrees Celsius (ºC) under the former tank farm area and Building 1. VOCs and SVOCs (including 1,4-dioxane to a limited extent) would be treated using this technology in the Shallow Groundwater Zone, Silt Layer and the Lower Aquifer at this temperature (TRS, 2020). According to vendors of this technology (TRS Group), heat dissipates approximately 10 feet beyond the heated area. Given the heat capacity of the soil and groundwater and the distance to Steigerwald Marsh from the source areas (approximately 200-300 feet downgradient), heat would migrate to the marsh, and carry the potential risk of adverse effects on the marsh. In addition, a slight increase in temperature downgradient of the source area would improve degradation of the chlorinated VOCs as degradation rates increase with slight increases in temperature. Another possible side effect, is creating soluble and bioavailable total organic carbon, which has benefits (as food to increase biodegradation) and potential complications (creating reducing conditions for dissolution of metals like arsenic.)

Although this technology would be difficult to implement on the active facility, it has been retained due to its ability to address COCs in both the Silt Layer and the Lower Aquifer below the former tank farm and east of Building 1.

5.3.12 In-Well Stripping

In-well air stripping is a process that has been proven in some applications for removal of VOCs from groundwater. Recirculation zones are created within the aquifer by injecting air into a specially designed vertical well with two or more screened sections. Compressed air is introduced into the well above the lower screen to simultaneously aerate the groundwater and strip volatile organics. The injected air reduces the density inside the well, causing groundwater to enter the deep screen and exit the well through the upper screen section. Volatile constituents present in the groundwater are transferred to the air, which flows up the well to a vapor collection system. Air vented from the well may require treatment by oxidation or adsorption systems to control emissions. The oxygenated groundwater created within the recirculation zone would also promote aerobic microbial activity to enhance biodegradation processes for constituents that degrade aerobically.

For the portions of the Site where chlorinated solvents were found, such as in the vicinity of the former tank farm and east of Building 1, the oxygenation of groundwater that occurs using this technology may interfere with the active natural anaerobic biodegradation processes that have been documented to be occurring in affected groundwater at the Site. However, in-well air stripping would create an aerobic zone conducive to degradation of VC and nonhalogenated VOCs. In addition to the potential to interfere with existing natural biological processes within the Site, other potential problems associated with in-well stripping include chemical fouling due to high iron concentrations in groundwater. In-well air stripping would not remediate several COCs, such as metals and 1,4-dioxane. In addition, other treatment technologies that are thought to be more effective for the shallow zone have been retained, such as chemical oxidation and enhanced biodegradation. Because of these issues and the considerations mentioned above, in-well air stripping has been rejected.

5.3.13 Passive/Reactive Treatment Walls

Permeable reactive barriers (PRBs) using zero-valent iron to chemically reduce chlorinated solvents are proven to be effective for groundwater remediation. This technology is typically implemented as a reactive barrier to destroy COCs migrating in impacted groundwater away from the source area. This technology would not remediate 1,4-dioxane.

In order to make this technology cost-effective, a zero-valent iron PRB is typically implemented as a funnel and gate system, in which a low-permeability barrier wall “funnel” is placed within the flow path of the affected groundwater to direct flow to the zero-valent iron “gate,” where the reaction occurs. Site constraints and the location of the COCs (Silt Layer) are not conducive to implementation of a “funnel and gate”. Due to the general downward hydraulic gradient through the Silt Layer, injectable zero-valent iron would be placed at the interface of the Shallow Groundwater Zone and Silt Layer and the interface of the Silt Layer and Lower Aquifer to passively treat COCs diffusing from the Silt Layer. This implementation would effectively “sandwich” the source area and allow long term treatment of the slow release of COCs from the Silt Layer. The zero-valent iron has been proven to reduce chlorinated solvents, such as TCE and *cis*-1,2, DCE, and VC and precipitate metals such as arsenic. This approach would be minimally invasive to implement using injections and could have a significant effect on reducing concentrations of groundwater COCs.

In general, PRBs are potentially applicable immediately downgradient of TCE or PCE source areas to remediate chlorinated VOCs; thus, targeted use of PRBs might be useful in reducing migration of contaminated groundwater beyond the Stericycle property boundary. For these reasons, PRBs have been retained for consideration for both the Shallow Groundwater Zone and the Lower Aquifer to treat the plume in the in the former tank farm area and area to the east of Building 1.

5.3.14 Groundwater Extraction and Treatment (Pump and Treat) -Hydraulic Control & Mass Reduction

Groundwater extraction followed by ex situ treatment has two possible applications at the Site: (1) COC mass removal, and (2) hydraulic control to prevent downgradient migration of impacted groundwater. For either application, this technology requires the installation of extraction wells to intercept impacted groundwater. Extracted groundwater would then be treated and either re-injected or discharged to surface water. For the surface water discharge configuration, the treated groundwater would either be discharged to the POTW or discharged to surface waters via a National Pollutant Discharge Elimination System (NPDES) permit. The local POTW does not accept groundwater for treatment by default. However, they would likely accept groundwater with sufficient pretreatment coordinated and approved by Ecology. Discharge to the POTW would be the preferred option for the Site due to the expense required to treat the extracted groundwater to the more stringent NDPES discharge limits. In addition, significantly greater operation and maintenance (O&M) costs would be required to meet the higher treatment standards for re-injection than the less stringent standards for discharge to the POTW. Extraction and treatment processes would likely aerate the groundwater and result in adverse impacts to ongoing natural anaerobic biodegradation processes.

COC mass removal from low the low permeability units would not be practicable. This technology could remove mobile COCs from the groundwater at the Site but is unlikely to remove groundwater COCs to below the preliminary CULs within a reasonable restoration time frame. Pump-and-treat systems are slow at mass removal in general, but at the Site the low rate of remediation would be exacerbated by the fact that the majority of COC mass is present in the lower permeability Silt Layer. Even if extraction wells were placed in the Silt Layer, they would either have very low flow or the wells would preferentially short circuit to the more permeable units above and below the Silt Layer. This technology is best suited for controlling migration of impacted groundwater in the vicinity of source areas. Migration of impacted groundwater could be controlled by implementing hydraulic control with a groundwater extraction program in which impacted groundwater is extracted to establish a hydraulic depression that prevents downgradient migration of groundwater. Groundwater extraction for hydraulic control requires placement of recovery wells (a line of closely spaced vertical wells or a long horizontal well extending laterally across the area of impacted groundwater) to intercept groundwater flow downgradient from source areas. Re-injecting the treated groundwater downgradient of the extraction wells would create a zone of elevated water levels, reinforcing the hydraulic barrier created by the extraction wells. As previously discussed, however, re-injection of the treated groundwater may adversely impact ongoing natural attenuation processes and would have significantly higher O&M costs (compared to discharge to the POTW). Groundwater extraction has been used effectively for source control and for controlling migration of impacted groundwater plumes.

The groundwater extraction system requires pumping of sufficient quantities of groundwater to provide effective containment and then treatment and discharge of the extracted groundwater. For a highly transmissive aquifer, as is present at the Site, large volumes of groundwater would likely need to be extracted to implement a groundwater extraction system to prevent downgradient migration of affected groundwater. Treatment would likely require air stripping for VOCs and media for removal of metals and 1,4-dioxane. These would require an enclosure for freeze protection and likely need to be implemented until source area COCs were treated by other methods or degraded by natural processes.

These technologies would be used at the Site to treat mobile COCs in the vicinity of the former tank farm and to the east of Building 1. O&M of the groundwater treatment system for even a few years would be extremely costly relative to other technologies. For these reasons, mass reduction pump and treat has been rejected for potential application in both the Shallow Groundwater Zone and the Lower Aquifer. Hydraulic containment could be used as an interim measure to limit off-site migration while other remedial technologies are implemented and therefore has been retained.

5.3.15 Dynamic Groundwater Recirculation

Dynamic Groundwater Recirculation (DGR) is a remedial technology that which creates dynamic groundwater flow to enhance the natural flushing process occurring within the impacted groundwater area. This technology requires the installation of extraction and injections wells to create preferential flow paths through the contaminated groundwater area to limit off-site migration of contaminants and increase time for natural biological degradation to reduce overall mass.

The groundwater recirculation system requires pumping of sufficient quantities of groundwater to provide effective containment. For a highly transmissive aquifer, as is present at the Site, large volumes of groundwater would likely need to be extracted to implement a groundwater recirculation system to prevent downgradient migration of affected groundwater.

This technology is best suited for controlling migration of impacted groundwater in the vicinity of source areas. This technology would contain all mobile COCs at the Site, but is unlikely to remove groundwater COCs to below the preliminary CULs within a reasonable restoration time frame. DGR systems are slow at mass removal in general because they depend on natural degradation processes, but at the Site the low rate of remediation would be exacerbated by the fact that the majority of COC mass is present in the lower permeability Silt Layer. Even if extraction wells were placed in the Silt Layer, they would either have very low flow or the wells would preferentially short circuit to the more permeable units above and below the Silt Layer.

This technology would be used at the Site to contain mobile COCs in the vicinity of the former tank farm and to the east of Building 1. O&M of the groundwater treatment system would be ongoing for a long time and would be extremely costly relative to other technologies. For these reasons, this technology has been rejected for potential application in both the Shallow Groundwater Zone and the Lower Aquifer.

5.3.16 Emulsified Zero-Valent Iron

Emulsified zero-valent iron (EZVI) is a remediation technology that has shown potential to treat dissolved-phase chlorinated solvents and DNAPL. EZVI is composed of nano- or micro-scale, ZVI emulsified in biodegradable vegetable oil and a food-grade surfactant (Quinn et al., 2005). The exterior of the oil membrane emulsion droplets has hydrophobic properties similar to DNAPL, and are therefore miscible with DNAPL. Chlorinated VOCs diffuse through the oil membrane and undergo reductive dechlorination in the presence of ZVI. In this reaction, the ZVI is essentially consumed; the ZVI becomes oxidized and has no further reactivity. In addition, the vegetable oil and surfactant in EZVI act as long-term electron donors and promote anaerobic biodegradation. EZVI can be delivered to the subsurface through direct-push injection, or hydraulic or pneumatic fracturing.

This technology presents several potential drawbacks:

- High cost compared to similar in situ technologies (e.g., ISCO); and
- Difficulties in obtaining effective distribution in the subsurface, especially at sites with complex hydrostratigraphy.

In the last 10 years, EZVI has been used to effectively treat metals and chlorinated organics. As part of an enhanced bioremediation program, EZVI may speed remediation time frames by aiding in development of the right geochemistry for organisms to thrive. Since active treatment of the Silt Layer has been requested by Ecology, EZVI has been retained for consideration in the vicinity of the former tank farm, underneath Building 1, and east of Building 1.

5.3.17 Solvent-Enhanced Aquifer Remediation

Solvent-enhanced aquifer remediation (SEAR) is the injection of surfactants coupled with conventional groundwater extraction methods to enhance the recovery of organic contaminants, including DNAPL. Surfactants are injected into the aquifer to increase the aqueous solubility and mobility of contaminants and promote the removal of these contaminants from the subsurface by a pump-and-treat system. Extracted groundwater undergoes ex situ treatment to separate the contaminants and groundwater from the surfactant, which can then be re-injected. Since this technology relies upon mobilizing COCs, the recovery of the surfactant and impacted groundwater is of primary concern for SEAR. Therefore, it is important to fully characterize hydrogeology prior to implementing SEAR. This technology would have limited to low effectiveness for VOCs. It also would not be effective for COCs with high solubility, such as 1,4-dioxane, and would function essentially as a pump-and-treat system. In general, SEAR and similar technologies have not been found to be highly effective, particularly at sites with tightly sorbed constituents (SEAR, 2002).

This technology would be used at the Site in the vicinity of the former tank farm, and underneath and to the east of Building 1, and would target VOCs (not 1,4-dioxane). Implementation of this technology at the Site would present the following potential drawbacks, which are similar to those associated with conventional pump-and-treat systems:

- Subsurface heterogeneities can interfere with the effective delivery and recovery of the surfactant solution. Aquifer heterogeneities may create preferential flow paths and result in significant channeling of the injected fluids, bypassing zones of contamination (Battelle and Duke Engineering Services, 2002).

- Low-permeability soils (such as the Silt Layer) are difficult to treat due to challenges associated with distributing and recovering the surfactants from the soils.

Therefore, SEAR has been rejected for the Shallow Groundwater Zone and the Lower Aquifer.

5.3.18 Co-Solvent Flooding

Co-solvent flooding is similar to, and may be used in conjunction with, SEAR. A co-solvent, typically a low-molecular-weight alcohol such as ethanol or propanol, is injected into the impacted aquifer to enhance the dissolution of DNAPL components into the aqueous phase. The co-solvent and dissolved-phase organics are then recovered with conventional groundwater extraction methods and treated ex situ. The selection of an appropriate co-solvent is an iterative process that involves bench tests and possibly several pilot studies. Due to the highly soluble nature of the co-solvents typically used (i.e., alcohols), this technology may leave very high concentrations of the co-solvent in groundwater. It also would not be effective for COCs with high water solubility, such as 1,4-dioxane. The design and effectiveness of the groundwater recovery component is of primary importance for implementation of this technology.

This technology would be implemented at the Site in the source area near the former tank farm and would target VOCs (but not 1,4-dioxane).

Potential barriers to the implementation of co-solvent flooding at the Site are the same as for SEAR. According to the information available at EPA's remediation technology screening website (EPA, 2009a), co-solvent flooding is difficult to implement in fine-grained soils due to the difficulty of distributing fluids in the soil. Subsurface heterogeneities may result in poor contact of the co-solvent with contaminants, and subsequently, poor mass removal. For these reasons, co-solvent flooding has been rejected for the Shallow Groundwater Zone and the Lower Aquifer.

5.3.19 Physical Containment – Barrier Wall

Containment can be achieved by hydraulic containment, physical containment, or a combination of the two methods. Hydraulic containment is accomplished by operating extraction wells at a rate sufficient to capture affected groundwater and prevent further migration. Hydraulic containment/control technology is discussed in Section 5.3.14. Physical containment requires construction of low- permeability barriers to contain the impacted groundwater or to prevent migration pathways. Barrier walls providing physical containment are frequently used in association with pump-and-treat hydraulic containment. For total containment, placement of a low-permeability (e.g., soil/bentonite) barrier wall keyed into the lower confining unit to physically restrict the flow of groundwater would be required.

Barrier walls have been constructed at some sites to completely enclose impacted groundwater in aquifers, as a partial barrier to reduce groundwater contact with Site COCs, or as a funnel to support use of PRBs or biobarriers. For the Site, the upper Sand Fill unit does not exist downgradient from the Stericycle property boundary, given the marsh located to the east. Therefore, a barrier wall would not be applicable for the Shallow Groundwater Zone. For the Lower Aquifer, no confining layer exists at a reasonable depth. Thus, total containment by physical means alone would not be possible. The only cost-effective ways to implement a barrier wall for the Lower Aquifer would be to install a “hanging” type barrier wall (the bottom of the wall would not be tied into any confining unit) combined with hydraulic control or simply install a partial barrier wall with the goal of reducing COC exposure to groundwater flow. Hydraulic control would add significant cost as noted in Section 5.3.14 above. Prevention of migration pathways could also include grouting of groundwater conduits, such as leaking stormwater lines or other utilities.

Construction of a hanging-type barrier wall to the depth needed at the Stericycle property would require specialized, heavy construction and extensive management to properly place the barrier and to maintain ongoing industrial activities at the Facility. Construction would require utility relocation and power outages, which would disrupt the active industrial operations at the Facility. In addition, since the “hanging wall” barrier wall would not be keyed into an impermeable unit, it would have limited effectiveness in preventing groundwater flow through the contaminated area.

The bedding of the stormwater line to the east of the Stericycle property line that drains from south to the north (just west of South 32nd Street) has been identified as a preferential groundwater flow pathway (or *leaky conduit*), allowing contaminants to migrate off-site (AMEC, 2013). The bedding of the stormwater line consists of gravel that serves as a drain for groundwater to the north of the Site. Grouting the bedding of the stormwater line would prevent contaminant migration to the Gibbons Creek remnant channel (GCRC) to the north of the Site.

Groundwater redirection by grouting highly permeable conduits has been retained for consideration due to its potential to prevent off-site migration of COCs through this preferential flow path. However, due to limited effectiveness, high cost, and management requirements, all other applications of physical containment technology have been rejected for the both the Shallow Groundwater Zone and the Lower Aquifer.

5.3.20 Air Stripping

Air stripping is an ex situ groundwater treatment technology used in pump-and-treat systems. This technology is generally used to support groundwater extraction systems. In air stripping, VOCs in groundwater are removed by conveying large volumes of air counter-current to the groundwater flow. VOCs are volatilized into the air stream, thus reducing their concentration in the water and transferring their mass into the air stream. This technology is not effective for metals or 1,4-dioxane. Generally, pH adjustment of the influent groundwater feed stream or addition of proprietary water treatment chemicals is necessary to minimize the precipitation of minerals on the air stripper. Chemicals in the air stripper off-gas may require further treatment to meet specified permit requirements or may be discharged directly to the atmosphere, depending on mass limitations for atmospheric discharge. It is common to apply granular activated carbon or thermal oxidation to the off-gas for treatment.

Since air stripping is used in conjunction with groundwater extraction and treatment and hydraulic control was retained, this technology has been retained for use in both the Shallow Groundwater Zone and the Lower Aquifer.

5.3.21 Oxidation

Oxidation can be used as an ex situ groundwater treatment technology as part of a pump-and-treat system. This technology is generally used to support groundwater extraction systems, much like air stripping discussed above. With oxidation, a chemical oxidant is added to the groundwater extraction flow to oxidize contaminant mass. The technology is effective for treatment of all key COCs, but reinjection of oxygenated groundwater into the aquifer could impact existing anaerobic degradation and may lead to significant fouling of extraction wells and the subsurface due to high iron concentration present in Site groundwater. Fouling could be controlled through the addition of proprietary water treatment chemicals to minimize precipitation, but may make reinjection of groundwater infeasible.

Since implementation of other oxidation methods are more easily implemented in conjunction with pump-and-treat, this technology has been rejected for use in both the Shallow Groundwater Zone and the Lower Aquifer.

5.3.22 Adsorption

Liquid-phase activated carbon adsorption is a full-scale technology in which groundwater is pumped through one or more vessels containing activated carbon to which dissolved organic contaminants adsorb. This technology is commonly used for groundwater extraction systems. It is effective for most VOCs. It is not effective for most metals, but is effective for some. Carbon adsorption is not effective for 1,4-dioxane. When the concentration of contaminants in the effluent from the bed exceeds a certain level, the carbon can be regenerated in place, removed and regenerated at an off-site facility, or removed and disposed. Carbon used for metals-contaminated groundwater probably cannot be regenerated and should be removed and properly disposed. Adsorption by activated carbon has a long history of use in treating drinking water as well as treating municipal, industrial, and hazardous wastes.

Since hydraulic control has been retained, this technology has been retained for use in both the

Shallow Groundwater Zone and the Lower Aquifer.

5.3.23 Deep Soil Mixing with Chemical Treatment

Deep soil mixing (DSM) is a proven technology that is similar to in situ solidification/stabilization in that chemical treatment is mixed into the soil in situ either by use of large-diameter augers or by mixing with a track-hoe. For groundwater treatment, large-diameter augers are typically used, and chemicals are injected as part of the soil mixing to promote treatment in situ of various contaminants. The soil mixing technology provides a more thorough and homogeneous mixing of the treatment chemicals than simply injecting chemicals via wells or geoprobes. The DSM technology can be particularly appropriate for addressing groundwater within heterogeneous soils and/or lower permeability units, such as the Silt Aquitard at the Site. Deep soil mixing has been used to deliver chemical oxidants, ZVI, and proprietary products, such as ORC and HRC. As such, it can be used to treat a wide variety of COCs depending on the chemical treatment employed.

DSM is a soil improvement technology that can be used to construct cutoff or retaining walls, and can be used to treat groundwater and/or stabilize contaminated soils in situ. DSM is accomplished with a series of overlapping stabilized soil columns (typically 36 to 96 inches in diameter and greater than 40 feet in depth). The stabilized soil columns are formed by a series of mixing shafts that typically number from two to four, guided by a crane-supported set of leads. As the mixing shafts are advanced into the soil, grout or slurry is pumped through the hollow stem of the shaft and injected into the soil at the tip. The auger flights and mixing blades on the shafts blend the soil with the grout or slurry in pug- mill fashion. A cement slurry can be used for stabilization/solidification of the soil resulting in a soil/cement mix. In recent years, DSM has also been used for injection and thorough mixing of chemical additives to treat contaminants within the soil.

For the Site, the use of DSM with injection of either chemical oxidants or ZVI to treat chlorinated solvents will be considered. DSM using treatment technology can also be followed by solidification/stabilization as part of the process.

Auger/caisson systems and injector head systems as well as simply mixing with a track-hoe are other techniques used for in situ DSM. These techniques apply chemical agents to soil and groundwater to trap, treat, or immobilize COCs. Deep soil mixing treatment techniques can be designed to directly target organic compounds. Addition of ZVI with DSM has been used effectively for in situ treatment of chlorinated solvents. Chemical oxidants have also been used with DSM to treat other organic compounds. One advantage of DSM is that it can extend well below the water table. As a result, DSM can be used as a combined soil/groundwater treatment.

Deep soil mixing processes result in a significant increase in soil volume or “swell,” ranging from as low as 10 percent for clean sands to as much as a 100 percent for clays. Reagent delivery and effective mixing are typically the biggest challenges for this technology. However, in some instances, such as in finer grained soils, soil mixing can provide better delivery of chemicals or reagents to the contaminants than other methods. For mixing of ZVI, clay is typically added to the mixing process to provide a more homogeneous mix. Adding clay has the disadvantage that the resulting finished mix has a low compressive strength, and additional ground improvements may be necessary prior to building on the area.

For the Site, this technology has been retained as a technology to be considered to address chlorinated solvents within the former tank farm area. In this application, DSM would be coupled with injection of ZVI and possibly clay to treat in situ solvents within the Shallow Groundwater Zone and the Silt Aquitard.

5.4 Vapor Pathway Remediation Technologies

The indoor air inhalation pathway interim measure was installed in order to prevent workers in Building 1 from exposure to VOCs (Section 2.5).

VOCs, such as TCE and VC, can migrate through the vadose zone from shallow groundwater and accumulate beneath building slabs and foundations. The Silt Layer source area is located beneath Building 1 and may contribute to shallow groundwater contamination through partitioning. Given the shallow depth to the groundwater from the slab of Building 1 (typically 4 to 6 feet, but less in the wet season) and the permeable soil, groundwater VOCs can volatilize into the soil vapor spaces and migrate by diffusion. In addition, soil contamination in the vadose zone may release VOCs into the soil gas phase that may migrate by diffusion toward Building 1. Differences in pressure between the shallow subsurface and building interiors can enhance migration of these VOCs through building slabs and basement walls (including through cracks and joints), potentially causing occupants to inhale these compounds. These pressure differences are typically caused by heating, ventilation, and air conditioning (HVAC) systems, bathroom fans, and other appliances that evacuate air from building interiors.

Preliminary CULs protective of building occupants have been established for groundwater in the Shallow Groundwater Zone. Until these preliminary groundwater CULs are achieved, vapor intrusion mitigation technologies, such as the IPIM, must continue to be implemented and maintained to protect building occupants from unacceptable VOC exposures. Remediation technologies that may be implemented to reduce existing groundwater concentrations below preliminary CULs were discussed in Section 5.3, and a summary of the technology screening is presented in Tables 5-3 and 5-4.

5.5 Technology Screening and Review of Retained Technologies

The retained remediation technologies for soil and groundwater are listed in Table 5-5. The technologies discussed in Section 5.2 and Section 5.3 were screened against the criteria described in Section 5.1 to identify technologies to be used in developing remedial alternatives for soil and groundwater at the Site. The technology screening, including the rationale for retention or rejection, is summarized in Tables 5-2 and 5-4 as well as in Sections 5.2 and 5.3. Technologies were either retained or rejected based on their prior application history, ability to meet the remediation objectives, suitability for conditions at the Site, and an evaluation against the screening criteria presented in Section 5.1. Because this FS is intended to be a focused feasibility study, this technology screening step is intended to produce a short list of only the most applicable, proven, and promising technologies for further consideration.

6.0 REMEDIAL ALTERNATIVES EVALUATION CRITERIA

This section presents the criteria used to evaluate the potential remedial alternatives identified for the Site and select the preferred alternative(s). The potential remedial alternatives are presented in Section 7.0 and were developed using the technologies retained during the initial screening of potentially applicable remediation technologies presented in Section 5.0. The remedial alternatives presented in Section 7.0 were designed to attain the remediation objectives presented in Section 4.2.

6.1 Feasibility Study Evaluation Criteria

As discussed in Section 4.1.2, MTCA (WAC 173-340-360) contains minimum requirements and procedures for selecting cleanup actions including:

- Protect human health and the environment;
- Comply with cleanup standards;
- Comply with applicable state and federal laws; and
- Provide for compliance monitoring.

All remedial alternatives provided in the FS meet the threshold requirements set forth under MTCA. In addition, when selecting from remedial alternatives that meet the threshold requirements, the following three criteria, identified in WAC 173-340-360(2)(b), must be considered:

- **Use permanent solutions to the maximum extent practicable.** A disproportionate cost analysis (DCA) involves comparing the costs and benefits of alternatives and selecting the alternative whose incremental costs are not disproportionate to the incremental benefits. The comparison of benefits and costs may be quantitative, but will often be qualitative and require the use of best professional judgement. General procedures for conducting a DCA is described in Section 7.4.

- **Provide a reasonable restoration time frame.** MTCA preferentially considers remedial alternatives which reduce overall restoration time frame. Factors to be considered in evaluating whether an alternative provides a reasonable restoration time frame are identified in WAC 173-340-360(4)(b).

- **Consider public concerns.** Consideration of public concern has been continually addressed as part of the Site cleanup process under MTCA (WAC 173-340-600) and was incorporated in the preparation of this document. Dependent on public response/comment, revisions to this report may be needed as part of finalization of an FS and concerns will need to be considered as part of the final remedy selection for the Site.

Additional cleanup action requirements are addressed in the remaining portions of WAC 173-340-360(2)(c through h). These are discussed in relation to specific alternatives developed in this FS in Section 7.

A Disproportionate Cost Analysis (DCA) may be conducted to determine whether a cleanup action uses permanent solutions to the maximum extent practicable. To determine if a cleanup alternative uses permanent solutions to the maximum extent practicable, MTCA provides evaluation criteria under WAC 173-340-360(3)(f). The evaluation criteria used for this FS must also address requirements of the Stericycle Facility RCRA Part B permit. The seven evaluation criteria provided under MTCA are as follows:

- protectiveness [WAC 173-340-360(3)(f)(i)],
- permanence [WAC 173-340-360(3)(f)(ii)],
- cost [WAC 173-340-360(3)(f)(iii)],
- effectiveness over the long-term [WAC 173-340-360(3)(f)(iv)],
- management of short-term risks [WAC 173-340-360(3)(f)(v)],
- technical and administrative implementability [WAC 173-340-360(3)(f)(vi)], and
- consideration of public concern [WAC 173-340-360(3)(f)(vii)].

The DCA is based on a comparative analysis of an alternatives cost against one another and the other six evaluation criteria provided above. Cost are disproportionate to benefits if the incremental costs of the alternative over that of a lower cost alternative exceed the incremental degree of benefits achieved by the alternative over that of the lower cost alternative per WAC 137-340-360(3)(e)(i).

The following sections describe the different criteria assessed in this FS.

6.2 Protectiveness

As described in WAC 173-340-360(3)(f)(i), this criterion involves evaluating "the degree to which existing risks are reduced, time required to reduce risk at the Site and attain cleanup standards, onsite and off-site risks resulting from implementing the alternative, and improvement of the overall environmental quality."

Evaluation of protectiveness and risk addresses long-term effects rather than short-term effects, which are evaluated under a different criterion. Alternatives that attain remediation levels and/or CULs are considered as protective under this criterion, and alternatives that meet remediation or CULs in a shorter time are considered to provide a higher level of risk reduction. Alternatives that rely on engineering controls or institutional controls to provide protectiveness and risk reduction are generally scored lower for this criterion than alternatives that do not rely on these controls.

Factors considered for evaluating this criterion include:

- Potential risks to human health and the environment during and following implementation of the alternative: current Site conditions will be used as a baseline to assess the reduction in risks that would result from implementing the remedial alternative;

- Present and future land use for the Site;
- Present and potential for future use of any water resources either associated with or affected by the constituents within the Site;
- Potential effectiveness and reliability of institutional controls associated with the alternative; and
- The ability of the remedy to reduce Site risk, including the capability of the alternative to limit and monitor migration of COCs and the toxicity of COCs.

6.3 Permanence

As described in WAC 173-340-360(3)(f)(ii), permanence is the degree to which a remediation alternative attains remediation objectives by permanently destroying COCs and the capability of the alternative to reduce contaminant toxicity, contaminant mobility, or the volume of affected media. This criterion includes the adequacy of the alternative in destroying the hazardous substances, the reduction or elimination of hazardous substance releases and sources of releases, the degree of irreversibility of waste treatment process, and the characteristics and quantity of treatment residuals generated.

Alternatives that actively degrade or destroy COCs would be scored higher for this criterion than alternatives that utilize onsite or off-site containment. In accordance with MTCA requirements, at least one permanent cleanup action alternative is required to be used as the baseline alternative against which other alternatives are compared. The other alternatives will be compared to the baseline alternative to identify the alternative that provides the greatest practicable degree of permanence. For the purposes of this FS, the term *practicable* shall be used as defined in WAC 173-340-200.

6.4 Cost

WAC 173-340-360(3)(f)(iii) describes the cost evaluation criteria. Costs of remedial alternatives include implementation costs, O&M costs, monitoring costs, and management/reporting costs. Cost estimates were prepared for each remedial alternative considered in this FS. The costs include both initial implementation costs as well as future costs over the estimated remediation life, as detailed in Appendix F. Future costs are included in the total alternative cost using net present value (NPV) estimates. Cost estimates were prepared in general accordance with EPA guidance for preparing FS cost estimates under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) (EPA, 2000).

The costs for implementing a remedial alternative include costs associated with engineering, permitting, public relations, construction, purchase of facilities and equipment, building demolition or utility relocation, transportation and disposal, building restoration, property access, and site restoration. Implementation costs typically occur at the beginning of the implementation program, but may also include costs that occur later in the remediation program, such as costs for replacement or major repair of key remedial system components. Details regarding cost estimates for each of the alternatives are presented in Appendix F.

Estimated costs for O&M (including minor repairs), monitoring, and reporting are generally calculated on an annual basis commencing after construction has been completed. These costs include longer term, repeating expenses associated with multiyear remediation activities. Reporting costs are incurred to document monitoring and operations activities and provide regulatory information to Ecology. Estimates of these ongoing, recurring, future costs usually include labor, power, utilities, sample analyses, subcontractors, agency oversight, and consumed materials. Future recurring costs are combined with initial implementation costs into a single NPV cost estimate for each remedial alternative. The NPV calculations consider an annual net discount rate (assumed to be 2.5 percent) that addresses the time value of money. The net discount rate is the interest rate that could be obtained from a prudent investment less a reasonable inflation rate. The net discount rate of 2.5 percent was selected in consultation with Ecology (as detailed in Appendix F). This NPV cost estimate, including initial implementation costs and future recurring costs, is used to assess the cost criterion and compare the cost of the remedial alternatives. Details concerning operations, maintenance, monitoring, and reporting costs are included in Appendix F.

6.5 Long-Term Effectiveness

WAC 173-340-360(3)(f)(iv) defines long-term effectiveness:

> Long-term effectiveness includes the degree of certainty that the alternative will be successful, the reliability of the alternative during the period of time hazardous substances are expected to remain onsite at concentrations that exceed CULs, the magnitude of residual risk with the alternative in place, and the effectiveness of controls required to manage treatment residues or remaining wastes.

For this criterion, the certainty that an alternative will be effective is assessed, in addition to the capability of a remedial alternative to reliably maintain its effectiveness over a long period of time. If an alternative includes technologies that are not reliable, have not been used under similar site conditions, or are in developmental stages and are not proven technologies, the alternative would be considered to have low long-term effectiveness.

As part of this criterion the production of residues is also assessed; alternatives that do not generate hazardous substance residues would have a greater long-term effectiveness than alternatives that do produce such residues. Permanent alternatives that result in destruction of COCs would provide better long-term effectiveness than alternatives relying on containment using engineering controls.

6.6 Management of Short-Term Risks

The short-term risk evaluation criteria are described in WAC 173-340-360(3)(f)(v). Short-term risks associated with remedial alternatives include potential risk to human health and the potential for environmental releases of COC containing media during implementation of the alternative. These types of releases could occur as a result of dust generation during excavation or handling of excavated materials, loss of affected soil or affected groundwater during treatment, or accidental releases during transport of affected media to a permanent disposal or treatment facility. Alternatives with potential risks that cannot be effectively managed would score lower than those with minimal short-term risks or alternatives in which the short-term risks can be effectively managed.

6.7 Technical and Administrative Implementability

As described in WAC 173-340-360(3)(f)(vi), the technical and administrative implementability criterion refers to the capability to effectively implement a remedial alternative. Technical implementability involves technical and physical factors, such as the presence of existing buildings that may affect implementation of an alternative or the need for specialized equipment for implementation. Administrative implementability involves factors such as permitting requirements or regulatory approvals needed for implementation. Administrative factors would most likely affect the implementation schedule, whereas technical factors could make an alternative ineffective or infeasible.

Simple, proven remedial alternatives would score high for technical implementability, while complex or unproven (developing) alternatives would score low. The primary reason for this is that the implementability of unproven technologies is unknown. Alternatives in developmental stages may not necessarily be less implementable than proven technologies, but the lack of information about developing alternatives means that additional technical or administrative steps must be taken prior to implementation. Alternatives with minimal permitting requirements and that are readily accepted by regulatory agencies would score high for administrative implementability.

Factors considered for evaluation of this criterion include:

- The size and complexity of the remedial alternative;
- The degree to which the remedial alternative can be integrated with existing operations and activities within affected areas;
- Regulatory requirements, including permitting;
- Present and future land use for the area above and adjacent to the project area, including any specific constraints land use may have on the alternative;

- Present and potential for future use of any water resources either associated with or that may be affected by the Site; and
- Potential constraints to implementation of institutional controls associated with the alternative.

6.8 Public Concern

Public concern is described in WAC 173-340-360(3)(f)(vii). For this criterion, we evaluate the potential that implementing the alternative would generate concern among the general public, individuals at adjacent facilities, and the community. Remedial alternatives likely to be readily accepted by the public would score higher than alternatives that may create issues that must be addressed. Potential public concerns include factors such as increased truck traffic, adverse traffic impacts, noise, dust, odors, release of vapors, use of hazardous materials, safety, and effects on property values. In addition, contamination of nearby water bodies and off-site groundwater are potential issues of public concern. Previously voiced public concerns include (1) assigning responsibility for the contamination, (2) conducting cleanup quickly, and (3) opportunities for public involvement as the process proceeds.

6.9 Reasonable Restoration Time frame

A reasonable restoration time frame is not an evaluation criterion included in WAC 173-340-360(3)(f); however, it is included as part of the protectiveness criterion [WAC 173-340-360(3)(f)(i)] and is a minimum requirement required under WAC 173-340-360(2)(b). Restoration time frame is considered as an additional evaluation criterion to determine if the restoration time frame for each alternative can be considered reasonable.

The restoration time frame is the time required for an alternative to attain remediation objectives.

Alternatives that achieve remediation objectives in a shorter time would score higher for this criterion than alternatives requiring a longer time. Alternatives that may not achieve remediation objectives for many years, if at all, would score lower than those alternatives that attempt to restore the environment, even if there is uncertainty about the ability of the alternative to achieve remediation objectives. The practicality and necessity of implementing an alternative within a shorter time and the potential effectiveness and reliability of any institutional controls associated with the alternative are also assessed for this criterion.

Factors [WAC 173-340-360(4)(b)] to be considered when determining whether a cleanup action provides for a reasonable restoration time frame include the following:

- Potential risks posed by the Site to human health and the environment;
- Practicality of achieving a shorter restoration time frame;

- Current use of the Site, surrounding areas, and associated resources that are, or may be, affected by releases from the site;
- Potential future use of the Site, surrounding areas, and associated resources that are, or may be, affected by releases from the Site;
- Availability of alternative water supplies;
- Likely effectiveness and reliability of institutional controls;
- Ability to control and monitor migration of hazardous substances from the Site;
- Toxicity of the hazardous substances at the Site; and
- Natural processes that reduce concentrations of hazardous substances and have been documented to occur at the Site or under similar site conditions.

A longer period of time may be used for the restoration time frame for a site to achieve CULs at the POC if the cleanup action selected has a greater degree of long-term effectiveness than onsite or off-site disposal, isolation, or containment options [WAC 173-340-360(4)(c)]. However, extending the restoration time frame cannot be used as a substitute for active remedial measures, when such actions are practicable [WAC 173-340-360(4)(f)].

7.0 DEVELOPMENT AND EVALUATION OF REMEDIAL ALTERNATIVES

This section presents the development and evaluation of remedial alternatives that could be implemented to address soil and groundwater impacts at the Site and selects a preferred alternative. These alternatives are based on remedial technologies identified in the screening of potentially applicable remedial technologies presented in Section 5.0. Potentially applicable remedial alternatives are evaluated relative to criteria specified in the MTCA rules to select the preferred alternative.

A discussion of active remediation and restoration time frame in provided in Section 7.1. The remedial alternatives developed for the Site are described in detail in Section 7.2. An evaluation of the remedial alternatives relative to the evaluation criteria summarized in Section 6.0 is presented in Section 7.3. The baseline alternative (as defined in MTCA) is identified in Section 7.3, and alternatives are evaluated relative to this baseline alternative using the criteria specified in the MTCA rules. This evaluation results in selection of a preferred alternative for the Site. A disproportionate cost analysis was conducted to assess the relative costs and benefits of alternatives, and the results are presented in Section 7.4. The preferred remedial alternative is described in Section 7.5. Ultimately the final cleanup approach will be selected following public involvement.

7.1 Active Remediation and Restoration Time frame

Active remediation is defined as the time frame from implementation of the remedial action until accelerated degradation rates are no longer observed and monitored attenuation becomes the primary remedial activity. The active remediation duration varies between alternatives (as noted in Table 7-1) and is discussed for each alternative below. Active remediation time frames were based on typical performance reported in publicly available data (including vendor supplied information, peer reviewed publications, government and academic publications, etc.) and engineering experience in applying each remedial technology to similar soil and aquifer conditions (if available).

Restoration time frame is defined under MTCA as the period of time needed to achieve the required CULs at the points of compliance established for the Site. Restoration time frame includes the active remediation duration, the time for monitored attenuation to reach CULs, and a single five-year review period to confirm the long term groundwater trends are indicative of a permanent solution.

The Site has been monitored for several decades since the tank farm soil removal interim action was completed and indications of ongoing natural biodegradation have been previously documented. The monitored attenuation duration for key contaminants to reach CULs was created by use of onsite data to estimate degradation rates. These projections are expected to be updated for the selected remedial alternative as part of the cleanup action plan.

It was assumed that treatment technologies would be as effective during active remediation as typically reported for sites with similar conditions. The estimated duration for monitored attenuation was then added onto the active remediation time frame. Bench testing and pilot testing are necessary to confirm assumed degradation rates during active remediation for several of the remedial technologies. However, for the more aggressive technologies (thermal and deep soil mixing) the active remediation time frame is unlikely to change significantly. The basis for restoration time frame estimates is described for each of the remedial alternatives below.

7.2 Development of Remedial Alternatives

This section outlines the remedial alternatives that have been developed from the remedial technologies described in Section 5.0. The evaluation of these alternatives requires that each be designed to attain the remedial objectives specific to the Site and the remedial considerations for different portions of the Site.

This FS updates previously presented information about potential remedial alternatives developed in the 2013 FS:

- To address comments received from Ecology;
- To update alternative design based on current Site conditions including the abundance of additional groundwater data gathered and trends that have become better defined since the 2013 FS submittal;
- To include evaluation of recently developed technologies; and
- To update alternative designs based on more recent and complete information on remedial technologies practicability, performance, and effectiveness.

Four remedial alternatives were developed as part of the 2013 FS (Alternatives 1 through 4) and three additional alternatives (Alternatives 5, 6, and 7) have been developed during preparation of this FS, taking into account Ecology concerns voiced during meetings and communications. The seven alternatives are:

- Alternative A-1- Capping and Monitored Natural Attenuation (MNA)
- Alternative A-2- Capping, In-Situ Bioremediation (ISB), In-Situ Chemical Oxidation (ISCO) and Monitored Attenuation (MA)
- Alternative A-3- Capping, Deep Soil Mixing, ISCO, ISB and MA
- Alternative A-4- Capping, Electrical Resistive Heating, ISB and MA
- Alternative A-5- Capping, Permeable Reactive Barrier with zero valent iron (ZVI), ISCO, and MA
- Alternative A-6- Capping, ISB, ISCO, Hydraulic Control, and MA
- Alternative A-7- Capping, Full Scale ISCO, ISB, and MA

Not all retained remedial technologies were used to develop the alternatives, but all were considered, and some were retained for use as contingent remedial technologies (biosparging, oxygen enhancement, phytoremediation, air sparging, barrier wall). The seven remedial alternatives developed for the Site incorporate one or more of the retained technologies. The alternatives are summarized on Table 7-1, which lists technologies employed to treat COCs for each area and depth of the Site. The seven remedial alternatives are described in more detail in Sections 7.2.2 through 7.2.8. Components of the cleanup action that are the same for all seven alternatives are described in Section 7.2.1.

7.2.1 Remedy Components Common to All Alternatives

All seven remedial alternatives share several common elements; however, one element is the same across all alternatives.

- Grouting of the storm drain utility bedding.

While shallow groundwater trends indicate ongoing biodegradation has shrunk the impacted area, there is still a possibility that contaminated groundwater could migrate in the bedding of utility lines when the water table is elevated in the wet season. Grouting of the storm drain utility line is proposed in four locations along the alignment east of the property line. A four-foot cube would be excavated around the pipe within the bedding material and the material would be replaced with cementitious controlled density fill (CDF) to prevent groundwater migration along the utility alignment in the higher permeability pipe bedding material.

The four actions below are common components of each alternative, but implementation would vary based on the restoration time frame for each alternative.

- Institutional controls;
- Groundwater monitoring;
- Inhalation Pathway Interim Measure (IPIM); and
- Augmenting existing surface cover.

Institutional controls are non-engineered instruments such as administrative and legal controls that help reduce the potential for human exposure to contamination and/or protect the integrity of the remedy, i.e. development restrictions. Institutional controls would be implemented following completion of the implementation phase of the selected remedial alternative and would be negotiated with Ecology to protect human health and the environment. Given that the Facility is an active industrial site and that several buildings with contamination under them are actively in use, long term institutional controls (primarily for low level soil contamination from inorganic COCs) and temporary institutional controls (for control during the remediation phase) are proposed for each alternative. Temporary institutional controls would be implemented to protect human health and the environment while

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remedial actions are underway. Once successful completion of remediation is confirmed, institutional controls would be removed.

Verification of groundwater remediation effectiveness would be implemented through a **groundwater monitoring** program. Duration and frequency of the program would be dependent on the selected remedial alternative and the alternative's effectiveness over time to obtain CULs. Once successful completion of remediation is confirmed by groundwater monitoring, the groundwater component of the action would be deemed complete and no further groundwater monitoring would be required.

The **IPIM** was previously implemented to prevent risk of exposure to workers in Building 1 to VOCs. The IPIM system decreases pressure under the building and conveys VOCs through a stack on the roof of the building, preventing VOCs in the soil from entering the building. As part of the selected alternative, this system would be operated as long as necessary to protect human health. Sub-slab vapor monitoring is planned as part of design, to better assess the time frame for IPIM operations. If results indicate the system is no longer necessary, shut down of the IPIM and confirmation sampling would be negotiated with Ecology to provide verification that shutdown of the IPIM does not adversely impact human health and the environment.

Surface cover would be added in areas of the Site that are unpaved to prevent direct contact with or surface water infiltration through soils with elevated concentrations of COCs. For the purposes of cost estimating, it has been assumed the cover will consist of 4-inches of hot mix asphalt pavement.

Details of how each of these measures are implemented for each alternative are provided in the sections below and on the associated tables and figures describing each alternative. Cumutively these common elements address WAC 173-340-740(6)(f)(i) through (v) (permanent to the maximum extent practicable, protective of human health, protective of terrestrial ecological receptors, institutional controls, and compliance monitoring).

7.2.2 Remedial Alternative A-1

Alternative A-1 would rely on surface cover, grouting of a potential groundwater conduit, and monitored natural attenuation to address soil and groundwater impacts within the Site. The following elements are included (Figure 7-1).

- Grouting of the potential groundwater conduit, the utility trench under the stormwater piping to the east of the Stericycle property in four locations;
- Continued operation of the existing IPIM under Building 1;
- Augmenting existing surface cover by paving select areas of the Site with 4-inches of hot mix asphalt pavement;
- Long-term monitoring and maintenance of the pavement cover;
- Monitored natural attenuation of groundwater downgradient of source areas;

- Groundwater monitoring is anticipated to evaluate MNA effectiveness for the duration of the restoration time frame (at least 30 years based on extrapolation of groundwater monitoring data trends through the first half of 2019). Once groundwater monitoring indicates MNA has permanently destroyed COCs to below CULs, remediation will be considered complete; and
- Institutional controls, including a deed restriction, as follows:
  - Maintain property as industrial land use;
  - Maintain engineering controls through inspections and maintenance, as needed, of capping, security fencing, and the monitoring well network;
  - Require use of appropriate personal protective equipment and compliance with hazardous waste operations and emergency response (HAZWOPER) requirements specified in 29 CFR 1910.120 for all subsurface work conducted within the property boundaries;
  - Prohibit use of Site groundwater until CULs have been attained; and
  - Provide annual notice to the public of Site cleanup status.

This alternative would utilize the natural reductive dechlorination process observed on the Site through recent groundwater sampling results to obtain groundwater CULs in the Shallow Groundwater Zone and the Lower Aquifer. Chlorinated solvent concentrations in the Shallow Groundwater Zone have steadily decreased within the source area indicating that degradation is likely to continue.

Reductive dechlorination has been actively observed in the Lower Aquifer within the former source area through the decrease in PCE and TCE. While increases in *cis*-1,2-DCE and VC have been observed, the dehalococcoides bacteria currently degrading the PCE and TCE, are likely to eventually degrade the *cis*-1,2-DCE and VC to reach CULs within the source area. Similar trends for chlorinated solvents have been observed in groundwater results from well MC-15D and the natural reductive dechlorination processes are expected to eventually obtain CULs under this alternative, though timing is difficult to predict with currently available trend data. The restoration time frame for VOCs in the Lower Aquifer may exceed 30 years. Trend plots for concentrations of selected COCs over time are presented in Appendix E.

Concentrations of 1,4-dioxane have remained consistent in the vicinity of MC-14 in the Shallow Groundwater Zone and in the former tank farm area in the Lower Aquifer. These concentrations would be expected to slowly dissipate over time through dilution and dispersion, but the restoration time frame could exceed 30 years based on current trend data.

The time frame was assumed to be 30 years based on a number of wells in slow decline, but this assumes that the flat or increasing trends in some wells (Appendix E) start to decline by year 15. Groundwater monitoring includes a well network of 40 wells initially, it is assumed this will be reduced to 23 wells after 10 years once long-term trends are confirmed (as detailed in Appendix F).

7.2.3 Remedial Alternative A-2

Alternative A-2 would supplement the natural biodegradation processes that would occur under Alternative A-1 with (1) injection of carbohydrates in the former tank farm area, near MC-118D, and MC-15D and (2) in-situ chemical oxidation (ISCO) to accelerate destruction of 1,4-dioxane in the area around well MC-14.

The following elements are included (Figure 7-2).

- Grouting the utility trench under the stormwater piping to the east of the Stericycle property in four locations;
- Continued operation of the existing IPIM under Building 1;
- Augmenting the existing surface cover by paving select areas of the Site with 4-inches of hot mix asphalt pavement;
- Long-term monitoring and maintenance of the pavement cover;
- Treatment near MC-14 - two rounds of ISCO injections to treat 1,4-dioxane and VOCs in the Shallow Groundwater Zone;
- Treatment in the former tank farm area and near the north fence line (near MC-118D) - two rounds of ISB injections utilizing carbohydrates and emulsified ZVI targeting chlorinated VOCs remaining in the Silt Layer and the upper portion of the Lower Aquifer;
- Treatment in the Lower Aquifer upgradient of and near MC-15D - ISB injection of carbohydrates near MC-15D to reduce risk of off-site migration of chlorinated VOCs in the upper portion of the Lower Aquifer;
- Monitored attenuation of the groundwater downgradient of the remediation areas;
- Groundwater monitoring would be used to evaluate ISB/ISCO effectiveness for the duration of the restoration time frame (15 years based on vendor experience and the extrapolation of groundwater monitoring data trends once source area remediation is complete). Once groundwater monitoring indicates ISB/ISCO and MA has permanently destroyed COCs to below CULs, remediation would be considered complete; and
- Institutional controls, as follows:
  - Maintain property as industrial land use;
  - Maintain engineering controls through inspections and maintenance, as needed, of capping, security fencing, and the monitoring well network;
  - Require use of appropriate personal protective equipment and compliance with hazardous waste operations and emergency response (HAZWOPER) requirements specified in 29 CFR 1910.120 for all subsurface work conducted within the property boundaries;
  - Prohibit use of Site groundwater until CULs have been attained; and
  - Provide annual notice to the public of Site cleanup status.

Prior to implementation of either ISCO or ISB, bench scale studies are proposed to confirm the appropriate substrate and dosage rates. Injection spacing design was based on typical spacing necessary for the soil types in each area and checked against spacing estimated by injection subcontractors. An assumption of 15-foot on-center (O.C.) was used for the Shallow Groundwater Zone sands, 10-foot O.C. for the Silt Layer, and 15-foot O.C. for the silty gravel in the Lower Aquifer. Further clarification of spacing will be included in the cost appendix of the FS.

ISCO would be utilized to address 1,4-dioxane concentrations in the vicinity of MC-14. Injections within the Shallow Groundwater Zone would be completed with a spacing of 15-feet O.C. and a 10-feet depth interval (two to 12 feet bgs). To minimize metals release to the groundwater a Modified Fenton's Reagents (MFR) is proposed to treat the 1,4-dioxane concentrations per an estimate provided by In-Situ Oxidative Technologies, Inc. (ISOTEC). Use of a MFR process reduces the overall pH decrease observed during injections, compared to other in-situ treatment reagents, effectively reducing the potential for metals to migrate into solutions, i.e. groundwater. Bench scale studies conducted prior to implementation will determine the optimal injectates to minimize metals releases. MFR injections would potentially include injections of a proprietary catalyst, sodium persulfate, and hydrogen peroxide. The area is estimated to be completed with nine injection locations.

A second ISCO injection event would be planned within a few months of the first injection to complete treatment of remaining COCs using approximately half the number of injection locations and half the initial treatment volume of hydrogen peroxide and MFR solution.

ISB injections within the former tank farm area, including the MC-118 well cluster area, would utilize an emulsified vegetable oil (EVO) and ZVI substrate to provide a carbon source for the natural bacteria and passively treat chlorinated solvents diffusing from the Silt Layer into the Lower Aquifer. Injections would be completed within the Silt Layer with a spacing of 15-feet O.C. (approximately 19 injection locations) and injections within the Lower Aquifer would be completed with a spacing of 25-feet O.C. (approximately seven injection locations). Treatment depths for the former tank farm would target the entire silt interval (10 to 18 feet bgs) and the upper 10 feet (18 to 28 feet bgs) of the Lower Aquifer. A second ISB injection event would be planned in the following year to polish treatment of remaining COCs using approximately half the number of injection locations and half the initial treatment volume of EVO and ZVI.

ISB injections within the vicinity of MC-15D would utilize an EVO substrate to provide a carbon source for the natural bacteria to break down chlorinated solvents in the Lower Aquifer. Injections within the Lower Aquifer would be completed with a spacing of 25 feet O.C., in the upper 10 feet (18 to 28 feet bgs) of the aquifer. The area is estimated to be completed with four injection locations.

The basis for the restoration time frame for alternative A-2 of 15 years is an active remediation time frame of 3 to 5 years (expected to reduce the contaminants of concern by greater than 50%), with polishing by monitored attenuation taking an additional 5 to 7 years based on available onsite trend data, with confirmational monitoring taking another 5 years.

Groundwater monitoring includes a well network of 40 wells initially, it is assumed this will be reduced to 23 wells after 5 years once active remediation is complete (as detailed in Appendix F).

7.2.4 Remedial Alternative A-3

Alternative A-3 would employ Deep Soil Mixing (DSM) with ZVI injection to treat the former tank farm area. This alternative would retain ISB to address chlorinated solvent concentrations around well MC-15D and ISCO near MC-14 from Alternative A-2, and also include ISCO near the northern fence line in the vicinity of MC-118D.

The following elements are included (Figure 7-3):

- Grouting the utility trench under the stormwater piping to the east of the Stericycle property in four locations;
- Continued operation of the existing IPIM under Building 1;
- Augmenting the existing surface cover by paving select areas of the Site with 4-inches of hot mix asphalt pavement;
- Long-term monitoring and maintenance of the pavement cover;
- Treatment near MC-14 - two rounds of ISCO injections to treat the 1,4-dioxane and VOCs in the Shallow Groundwater Zone;
- Treatment in the former tank farm area using DSM with ZVI;
- Treatment along the North Fence Line (near MC-118D) using ISCO of the silt and Lower Aquifer;
- Treatment in the Lower Aquifer upgradient of and near MC-15D - ISB by injection of carbohydrates near MC-15D to reduce risk of off-site migration of chlorinated VOCs in the upper portion of the Lower Aquifer;
- Monitored attenuation of the groundwater downgradient of source remediation areas;
- Groundwater monitoring would be used to evaluate DSM/ISCO/ISB effectiveness for the duration of the restoration time frame (10 years based on vendor experience and the extrapolation of groundwater monitoring data trends once source area remediation is complete). Once groundwater monitoring indicates DSM/ISCO/ISB and MA has permanently destroyed COCs to below CULs, remediation would be considered complete; and
- Institutional controls, as follows:
  - Maintain property as industrial land use;
  - Maintain engineering controls through inspections and maintenance, as needed, of capping, security fencing, and the monitoring well network;
  - Require use of appropriate personal protective equipment and compliance with hazardous waste operations and emergency response (HAZWOPER) requirements

specified in 29 CFR 1910.120 for all subsurface work conducted within the property boundaries;

- Prohibit use of Site groundwater until CULs have been attained; and
- Provide annual notice to the public of Site cleanup status.

Prior to implementation of DSM, ISCO, or ISB, bench scale studies are proposed to confirm the appropriate substrate and dosage rates. Injection spacing design was based on typical spacing necessary for the soil types in each area and checked against spacing estimated by injection subcontractors. An assumption of 15-foot O.C. was used for the Shallow Groundwater Zone sands, 10-foot O.C. for the Silt Layer, and 15-foot O.C. for the silty gravel in the Lower Aquifer.

ISCO would be utilized to address 1,4-dioxane concentrations in the vicinity of MC-14 and the north fence line (near MC-118D). To minimize metals release to the groundwater a MFR is proposed to treat the 1,4-dioxane concentrations per an estimate provided by In-Situ Oxidative Technologies, Inc. (ISOTEC). Use of a MFR process reduces the overall pH decrease observed during injections, compared to other in-situ treatment reagents, effectively reducing the potential for metals to migrate into solutions, i.e. groundwater. Bench scale studies conducted prior to implementation will determine the optimal injectates to minimize metals releases. MFR injections would potentially include injections of a proprietary catalyst, sodium persulfate, and hydrogen peroxide. The area is estimated to be completed with nine injection locations.

Injections within the Shallow Groundwater Zone near MC-14 would be completed the same as Alternative A-2, with a spacing of 15 feet O.C. and a 10 feet depth interval (two to 12 feet bgs). ISCO injections within the Silt Layer and Lower Aquifer around the MC-118D well cluster would be completed with a spacing of 10 feet O.C. in the Silt Layer (eight to 18 feet bgs) and 15 foot O.C. for the upper 10 feet (18 to 28 feet bgs) of the Lower Aquifer. An estimated 11 injections would be necessary to address the Silt Layer and five injections to treat the Lower Aquifer.

A second ISCO injection event would be planned within a few months of the first injection to complete treatment of remaining COCs using approximately half the number of injection locations and half the initial treatment volume of hydrogen peroxide and MFR solution.

DSM would be implemented within the former tank farm area to address the chlorinated solvent source within the Silt Layer and upper zone of the Lower Aquifer (five to 20 feet bgs). DSM would require excavation of the upper five feet of soil within the proposed treatment area (12,750 square feet) to allow for swell and substrate addition during DSM. The addition of two percent by weight ZVI and one percent bentonite would treat COCs and reduce the permeability of the source soils in the former tank farm within the Silt Layer. Following DSM, the upper five feet of soil would need to be amended with Portland cement to stabilize the soils and allow for the area of the Site to be utilized for normal Facility operations. Three months following treatment, it is assumed the area will have stabilized and will be ready for re-paving.

ISB injections within the vicinity of MC-15D would utilize an EVO substrate to provide a carbon source for the natural bacteria to break down chlorinated solvents in the Lower Aquifer. Injections within the Lower Aquifer would be completed the same as in Alternative A-2, with a spacing of 25 feet O.C., in the upper 10 feet (18 to 28 feet bgs) of the aquifer. The area is estimated to be completed with four injection locations.

The basis for the restoration time frame for Alternative A-3 of 10 years is an active remediation time frame of 1 to 1.5 years (expected to reduce the contaminants of concern from 50 to 70%), with polishing by monitored attenuation taking an additional 3.5 to 4 years based on available onsite trend data, with confirmational monitoring taking another 5 years.

Groundwater monitoring includes a well network of 40 wells initially, it is assumed this will be reduced to 19 wells after 5 years for confirmational monitoring (as detailed in Appendix F).

7.2.5 Remedial Alternative A-4

Alternative A-4 would employ electrical resistive heating (ERH) to address source area COCs in both the vadose and saturated zone in the tank farm area and in the area downgradient around MC-14. The following elements are included (Figure 7-4):

- Grouting the utility trench under the stormwater piping to the east of the Stericycle property in four locations;
- Short term operation of the existing IPIM under Building 1;
- Augmenting the existing surface cover by paving select areas of the Site with 4-inches of hot mix asphalt pavement;
- Long-term monitoring and maintenance of the pavement cover;
- Treatment of the former tank farm area, the north fence line area (near MC-118D) via ERH of the Shallow Groundwater Zone, Silt Layer and upper portion of the Lower Aquifer;
- Treatment of the area under Building 1 and around well MC-14 via ERH of the Shallow Groundwater Zone;
- Treatment in the Lower Aquifer upgradient of and near MC-15D via ISB by injection of carbohydrates to reduce risk of off-site migration of chlorinated VOCs;
- Monitored attenuation of groundwater downgradient of source area remediation area;
- Groundwater monitoring would be used to evaluate ERH/ISB effectiveness for the duration of the restoration time frame (10 years based on vendor experience and the extrapolation of groundwater monitoring data trends once source area remediation is complete). Once groundwater monitoring indicates ERH/ISB and MA has permanently destroyed COCs to below CULs, remediation would be considered complete; and

- Institutional controls, as follows:
  - Maintain property as industrial land use;
  - Maintain engineering controls through inspections and maintenance, as needed, of capping, security fencing, and the monitoring well network;
  - Require use of appropriate personal protective equipment and compliance with hazardous waste operations and emergency response (HAZWOPER) requirements specified in 29 CFR 1910.120 for all subsurface work conducted within the property boundaries;
  - Prohibit use of Site groundwater until CULs have been attained; and
  - Provide annual notice to the public of Site cleanup status.

Prior to implementation of ISB, bench scale studies are proposed to confirm the appropriate substrate and dosage rates. Injection spacing design was based on typical spacing necessary for the soil types in each area and checked against spacing estimated by injection subcontractors. An assumption of 15-foot O.C. for the silty gravel in the Lower Aquifer.

ISB injections within the vicinity of MC-15D would utilize an EVO substrate to provide a carbon source for the natural bacteria to break down chlorinated solvents in the Lower Aquifer. Injections within the Lower Aquifer would be completed the same as in Alternative A-2 with a spacing of 25 feet O.C., in the upper 10 feet (18 to 28 feet bgs) of the aquifer. The area is estimated to be completed with four injection locations.

ERH would address chlorinated solvents and 1,4-dioxane within the Silt Layer and upper portion of the Lower Aquifer (10 to 18 feet bgs) in the vicinity of the former tank farm and address 1,4-dioxane around MC-14 and Building 1 in the Shallow Groundwater Zone (two to 10 feet bgs). As noted in Section 5.3.11 ERH is a thermal treatment that heats the subsurface and collects the vapors using SVE. Active heating following installation would operate for an estimated six months per a quote prepared by TRS Group, Inc. TRS Group estimated the use of 73 electrodes, 55 multi-phase extraction points, and 8 temperature monitoring points for treatment of 13,400 cubic yards (CY) of soil. Following heating, a cool down period of approximately one year would be necessary before pre-ERH groundwater conditions would be expected to return to normal. Elevated temperatures are expected to increase biological activity which may affect pH, REDOX, conductivity, dissolved oxygen, and other water quality indicators. During the cool down period, biodegradation would be expected to accelerate due to increased subsurface temperatures, helping to provide polishing of Site COCs in the Lower Aquifer.

The basis for the restoration time frame for Alternative A-4 of 10 years is an active remediation time frame of 1 to 1.5 years (expected to reduce the contaminants of concern from 50 to 70%), with polishing by monitored attenuation taking an additional 3.5 to 4 years based on available onsite trend data, with confirmational monitoring taking another 5 years.

Groundwater monitoring includes a well network of 40 wells initially, it is assumed this will be reduced to 20 wells after 5 years for confirmational monitoring (as detailed in Appendix F).

7.2.6 Remedial Alternative A-5

Alternative A-5 would employ a ZVI permeable reactive barrier to address source area COCs in both the vadose and saturated zone in the tank farm area, below Building 1, along the north fence line near MC-118D and MC-118D2, and in the area downgradient around MC-14. Alternative A-4 comprises the following elements (Figure 7-5):

- Grouting the utility trench under the stormwater piping to the east of the Stericycle property;
- Continued operation of the existing IPIM under Building 1;
- Augmenting the existing surface cover by paving select areas of the Site with 4-inches of hot mix asphalt pavement;
- Long-term monitoring and maintenance of the pavement cover;
- Treatment near MC-14 - two rounds of ISCO injections to treat 1,4-dioxane and VOCs in Shallow Groundwater Zone;
- Treatment in the former tank farm area and the north fence line (near MC-118D) via placement of PRBs by hydraulic fracturing of coarse grained ZVI using direct push methods, through the lower portion of the shallow zone (11 feet bgs) into the Silt Layer (10 to 20 feet bgs) and the upper portion of the Lower Aquifer (18 to 23 feet bgs) within the footprint of the former tank farm excavation and around the MC-118 well cluster.
- Treatment in the Lower Aquifer upgradient of and near MC-15D via placement of a PRB using hydraulic fracturing injection of fine grained ZVI through cased hole injections within the upper 10 feet of the Lower Aquifer (18 to 28 feet bgs) around MC-15D;
- Monitored attenuation of groundwater downgradient of remediation areas;
- Groundwater monitoring would be used to evaluate PRB/ISCO effectiveness for the duration of the restoration time frame (10 years based on vendor experience and the extrapolation of groundwater monitoring data trends once source area remediation is complete). Once groundwater monitoring indicates PRB/ISCO and MA has permanently destroyed COCs to below CULs, remediation would be considered complete; and
- Institutional controls, as follows:
    - Maintain property as industrial land use;
    - Maintain engineering controls through inspections and maintenance, as needed, of capping, security fencing, and the monitoring well network;
    - Require use of appropriate personal protective equipment and compliance with hazardous waste operations and emergency response (HAZWOPER) requirements specified in 29 CFR 1910.120 for all subsurface work conducted within the property boundaries;

- Prohibit use of Site groundwater until CULs have been attained; and
- Provide annual notice to the public of Site cleanup status.

Prior to implementation of ISCO, bench scale studies are proposed to confirm the appropriate substrate and dosage rates. Injection spacing design was based on typical spacing necessary for the soil types in each area and checked against spacing estimated by injection subcontractors. An assumption of 15-foot O.C. was used for the Shallow Groundwater Zone sands for ISCO and spacing for ZVI fractures was assumed to be 15-foot O.C. for the Silt Layer, and 13-foot O.C. for the silty gravel in the Lower Aquifer.

ISCO would be utilized to address 1,4-dioxane concentrations in the vicinity of MC-14, the same as in Alternative A-2. Injections within the Shallow Groundwater Zone would be completed with a spacing of 15 feet O.C. and a 10 feet depth interval (two to 12 feet bgs). To minimize metals release to the groundwater MFR is proposed to treat the 1,4-dioxane concentrations per an estimate provided by In-Situ Oxidative Technologies, Inc. (ISOTEC). Use of a MFR process reduces the overall pH decrease observed during injections, compared to other in-situ treatment reagents, effectively reducing the potential for metals to migrate into solutions, i.e. groundwater. Bench scale studies conducted prior to implementation will determine the optimal injectates to minimize metals releases. MFR injections would potentially include injections of a proprietary catalyst, sodium persulfate, and hydrogen peroxide. The area is estimated to be completed with nine injection locations.

A second ISCO injection event would be planned within a few months of the first injection to complete treatment of remaining COCs using approximately half the number of injection locations and half the initial treatment volume of hydrogen peroxide and MFR solution.

The source area PRB would utilize direct-push drilling methods for installation of a PRB above, within, and below the Silt Layer. An estimated 84 fracks placed through 21 injection locations (15-foot O.C.) would be necessary to install the PRB in the former tank farm and north fence line area. Fractures would occur at approximate depths of 11 to 12 feet, 15 to 16 feet, 20 feet, and 23 feet bgs. Placement of approximately 2,000 pounds of ZVI would occur with each fracture. Through installation of the source area PRB, Site COCs diffusing from the Silt Layer into the Shallow Groundwater Zone or Lower Aquifer would be destroyed. Prior to implementation of the former tank farm PRB, a pilot study would be necessary to determine the appropriate injection method and spacing, and volume of ZVI to be injected at each fracture.

The downgradient PRB placed around MC-15D would be installed with a different method than the source area PRB. Due to the increased depth of placement of the PRB, four-inch diameter cased borings would be installed by sonic drilling methods to a depth of 35-feet bgs. The cased borings would be installed in two rows, each containing four locations. A total of 16 fractures would be completed in the eight cased boring locations (13-foot O.C.) with fractures occurring at 25-feet and 28-feet bgs. Each fracture would place approximately 2,000 pounds of ZVI, similar to the source area. PRB placement around MC-15D would treat Site COCs prior to migration off-site along the eastern property boundary.

The basis for the restoration time frame for Alternative A-5 of 10 years is an active remediation time frame of 3 to 10 years. Unlike other alternatives, the ZVI amendment may outlast the contaminants being released from the low permeability units and would not rely on monitored attenuation alone for polishing. Hence, the active remedial time frame lasting up to the entire restoration time frame of 10 years. This alternative is expected to reach CULs by year 5, with confirmational monitoring taking another 5 years.

Groundwater monitoring includes a well network of 40 wells initially, it is assumed this will be reduced to 23 wells after 5 years for confirmational monitoring (as detailed in Appendix F).

7.2.7 Remedial Alternative A-6

Alternative A-6 would supplement the remedial technologies from Alternative A-2 with short term hydraulic control.

The following elements are included (Figure 7-6):

- Grouting the utility trench under the stormwater piping to the east of the Stericycle property in four locations;
- Continued operation of the existing IPIM under Building 1;
- Augmenting the existing surface cover by paving select areas of the Site with 4-inches of hot mix asphalt pavement;
- Long-term monitoring and maintenance of the pavement cover;
- Treatment near MC-14 via two rounds of ISCO injections to treat the 1,4-dioxane and VOCs in the Shallow Groundwater Zone;
- Treatment in the former tank farm area and the north fence line area (near MC-118D) via two rounds of ISB injections utilizing carbohydrates and emulsified ZVI targeting chlorinated VOCs remaining in the Silt Layer and the upper portion of the Lower Aquifer;
- Short Term Hydraulic control of the Lower Aquifer;
- Treatment in the Lower Aquifer upgradient of and near MC-15D via ISB by injection of carbohydrates to reduce risk of off-site migration of chlorinated VOCs in the Lower Aquifer;
- Monitored attenuation of the groundwater downgradient of the remediation areas;
- Groundwater monitoring would be used to evaluate ISB/ISCO effectiveness for the duration of the restoration time frame (15 years based on vendor experience and the extrapolation of groundwater monitoring data trends once source area remediation is complete). Once groundwater monitoring indicates ISB/ISCO and MA has permanently destroyed COCs to below CULs, remediation would be considered complete; and
- Institutional controls, as follows:

- Maintain property as industrial land use;
- Maintain engineering controls through inspections and maintenance, as needed, of capping, security fencing, and the monitoring well network;
- Require use of appropriate personal protective equipment and compliance with hazardous waste operations and emergency response (HAZWOPER) requirements specified in 29 CFR 1910.120 for all subsurface work conducted within the property boundaries;
- Prohibit use of Site groundwater until CULs have been attained; and
- Provide annual notice to the public of Site cleanup status.

Prior to implementation of either ISCO or ISB, bench scale studies are proposed to confirm the appropriate substrate and dosage rates. Injection spacing design was based on typical spacing necessary for the soil types in each area and checked against spacing estimated by injection subcontractors. . An assumption of 15-foot O.C. was used for the Shallow Groundwater Zone sands, 10-foot O.C. for the Silt Layer, and 15-foot O.C. for the silty gravel in the Lower Aquifer.

ISCO would be utilized to address 1,4-dioxane concentrations in the vicinity of MC-14, the same as in Alternative A-2. Injections within the Shallow Groundwater Zone would be completed with a spacing of 15 feet O.C. and a 10 feet depth interval (two to 12 feet bgs). To reduce metals release to the groundwater MFR is proposed to treat the 1,4-dioxane concentrations per an estimate provided by ISOTEC. Use of a MFR process reduces the overall pH decrease observed during injections, compared to other in-situ treatment reagents, effectively reducing the potential for metals to migrate into solutions, i.e. groundwater. Bench scale studies conducted prior to implementation will determine the optimal injectates to minimize metals releases. MFR injections would potentially include injections of a proprietary catalyst, sodium persulfate, and hydrogen peroxide. The area is estimated to be completed with nine injection locations.

A second ISCO injection event would be planned within a few months of the first injection to complete treatment of remaining COCs using approximately half the number of injection locations and half the initial treatment volume of hydrogen peroxide and MFR solution.

ISB injections within the former tank farm area, including the MC-118 well cluster area, would utilize EVO and ZVI substrate to provide a carbon source for the natural bacteria and passively treat chlorinated solvents diffusing from the Silt Layer into the Lower Aquifer, the same as in Alternative A-2. Injections would be completed within the Silt Layer with a spacing of 15 feet O.C. (approximately 19 injection locations), and injections within the Lower Aquifer would be completed with a spacing of 25 feet O.C. (approximately seven injection locations). Treatment depths for the former tank farm would target the entire silt interval (8 to 10 to 18 to 20 feet bgs) and the upper 10 feet (18 to 20 to 28 to 30 feet bgs) of the Lower Aquifer. A second ISB injection event would be planned in the following year to polish treatment of remaining COCs using approximately half the number of injection locations and half the initial treatment volume of EVO and ZVI.

ISB injections within the vicinity of MC-15D would utilize an EVO substrate to provide a carbon source for the natural bacteria to break down chlorinated solvents in the Lower Aquifer. Injections within the Lower Aquifer would be completed the same as in Alternative A-2 with a spacing of 25 feet O.C., in the upper 10 feet (18 to 20 to 28 to 30 feet bgs) of the aquifer. The area is estimated to be completed with four injection locations.

Hydraulic control would be implemented through installation of four groundwater extraction wells within the former tank farm and the MC-118 well cluster and installation of two groundwater extractions wells in the downgradient area around MC-15D. Each extraction well would be six-inch diameter and completed to approximately 30 feet bgs, screened within the Lower Aquifer (20 to 30 feet bgs). Using hydraulic conductivity values calculated in the 2013 RI report (AMEC, 2013b) from wells screened in the upper portion of the Lower Aquifer, an estimated flow rate in gallons per minute (gpm) was calculated with an assumed aquifer thickness of 35 feet. Estimated flow rates were calculated for site-specific high, average, and low conductivity values (ranging from 4 to 22 gpm per well). These were used to evaluate potential variability, but the flow rate calculated using the site-specific average conductivity (5.5 gpm per well) was used to estimate the average combined flow from the six wells (at 5.5 gpm) to contain the known areas of groundwater contamination. The combined flow rate would be approximately 33 gallons per minute, but the flow rate would vary with hydraulic conductivities across the Site. It is assumed that prior to installation of the full hydraulic control system, a single extraction well would need to be installed and a pump test performed to determine site-specific groundwater extraction rates to properly size all other system components.

The hydraulic containment treatment system would need to be housed in a separate building with a containment foundation. Conveyance piping between wells, treatment, and discharge would be installed below grade to allow for reduced disturbance to Facility operations. For the purposes of this FS, it is assumed the treatment system would include an air-stripper to remove VOCs from the water and vapor treatment vessels (with granular activated carbon and potassium permanganate media for VC) to adsorb and destroy the VOCs once they are transferred to vapor phase.

It is assumed that discharges could be sent to the Washougal publicly owned treatment works (POTW). The POTW confirmed they have capacity to receive the treated groundwater. However, the POTW does not accept industrial wastewater without an Ecology managed NPDES permit and does not accept groundwater by default. Additional permitting time and Ecology backing would be necessary to convince the POTW to accept the treated groundwater discharge.

The basis for the restoration time frame for alternative A-6 of 15 years is an active remediation time frame of 3 to 5 years (expected to reduce the contaminants of concern by greater than 50%), with polishing by monitored attenuation taking an additional 5 to 7 years based on available onsite trend data, with confirmational monitoring taking another 5 years. Hydraulic controls are unlikely to speed up contaminant release from the low permeability units, so it is unlikely to affect remediation time frames. Groundwater monitoring includes a well network of 40 wells initially, it is assumed this will be reduced to 23 wells after 5 years once active remediation is complete (as detailed in Appendix F).

7.2.8 Remedial Alternative A-7

Alternative A-7 would employ Full Scale ISCO across the major source areas to accelerate destruction of chlorinated solvents in the source area, along the northern property line, and near MC-14.

The following elements are included (Figure 7-7):

- Grouting of the utility trench under the stormwater piping to the east of the Stericycle property;
- Continued operation of the existing IPIM under Building 1;
- Augmenting the existing surface cover by paving select areas of the Site with 4-inches of hot mix asphalt pavement;
- Long-term monitoring and maintenance of the pavement cover;
- Treatment of the former tank farm area, the north fence line area (near MC-118D) via ISCO targeting the Shallow Groundwater Zone and Silt Layer;
- Treatment of the Shallow Groundwater Zone near MC-14 via ISCO;
- Treatment in the Lower Aquifer upgradient of and near MC-15D via ISB by injection of carbohydrates to reduce risk of off-site migration of chlorinated VOCs;
- Monitored natural attenuation of groundwater downgradient of source remediation areas;
- Groundwater monitoring would be used to evaluate ISCO/ISB effectiveness for the duration of the restoration time frame (10 years based on vendor experience and the extrapolation of groundwater monitoring data trends once source area remediation is complete). Once groundwater monitoring indicates ISCO/ISB and MA has permanently destroyed COCs to below CULs, remediation would be considered complete; and
- Institutional controls, as follows:
    - Maintain property as industrial land use;
    - Maintain engineering controls through inspections and maintenance, as needed, of capping, security fencing, and the monitoring well network;
    - Require use of appropriate personal protective equipment and compliance with hazardous waste operations and emergency response (HAZWOPER) requirements specified in 29 CFR 1910.120 for all subsurface work conducted within the property boundaries;
    - Prohibit use of Site groundwater until cleanup standards have been attained; and
    - Provide annual notice to the public of Site cleanup status.

Prior to implementation of either ISCO or ISB, bench scale studies are proposed to confirm the appropriate substrate and dosage rates. Injection spacing design was based on typical spacing necessary for the soil types in each area and checked against spacing estimated by injection subcontractors. . An assumption of 15-foot O.C. was used for the Shallow Groundwater Zone sands, 10-foot O.C. for the Silt Layer, and 15-foot O.C. for the silty gravel in the Lower Aquifer.

ISCO would be utilized to address CVOCs in the former tank farm area for the Silt Layer (12 to 20 feet bgs) and the upper 10 feet of the Lower Aquifer (20 to 30 feet bgs) and along the northern fence line in the vicinity of the MC-118 well cluster for Shallow Groundwater Zone (2 to 12 feet bgs), the Silt Layer, and the upper 10 feet of the Lower Aquifer. ISCO would also be utilized to address 1,4-dioxane concentrations in the vicinity of MC-14. Injections would be completed with a spacing of 15-feet O.C. for all three treatment intervals. To minimize metals release to the groundwater a MFR is proposed to treat the 1,4-dioxane and chlorinated VOC concentrations per an estimate provided by ISOTEC. Use of a MFR process reduces the overall pH decrease observed during injections, compared to other in-situ treatment reagents, effectively reducing the potential for metals to migrate into solutions, i.e. groundwater. Bench scale studies conducted prior to implementation will determine the optimal injectates to minimize metals releases. MFR injections would potentially include injections of a proprietary catalyst, sodium persulfate, and hydrogen peroxide. The area is estimated to be completed with the following number of injection locations by area:

- Northern Fence Line – 26 injection locations;
- Former Tank Farm Area – 102 injection locations; and
- MC-14 Area – 9 injection locations.

A second ISCO injection event would be planned within a few months of the first injection to complete treatment of remaining COCs using approximately half the number of injection locations and half the initial treatment volume of hydrogen peroxide and MFR solution.

ISCO would destroy other key COCs as well as 1,4-dioxane and chlorinated VOCs, but the goal would be to significantly reduce concentrations of 1,4-dioxane near MC-14 and chlorinated VOCs in the Former Tank Farm area and along the northern fence line, since these areas contains the highest remaining concentrations at the Site. Since 1,4-dioxane in the vicinity of MC-14 and chlorinated VOCs in the Silt Layer are each partially responsible for the extended time frame to achieve CULs, ISCO would shorten the remediation time frame by reducing the total mass of COCs.

ISB injections within the vicinity of MC-15D would utilize an EVO substrate to provide a carbon source for the natural bacteria to break down chlorinated solvents in the Lower Aquifer. Injections within the Lower Aquifer would be completed the same as in Alternative A-2 with a spacing of 25 feet O.C., in the upper 10 feet (18 to 28 feet bgs) of the aquifer. The area is estimated to be completed with four injection locations.

The basis for the restoration time frame for Alternative A-7 of 10 years is an active remediation time frame of 1 to 1.5 years (expected to reduce the contaminants of concern from 50 to 70%), with polishing by monitored attenuation taking an additional 3.5 to 4 years based on available onsite trend data, with confirmational monitoring taking another 5 years. Groundwater monitoring includes a well network of 40 wells initially, it is assumed this will be reduced to 23 wells after 5 years for conformational monitoring (as detailed in Appendix F).

7.3 Evaluation of Remedial Alternatives

The objectives for the seven remedial alternatives considered for the Site are to meet the remedial action objectives specified in Section 4.2 while supporting current and future operations at the Facility. A comparison of remedial alternative components is provided in Table 7-1, which also provides a summary of the timing for each alternative.

This section compares and evaluates the remedial alternatives based on the MTCA criteria discussed in Section 6.0. In the subsections below, the alternatives are evaluated relative to each of the criteria. For each criterion, the alternatives are evaluated on a scale of 1 to 10. A rating of 10 means the alternative is expected to most completely meet the criterion. For example, only alternatives that would result in meeting the cleanup criteria for all COCs would receive a rating of 10 for permanence and risk reduction.

A rating of 1 indicates that the alternative is expected to perform poorly for that criterion, relative to the other alternatives. A rating of 1 does not necessarily mean that the alternative would not adequately meet the criterion; it only means that other alternatives would be more effective in meeting that specific criterion.

All of the remedial alternatives under consideration attain the remediation objectives outlined in Section 4.2. Institutional controls (ICs) and long-term groundwater monitoring have been included in all of the alternatives. The IPIM must be maintained until VOCs have been remediated in soil and groundwater to levels protective for the inhalation pathway.

Results of the evaluation are summarized for all evaluation criteria in Table 7-2. A detailed list of the factors affecting the score for each alternative is provided in Table 7-3.

7.3.1 Determination of the Baseline Alternative

MTCA [173-340-350 (8)(c)(ii)(A) states, *“the feasibility study shall include at least one permanent cleanup action alternative, as defined in WAC 173-340-200, to serve as a baseline against which other alternatives shall be evaluated for the purpose of determining whether the cleanup action selected is permanent to the maximum extent practicable. The most practicable permanent cleanup* *alternative shall be included."*

MTCA [WAC 173-340-360(3)(e)(ii)(B)] states, *"The most practicable permanent solution evaluated in the feasibility study shall be the baseline cleanup action alternative against which cleanup action alternatives are compared. If no permanent solution has been evaluated in the feasibility study, the cleanup action alternative evaluated in the feasibility study that provides the greatest degree of permanence shall be the baseline cleanup action alternative.*

MTCA defines "permanent" with regards to cleanup as a cleanup action in which cleanup standards of WAC 173-340-700 through 173-340-760 can be met without further action being required at the Site being cleaned up or any other site involved with the cleanup action, other than the approved disposal of any residue from the treatment of hazardous substances.

All of the alternatives in this FS are expected to be permanent alternatives, with perhaps the exception of Alternative A-1 (while MNA will permanently destroy the COCs the restoration time frame to do so could be significantly more than 30 years based on current data trends), so practicability was considered in establishing the baseline alternative. MTCA defines "practicable" as capable of being designed, constructed and implemented in a reliable and effective manner including consideration of cost. When considering cost under this analysis, an alternative shall not be considered practicable if the incremental costs of the alternative are disproportionate to the incremental degree of benefits provided by the alternative over other lower cost alternatives.

Alternatives are scored higher for permanence if the technologies utilized treated more site COCs or more COCs more aggressively. All of the alternatives presented above are permanent, with alternative A-4 being the most permanent. However, Alternative A-4 has the highest cost and scores second lowest for technical and administrative implementability, which combine to give it the highest cost per benefit of any of the alternatives. As a result, Alternative A-4 is one of the least practicable alternatives. Therefore, Alternative A-2 has been designated the "baseline alternative" because it has the highest Cost to Benefit ratio and is therefore the most practicable permanent solution evaluated in the FS (see Table 7-2 and section 7.2.4).

7.3.2 Protectiveness

The ratings of the alternatives for protectiveness and risk reduction are shown in Table 7-2. In general terms, the protectiveness and risk reduction criterion involve the degree to which remedial alternatives protect human health and the environment and provide a reduction in risks posed by the contamination. However, this criteria has several additional sub-criteria (time required to reduce risk at the Site and attain cleanup standards, onsite and off-site risks resulting from implementing the alternative, and improvement of the overall environmental quality) that may lead to contradictory scoring (e.g. if an alternative scores well for minimal onsite risks but poorly for having higher off-site risks, how should the alternative be scored). Given the number of sub-criteria with potentially differing scores, all of the Protectiveness sub-criteria were scored with supporting reasoning given for each sub-criterion in Table 7-3. The average score of the sub-criteria was then rounded to the nearest whole number (e.g. 7.6 became 8) for the Protectiveness score in Table 7-2.

All of the alternatives under consideration are expected to significantly reduce risks and be protective of human health and the environment. Overall, all of the active alternatives scored well (8 to 9), while Alternative A-1 (MNA) scored poorly (4). Given the number of sub-criteria, the active remedies (including the baseline remedial alternative A-2) were all relatively close in scoring (all scored 8 or 9) because the differences in sub-criteria ended up averaging out in the overall Protectiveness score. For example, Alternative A-3 some scored high for aggressive removal of COCs, but also scored low for implementation risks (Table 7-3).

7.3.3 Permanence

The permanence criterion, as defined in MTCA, involves the degree to which the remedial alternative would reduce the toxicity and mobility of affected media through permanent destruction of hazardous substances. All of the alternatives incorporate monitored attenuation, resulting in the permanent removal of COCs. All of the alternatives would result in reduction in total mass of COCs. The baseline alternative A-2 (ISB) scored an 8. Overall, most of the active alternatives scored well (8 to 10), while Alternative A-1 (MNA) scored poorly (5) [Table 7-2]. Alternatives A-3 (DSM) and A-4 (ERH) scored highest (9 and 10, respectively) since they were the most aggressive technologies in addressing all of the COCs.

Alternative A-7 (Full Scale ISCO) scored lowest (7) of the active remedy alternatives because of its dependence on direct contact, which may be hard to achieve in low permeability soils that are the bulk of the former tank farm treatment area [Table 7-3]. Until bench/pilot testing is completed, the permanence Alternative A-7 (as designed) is more uncertain than other alternatives. Other injection technology alternatives based on ISB or PRBs don't depend on direct contact or have longer lasting effects. This means that contaminants in the lower permeability units will be actively treated for years with ISB or PRBs which reduces uncertainty for alternatives based on those technologies.

7.3.4 Cost

NPV cost estimates prepared for Alternatives A-1 through A-7 are summarized in Table 7-4. Assumptions used to develop the cost estimates and a more detailed breakdown of costs for each alternative are presented in Appendix F. The NPV cost estimates combine initial costs for implementation of an alternative with recurring costs for future operation, maintenance, and monitoring. NPV cost estimates allow the alternatives to be compared on an equal basis. Some implementation costs would occur in the future, after initial remediation or planning tasks are completed. During revision of the FS, Ecology requested additional analysis of the alternatives costing to clarify the effects of various assumptions on the relative costs of the alternatives. DOF performed a sensitivity analysis as part of FS costing to satisfy this request. It is included in Section 4 of the Appendix F.

Implementation costs include estimated costs for obtaining access to conduct the remediation; for engineering and planning; for purchasing equipment, materials, and chemicals; for permitting; and for construction. Recurring costs include estimates for operation and maintenance labor, Ecology oversight, materials and chemicals used in remediation, periodic replacement of remediation equipment, long-term property access, power and waste disposal, water quality monitoring, and project management. As detailed in Appendix B, the NPV costs are based on the implementation and operation period for each of the alternatives.

Timing for each alternative was based on the average of trends in existing Shallow Groundwater Zone and Lower Aquifer wells (Appendix E). Once source area remediation is complete, natural degradation rates were assumed to be on the same approximate time scale of existing wells that have declining COC trends. For the FS, that means for technologies that are predicted to destroy almost all COCs (greater than 90 percent) during implementation, the timeline of 10 years is based on a substantial decline after year 0 (the year of implementation) followed by minor polishing by monitored attenuation in the next five years, and a further five year review period to monitor for rebound. For technologies that take an additional 1 to 3 years to remove greater than 90 percent of COCs, the timeline was extended for an additional 5-year review period (for a total of 15 years.) For MNA, the timeline was assumed to be 30 years based on a number of wells in slow decline, but this assumes that the flat or increasing trends in some wells (Appendix E) start to decline by year 15.

In the 2013 FS, the NPV costs were compared by alternative and the alternatives were simply ranked on their costs compared to the other alternatives. Per Ecology's recommendation for this FS, cost was not included as part of the benefit score subtotals but used in combination with the overall benefit score to come up with a Cost per Benefit score (as shown in Table 7-2).

The baseline alternatives A-2 (ISB) and alternative A-5 (PRB) are ranked 1 and 2 for Cost per Benefit (at approximately $53,000 each) and are almost 50% more cost effective than the 3rd ranked alternative (A-7 ISCO). The lowest Cost per Benefit ranking is for Alternative A-4 (ERH) which has more than double the Cost per Benefit ($126,000) than the highest ranked alternatives.

7.3.5 Long-Term Effectiveness

Long-term effectiveness includes the degree of certainty and reliability of the alternative to maintain its effectiveness over the long term. This criterion also includes whether treatment residue would remain from the alternative that would require management. The benefits realized by an alternative are compared to the negative consequences associated with the alternative in assessing long-term effectiveness. All of the alternatives leave soil in place on the Stericycle property that exceeds preliminary CULs. As a result, all of the alternatives under consideration incorporate the same ICs for soil; therefore, the ICs for each alternative would have essentially the same effectiveness and reliability for soil.

The difference between alternatives was based mostly on long-term effectiveness of groundwater treatment. The baseline alternative A-2 (ISB) scored an 8. Overall, most of the active alternatives scored well (8 to 10), while Alternative A-1 (MNA) scored poorly (4) [Table 7-2]. Alternatives A-3 (DSM) and A-4 (ERH) scored highest since they were the most aggressive technologies with the least amount of uncertainty in effectiveness for treating all of the COCs.

Alternative A-7 (Full Scale ISCO) scored lowest (7) of the active remedy alternatives because of its dependence on direct contact, which may be hard to achieve in low permeability soils that are the bulk of the former tank farm treatment area [Table 7-3]. ISCO is tied with DSM and ERH for the highest ceiling- as it could effectively treat all the COCs if the chemicals make contact. However, until bench/pilot testing is completed, the effectiveness of Alternative A-7 (as designed) is more uncertain than other alternatives. Other injection technology alternatives based on ISB or ZVI injections don’t depend on direct contact or have longer lasting effects. This means that contaminants in the lower permeability units will be actively treated for years with ISB or ZVI which significantly increases the odds of long-term effectiveness.

7.3.6 Management of Short-Term Risks

Short-term risk refers to the risk to human health and the environment during implementation of an alternative. Although it is possible to design remedial actions to mitigate or minimize potential risks, it is not possible to eliminate risks through design or actions. In assessing this criterion, it has been assumed that alternatives have been designed to incorporate appropriate and proven methods to mitigate short-term risks. However, regardless of the approach taken, remedial actions that remove soil or require construction of any type have higher short-term risks than those that do not. Although measures to mitigate these risks are not discussed in this section, appropriate measures have been included in the cost analysis as part of this FS to minimize short-term risks in all alternatives.

Overall, the highest scoring alternative (9) was the only completely passive alternative, Alternative A-1 (MNA) and Alternative A-4 (ERH) was the lowest scoring alternative (4) [Table 7-2] since it was the most aggressive alternative with multiple waste streams and the highest number of hazards during implementation (Table 7-3). The baseline alternative A-2 (ISB) and alternative A-5 (PRB) scored well (both 8) due to being mostly in-situ (fewer wastes) with relatively low risk chemical use for the bulk of the treatment. Alternatives A-3 (DSM) scored low (6) due to having the most physical hazards during implementation and a large amount of off-site soil disposal. Alternative A-7 (Full Scale ISCO) scored low (6) due to the use of a large amount of corrosive chemicals during implementation. While Alternative A-6 (ISB with hydraulic control) scored low (5) primarily due to the extended time of implementation (3 years for operation of a pump and treat system with multiple waste streams).

7.3.7 Technical and Administrative Implementability

This criterion involves both technical and administrative issues related to construction and operation of the remedial alternatives. Factors considered in assessing the alternatives against this criterion include administrative/regulatory requirements, impact on existing land uses, the means for implementing and enforcing ICs, and requirements for extensive construction or ongoing operation and maintenance.

As shown in Table 7-2, Alternative A-1 (MNA) was rated highest of all the alternatives under consideration because it would rely on installing a paved cover, simple minor construction (grouting), groundwater monitoring, and the existing IPIM. Alternative A-1 would rely on the most basic of remedial technologies among all the alternatives and therefore receives a rating of 10 (Table 7-2).

The baseline alternative A-2 (ISB) is rated the highest for active remedies (8), since it would be relatively manageable to implement around ongoing operations at the Facility and provides more certainty with a longer lasting treatment technology.

Alternative A-3 (DSM) is given a rating of 2 due to the difficulties in implementing DSM in an actively operating Facility. Alternative A-4 (ERH) scores only slightly higher (3). While ERH would be more effective at addressing both the Silt Layer and the soils under Building 1 than DSM or enhanced bioremediation, the ERH treatment would include air discharges from the ERH treatment system and discharge of condensate to the POTW. This would require additional permitting or permit modifications. This technology also would present serious safety concerns during implementation at an actively operating Facility that would require additional management.

7.3.8 Public Concern

Potential community concerns with implementation of each remedial alternative are assessed for this criterion, including general concerns of the public, local governments, and specific concerns of neighboring landowners. General public concerns could be related to restoration time frames. The period of active implementation of the various alternatives could range from as little as a few months for MNA to as much as 2 or 3 years for the injection technologies. The longer periods of implementation could result in public concerns about traffic and the resulting noise and pollution potential.

Alternative A-1 (MNA) received the lowest rating (4) for this criterion, because it would likely have the longest restoration time frame of the seven alternatives although there is limited risk to receptors given the relatively low concentrations of COCs and mostly shrinking groundwater plumes (Table 7-3). The lack of an active remedy could be perceived negatively by the public; however, Alternative A-1 (MNA) is the easiest to implement and could be completed and implemented with little impact from waste disposal or noise from construction.

The baseline alternative A-2 (ISB) received the highest rating of 8, with very little waste disposal or off-site impacts and immediate reductions of COCs at implementation. Alternative A-5 (PRB) was scored lower (7) because the use of hydraulic fracturing which may cause public concern. The other alternatives scored 5 or 6 mostly since they would create noticeable and prolonged nuisances such as noise, traffic, and air emissions, except for ISCO, which was driven lower by the uncertainties with treatment until bench/pilot scale studies could be completed (Table 7-3).

7.3.9 Restoration Time frame

Restoration time frame is not an Evaluation Criteria under MTCA [WAC 173-340-360 (3)(e)(ii)(C)(f)], but MTCA does require that a cleanup action provide for a reasonable restoration time frame [WAC 173-340-360(2)(b)(ii)].

Restoration time frame involves the urgency of achieving remediation objectives and the practicability of attaining a shorter restoration time frame, with consideration given to a number of factors, such as Site risks, Site use and potential use, availability of alternative water supply, effectiveness and reliability of ICs, and toxicity of hazardous substances at the Site. The criteria for evaluating if a restoration time frame is reasonable are provided in WAC 173-340-360(4). The following criteria, as listed in WAC 173-340-360(4), were considered to determine if each of the alternatives provides a reasonable restoration time frame:

- **Potential risks posed by the Site to human health and the environment.** Each alternative includes ICs to manage risk and prevent the Site from posing an unacceptable risk; therefore, each of the alternatives meet this criterion.
- **Practicability of achieving a shorter restoration time frame**. The alternatives provide a range of remediation time frames. The practicability and cost-benefit of each alternative is discussed in the alternative’s evaluation provided as part of this FS.
- **Current use of the Site, surrounding areas, and associated resources that are, or may be, affected by releases from the Site**. The Site is currently an active industrial facility

and is largely surrounded by industrial properties. Groundwater beneath the Site is not a source of drinking water. Steigerwald Marsh and the Gibbons Creek Remnant Channel are resources near the Site, but observed concentrations in near or in these locations do not pose an unacceptable risk to human health or ecological receptors.

- **Potential future use of the Site, surrounding areas, and associated resources that are, or may be, affected by releases from the Site**.; The Site is currently zoned for industrial use and heavy industrial use is planned at the Site for the foreseeable future. Each alternative is designed to mitigate unacceptable Site risks and no unacceptable risk has been identified in the nearby Steigerwald Marsh and Gibbons Creek Remnant Channel.
- **Availability of alternative water supplies**. Groundwater at the Site is not currently a drinking water source and alternative water supplies are available and in use.
- **Likely effectiveness and reliability of ICs**. Because the property is an active industrial facility, ICs are very likely to be effective. Regular use of the Site is also likely to result in regular maintenance of controls, thereby increasing their reliability.
- **Ability to control and monitor migration of hazardous substances from the Site.** Groundwater monitoring has been ongoing at the Site both on the Stericycle property and on adjacent properties, and continued groundwater monitoring is included in each of the alternatives.
- **Toxicity of the hazardous substances at the Site**. The toxicity of the hazardous substances has been evaluated in the RI report, and a cleanup standard for each COC has been established, including both a preliminary CUL and a point of compliance. At the concentrations present in the soil and groundwater, risk from the COCs is low.
- **Natural processes that reduce concentrations of hazardous substances and have been documented to occur at the Site or under similar site conditions.** Natural attenuation of many COCs has been observed and documented at the Site, with most wells showing shrinking plumes in both the Shallow Groundwater Zone and Lower Aquifer.

Based on the current trends in groundwater concentrations, Alternatives, A-3, A-4, A-5, and A-7 would meet the preliminary CULs within 10 years with Alternatives A-2 and A-6 predicted to take 15 years (Table 7-2). This five year difference results in a slightly higher risk to terrestrial or human receptors onsite, which can be controlled, but is unlikely to change risk for off-site receptors, as each of the active groundwater remedies employed will intercept the downgradient plume during the first year of implementation (Table 7-1, start of significant COC reduction). Only Alternative A-1 which utilizes MNA to reduce COC concentrations offsite will leave risk to off-site receptors as they currently stand. The alternatives also have different time frames for active remediation (Table 7-1), with the more aggressive technologies completing active remediation in the first year of implementation, and others with active remediation lasting 3 to 10 years. The longer time frames for active remediation generally result in an overall longer restoration time frame (with the exception of Alternative A-5), but they also provide for a longer period of treating COCs desorbing from the lower permeability units onsite. Thus, while Alternative A-2 and A-6 have a 50% longer remedial time frame, the risk to off-site receptors is reduced to a similar time frame to the other alternatives, while Alternatives A-2 and A-6 provide additional time to treat desorbing COCs from the low permeability units (which only Alternative A-5 can do in a shorter restoration time frame).

Downgradient monitoring already indicates that ongoing biodegradation and attenuation are showing decreasing concentrations in shallow groundwater monitoring wells (Appendix E). Groundwater monitoring well trends in the Lower Aquifer are increasing in some areas onsite, but current trends (without treatment) indicate that Lower Aquifer COCs are unlikely to reach receptors before degrading to below preliminary CULs off-site: i.e. before reaching the river or the shallow aquifer (Appendix E). Given the relatively low concentrations of COCs onsite, the ongoing industrial use of the facility, and the ICs employed, the difference of five years in reasonable restoration time frame is considered marginal.

Alternative A-1 has by far the longest restoration time frame and may require longer than 30 years to meet the cleanup standards (as per the sensitivity analysis in Appendix F), and three other alternatives have a better Cost per Benefit score (Table 7-2), indicating that there are more practicable remedies with shorter restoration time frames.

7.4 Disproportionate Cost Analysis

The MTCA DCA is used to evaluate which of the alternatives that meet the threshold requirements are permanent to the maximum extent practicable. This analysis involves comparing the costs and benefits of alternatives and selecting the alternative whose incremental costs are not disproportionate to the incremental benefits. The evaluation criteria for the DCA are specified in WAC 173-340-360(2) and (3) and include protectiveness, permanence, cost, long-term effectiveness, management of short-term risks, implementability, and consideration of public concerns. For this DCA, restoration time frame will also be considered.

As outlined in WAC 173-340-360(3)(e), MTCA provides a methodology that uses these criteria to determine whether the costs associated with each cleanup alternative are disproportionate relative to the incremental benefit of the alternative above the next lowest cost alternative. The comparison of benefits relative to costs may be quantitative but will often be qualitative and require the use of best professional judgment. (WAC 173-340-360(3)[e][ii](C)). Costs are disproportionate to benefits if the incremental costs of the more permanent alternative exceed the incremental degree of benefits achieved by the other lower-cost alternative (WAC 173-340-360(3)[e][i]). Where two or more alternatives are equal in benefits, Ecology selects the less costly alternative (WAC 173-340-360[e][ii][c]). Each criterion is weighted equally in this DCA.

Each of the alternatives is expected to meet the threshold criteria and use permanent solutions to the maximum extent practicable. Alternative A-1 includes a passive groundwater remedy that will have a long restoration time frame but will ultimately prove to be permanent. As a result, it received the lowest Benefit score (36) and still costs more than more aggressive remedial alternatives A-2 an A-5.

The baseline alternatives A-2 (ISB) and A-5 (PRB) have the highest benefit scores (48 and 46 respectively) and Cost per Benefit ranking of approximately $53,000 (Table 7-2).

Alternatives A-3, A-4, A-6, and A-7 are on the second tier for benefit score (40 to 42), but only A-7 ranks relatively well for Cost per Benefit (Table 7-2) of $74,075. Alternatives A-3, A-4, and A-6 are considered to have disproportionately high costs when given the substantially higher costs for less benefit compared to the baseline alternative A-2 (ISB).

7.5 Selection of the Preferred Remedial Alternative

Selection of a preferred alternative under MTCA requires that preference be given to alternatives that use permanent solutions to the maximum extent practicable, provide for a reasonable restoration time frame, and consider public concerns. According to MTCA (WAC 173-340-200), a permanent solution or permanent cleanup action means an action in which cleanup standards can be met without further action being required at the Site involved, other than the approved disposal of any residue from the treatment of hazardous substances.

For the Site, seven remedial alternatives have been established as potentially applicable to the Site.

As shown in Table 7-2 and discussed in Section 7.4, the baseline Alternative A-2 (ISB) received the highest total benefit score and cost per benefit ranking, followed closely by Alternative A-5 (PRB). There was a significant gap in benefit score between the top two alternatives and alternatives A-3, A-4, A-6, and A-7, but Alternative A-7 (full scale ISCO) was clearly a level above the other alternatives ranking 3rd in cost per benefit. Alternative A-1 scored much lower than the other three alternatives for total benefit, but was ranked 4th by cost per benefit ranking.

When comparing restoration time frames, at first glance the baseline Alternative A-2 had the longest restoration time frame (tied with Alternative A-6), which is 50% more time than the 10 year remedial time frame for Alternatives A-3, A-4, A-5, and A-7. However, the extra length in time is due to allow for polishing low level concentrations of COCs from groundwater onsite, with the off-site plume expected to be reduced within the same time frame as the other alternatives. Given the ongoing site use and low risk to human and ecological receptors, the restoration time frame of 10 or 15 years were both considered reasonable, with the restoration time frame of 30 years for Alternative A-1 deemed significantly worse. Alternative A-5 (PRB) scores similarly to A-2, but with a shorter restoration time frame. While the shorter restoration time frame is better, as noted above, it provides marginally better risk reduction. And implementation of the PRB includes hydraulic fracturing to penetrate the low permeability aquifer for distribution of the ZVI. This technology has been shown to work in similar formations in other places across the country and internationally, but there are many successful implementations of ISB technology utilized in Alternative A-2 in Washington State specifically. Hydraulic fracturing could face significant permitting hurdles as well, given that the technology may trigger more public scrutiny.

Alternative A-7 (ISCO) has the third highest benefit score (significantly lower than A-2 or A-5), but with a shorter restoration time frame than Alternative A-2. While the shorter restoration time frame is better, as noted above, it provides marginally better risk reduction. Implementation of ISCO requires direct contact with the contaminants in a short window of time before the oxidation chemicals are spent. For lower permeability aquifers, this leaves a relatively short period of time (weeks to months) for COCs to desorb from the low permeability unit and be treated. While the ISB technology in Alternative A-2 is slower to treat contaminants, it also provides a longer lasting source of substrate that can continue to treat desorbing COCs for years.

Review of recent ISCO injection implementation in Washington State have shown a high variability in performance, requiring tighter spacing and repeat injections to even approach 50% reduction in COCs in low permeability units (DOF, 2020).

Overall the most practicable permanent solution is the baseline alternative A-2 (ISB). Each alternative was scored based on best professional judgement of how technologies would likely perform in context of available Site data and general technology performance data site-specific testing for ISB, ZVI, and ISCO technologies(bench scale and pilot testing results) could indicate that ZVI or ISCO will perform better under site-specific conditions than ISB, which could potentially lead to Alternative A-5 or A-7 scoring a higher benefit score and cost to benefit ranking. The other alternatives either score too low on overall benefit (Alternative A-1 (MNA)) or have costs that are disproportionate to the incremental degree of benefits provided by the alternative over other lower cost alternatives.

Based on the numerical comparison and DCA presented above, the preferred remedial alternative for the Site is Alternative A-2. Results of the sensitivity analysis further support this selection (Appendix F Tables F-23 through F-26)), as summarized below:

- The baseline Alternative A-2 includes the second highest amount true contingency built into the costs relative to the other alternatives.
- The baseline Alternative A-2 costs are significantly lower than most alternatives even with a higher contingency included:
    - The three highest cost Alternatives A-3, A-4, and A-6 are more costly even when comparing the better performance scenario for those alternatives against a worse performance scenario for the baseline scenario (Alternative A-2).

- Alternatives A-1 and A-7 cost at least $400,000 more than the baseline Alternative A-2 under better or worse performance scenarios.
- Alternative A-5 is the only alternative with similar cost performance to baseline Alternative A-2, with only slightly higher costs under the different performance scenarios.

The Preferred Alternative for the Site, Alternative A-2, would fully attain remediation objectives, provides a permanent solution to the maximum extent practicable, with a reasonable restoration time frame, and considers public concerns. Specifically, the Preferred Alternative would:

- Prevent direct contact with soils and inhalation of dust within the Site and be protective of industrial workers;
- Address both chlorinated VOCs and 1,4-dioxane and thereby reduce the restoration time frame to approximately 15 years to meet CULs at the POC;
- Reduce current risks due to inhalation of vapors prior to when CULs are attained by incorporating ICs;
- Require vapor intrusion provisions until soil and groundwater are remediated to eliminate this pathway;
- Protect potential off-site human and ecological receptors in the Steigerwald Marsh by destroying groundwater COCs and limiting the further release of COCs by removal/treatment of Site soils; and
- Support current and future industrial use of the Stericycle property.

In addition, the Preferred Alternative would provide:

- A reliable remediation approach using proven, robust technologies with low long-term maintenance requirements; and
- An approach that would create moderate short-term risks and have minimal potential for causing public concern about exposure to Site constituents during construction.

The Preferred Alternative (A-2) would fully comply with MTCA, the Dangerous Waste Regulations (WAC 173-303), and the RCRA regulations. The Preferred Alternative would comply with the requirements of the Permit and achieve the environmental indicator standards for controlling potential exposure to both soil and groundwater for affected media located at and near the Site.

7.6 Contingent Remedy Options

The Preferred Remedial Alternative is the most likely practicable permanent solution based on the available data on the remedial technologies and the available site-specific data at the time of writing of this report. This determination, while based on sound engineering judgement, may be reassessed as more site-specific information is collected, or as more data becomes available for technologies tested at similar sites in Washington State. In particular, the preferred remedial alternative includes bench testing and pilot testing in order to improve performance for ISCO, ISB, and ZVI technologies. The results of the bench and pilot testing could provide valuable site-specific data on effectiveness of those technologies with regards to Site groundwater chemistry and soil characteristics. Based on the available information and engineering judgement, bench and pilot testing is likely to confirm that the Preferred Remedial Alternative as the most practicable and permanent solution. However, it is possible that bench or pilot testing could provide different results than anticipated, which may necessitate review of the ranking of the three highest scoring alternatives for Cost/Benefit ratio or the use of a contingent remedy. For example:

1. If bench testing shows ZVI substrate dosing to be significantly more effective in dispersion and treatment than standard EVO substrate, a different ratio of technologies may be used.
2. If pilot testing shows distribution of ISB or ISCO substrates is inconsistent and is likely to perform worse than expected in the FS, PRB injection technology may be considered instead.
3. If bench and/or pilot testing shows that timelines are longer or treatment effectiveness is worse than anticipated for all three of the highest scoring remedial alternatives, hydraulic control may need to be revisited.

Retaining contingent remedy technologies are necessary in the event the Preferred Remedial Alternative does not meet design goals or CULs within the restoration time frame. The following technologies are retained as potential contingent remedies:

- Permeable Reactive Barrier,
- Full Scale In-Situ Chemical Oxidation, and
- Hydraulic Containment.

These technologies were presented above as part of other remedial alternatives and are the most viable options for used as a contingent remedy. Viability of these technologies was determined through the ranking process performed during Preferred Alternative selection. Alternatives A-5 and A-7 were the alternatives with the highest cost-to-benefit ratio, behind Alternative A-2, which utilized PRB and ISCO technologies as the primary treatment. Hydraulic control was introduced in Alternative A-6, which includes the components of Alternative A-2 with the addition of hydraulic control.

8.0 CLOSING AND LIMITATIONS

Within the limitations of the agreed-upon scope of work, this assessment has been undertaken and performed in a professional manner in accordance with generally accepted practices, using the degree of skill and care ordinarily exercised by reputable environmental consultants under similar circumstances. Due to physical limitations inherent to this or any environmental assessment, DOF expressly do not warrant that the Site is free of pollutants or that all pollutants have been identified. No other warranties, express or implied, are made.

In preparing this report, DOF has relied upon documents provided by the others. Except as discussed within the report, DOF did not attempt to independently verify the accuracy or completeness of that information. To the extent that the conclusions in this report are based in whole or in part on such information, those conclusions are contingent on its accuracy and validity. DOF assumes no responsibility for any consequence arising from any information or condition that was concealed, withheld, misrepresented, or otherwise not fully disclosed or available to DOF.

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This report does not constitute legal advice. In addition, DOF makes no determination or recommendation regarding the decision to purchase, sell, or provide financing for this Site.

9.0 REFERENCES

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Tables

TABLE 2-1

CONSTITUENTS OF CONCERN IN SOIL [1,2]

Stericycle Washougal Facility

Washougal, Washington

Metals		PCBs/Pesticides		TPH
Barium	Nickel	Total PCBs	Endrin	Gasoline
Cadmium	Selenium	4,4'-DDD	Heptachlor	Lube oil range hydrocarbons
Chromium	Silver	4,4'-DDT	Heptachlor epoxide	
Copper	Thallium	Aldrin	Lindane	
Cyanide	Vanadium	delta-BHC	Toxaphene	
Lead	Zinc	Dieldrin		
Mercury				
SVOCs				
1,4-Dioxane	2-Chloronaphthalene	Benzo(a)anthracene	Dibenzo(a,h)anthracene	Nitrobenzene
2,4,6-Trichlorophenol	2-Chlorophenol	Benzo(a)pyrene	Dibenzofuran	N-Nitroso-di-n-propylamine
2,4-Dichlorophenol	3,3'-Dichlorobenzidine	Benzo(b)fluoranthene	Hexachlorobenzene	N-Nitrosodiphenylamine
2,4-Dimethylphenol	4-Chloroaniline (p-chloroaniline)	Benzo(k)fluoranthene	Isophorone	Pentachlorophenol
2,4-Dinitrophenol	4-Methylphenol	bis(2-Chloroethyl) ether	Indeno(1,2,3-cd)pyrene	
2,4-Dinitrotoluene	Acetophenone	bis(2-Ethylhexyl) phthalate	Hexachlorobutadiene	
2,6-Dinitrotoluene	Benzidine	Chrysene	Hexachloroethane	
VOCs				
1,1,1-Trichloroethane	1,2-Dichloroethane	Acrylonitrile	Chloroethane	Methylene chloride
1,1,2,2-Tetrachloroethane	1,2-Dichloropropane	Benzene	Chloroform	Styrene
1,1,2-Trichloroethane	1,3,5-Trimethylbenzene	Bromodichloromethane	Chloromethane	Tetrachloroethene
1,1-Dichloroethene	1,4-Dichlorobenzene	Bromoform	cis-1,2-Dichloroethene	Toluene
1,2,3-Trichloropropane	2-Chlorotoluene (o-chlorotoluene)	Bromomethane	Dibromochloromethane	trans-1,2-Dichloroethene
1,2,4-Trimethylbenzene	4-Methyl-2-pentanone	Carbon disulfide	Dichlorodifluoromethane	Trichloroethene
1,2-Dibromo-3-chloropropane	Acetone	Carbon tetrachloride	Ethylbenzene	Vinyl chloride
1,2-Dibromoethane	Acrolein	Chlorobenzene	m,p-Xylenes	

Notes

1. Constituents were evaluated as constituents of concern based on criteria described in text.
2. The COC list provided was derived from a conservative screening process as discussed in the 2013 RI, the primary COC detected above preliminary cleanup levels are those used for alternative design in this FS.

Abbreviations

PCBs = polychlorinated biphenyls

SVOCs = semivolatile organic compounds

TPH = total petroleum hydrocarbons

VOCs = volatile organic compounds

COC = constituent of concern

RI = remedial investigation

FS = feasibility study

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TABLE 2-2

CONSTITUENTS OF CONCERN IN GROUNDWATER [1,2]

Stericycle Washougal Facility

Washougal, Washington

Inorganics	SVOCs	
Ammonia (as nitrogen)	1,4-Dioxane	bis(2-Chloroethyl) ether
Arsenic	1,4-Dichlorobenzene	bis(2-Ethylhexyl) phthalate
Barium	2,4,6-Trichlorophenol	Chrysene
Cadmium	2,4-Dichlorophenol	Dibenzo(a,h)anthracene
Chromium	2,4-Dinitrophenol	Dibenzofuran
Copper	2,4-Dinitrotoluene	Dinoseb
Cyanide	2,6-Dinitrotoluene	Hexachlorobenzene
Iron	2-Chlorophenol	Hexachlorobutadiene
Lead	3,3'-Dichlorobenzidine	Hexachlorocyclopentadiene
Manganese	4-Chloroaniline (p-chloroaniline)	Indeno(1,2,3-cd)pyrene
Nickel	Aniline	Isophorone
Silver	Benzo(a)anthracene	Nitrobenzene
Vanadium	Benzo(a)pyrene	N-Nitrosodi-n-propylamine
Zinc	Benzo(b)fluoranthene	N-Nitrosodiphenylamine
TPH	Benzo(k)fluoranthene	Pentachlorophenol
Gasoline range hydrocarbons		
Lube oil range hydrocarbons		
VOCs		
1,1,1,2-Tetrachloroethane	1,4-Dichlorobenzene	Dibromochloromethane
1,1,1-Trichloroethane	2-Methylnaphthalene	Dichlorodifluoromethane
1,1,2,2-Tetrachloroethane	Benzene	Hexachloroethane
1,1,2-Trichloroethane	Bromodichloromethane	m,p-Xylenes
1,1-Dichloroethane	Bromoform	Methylene chloride
1,1-Dichloroethene	Bromomethane	Styrene
1,2,3-Trichloropropane	Carbon disulfide	Tetrachloroethene
1,2,4-Trichlorobenzene	Carbon tetrachloride	Toluene
1,2-Dibromo-3-chloropropane	Chlorobenzene	Trans-1,2,-Dichloroethene
1,2-Dibromoethane	Chloroethane	Trichloroethene
1,2-Dichloroethane	Chloroform	Vinyl chloride
1,2-Dichloroethene (total)	Chloromethane	
1,2-Dichloropropane	cis-1,2-Dichloroethene	

Notes

1. Constituents were evaluated as constituents of concern based on criteria described in text.
2. The COC list provided was derived from a conservative screening process as discussed in the 2013 RI, the primary COC detected above preliminary cleanup levels are those used for alternative design in this FS.

Abbreviations

SVOCs = semivolatile organic compounds
TPH = total petroleum hydrocarbons
VOCs = volatile organic compounds
COC = constituent of concern
RI = remedial investigation
FS = feasibility study

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TABLE 3-1
GROUNDWATER PRELIMINARY CLEANUP LEVELS
SHALLOW GROUNDWATER ZONE AND LOWER AQUIFER
Stericycle Washougal Facility
Washougal, Washington

Concentrations in micrograms per liter (µg/L)

Constituent	CAS Number	Shallow Groundwater Zone Preliminary Cleanup Level	Lower Aquifer Preliminary Cleanup Level
Inorganics			
Ammonia (as nitrogen)	7664-41-7	--	--
Arsenic, inorganic	7440-38-2	22.84	1.42
Barium	7440-39-3	1,000	1,000
Cadmium	7440-43-9	1	1
Chromium	7440-47-3	50	50
Copper	7440-50-8	11	11
Cyanide	57-12-5	10	10
Iron	7439-89-6	1,000	1,000
Lead	7439-92-1	3	3
Manganese	7439-96-5	50	50
Nickel	7440-02-0	52	52
Silver	7440-22-4	5	5
Vanadium	7440-62-2	80	80
Zinc	7440-66-6	100	100
VOCs			
Benzene	71-43-2	1	1
Bromodichloromethane	75-27-4	1	1
Bromoform	75-25-2	4.6	4.6
Bromomethane	74-83-9	11	11
Carbon disulfide	75-15-0	400	800
Carbon tetrachloride	56-23-5	1	1
Chlorobenzene	108-90-7	100	100
Chloroform	67-66-3	1.2	1.4
Chloromethane	74-87-3	150	--
1,2-Dibromo-3-chloropropane	96-12-8	2	2
Dibromochloromethane	124-48-1	1	1
1,4-Dichlorobenzene	106-46-7	4.9	8.1
1,1-Dichloroethane	75-34-3	7.7	7.7
1,2-Dichloroethane	107-06-2	1	1
1,1-Dichloroethene	75-35-4	7	7
1,2-Dichloroethene (total)	540-59-0	72	72
cis-1,2-Dichloroethene	156-59-2	16	16
trans-1,2-Dichloroethene	156-60-5	1	1
Dichlorodifluoromethane	75-71-8	5.6	--
1,2-Dichloropropane	78-87-5	1	1

TABLE 3-1
GROUNDWATER PRELIMINARY CLEANUP LEVELS
SHALLOW GROUNDWATER ZONE AND LOWER AQUIFER
Stericycle Washougal Facility
Washougal, Washington
Concentrations in micrograms per liter (µg/L)

Constituent	CAS Number	Shallow Groundwater Zone Preliminary Cleanup Level	Lower Aquifer Preliminary Cleanup Level
Ethyl chloride (chloroethane)	75-00-3	--	--
Ethylene dibromide (EDB)	106-93-4	1	1
Methylene chloride	75-09-2	5	5
Styrene	100-42-5	100	100
1,1,1,2-Tetrachloroethane	630-20-6	1.68	1.68
1,1,2,2-Tetrachloroethane	79-34-5	1	1
Tetrachloroethene	127-18-4	2.4	2.4
Toluene	108-88-3	57	57
1,2,4-Trichlorobenzene	120-82-1	1	1
1,1,1-Trichloroethane	71-55-6	200	200
1,1,2-Trichloroethane	79-00-5	1	1
Trichloroethene	79-01-6	1	1
1,2,3-Trichloropropane	96-18-4	2	2
Vinyl chloride	75-01-4	0.02	0.02
m,p-Xylene	106-42-3	330	1600
SVOCs			
2,4,6-Trichlorophenol	88-06-2	10	10
2-Chlorophenol	95-57-8	15	15
2-Methylnaphthalene	91-57-6	32	32
Aniline	62-53-3	7.7	7.7
Benzo(a)anthracene	56-55-3	0.2	0.2
Benzo(a)pyrene	50-32-8	0.2	0.2
Benzo(b)fluoranthene	205-99-2	0.2	0.2
Benzo(k)fluoranthene	207-08-9	0.2	0.2
bis(2-Chloroethyl) ether	111-44-4	10	10
bis(2-Ethylhexyl) phthalate	117-81-7	20	20
Chrysene	218-01-9	0.2	0.2
3,3'-Dichlorobenzidine	91-94-1	10	10
1,4-Dioxane	123-91-1	1	1
2,4-Dichlorophenol	120-83-2	10	10
2,4-Dinitrophenol	51-28-5	20	20
2,4-Dinitrotoluene	121-14-2	0.5	0.5
2,6-Dinitrotoluene	606-20-2	0.5	0.5
Dibenzo[a,h]anthracene	53-70-3	0.2	0.2
Dibenzofuran	132-64-9	20	20
Dinoseb	88-85-7	7	7
Hexachlorobenzene	118-74-1	0.05	0.05

TABLE 3-1
GROUNDWATER PRELIMINARY CLEANUP LEVELS
SHALLOW GROUNDWATER ZONE AND LOWER AQUIFER
Stericycle Washougal Facility
Washougal, Washington
Concentrations in micrograms per liter (µg/L)

Constituent	CAS Number	Shallow Groundwater Zone Preliminary Cleanup Level	Lower Aquifer Preliminary Cleanup Level
Hexachlorobutadiene	87-68-3	1	1
Hexachlorocyclopentadiene	77-47-4	1	1
Hexachloroethane	67-72-1	10	10
Indeno(1,2,3-cd)pyrene	193-39-5	0.2	0.2
Isophorone	78-59-1	27	27
N-Nitroso-di-n-propylamine	621-64-7	10	10
N-Nitrosodiphenylamine	86-30-6	10	10
Nitrobenzene	98-95-3	10	10
p-Chloroaniline	106-47-8	10	10
Pentachlorophenol	87-86-5	20	20
TPH			
Gasoline	86290-81-5	800	800
Lube oil	NA	500	500

Abbreviations
-- = no cleanup level calculated
CAS = Chemical Abstracts Service
PCBs = polychlorinated biphenyls
SVOCs = semivolatile organic compounds
TPH = total petroleum hydrocarbons
VOCs = volatile organic compounds

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TABLE 3-2
SOIL PRELIMINARY CLEANUP LEVELS
Stericycle Washougal Facility
Washougal, Washington

Concentrations are in milligrams per kilogram (mg/kg)

Constituent	CAS Number	Soils on Stericycle Property Preliminary Cleanup Level	Soils Off Stericycle Property Preliminary Cleanup Level
Inorganics			
Barium	7440-39-3	500	500
Cadmium	7440-43-9a	1.1	1.1
Chromium (total)	7440-47-3	42	42
Copper	7440-50-8	34	34
Cyanide	57-12-5	--	--
Lead	7439-92-1	50	50
Mercury	7439-97-6	0.1	0.1
Nickel	7440-02-0	30	30
Selenium and compounds	7782-49-2	0.5	0.5
Silver	7440-22-4	0.85	0.85
Thallium, soluble salts	7440-28-0	0.23	0.23
Vanadium	7440-62-2	2	2
Zinc	7440-66-6	96	96
PCBs/Pesticides			
Aldrin	309-00-2	0.1	0.039
delta-BHC	319-86-8	--	--
4,4'-DDD	72-54-8	9.6	1.9
4,4'-DDT	50-29-3	8.5	1.9
Dieldrin	60-57-1	0.07	0.034
Endrin	72-20-8	0.2	0.2
Heptachlor	76-44-8	0.63	0.13
Heptachlor epoxide	1024-57-3	0.33	0.07
Lindane	58-89-9	--	--
Toxaphene	8001-35-2	2.1	0.49
Polychlorinated biphenyls, total	1336-36-3	0.94	0.23
SVOCs			
Acetophenone	98-86-2	120,000	7,800
Benzidine	92-87-5	--	--
Benzo(a)anthracene	56-55-3	1.43	1.10
Benzo(a)pyrene	50-32-8	2.10	0.11
Benzo(b)fluoranthene	205-99-2	4.92	1.10
Benzo(k)fluoranthene	207-08-9	4.92	4.92
p-Chloroaniline (4-chloroaniline)	106-47-8	0.33	0.33
bis(2-Chloroethyl) ether	111-44-4	0.33	0.33
2-Chloronaphthalene	91-58-7	60,000	4,800
2-Chlorophenol	95-57-8	0.33	0.33
Chrysene	218-01-9	1.59	1.59
3,3'-Dichlorobenzidine	91-94-1	0.66	0.66

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TABLE 3-2
SOIL PRELIMINARY CLEANUP LEVELS
Stericycle Washougal Facility
Washougal, Washington

Concentrations are in milligrams per kilogram (mg/kg)

Constituent	CAS Number	Soils on Stericycle Property Preliminary Cleanup Level	Soils Off Stericycle Property Preliminary Cleanup Level
2,4-Dichlorophenol	120-83-2	0.33	0.33
Dibenzo[a,h]anthracene	53-70-3	2.1	0.11
Dibenzofuran	132-64-9	1,000	73
2,4-Dimethylphenol	105-67-9	16,000	1,300
2,4-Dinitrophenol	51-28-5	--	--
2,4-Dinitrotoluene	121-14-2	0.1	0.1
2,6-Dinitrotoluene	606-20-2	0.1	0.1
1,4-Dioxane	123-91-1	--	--
bis(2-Ethylhexyl) phthalate	117-81-7	44.50	39
Hexachlorobenzene	118-74-1	0.08	0.08
Hexachlorobutadiene	87-68-3	1.08	1.08
Hexachloroethane	67-72-1	8	1.8
Indeno(1,2,3-cd)pyrene	193-39-5	13.9	1.1
Isophorone	78-59-1	0.33	0.33
4-Methylphenol	106-44-5	82,000	6,300
N-Nitroso-di-n-propylamine	621-64-7	0.33	0.33
N-Nitrosodiphenylamine	86-30-6	0.33	0.33
Nitrobenzene	98-95-3	0.1	0.1
Pentachlorophenol	87-86-5	0.66	0.66
2,4,6-Trichlorophenol	88-06-2	0.33	0.33
TPH			
Gasoline	86290-81-5	100	100
Lube Oil		2,000	2,000
VOCs			
Acetone	67-64-1	29	29
Acrolein	107-02-8	0.6	0.14
Acrylonitrile	107-13-1	1.1	0.25
Benzene	71-43-2	0.00564	0.00564
Bromodichloromethane	75-27-4	0.00521	0.00521
Bromoform	75-25-2	0.0302	0.0302
Bromomethane	74-83-9	0.0509	0.0509
Carbon disulfide	75-15-0	2.83	2.83
Carbon tetrachloride	56-23-5	0.00921	0.00921
Chlorobenzene	108-90-7	0.874	0.874
Chloroform	67-66-3	0.00638	0.00638
Chloromethane	74-87-3	460	110
2-Chlorotoluene	95-49-8	23000	1600
1,2-Dibromo-3-chloropropane	96-12-8	0.064	0.01
Dibromochloromethane	124-48-1	0.00532	0.00532
1,4-Dichlorobenzene	106-46-7	0.0808	0.0808

TABLE 3-2
SOIL PRELIMINARY CLEANUP LEVELS
Stericycle Washougal Facility
Washougal, Washington

Concentrations are in milligrams per kilogram (mg/kg)

Constituent	CAS Number	Soils on Stericycle Property Preliminary Cleanup Level	Soils Off Stericycle Property Preliminary Cleanup Level
Dichlorodifluoromethane	75-71-8	370	87
1,2-Dichloroethane	107-06-2	0.005	0.005
1,1-Dichloroethene	75-35-4	0.0501	0.0501
cis-1,2-Dichloroethene	156-59-2	0.08	0.08
trans-1,2-Dichloroethene	156-60-5	0.00543	0.00543
Ethyl chloride (chloroethane)	75-00-3	57,000	14,000
Ethylbenzene	100-41-4	5.9	5.8
Ethylene dibromide (EDB)	106-93-4	0.16	0.036
4-Methyl-2-pentanone	108-10-1	140000	6400
Methylene Chloride	75-09-2	0.0218	0.0218
Styrene	100-42-5	2.24	2.24
1,1,2,2-Tetrachloroethane	79-34-5	0.0056	0.0056
Tetrachloroethene	127-18-4	0.0255	0.0255
1,1,1-Trichloroethane	71-55-6	1.58	1.58
1,1,2-Trichloroethane	79-00-5	0.00556	0.00556
Trichloroethene	79-01-6	0.00661	0.00661
1,2,3-Trichloropropane	96-18-4	0.11	0.02
1,2,4-Trimethylbenzene	95-63-6	1800	300
1,3,5-Trimethylbenzene	108-67-8	1500	270
Toluene	108-88-3	0.414	0.414
Vinyl chloride	75-01-4	0.005	0.005
m,p-Xylene	106-42-3	3.02	3.02

Abbreviations
CAS = Chemical Abstracts Service
PCBs = polychlorinated biphenyls
SVOCs = semivolatile organic compounds
TPH = total petroleum hydrocarbons
VOCs = volatile organic compounds

TABLE 5-1
SUMMARY OF REMEDIATION TECHNOLOGIES CONSIDERED FOR SOIL
Stericycle Washougal Facility
Washougal, Washington

Technology Characteristics							
General Response Actions	**Remediation Technologies**	**Text Section**	**Technology Description**	**Technology Development Status**	**General Performance Record**	**Site Areas Addressed**	**Contaminants Typically Addressed by Technology**
In Situ Biological Treatment	Bioventing	5.2.1.1	Oxygen is delivered to contaminated unsaturated soils by forced air movement (either extraction or injection of air) to increase oxygen concentrations and stimulate biodegradation.	Full-Scale	Performs well for nonhalogenated organic compounds in moist soils that biodegrade aerobically (such as BTEX). Low effectiveness for halogenated organics. Ineffective on PCBs, inorganics, and in dry soils	Upper Sand Unit east of Building 1 and in the former tank farm area.	TPH Constituents and VC.
	Enhanced Bioremediation	5.2.1.2	The activity of naturally occurring microbes is stimulated by circulating water-based solutions through contaminated soils to enhance in situ biological degradation of organic contaminants. Nutrients, oxygen, or other amendments may be used to enhance bioremediation and contaminant desorption from subsurface materials.	Full-Scale	Anaerobic bioremediation has been moderately effective on halogenated VOCs. Aerobic bioremediation has been moderately effective for VC, SVOCs and effective for TPH. Ineffective on inorganics and PCBs.	Areas located beneath the former fuel farm area and Building 1 (Upper and Lower Aquifer Units).	Halogenated VOCs (ethenes and TCP), SVOCs, TPH (BTEX).
	Phytoremediation	5.2.1.3	Broadly defined as the use of vegetation to address in situ biological degradation, sequestration, or capture of contaminants.	Full-Scale	Typical organic contaminants, such as petroleum hydrocarbons, gas condensates, crude oil, chlorinated compounds, pesticides, and explosive compounds, can be addressed using plant-based methods. Phytotechnologies also can be applied to typical inorganic contaminants, such as heavy metals, metalloids, radioactive materials, and salts (ITRC 2009).	Areas located along the east fence line and the area west of the waste oil tank system.	Halogenated VOCs, SVOCs, TPH, metals, and 1,4-dioxane.
In Situ Physical/Chemical Treatment	Chemical Oxidation	5.2.1.4	Oxidation chemically converts hazardous contaminants to nonhazardous or less toxic compounds that are more stable, less mobile, and/or inert. The oxidizing agents most commonly used are ozone, hydrogen peroxide, persulfate, or permanganate. Reaction occurs only in aqueous solution.	Full-Scale	Technology demonstrated to be effective under certain site conditions. Ineffective for most inorganics, but would be effective for cyanide.	Areas located beneath the former fuel farm area and Building 1 (Upper and Lower Aquifer Units).	Halogenated and nonhalogenated VOCs and SVOCs, TPH compounds, and 1,4-dioxane.
	Soil Flushing	5.2.1.5	Water, or water containing an additive to enhance contaminant solubility, is applied to the soil or injected into the groundwater to raise the water table into the contaminated soil zone. Contaminants are leached into the groundwater, which is then extracted and treated.	Full-Scale	Poor performance record. Few sites have been successfully remediated using this technology.	Vadose zone soil areas located beneath the former fuel farm area and east of Building 1.	Some inorganics and some organics, depending on site and constituent conditions and additive used (i.e. metals with chelatants, solvents with cosolvents, etc.).

TABLE 5-1
SUMMARY OF REMEDIATION TECHNOLOGIES CONSIDERED FOR SOIL
Stericycle Washougal Facility
Washougal, Washington

Technology Characteristics							
General Response Actions	**Remediation Technologies**	**Text Section**	**Technology Description**	**Technology Development Status**	**General Performance Record**	**Site Areas Addressed**	**Contaminants Typically Addressed by Technology**
In Situ Physical/Chemical Treatment (cont.)	Soil Vapor Extraction	5.2.1.6	Removes volatile constituents from the vadose zone. Using a blower, a vacuum is applied to wells screened in the vadose zone, and the volatiles are entrained in the extracted air and removed with the soil vapor. Off gases are generally treated to control emissions using thermal destruction or adsorption technologies.	Full-Scale	Proven reliable and effective technology for VOCs. Not effective for SVOCs, PCBs, and inorganics.	Vadose zone soil areas on site around the former tank farm area and Building 1 .	Halogenated VOCs and TPH Constituents.
	Solidification/ Stabilization	5.2.1.7	Contaminants are physically bound or enclosed within a stabilized mass (solidification), or chemical reactions are induced between the stabilizing agent and contaminants either to reduce their mobility (stabilization) or to treat contaminated soil in situ (deep soil mixing).	Full-Scale	Several different field methods are used for this generalized approach. Stabilization reagents can be effective. Complete mixing can be difficult. Can be combined with variants such as deep soil mixing employing treatment technologies (e.g. zero-valent iron) to treat various COCs.	Vadose zone soil and silt around the former fuel tank area and around Building 1.	Metals and if deep soil mixing with ZVI is used; organics.
In Situ Thermal Treatment	High-Temperature Volatilization	5.2.1.8	Steam, electrical energy, or soil heaters are injected below the contaminated zone to heat contaminated soil. The heating enhances the release of contaminants from the soil matrix. Some VOCs and SVOCs are stripped from the contaminated zone and brought to the surface through soil vapor extraction.	Full-Scale	Performance of steam injection and stripping is highly variable and site specific. Installation of soil heaters will result in uneven heating and may desiccate soils. Electrical resistive heating would be the most effective technology but may require excess energy and time to adequately treat the target VOCs and SVOCs.	All primary impacted soil areas around the former fuel tank area and beneath/around Building 1.	VOCs, SVOCs
Containment	Cap/Surface Cover	5.2.1.9	Surface caps constructed of asphalt concrete, Portland cement concrete, or flexible membrane liners prevent direct exposure to soil contaminants, control erosion, and reduce infiltration of storm water into the subsurface, reducing the leaching of COCs to groundwater.	Full-Scale	Proven effective for preventing surface exposure to buried waste and for reducing infiltration of surface water through waste, limiting leaching of COCs to groundwater.	All impacted soil areas around the former fuel tank area, building 2 and building 3, and west of the waste oil tank system.	VOCs, SVOCs, TPH, inorganics
Ex Situ Biological Treatment (assumes excavation)	Biopiles	5.2.2.1	Excavated soils are mixed with soil amendments and placed on a treatment area that includes leachate collection systems and some form of aeration to support bioremediation of organic constituents in excavated soils. Moisture, heat, nutrients, oxygen, and pH can be controlled to enhance biodegradation.	Full-Scale	Effective for nonhalogenated VOCs and TPH. Less effective on halogenated VOCs and poor effectiveness on PCBs. Ineffective for inorganics.	Vadose zone soil areas around the former tank farm area and east of Building 1 with BTEX.	TPH (BTEX)
Ex Situ Physical/Chemical Treatment (assumes excavation)	Soil Washing	5.2.2.2	Contaminants sorbed onto fine soil particles are separated from bulk soil in an aqueous-based system on the basis of particle size. The wash water may be augmented with a basic leaching agent, surfactant, pH adjustment, or chelating agent to help remove organics and heavy metals.	Full-Scale	Not widely commercially applied in the United States. Technology sometimes has difficulties treating complex mixtures of organics and inorganics.	Vadose zone soil areas around the former tank farm area and east of Building 1.	VOCs, SVOCs, inorganics, TPH

TABLE 5-1
SUMMARY OF REMEDIATION TECHNOLOGIES CONSIDERED FOR SOIL
Stericycle Washougal Facility
Washougal, Washington

Technology Characteristics							
General Response Actions	**Remediation Technologies**	**Text Section**	**Technology Description**	**Technology Development Status**	**General Performance Record**	**Site Areas Addressed**	**Contaminants Typically Addressed by Technology**
Ex Situ Physical/Chemical Treatment (assumes excavation)	Solidification/ Stabilization	5.2.2.3	Contaminants are physically bound or enclosed within a stabilized mass (solidification), or chemical reactions are induced between the stabilizing agent and contaminants to reduce their mobility (stabilization).	Full-Scale	Generally effective for inorganics. Mature technology with documented performance record. Poor effectiveness for organics.	Vadose zone and silt soils in and around the former tank farm area.	Inorganics
Ex Situ Thermal Treatment (assumes excavation)	Thermal Desorption	5.2.2.4	Wastes are heated to volatilize water and organic contaminants. A carrier gas or vacuum system transports volatilized water and organics to the gas treatment system.	Full-Scale	Proven effective at low temperature for TPH and VOCs; at high temperature, effective for SVOCs, PAHs, and PCBs. Proven and commercial off-the-shelf technology offered by multiple vendors. Not effective for inorganics.	Vadose zone and silt soils in and around the former tank farm area and east of Building 1.	VOCs, SVOCs, TPH
Excavation/Disposal	Excavation and Off- Site Disposal	5.2.2.5	Wastes exceeding site remedial goals are excavated and transported off site to an appropriate hazardous waste land disposal facility.	Full-Scale	Proven effective for all site COCs.	Vadose zone and silt soils in and around the former tank farm area and east of Building 1.	VOCs, SVOCs, TPH, inorganics

Abbreviations
SVOCs = semivolatile organic compounds
RCRA = Resource Conservation and Recovery Act
COCs = constituents of concern
RI/FS = Remedial Investigation and Feasibility Study
PAHs = polycyclic aromatic hydrocarbon
TPH = total petroleum hydrocarbons
PCBs = polychlorinated biphenyls
VOCs = volatile organic compounds

TABLE 5-2
REMEDIATION TECHNOLOGY SCREENING FOR SOIL
Stericycle Washougal Facility
Washougal, Washington

Technology Characteristics					
General Response Actions	**Remediation Technologies**	**Text Section**	**Site-Specific Issues Affecting Technology or Implementation**	**Rationale for Retention or Rejection**	**Screening Result**
In Situ Biological Treatment	Bioventing	5.2.1.1	Effectiveness of in situ degradation of halogenated VOCs and SVOCs is low. Technology is ineffective on inorganics and pesticides. Technology will leave a lot of mass of non-halogenated VOCs in subsurface that are buried in silts.	Low effectiveness on high-molecular-weight organic COCs (SVOCs) and halogenated VOCs, and ineffective for inorganics. Unlikely achieve CULs in source area for VOCs.	Reject
	Enhanced Bioremediation	5.2.1.2	In situ degradation of VOCs (chlorinated and non-chlorinated) is only moderately effective. Ineffective for other site COCs. Would require a system of numerous injection points to distribute bioremediation fluids to the subsurface across a large area, some of which is under existing buildings. Sequential anaerobic/aerobic treatment would be needed to address most of the organic COCs. Would be very difficult to apply substrate to unsaturated soils.	Only moderately effective on halogenated organics and SVOCs and likely would not obtain CULs in contaminant source areas but would likely meet CULs downgradient. Likely ineffective on inorganics and pesticides. Very long treatment time likely. Very high cost to implement for soils compared to other technologies, such as chemical oxidation, given uncertainty in performance, multiple injections required, and monitoring requirements.	Reject
	Phytoremediation	5.2.1.3	Only viable in non-containment areas. Would require irrigation systems for the dry season. Soil amendments may be necessary to ensure rapid and sustained growth	Environmentally-friendly “green” and low-tech remedial technology. Operation and maintenance costs are typically lower than those required for traditional remedies (such as soil vapor extraction), because the remedy is generally resilient and self-repairing. Plants can improve site aesthetics (visual appearance and noise).	Retain
In Situ Physical/Chemical Treatment	Chemical Oxidation	5.2.1.4	Handling of oxidant chemicals during remediation presents a safety concern. Chemical oxidant demand of soil can consume large quantities of oxidant (pilot test recommended). Establishing effective oxidant delivery system for even vadose zone distribution difficult. Oxidants can mobilize some metals. This technology may require multiple injection rounds and it may be difficult to implement under Building 1.	Treats all key COCs; remediation time frame is relatively short and depending on the treatment area, may achieve stringent CULs. However, silt source area distribution of oxidant in low-permeability soils is difficult (dependent on bench/pilot testing to confirm viability).	Retain
	Soil Flushing	5.2.1.5	Requires recovery of water (hydraulic capture) and surfactant and separation facilities. Recovered water requires treatment, disposal, and management of treatment residuals. Site would require different surfactants to treat all COCs. Large injection galleries or trenches would require extensive disruption of facility operations. Implementation under Building 1 would be difficult.	Technology is not proven effective. Requires extensive and complex fluids delivery system and recovered fluids treatment system. Technology would not remove sufficient mass from source areas to meet CULs.	Reject

TABLE 5-2
REMEDIATION TECHNOLOGY SCREENING FOR SOIL
Stericycle Washougal Facility
Washougal, Washington

Technology Characteristics					
General Response Actions	**Remediation Technologies**	**Text Section**	**Site-Specific Issues Affecting Technology or Implementation**	**Rationale for Retention or Rejection**	**Screening Result**
In Situ Physical/Chemical Treatment (cont.)	Soil Vapor Extraction	5.2.1.6	Limited vadose zone at Stericycle facility; most contaminants are trapped in the Silt Layer below water table. Contamination in a large percentage of the vadose zone is likely due to smear effects of seasonal water table. Thus, the lower end of the vadose zone is likely to be recontaminated regularly.	The contaminant distribution and hydrogeology at the site are likely to lead to low mass removal and limited effectiveness using this technology. Technology will not meet cleanup levels in vadose zone soils.	Reject
In Situ Physical/Chemical Treatment (cont.)	Solidification/ Stabilization	5.2.1.7	Increases in soil volume due to stabilization or solidification reagents ("bulk up" or "fluff") can be significant. Excess soil may require disposal as hazardous waste. Presence of solidified material could affect future site development by creating structural challenges for new buildings. Combining containment and treatment with additives would still not address all COCs.	Deep soil mixing with zero-valent iron has been identified as a potential field method that would remediate organics and reduce COC contact with groundwater, thereby limiting migration of COCs from the property.	Retain
In Situ Thermal Treatment	High-Temperature Volatilization	5.2.1.8	Effectiveness can be hindered by high organic carbon content or high moisture content (e.g., soil in the capillary fringe). Would require extensive network of steam distribution points or electrodes to heat soil effectively. For steam injection, significant volumes of water are added to the subsurface, which may flush contaminants from unsaturated soil to groundwater. Volatilization of contaminants may prevent inhalation risk for workers.	ERH is one of the most effective treatment technologies in silt formations and may achieve CULs in the source areas and the other target areas. Has been retained for use in soils and groundwater.	Retain
Containment	Cap/Surface Cover	5.2.1.9	The site is a patch-work of different coverings. Would require patching or paving areas of risk to prevent offsite migration or worker exposure.	Would be effective in preventing exposure of workers at the facility to contaminated soils. Would not meet CULs nor reduce any mass of COCs.	Retain
Ex Situ Biological Treatment (assumes excavation)	Biopiles	5.2.2.1	Would require extensive site excavation and soil management and removal of existing concrete cover. Extensive shoring and supporting systems would be required for excavations near existing structures. Some impacted soils would likely remain in place due to the presence of existing structures/buildings. Emission control measures (e.g., tenting site) would likely be required during excavation. Treatability tests required to assess feasibility. RCRA treatment permit would likely be required.	Unproven effectiveness on halogenated VOCs. Ineffective on inorganics. Large excavation would disrupt existing facility cover. Increased worker and public exposure risk associated with excavation and treatment process. Contaminated soils that would be left in place would be above CULs.	Reject

TABLE 5-2
REMEDIATION TECHNOLOGY SCREENING FOR SOIL
Stericycle Washougal Facility
Washougal, Washington

Technology Characteristics					
General Response Actions	**Remediation Technologies**	**Text Section**	**Site-Specific Issues Affecting Technology or Implementation**	**Rationale for Retention or Rejection**	**Screening Result**
Ex Situ Physical/Chemical Treatment (assumes excavation)	Soil Washing	5.2.2.2	Would require extensive site excavation, soil management, and removal of existing concrete cover. Extensive shoring and support systems would be required for excavations near existing structures. Some impacted soils would likely remain in place due to the presence of existing structures/buildings. Emission control measures (e.g., tenting site) would likely be required during excavation. Worker and public exposure to impacted soils is significantly increased by this approach. Treatability tests would be required to assess feasibility. Produces wash water and soil residuals, which would require further treatment and off-site disposal. Significant concentrations of humus (natural organics) or clay in soil can disrupt process. RCRA treatment permit would likely be required.	Soil washing may not be effective for complex mixture of organics and inorganics. Extensive shoring and supporting systems would be required for excavations near existing structures. Worker and public exposure risks associated with excavation and treatment process. Contaminated soils that would be left in place would be above CULs.	Reject
Ex Situ Physical/Chemical Treatment (assumes excavation) (cont.)	Solidification/ Stabilization	5.2.2.3	Would require excavation and soil management. Extensive shoring and support systems would be required for excavations near existing structures. Some impacted soils would likely remain in place due to the presence of existing structures/buildings. Emission control measures (e.g., tenting site) would likely be required during excavation. Treatability tests would be required to assess feasibility. Can result in significant increases in soil volume ("bulk up") that would likely result in off-site disposal of excess material. Because organic wastes would be encapsulated but not destroyed, long-term management of wastes would be required. RCRA treatment permit would likely be required.	Extensive shoring and support systems would be required for excavations near existing structures. Volume increase (bulk up) would result in excess material requiring off-site disposal. Post-treatment waste left on the property would remain a long-term management issue. Not proven effective for organics. Increased worker and public exposure risk associated with excavation and treatment process. Contaminated soils that would be left in place would be above CULs.	Reject
Ex Situ Thermal Treatment (assumes excavation)	Thermal Desorption	5.2.2.4	Would require excavation and soil management. Extensive shoring and support systems would be required for excavations near existing structures. Some impacted soils would likely remain in place due to the presence of existing structures/buildings. Emission control measures (e.g., tenting site) would likely be required during excavation. Worker and public exposure to impacted soils is significantly increased by this approach. Treatability tests would be required to assess feasibility. Requires large working area for setup of equipment. High soil moisture can increase costs due to extended soil drying. Emissions from thermal desorption must be captured and treated prior to discharge to the atmosphere. RCRA treatment permit would likely be required.	Large excavation and treatment footprint would disrupt existing facility operations. High temperature desorption would address high molecular weight organics (SVOCs), but would also potentially create emissions containing metals. Increased worker and public exposure risk associated with excavation. Contaminated soils that would be left in place would be above CULs.	Reject

TABLE 5-2
REMEDIATION TECHNOLOGY SCREENING FOR SOIL
Stericycle Washougal Facility
Washougal, Washington

Technology Characteristics					
General Response Actions	Remediation Technologies	Text Section	Site-Specific Issues Affecting Technology or Implementation	Rationale for Retention or Rejection	Screening Result
Excavation/Disposal	Excavation and Off-Site Disposal	5.2.2.5	Would require extensive site excavation and soil management. Extensive shoring and support systems would be required for excavations near existing structures. Some impacted soils would likely remain in place due to the presence of existing structures/buildings.	Capable of addressing all contaminants in vadose zone soil. Least administratively, logistically, and technically complex ex situ remediation technology. Potentially applicable to hot spots where other technologies are difficult to implement or expensive. Contaminated soils that would be left in place under structures would be above CULs.	Retain

Abbreviations

COCs = constituents of concern
CUL = cleanup level
ERH = electrical resistance heating
RCRA = Resource Conservation and Recovery Act
SVOCs = semivolatile organic compounds
VOCs = volatile organic compounds
ZVI = zero-valent iron

TABLE 5-3
SUMMARY OF REMEDIATION TECHNOLOGIES CONSIDERED FOR GROUNDWATER
Stericycle Washougal Facility
Washougal, Washington

Technology Characteristics							
General Response Actions	**Remediation Technologies**	**Text Section**	**Technology Description**	**Technology Development Status**	**General Performance Record**	**Site Area Addressed**	**Site Contaminants Addressed**
In Situ Biological Treatment	Enhanced Biodegradation with Biosparging	5.3.1	Air and nutrients, if needed, are injected into the saturated zone to increase oxygen levels and promote aerobic biological activity. Air is delivered using a compressor and vertical or horizontal injection wells.	Full-Scale	Performs well for organic compounds that biodegrade aerobically. Not effective for inorganics or chlorinated VOCs. Primarily used at petroleum-impacted sites.	Shallow groundwater and Deep Aquifer around the former tank farm area, along the northern property line and east of Building 1.	VC
	Oxygen Enhancement with Hydrogen Peroxide or ORC	5.3.2	Oxygen is added to the saturated zone by adding chemicals such as hydrogen peroxide or ORC®. The increased oxygen levels promote aerobic biological activity. Hydrogen peroxide or ORC solutions can be injected into the aquifer or introduced through slow release mechanisms placed in wells.	Full-Scale	Has been effectively used at TPH sites. Performance is similar to but less effective than biosparging.	Shallow groundwater and Lower Aquifer around the former tank farm area and along the northern property line.	VC
	Co-Metabolic Treatment	5.3.3	Chloroethenes and 1,4-dioxane are organically degraded by aerobic co-metabolism with alkane substrates, such as ethane, by indigenous microbes. Oxygen and the alkane substrate can be added through passive diffusion or through groundwater circulation system.	Full-Scale	Has been effective for degradation of chlorinated solvents and 1,4-dioxane.	Shallow groundwater and Lower Aquifer around the former tank farm area, the northern property line, and east of Building 1.	PCE, TCE, *cis* -1,2-DCE, VC, 1,4-dioxane
	Biostimulation of Reductive Dechlorination (Anaerobic)	5.3.4	A carbohydrate (e.g., molasses, sodium lactate) is injected into the affected groundwater to serve as an electron donor for indigenous organisms to enhance reductive dechlorination. A carbohydrate solution is distributed with injection wells, direct-push probes, or groundwater recirculation systems.	Full-Scale	Proven effective under proper conditions for degradation of chlorinated solvents.	Shallow groundwater and Lower Aquifer around the former tank farm area and along the northern property line.	PCE, TCE, *cis* -1,2-DCE, and VC
	Bioaugmentation	5.3.5	Injection of specialty, nonindigenous microbes to enhance biodegradation. Microorganisms are commercially available for both aerobic and anaerobic degradation of chlorinated organics and petroleum hydrocarbons.	Full-Scale	Has been effective for biodegradation of chlorinated solvents. Requires application of specific microbial seed (*Dehalococcoides*). May require repeated application.	Shallow groundwater and Lower Aquifer around the former tank farm area and along the northern property line.	PCE, TCE, *cis* -1,2-DCE, and VC
	Monitored Natural Attenuation	5.3.6	Intrinsic attenuation of groundwater constituents via the natural processes of biodegradation (aerobic and/or anaerobic), adsorption, and dilution. This passive technology relies on natural conditions within impacted groundwater.	Full-Scale	Has been proven effective at sites with appropriate conditions.	All areas of site in the Shallow and Lower Aquifer Groundwater Zones with appropriate conditions.	chlorinated VOCs, and 1,4-dioxane

TABLE 5-3
SUMMARY OF REMEDIATION TECHNOLOGIES CONSIDERED FOR GROUNDWATER
Stericycle Washougal Facility
Washougal, Washington

Technology Characteristics							
General Response Actions	Remediation Technologies	Text Section	Technology Description	Technology Development Status	General Performance Record	Site Area Addressed	Site Contaminants Addressed
In Situ Physical/Chemical Treatment	Phytoremediation	5.3.7	Dense plants and trees can supply nutrients to promote microbial growth that reduce contaminant concentrations in groundwater, or plants can directly uptake contaminants in groundwater. New implementation technology allows for treatment depths of more than 50 feet below ground surface and has shown effective hydraulic control.	Full-Scale	Has been proven effective at sites with appropriate conditions.	As a potential contingent remedy for groundwater zones along the northeast and east sides of the site.	VOCs, metals, 1,4-dioxane.
	Carbon Augmentation	5.3.8	Colloidal activated carbon is injected into the saturate zone with an organic stabilizer to sequester and reduce contaminant concentrations. The activated carbon disperses through the subsurface during injection and dispersion continues over time with groundwater flow.	Full Scale	Has been proven effective at sites with appropriate conditions. Effectively used for chlorinated VOCs and TPH. Not effective for inorganics.	Shallow groundwater and Lower Aquifer around the former tank farm area, along the northern property line, and underneath and east of Building 1.	PCE, TCE, cis -1,2-DCE, 1,4- dioxane
	Air Sparging	5.3.9	Air is injected into the saturated zone to volatilize organic compounds or oxygenate aquifer to promote precipitation of metals. An air compressor is used to supply air to the saturated zone typically through air sparge wells. Similar to biosparging, but does not rely on biodegradation.	Full-Scale	Has been effectively used at non-chlorinated VOC-impacted sites. Difficult to implement for deep groundwater.	Shallow groundwater and Lower Aquifer around the former tank farm area and along the northern property line.	VC, metals
	Chemical Oxidation-Active	5.3.10.1	An oxidizing chemical (permanganate, hydrogen peroxide, Fenton's Reagent, RegenOx) is actively injected through wells or via direct-push technology to the groundwater to chemically oxidize contaminants. Pilot test would be required	Full-Scale	Can be effective depending on oxidant demand of native material, tightness of formation, and number of injections. Not effective for most metals.	Shallow groundwater and Lower Aquifer around the former tank farm area, along the northern property line, and underneath and east of Building 1.	VOCs,1,4- dioxane
	Chemical Oxidation-Passive	5.3.10.2	An oxidizing chemical (potassium permanganate, sodium persulfate) is suspended in a monitoring on an inert media to passively release chemical oxidizer for treatment of contaminants. Pilot test would be required	Full-Scale	Can be effective depending on oxidant demand of native material, tightness of formation, and number of injections. Not effective for most metals and 1,4-dioxane.	Shallow groundwater and Lower Aquifer around the former tank farm area, along the northern property line, and underneath and east of Building 1.	VOCs
	Thermal Treatment	5.3.11	Temperature in the saturated zone is increased by injecting steam or applying an electrical current. The increased temperature volatilizes organic compounds, which would be collected from the vadose zone using SVE.	Full-Scale	Mixed performance record with improved performance in silts compared to other technologies. Some applications have been effective, while others have been unsuccessful in attaining cleanup objectives. Not effective for inorganics, can release metals.	Shallow Groundwater Zone, Silt Layer, and Lower Aquifer around the former tank farm area, along the northern property line, and underneath and east of Building 1.	VOCs, 1,4- dioxane, and metals

TABLE 5-3
SUMMARY OF REMEDIATION TECHNOLOGIES CONSIDERED FOR GROUNDWATER
Stericycle Washougal Facility
Washougal, Washington

Technology Characteristics							
General Response Actions	Remediation Technologies	Text Section	Technology Description	Technology Development Status	General Performance Record	Site Area Addressed	Site Contaminants Addressed
In Situ Physical/Chemical Treatment (cont.)	In-Well Stripping	5.3.12	Air is injected into a double-screened well, lifting the water in the well and forcing it out the upper screen. Simultaneously, additional water is drawn in the lower screen. Volatile compounds are transferred to the vapor phase and removed by vapor extraction. Groundwater in radius of influence is aerated.	Full-Scale	Mixed performance record. Some applications have been very effective, while others have been unsuccessful in attaining cleanup objectives.	Shallow Groundwater Zone and Lower Aquifer around the former fuel tank area.	VC
	Passive/Reactive Treatment Walls	5.3.13	Contaminant concentrations in groundwater are reduced as the groundwater flows through the permeable reactive barrier containing zero-valent iron.	Full-Scale	Has been effectively used to reduce chlorinated VOC and metals concentrations in groundwater.	Shallow Groundwater Zone and Lower Aquifer to the east of Building 1.	chlorinated VOCs, some metals
Groundwater Extraction and Treatment (Pump and Treat)	Hydraulic Control	5.3.14	Groundwater extraction wells are installed to create a hydraulic gradient to control contaminant migration. Extracted water is then treated and discharged.	Full-Scale	Has been effectively used to control contaminant migration. Is a long-duration technology. Cannot attain cleanup levels.	Shallow Groundwater Zone and Lower Aquifer around the former tank farm area and east of Building 1.	VOCs,1,4-dioxane, metals
	Mass Reduction	5.3.14	Groundwater extraction wells are installed in source areas to aggressively remove contaminated groundwater, thereby reducing contaminant mass. Extracted water is then treated and discharged.	Full-Scale	Has been effectively used to remove contaminants. Is a long- duration technology.	Same as Hydraulic Control Technology.	VOCs,1,4-dioxane, metals
	Dynamic Groundwater Recirculation (DGR)	5.3.15	DGR creates dynamic groundwater flow conditions that enhances the natural flushing processes occurring within an impacted area.	Full-Scale	Has been proven effective in homogeneous aquifers to remove COCs in solution.	Shallow Groundwater Zone and the Lower Aquifer in the vicinity of the former tank farm, along the northern property line, underneath Building 1 and to the east of Building 1.	VOCs, 1,4-dioxane, metals
In Situ Physical/Chemical Treatment	Emulsified Zero-Valent Iron	5.3.16	Zero-valent iron emulsified in vegetable oil and surfactant is injected into groundwater. Zero-valent iron causes abiotic reductive dechlorination, and vegetable oil and surfactant act as long-term electron donors for biotic reductive dechlorination.	Full-Scale	Has been effectively used to reduce chlorinated VOCs and metals concentrations in groundwater.	Shallow Groundwater Zone and the Lower Aquifer in the vicinity of the former tank farm, along the northern property line, underneath Building 1 and to the east of Building 1.	chlorinated VOCs, Arsenic

TABLE 5-3

SUMMARY OF REMEDIATION TECHNOLOGIES CONSIDERED FOR GROUNDWATER

Stericycle Washougal Facility

Washougal, Washington

Technology Characteristics							
General Response Actions	**Remediation Technologies**	**Text Section**	**Technology Description**	**Technology Development Status**	**General Performance Record**	**Site Area Addressed**	**Site Contaminants Addressed**
In Situ Physical/Chemical Treatment (cont.)	Surfactant-Enhanced Aquifer Remediation (SEAR)	5.3.17	Surfactants are injected to increase the solubility and mobility of organic contaminants, including NAPLs. Surfactants and contaminants are then recovered with conventional pump-and-treat methods. The surfactants are separated from the groundwater and contaminants and reinjected.	Full-Scale	Has been used to enhance recovery of chlorinated VOCs and DNAPL. Limited full-scale applications.	Shallow Groundwater Zone and the Lower Aquifer in the vicinity of the former tank farm, along the northern property line, underneath Building 1 and to the east of Building 1.	chlorinated VOCs
	Co-Solvent Flooding	5.3.18	Co-solvents, typically alcohols, are injected to enhance dissolution and recovery of DNAPL components. Co-solvent and dissolved- phase organics are recovered with conventional groundwater extraction methods.	Full-Scale	Has been used to enhance recovery of DNAPL. Limited prior full-scale applications.	Shallow Groundwater Zone and Lower Aquifer in the vicinity of the former tank farm source areas.	chlorinated VOCs, SVOCs
Physical Containment	Barrier Wall	5.3.19	Placement of a barrier wall that physically restricts flow of groundwater or grouting/cementing potential COC migration conduits. The barrier wall must be keyed into lower confining unit for total containment.	Full-Scale	Has been effectively used to contain contaminated groundwater. Cannot attain cleanup levels as sole remedial technology.	Barrier wall used to border the former tank farm in the Shallow Groundwater Zone and the Lower Aquifer.	VOCs, 1,4-dioxane, metals
Ancillary/Support Technologies	Air Stripping	5.3.20	This technology is used in conjunction with pump- and-treat systems. Extracted groundwater is passed downward against a stream of rising air. The countercurrent stream of air strips VOCs from the water. Contaminants in the air stream are then removed or treated by oxidation or adsorption technologies.	Full-Scale	Has been effectively used to remove VOCs (both chlorinated and non-chlorinated) from groundwater.	Same as Hydraulic Control Technology.	VOCs, metals
	Oxidation	5.3.21	This technology can be used in conjunction with pump-and-treat systems. Extracted groundwater is augmented with an oxidant, such as hydrogen peroxide or potassium permanganate, to degrade COCs.	Full-Scale	Has been effectively used to remove chlorinated and non-chlorinated VOCs and 1,4-dioxane from groundwater	Same as Hydraulic Control Technology.	VOCs, 1,4-dioxane, metals
	Adsorption	5.3.22	This technology is used in conjunction with pump- and-treat systems. Extracted groundwater or VOC- containing air is passed through vessels containing granular activated carbon. Organic compounds with an affinity for carbon are transferred from the aqueous or vapor phase to the solid phase by sorption to the carbon. Treated carbon products are available to address VOCs such as VC that have a low affinity for conventional carbon.	Full-Scale	Has been effectively used to remove chlorinated and non-chlorinated VOCs, 1,4-dioxane, and metals from groundwater	Same as Hydraulic Control Technology.	VOCs, 1,4-dioxane, metals

TABLE 5-3

SUMMARY OF REMEDIATION TECHNOLOGIES CONSIDERED FOR GROUNDWATER

Stericycle Washougal Facility

Washougal, Washington

Technology Characteristics							
General Response Actions	**Remediation Technologies**	**Text Section**	**Technology Description**	**Technology Development Status**	**General Performance Record**	**Site Area Addressed**	**Site Contaminants Addressed**
Ancillary/Support Technologies (cont.)	Deep Soil Mixing	5.3.23	This technology is used in conjunction with several other technologies above. An auger is used to drill down into the soil, and a substrate (sand, clay, or cement) is injected as the auger goes down and is then pulled back up. Different additives can be combined with different substrates in order to accomplish a variety of objectives. It can be used as a delivery method for in situ chemical oxidation or in situ enhanced bioremediation. It can also be used to install passive reactive barriers or to help build physical containment.	Full-Scale	Has been effectively used to treat chlorinated and non-chlorinated VOCs, SVOCs (including 1,4-dioxane), and TPH in groundwater or to contain metals, TPH, chlorinated and non-chlorinated VOCs, SVOCs, and metals.	Shallow Groundwater Zone and Silt Layer around the former tank farm area. Addressing Silt Layer addresses Lower Aquifer.	VOCs, 1,4-dioxane, metals

Abbreviations

cis -1,2-DCE = *cis* -1,2-dichloroethene
BTEX = benzene, toluene, ethylbenzene, and xylenes
DNAPL = dense nonaqueous-phase liquids
SVE = soil vapor extraction
SVOCs = semivolatile organic compounds
TCE = trichloroethene
NAPL = nonaqueous phase liquids
ORC = oxygen-releasing compound
PCE = tetrachloroethane
TPH = total petroleum hydrocarbon
VC = vinyl chloride
VOCs = volatile organic compounds

TABLE 5-4
REMEDIATION TECHNOLOGY SCREENING FOR GROUNDWATER
Stericycle Washougal Facility
Washougal, Washington

General Response Actions	Remediation Technologies	Text Section	Site-Specific Issues Affecting Technology or Implementation				Site-Specific Issues Affecting Technology or Implementation			Rationale for Retention or Rejection	Screening Result
			Protectiveness	Permanence	Cost	Effectiveness over long-term	Management of short-term Risks	Technical and Administrative Implementability	Consideration of Public Concerns		
In Situ Biological Treatment	Enhanced Biodegradation with Biosparging	5.3.1	Addresses vinyl chloride (VC), but inhibits the degradation of other chlorinated VOCs. Potentially exacerbates the vapor intrusion pathway by volatilizing VOCs in groundwater.	Inhibits degradation of chlorinated VOCs with the exception of VC. Technology ineffective in silts and does not address 1,4-dioxane.	Higher implementation costs due to active industrial facility, large number of wells, large chemical oxygen demand (due to anaerobic conditions and metals), long-term run time (high O&M) and longer term groundwater monitoring costs necessary to effectively treat the silt layer.	The aquifer is reducing, so the effects of air on the aquifer chemistry will be limited to while the system is active. Technology does not address chlorinated VOCs with the exception of VC and does not treat 1,4-dioxane.	Since this is an active facility with enclosed buildings, this technology increases risk to human health due to the potential for increased volatilization of chlorinated VOCs (which could be mitigated with operation of an SVE system.)	Since this is an active facility with high traffic and chlorinated mass trapped in silts, the implementation options are limited and more technically challenging. High groundwater at the facility makes operation of an SVE system in conjunction with air sparge potentially infeasible.	Technology is unlikely to migrate off site to neighboring properties, through utilities, or to the marsh, so public concern should be minimal.	This technology will not work for all site COCs and would cause major disturbance to site activities if implemented in the source areas. However, if implemented in select locations and for specific COCs onsite (in conjunction with other technologies or as a contingent remedy), it could speed the remedial time frame while adding minimal additional risks.	Retain
	Oxygen Enhancement with Hydrogen Peroxide or ORC	5.3.2	Potentially addresses all the contaminants, but may inhibit the anaerobic degradation of other chlorinated VOCs and release additional metals.	Inhibits degradation of chlorinated VOCs with the exception of VC. Technology may be ineffective in silts.	Higher implementation costs due to active industrial facility, multiple injection rounds, large chemical oxygen demand (due to anaerobic conditions and metals), and large number of wells necessary to implement the technology in silt layer. If effective, may reduce long-term groundwater monitoring costs.	The aquifer is reducing and the majority of mass for chlorinated VOCs is trapped in the silt layer, so its unlikely oxygen addition will last long-term to treat the secondary source release from the silt layer.	Some short-term risks due to chemicals exposure possible for personnel implementing technology, typically managed with proper use of PPE.	Distribution of substrate in silts would require tighter spacing of wells and repeat injections. Implementation on an active high traffic industrial facility would require coordination of work (off hours work potentially).	Technology is unlikely to migrate off site to neighboring properties, through utilities, or to the marsh, but metals may be released to groundwater as part of treatment. Bench testing should be utilized to reduce potential for metals release.	This technology will not work for all site COCs and would cause major disturbance to site activities if implemented in the source areas. However, if implemented in select locations and for specific COCs onsite (in conjunction with other technologies or as contingent remedy), it could speed the remedial time frame while adding minimal additional risks.	Retain
	Co-Metabolic Treatment	5.3.3	Effective treatment for 1,4-dioxane and some chlorinated VOCs, but does not address metals.	Effective treatment for 1,4-dioxane and chlorinated VOCs, but does not address metals and may be ineffective in silts.	Higher implementation costs due to active industrial facility, large number of wells, long-term run time (high O&M), and longer term groundwater monitoring costs necessary to effectively treat the silt layer.	Technology will work with existing reducing conditions, but substrate injection would need to continue long-term for co-metabolic effectiveness to address secondary source in silt layer.	Active facility with enclosed buildings increases risk to human health due to use of fuels (such as propane) as substrate.	Since this is an active facility with high traffic, enclosed buildings, and chlorinated mass trapped in silts, the implementation options are limited and more technically challenging.	Technology is unlikely to migrate off site to neighboring properties or to the marsh, but some substrates like propane could potentially build up and migrate through utilities.	This technology will not work for all site COCs and would cause major disturbance to site activities if implemented in the source areas. Not likely to be as effective as biostimulation given the site conditions and data supporting ongoing anaerobic degradation. In addition, it poses significant additional safety concerns.	Reject
	Biostimulation of Reductive Dechlorination (Anaerobic)	5.3.4	Technology addresses chlorinated VOCs, but does not address metals or 1,4-dioxane.	Technology is longer lasting than oxidation substrates and permanently destroys chlorinated VOCs, but does not address metals or 1,4-dioxane.	Lower implementation costs than other technologies, even with multiple injections of substrate (as typically required for effective treatment in silts.) However, this is balanced by longer term groundwater monitoring costs which may increase overall project cost.	Technology is longer lasting than oxidation substrates and permanently destroys chlorinated VOCs, but does not address metals or 1,4-dioxane.	Minimal short-term risks possible to personnel implementing technology.	Distribution of substrate in silts would require tighter spacing of wells and repeat injections. Implementation on an active high traffic industrial facility would require coordination of work (off hours work potentially), but since substrates last longer in-situ than oxidation substrates, the total disruption to facility operations is likely lower.	Substrate is unlikely to migrate off site through utilities, neighboring properties, or to the marsh, but overdosing could lead to excess methane generation or metals release to groundwater. Bench testing should be utilized to reduce potential for overdosing.	This technology will not work for all site COCs but would cause minimal disturbance to site activities if implemented in the source areas. Potentially the most cost effective treatment for chlorinated VOCs, and once those are remediated may also allow metals concentrations to return to background levels.	Retain
	Bioaugmentation	5.3.5	Addresses chlorinated VOCs, but does not address metals or 1,4-dioxane. Typically used in concert with biostimulation.	Addresses chlorinated VOCs, but does not address metals or 1,4-dioxane. Typically used in concert with biostimulation.	Given the demonstrated decline in chlorinated VOCs onsite, bioaugmentation is unnecessary and would only add additional cost to biostimulation costs. Multiple injections of nonindigenous organisms are typically required, increasing technology cost.	Nonindigenous organisms are unlikely to out-compete local organisms, likely requiring ongoing injections for long-term effectiveness.	Minimal short-term risks possible to personnel implementing technology.	Distribution of nonindigenous organisms in silts is difficult and implementation on an active industrial facility would present the same challenges as for biostimulation. However, more frequent injections would be likely increasing disruption to facility operations.	Technology is unlikely to migrate off site through utilities, neighboring properties, or to the marsh, but typically used in concert with biostimulation so public concern should be equivalent to biostimulation concerns.	This technology will not work for all site COCs but would cause minimal disturbance to site activities if implemented in the source areas. This is likely unnecessary given the demonstrated ongoing degradation of chlorinated VOCs, but is retained as a potential supplement to biostimulation if site groundwater conditions change.	Retain
	Monitored Natural Attenuation	5.3.6	Potentially addresses all the contaminants, but is the slowest technology and metals may persist.	Technology would likely eventually attain CULs for chlorinated VOCs and 1,4-dioxane but metals may persist.	Implementation costs are minimal. Long-term groundwater monitoring costs could be substantial depending on remedial time frame.	Technology potentially addresses all contaminants but likely to have a longer timeline than active treatment options.	Minimal short-term risks possible to personnel implementing long-term monitoring.	Minimal impacts on facility operations, facility has demonstrated ability to perform long-term groundwater monitoring and results show effective degradation in areas where source removal has been completed.	Observations of natural attenuation shows constituents migrating off site, but a shrinking/receding plume in the shallow aquifer. Concerns with long-term migration in the lower aquifer may require additional offsite wells (if technology not combined with other remedial actions.)	This technology will not work for all site COCs but would cause minimal disturbance to site activities if implemented in the source areas. Natural attenuation has been documented to be actively occurring at the site. May be used in conjunction with other technologies as a polishing step to reach site CULs.	Retain

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TABLE 5-4
REMEDIATION TECHNOLOGY SCREENING FOR GROUNDWATER
Stericycle Washougal Facility
Washougal, Washington

General Response Actions	Remediation Technologies	Text Section	Site-Specific Issues Affecting Technology or Implementation				Site-Specific Issues Affecting Technology or Implementation			Rationale for Retention or Rejection	Screening Result
			Protectiveness	Permanence	Cost	Effectiveness over long-term	Management of short-term Risks	Technical and Administrative Implementability	Consideration of Public Concerns		
In Situ Physical/Chemical Treatment	Phytoremediation	5.3.7	Potentially addresses site COCs.	Technology would likely eventually attain CULs for the site COCs.	Implementation costs would be substantial to institute for all source areas. Most of the source area is paved or covered with buildings, making installation incompatible with facility operations. High cost due to the need for large diameter conductor casing being used to allow for mass reduction in the lower aquifer. However, implementation costs could be minimized with use in specific areas of the facility. Long-term groundwater monitoring costs could be substantial depending on remedial time frame.	Several studies have shown good long-term effectiveness for COC destruction and hydraulic control. Could be used in conjunction with other active technologies for polishing on remaining mass.	Minimal short-term risks possible to personnel implementing technology.	Technology cannot be used in active areas (buildings, paved areas, high traffic areas, equipment storage areas) of the industrial facility due to interference with operations, but could be used as polishing following implementation of other technologies.	Generally considered a benefit to the public (low energy use, carbon neutral, and aesthetically pleasing). Technology does not pose concerns to off site features.	This technology could potentially address all site COCs but would cause major disturbance to site activities if implemented in the source areas. However, if implemented in select locations (in conjunction with other technologies or as a contingent remedy), it could speed the remedial time frame while adding minimal additional risks.	Retain
	Carbon Augmentation	5.3.8	Technology addresses most chlorinated VOCs but ineffective for 1,4-dioxane and metals.	Technology would sequester chlorinated VOCs and may provide carbon source for biodegradation of COC mass. May exacerbate release of metals as a carbon source.	Higher implementation costs due to active industrial facility, multiple injection rounds, new proprietary technology (nano carbon), and large number of wells necessary to implement the technology in silt layer. If effective, may reduce long-term groundwater monitoring costs.	Technology relies on contact with constituents and good distribution within the subsurface (which is difficult in silt) to treat chlorinated VOCs. Ineffective for 1,4-dioxane and may exacerbate release of metals.	Minimal short-term risks possible to personnel implementing technology.	Distribution of substrate in silts would require tight spacing of wells and likely overlapping injections. Implementation on an active high traffic industrial facility would require coordination of work (off hours work potentially), but since substrates last longer than oxidation or biostimulation substrates, repeat rounds likely to be unnecessary.	Substrate is unlikely to migrate off site through utilities, neighboring properties, or to the marsh, but long-term carbon source could result in metals release to groundwater.	This technology will not work for all site COCs (may exacerbate metals) and would cause major disturbance to site activities if implemented in the source areas. Not likely to be as effective as biostimulation given the site conditions.	Reject
	Air Sparging	5.3.9	Active, natural, biological anaerobic degradation of chlorinated VOCs would be inhibited by the addition of oxygen (with the exception of VC). Ineffective for 1,4-dioxane treatment. Possibly effective for treatment of metals.	Likely to hinder anaerobic degradation processes for chlorinated solvents. May help sequester metals in the short-term, but reducing conditions in the aquifer may re-dissolve metals in the long-term. Could be used following primary treatment for removal of vinyl chloride.	Higher implementation costs due to active industrial facility, large number of wells, large chemical oxygen demand (due to anaerobic conditions and metals), long-term run time (high O&M) and longer term groundwater monitoring costs necessary to effectively treat the silt layer.	The aquifer is reducing, so the effects of air on the aquifer chemistry may be limited to while the system is active (precipitated metals may re-dissolve). Technology does not address chlorinated VOCs without being used in combination with SVE and does not treat 1,4-dioxane.	Since this is an active facility with enclosed buildings, this technology increases risk to human health due to the potential for increased volatilization of chlorinated VOCs (which could be mitigated with operation of an SVE system or strategic design of lower flow air sparging wells away from enclosed buildings).	Implementation at higher flow rates adjacent to Building 1 would likely overwhelm the existing inhalation pathway interim measure venting system. Associated SVE would be necessary if installed adjacent to Building 1 to prevent migration. However, implementation farther away from Building 1 at lower flow rates may be possible (with confirmation measurements taken at Building 1). Implementation of low flow rate (without SVE) along the northeast and eastern property lines would be feasible in the shallow and deep aquifer.	Technology is unlikely to migrate contaminants off site to neighboring properties or to the marsh. This technology has led to volatiles building up in utility corridors, but implementation at a lower flow rate as a contingent remedy for polishing metals and only low VOC concentrations (or no VOCs) could limit public concern.	This technology will not work for all site COCs and would cause major disturbance to site activities if implemented in the source areas. However, if implemented in select locations and for specific COCs onsite (in conjunction with other technologies or as a contingent remedy), it could speed the remedial time frame while adding minimal additional risks.	Retain
	Chemical Oxidation-Active	5.3.10.1	Potentially treats all key COCs with a relatively short timeframe, may release metals.	Technology permanently destroys chlorinated VOCs and 1,4-dioxane, assuming effective contact.	Higher implementation costs due to active industrial facility, multiple injection rounds, large chemical oxygen demand (due to anaerobic conditions and metals), and large number of wells necessary to implement the technology in silt layer. If effective, may reduce long-term groundwater monitoring costs.	Technology relies on contact with constituents and distribution within the silt is difficult, but removes all COCs for source areas.	Injection substrate is reactive and poses short-term risks to implementation personnel, typically managed with proper use of PPE and secondary containment.	Implementable in shallow and lower aquifer to treat all key COCs. Would be difficult to implement in the silt.	Technology is unlikely to migrate off site to neighboring properties, through utilities, or to the marsh, but metals may be released to groundwater as part of treatment. Bench testing should be utilized to reduce potential for metals release.	This technology could potentially address all site COCs but would cause significant disturbance to site activities if implemented in the source areas. However, if implemented in select locations, it could speed the remedial time frame while adding minimal additional risks.	Retain
	Chemical Oxidation-Passive	5.3.10.2	Potentially treats chlorinated VOCs, unlikely to degrade 1,4-dioxane, and may release metals.	Technology permanently destroys chlorinated VOCs, assuming effective contact.	Lower implementation costs than active ISCO, but likely large chemical oxygen demand (due to anaerobic conditions and metals) and large number of wells necessary to implement the technology to address long-term release from the silt layer. If effective, may reduce long-term groundwater monitoring costs.	Technology is longer lasting than active oxidation and permanently destroys chlorinated VOCs, but does not address metals or 1,4-dioxane.	Significant but limited short-term risks related to handling of passive ISCO chemicals and installation of new wells, typically managed with proper use of PPE.	Implementable in shallow and lower aquifer to treat all key COCs. Would be difficult to implement in the silt.	Technology is unlikely to migrate off site to neighboring properties, through utilities, or to the marsh, but metals may be released to groundwater as part of treatment. Bench testing should be utilized to reduce potential for metals release.	This technology will not work for all site COCs (may exacerbate metals) and would cause major disturbance to site activities if implemented in the source areas. Not likely to be as effective as active oxidation given the site conditions.	Reject

TABLE 5-4
REMEDIATION TECHNOLOGY SCREENING FOR GROUNDWATER
Stericycle Washougal Facility
Washougal, Washington

General Response Actions	Remediation Technologies	Text Section	Site-Specific Issues Affecting Technology or Implementation				Site-Specific Issues Affecting Technology or Implementation			Rationale for Retention or Rejection	Screening Result
			Protectiveness	Permanence	Cost	Effectiveness over long-term	Management of short-term Risks	Technical and Administrative Implementability	Consideration of Public Concerns		
In Situ Physical/Chemical Treatment (cont.)	Thermal Treatment	5.3.11	Potentially addresses site COCs.	Technology degrades or removes site COCs.	Implementation costs would be substantial to institute for all source areas. Most of the source area is paved high traffic area or covered with buildings, making installation more complicated. Lower aquifer is connected to adjacent waterbodies, likely increasing water production and heating costs. Long-term groundwater monitoring costs could be substantially reduced.	Could achieve CULs in relatively short timeframe, may release dissolved carbon (which would aid in biodegradation of chlorinated VOCs), but could exacerbate metals release to groundwater.	Installation of heating elements or steam injection points pose a risk for contact with COC impacted groundwater. Operation of the system could impact utilities in the vicinity dependent on material type.	Implementation and ongoing operations and maintenance of an thermal treatment system on an active industrial facility would be difficult. High groundwater at the facility makes operation of an SVE system in conjunction with heating difficult. Buildings are present over the source area complicating installation. Lower aquifer connection to adjacent water bodies may increase water production and heating costs.	Technology is unlikely to directly affect off site property (neighboring properties or the marsh), but plastic utility lines would need to be replaced in the upper treatment zone. Heated groundwater has the potential to migrate off site and into the marsh for a short time. Dissolving of entrained carbon could release metals to groundwater.	This technology could potentially address all site COCs but would cause significant disturbance to site activities if implemented in the source areas and could potentially exacerbate release of metals. Potentially one of the most effective treatment technologies for the silt layer.	Retain
	In-Well Stripping	5.3.12	Addresses vinyl chloride (VC), but inhibits the degradation of other chlorinated VOCs. Potentially exacerbates the vapor intrusion pathway by volatilizing VOCs in groundwater.	Inhibits degradation of chlorinated VOCs with the exception of VC. Technology ineffective in silts and does not address 1,4-dioxane.	Higher implementation costs due to active industrial facility, large number of wells, large chemical oxygen demand (due to anaerobic conditions and metals), likelihood of iron precipitation and/or biological fouling. Long-term operation and maintenance would be costly due to the within the stripping wells.	The aquifer is reducing, so the effects of air on the aquifer chemistry will be limited to while the system is active. Technology does not address chlorinated VOCs with the exception of VC and does not treat 1,4-dioxane.	Since this is an active facility with enclosed buildings, this technology increases risk to human health due to the potential for increased volatilization of chlorinated VOCs (which could be mitigated with operation of an SVE system.)	Since this is an active facility with high traffic and chlorinated mass trapped in silts, the implementation options are limited and more technically challenging. High groundwater at the facility makes operation of an SVE system in conjunction with air sparge potentially infeasible.	Technology is unlikely to migrate off site to neighboring properties, through utilities, or to the marsh, so public concern should be minimal.	This technology has a mixed performance record, would not address all site COCs, and could inhibit the ongoing active anaerobic biodegradation. Not likely to be as effective as active chemical oxidation or traditional air sparging given the site conditions.	Reject
	Passive/Reactive Treatment Walls	5.3.13	Substrate such as zero valent iron (ZVI) would address chlorinated VOCs and metals but would not treat 1,4-dioxane.	Technology could reduce mass in the short-term and provide long-term passive treatment of chlorinated VOCs and metals.	Implementation costs could range widely depending on type of installation (low cost for widely spaced injections, higher cost for slurry wall or tightly spaced injections). However, implementation costs could be minimized with use in specific target zones (in sandy aquifer only). Bench or pilot testing likely necessary to accurately estimate costs. Could reduce long-term groundwater monitoring costs.	Technology could passively treat secondary source from silt until source has been degraded to below the CULs. Would need to be used in conjunction with other technologies for 1,4-dioxane.	Minimal short-term risks possible to personnel implementing technology.	Injections within the source area above and below the silt layer, within the sand units, would allow for even distribution of substrate during construction of the passive treatment barriers.	Technology will utilize substrate which will remain in the injection area and is unlikely to migrate off site through utilities, neighboring properties, or to the marsh, so public concern should be minimal.	This technology will not work for all site COCs and would cause major disturbance to site activities if implemented in the source areas. However, if implemented in select locations and for specific COCs onsite (in conjunction with other technologies), it could speed the remedial time frame while adding minimal additional risks.	Retain
Groundwater Extraction and Treatment (Pump and Treat)	Hydraulic Control	5.3.14	Could further reduce the footprint or speed up the reduction of the groundwater plume in the shallow and lower aquifer and potentially addresses all the contaminants.	Ex-situ treatment of COCs would be necessary to remove COC mass. long-term operation would be necessary to continually protect from release of COCs from silt.	Implementation costs may be significant to achieve control in the lower aquifer (given the connection to nearby surface water bodies). Long-term operations and maintenance costs would be high due to the long duration of operation necessary to continue capture of the ongoing slow release of COCs from the silt (and likelihood of iron precipitation and/or biological fouling.)	Could effectively contain COC's onsite, but due to entrainment of COC's in silts likely long-term operation required for lower aquifer. Long-term operation of the hydraulic control system would cause the restoration timeframe to increase significantly compared to other active treatment technologies.	System installation would require trenching for installation of conveyance piping in and around the source area as well as ex-situ management of contaminated groundwater increasing the potential for worker exposure to COCs.	Implementation and ongoing operations and maintenance of a hydraulic control system on an active industrial facility would be difficult compared to a vacant site, but not as disruptive as excavation, thermal, or deep soil mixing. Water is likely to flow from the more permeable layers of the aquifer (which are connected to adjacent water bodies or are impacted by seasonal high water) not from the suspected source area (the silt layer). POTW does not accept groundwater by rule, would require additional permitting effort and Ecology request.	Technology would keep site COCs within the property boundary, so is unlikely to cause public concern and likely to be seen as generally beneficial.	This technology could capture all site COCs, but is unlikely to speed up the remedial time frame. On its own this technology would be rejected, but could provide temporary control of offsite migration in conjunction with other technologies. Other permanent remedial technologies are implementable with reduced restoration timeframe or are less disruptive to site activities compared to this technology.	Retain
	Mass Reduction	5.3.14	Would remove COCs from higher permeability units (sand) but would be ineffective at extracting mass from the silt layer (source area).	Technology unlikely to significantly speed up mass removal from silt layer. Unlikely to significantly speed up attainment of CUL within source area or downgradient.	Implementation costs may be significant to achieve control in the lower aquifer (given the connection to nearby surface water bodies). Long-term operations and maintenance costs would be high due to the long duration of operation necessary to continue capture of the ongoing slow release of COCs from the silt (and likelihood of iron precipitation and/or biological fouling.)	Minimal long-term effectiveness due to inability for technology to address COCs within the silt.	System installation would require trenching for installation of conveyance piping in and around the source area as well as ex-situ management of contaminated groundwater increasing the potential for worker exposure to COCs.	Implementation and ongoing operations and maintenance of a hydraulic control system on an active industrial facility would be difficult compared to a vacant site, but not as disruptive as excavation, thermal, or deep soil mixing. Water is likely to flow from the more permeable layers of the aquifer (which are connected to adjacent water bodies or are impacted by seasonal high water) not from the suspected source area (the silt layer). POTW does not accept groundwater by rule, would require additional permitting effort and Ecology request.	Technology would keep site COCs within the property boundary, so is unlikely to cause public concern and likely to be seen as generally beneficial.	This technology could capture all site COCs, but is unlikely to speed up the remedial time frame. Other permanent remedial technologies are implementable with reduced restoration timeframe compared to this technology.	Reject

TABLE 5-4
REMEDIATION TECHNOLOGY SCREENING FOR GROUNDWATER
Stericycle Washougal Facility
Washougal, Washington

General Response Actions	Remediation Technologies	Text Section	Site-Specific Issues Affecting Technology or Implementation				Site-Specific Issues Affecting Technology or Implementation			Rationale for Retention or Rejection	Screening Result
			Protectiveness	Permanence	Cost	Effectiveness over long-term	Management of short-term Risks	Technical and Administrative Implementability	Consideration of Public Concerns		
Groundwater Extraction and Treatment (Pump and Treat) (cont.)	Dynamic Groundwater Recirculation (DGR)	5.3.15	Would remove COCs from higher permeability units (sand) but would be ineffective at extracting mass from the silt layer (source area).	Technology unlikely to significantly speed up mass removal from silt layer. Unlikely to significantly speed up attainment of CUL within source area or downgradient.	High long-term operation and maintenance costs due to the technologies inability to attain CULs within the source area.	Minimal long-term effectiveness due to inability for technology to address COCs within the silt.	System installation would require trenching for installation of conveyance piping in and around the source area increasing the potential for worker exposure to COCs.	Implementation and ongoing operations and maintenance of a hydraulic control system on an active industrial facility would be difficult compared to a vacant site, but not as disruptive as excavation, thermal, or deep soil mixing. Water is likely to flow from the more permeable layers of the aquifer (which are connected to adjacent water bodies or are impacted by seasonal high water) not from the suspected source area (the silt layer). POTW does not accept groundwater by rule, would require additional permitting effort and Ecology request.	Technology would keep site COCs within the property boundary, so is unlikely to cause public concern and likely to be seen as generally beneficial.	This technology could capture all site COCs, but is unlikely to speed up the remedial time frame. Other permanent remedial technologies are implementable with reduced restoration timeframe compared to this technology.	Reject
In Situ Physical/Chemical Treatment	Emulsified Zero-Valent Iron	5.3.16	Technology would address chlorinated VOCs and metals in shallow and lower aquifer, but would not address 1,4-dioxane.	Distribution of injected material is difficult in silts, but can be completed in shallow and lower aquifer above and below silts. Technology does not address 1,4-dioxane.	Implementation costs could range widely depending on type of installation (low cost for widely spaced injections, higher cost for slurry wall or tightly spaced injections). However, implementation costs could be minimized with use in specific target zones (in sandy aquifer only). Bench or pilot testing likely necessary to accurately estimate costs. Could reduce long-term groundwater monitoring costs.	Technology addresses chlorinated VOCs and metals, but does not address 1,4-dioxane.	Minimal short-term risks possible to personnel implementing technology.	Implementable in shallow and lower aquifer to treat chlorinated VOCs and metals. Would be difficult to implement in the silt and does not address 1,4-dioxane.	Technology will utilize substrate which will remain in the injection area and is unlikely to migrate off site through utilities or to the marsh, so is unlikely to cause public concern and likely to be seen as generally beneficial.	This technology will not work for all site COCs but may cause less disturbance to site activities if implemented in the source areas than other technologies. If implemented for specific COCs onsite (in conjunction with other technologies), it could speed the remedial time frame while adding minimal additional risks.	Retain
	Solvent-Enhanced Aquifer Remediation (SEAR)	5.3.17	Injection of surfactant would improve mobility of chlorinated VOCs followed by pump-and-treat extraction to remove mobile chlorinated VOCs in solution. Technology would not address metals or 1,4-dioxane.	Technology unlikely to significantly speed up mass removal from silt layer. Unlikely to significantly speed up attainment of CUL within source area or downgradient. Technology would not address metals or 1, 4-dioxane.	Implementation costs may be significant to achieve control in the lower aquifer (given the connection to nearby surface water bodies). Long-term operations and maintenance costs would be high due to the long duration of operation necessary to continue capture of the ongoing slow release of COCs from the silt (and likelihood of iron precipitation and/or biological fouling.)	Technology addresses chlorinated VOCs in sands and some of the silt, but does not address metals or 1,4-dioxane. Injections of surfactants could create preferential pathways for groundwater flow potentially mobilizing COCs (and surfactants) outside the radius of influence from extraction wells.	System installation would require trenching for installation of conveyance piping in and around the source area as well as ex-situ management of contaminated groundwater increasing the potential for worker exposure to COCs.	Implementation and ongoing operations and maintenance of the system on an active industrial facility would be difficult compared to a vacant site. High groundwater extraction rates paired with high seasonal groundwater at the facility would increase water production and management costs. Technology depends on contact with COCs in the silt and distribution in the silt will be difficult.	Technology is designed to keep site COCs within the property boundary, but may inadvertently mobilize site COCs and surfactants outside the property boundary, so there would be higher public concern than for standard hydraulic mass removal.	This technology will not work for all site COCs (may exacerbate metals) and poses significant additional concerns with potential migration of contaminants offsite.	Reject
In Situ Physical/Chemical Treatment (cont.)	Co-Solvent Flooding	5.3.18	Injection of solvents, typically ethanol or propanol, would improve mobility of chlorinated VOCs followed by pump-and-treat extraction to remove mobile chlorinated VOCs in solution. Technology would not address metals or 1,4-dioxane.	Technology unlikely to significantly speed up mass removal from silt layer. Unlikely to significantly speed up attainment of CUL within source area or downgradient. Technology would not address metals or 1, 4-dioxane.	Implementation costs may be significant to achieve control in the lower aquifer (given the connection to nearby surface water bodies). Long-term operations and maintenance costs would be high due to the long duration of operation necessary to continue capture of the ongoing slow release of COCs from the silt (and likelihood of iron precipitation and/or biological fouling.)	Technology addresses chlorinated VOCs in sands and some of the silt, but does not address metals or 1,4-dioxane. Injections of solvents could create preferential pathways for groundwater flow potentially mobilizing COCs (and surfactants) outside the radius of influence from extraction wells. In addition, additional carbon source could exacerbate metals release to groundwater.	Injection of solvents , typically ethanol or propanol, pose an elevated risk to operators of the system and facility staff. Installation of the treatment system for injection of solvents and extraction of COCs pose a higher risk to installation personnel.	Implementation and ongoing operations and maintenance of the system on an active industrial facility would be difficult compared to a vacant site. High groundwater extraction rates paired with high seasonal groundwater at the facility would increase water production and management costs. Technology depends on contact with COCs in the silt and distribution in the silt will be difficult.	Technology is designed to keep site COCs within the property boundary, but may inadvertently mobilize site COCs and solvents outside the property boundary, so there would be higher public concern than for standard hydraulic mass removal.	This technology will not work for all site COCs (may exacerbate metals) and poses significant additional concerns with potential migration of contaminants offsite.	Reject
Physical Containment	Barrier Wall	5.3.19	Installation of a barrier wall would limit mobility of all COCs remaining on site, but would not reduce COC concentrations and may slow attenuation and degradation of contaminants.	The technology would completely reduce the mobility of the site COCs. The volume and toxicity of the COCs would not be addressed through this technology.	High implementation cost compared to most other alternatives to construct a barrier wall for both the shallow and lower aquifers. Long-term costs are minimal and technology could reduce long-term groundwater monitoring costs when used in conjunction with hydraulic control.	Technology potentially addresses all contaminants but likely to have a longer timeline than active treatment options.	Increased short-term risk during implementation due to displacement of large volumes of soil and potentially groundwater. Typically managed with proper use of PPE and secondary containment.	Implementation on an active industrial facility would be difficult compared to a vacant site.	A barrier wall would stop off site migration of COCs, so is unlikely to cause public concern and likely to be seen as generally beneficial.	This technology could work to capture all site COCs, but would not speed up the remedial time frame. However, it could be used in conjunction with other technologies to minimize disturbance to site activities if implemented strategically.	Retain

TABLE 5-4
REMEDIATION TECHNOLOGY SCREENING FOR GROUNDWATER
Stericycle Washougal Facility
Washougal, Washington

General Response Actions	Remediation Technologies	Text Section	Site-Specific Issues Affecting Technology or Implementation				Site-Specific Issues Affecting Technology or Implementation			Rationale for Retention or Rejection	Screening Result
			Protectiveness	Permanence	Cost	Effectiveness over long-term	Management of short-term Risks	Technical and Administrative Implementability	Consideration of Public Concerns		
Ancillary/Support Technologies	Air Stripping	5.3.20	Technology addresses chlorinated VOCs and metals but not 1,4-dioxane.	Technology would remove VOCs, but effluent vapor would be treated through catalytic oxidation or adsorption. Technology does not address 1,4-dioxane and may only temporarily stabilize metals.	Minimal implementation costs when compared to installation of a pump-and-treat system. Long-term cost to operate an air stripper is relatively minimal during operation of the pump-and-treat system, but iron precipitation would likely cause significant fouling, increasing long-term maintenance costs.	Technology addresses chlorinated VOCs, but does not address 1,4-dioxane and may only temporarily stabilize metals.	Increased short-term risk during operation of the air stripper due to volatilization of VOCs . Maintenance of the air stripper and wastes generated pose additional short-term risks. Typically managed with proper use of PPE, vapor treatment, and secondary containment.	The addition of an air stripping system into a pump-and-treat system would further complicate implementation of hydraulic control remedies, as noted above.	Air stripping removes VOCs from groundwater and transfers them to the air phase. This technology could cause public concern related to air emissions.	Retained since hydraulic control was retained.	Retain
	Oxidation	5.3.21	Ex-situ oxidation would be effective in reducing contaminant mass for chlorinated VOCs, metals, and 1,4-dioxane.	Technology would destroy contaminant mass when used in conjunction with pump-and-treat.	Minimal implementation costs when compared to installation of a pump-and-treat system. Long-term costs can be variable, dependent on oxidant used, but high costs are expected with long-term operations and maintenance.	While this technology would treat all contaminants, reinjection of oxygenated water into the aquifer could impact existing anaerobic degradation and may lead to significant fouling.	Short-term risks are increased due to use of a pump-and-treat system as a remedial alternative and oxidants are an additional hazard to personnel. Typically managed with proper use of PPE and secondary containment.	The addition of an oxidant augmentation system into a pump-and-treat system would further complicate implementation of hydraulic control remedies, as noted above.	Effluent from a pump-and-treat system actively augmented with an oxidant could add to public concerns for a pump a treat system.	Retained since hydraulic control was retained.	Retain
	Adsorption	5.3.22	Potentially addresses site COCs.	Different adsorbent media are utilized for different contaminants. If media can be used effectively in a treatment train, would permanently remove contaminants.	Potentially high implementation costs and long term operations costs, depending on effectiveness of media and volumes of water needing treatment.	New adsorption media has been developed using resins for 1,4-dioxane and VC removal. Effectiveness is highly variable on groundwater chemistry, bench testing would be necessary to determine long term performance.	Short-term risks possible to personnel implementing technology depending on type of media utilized. Short-term risks are increased due to use of a pump-and-treat system as a remedial alternative. Typically managed with proper use of PPE and secondary containment.	The addition of adsorption units into a pump-and-treat system would further complicate implementation of a remedy, but potentially less complicated than oxidation or air stripping.	Adsorption technology is unlikely to contribute chemicals to offsite discharge, so is unlikely to cause public concern and likely to be seen as generally beneficial.	Retained since hydraulic control was retained.	Retain
	Deep Soil Mixing	5.3.23	Potentially addresses site COCs.	Technology oxidizes, reduces or sequesters depending on substrate used during mixing to permanently reduce COC mass.	Implementation costs would be substantial to institute for all source areas. Most of the source area is paved high traffic area or covered with buildings and this technology requires significant excavation as part of the work, making installation more complicated. Long-term monitoring costs would be less than most other alternatives as mass should be treated quickly.	Technology does not rely on flow through pore spaces for distribution, but physically mixes in treatment substrates. There is a high likelihood the technology would effectively treat all contaminants.	Increased short-term risk during implementation due to displacement of large volumes of soil and potentially groundwater as well as exposure to treatment chemicals. Typically managed with proper use of PPE and secondary containment.	Since this is an active facility with high traffic, enclosed buildings, and chlorinated mass trapped in silts, the implementation options are limited and more technically challenging. Implementation on an active high traffic industrial facility would require coordination of work (off hours work potentially).	Technology could potentially treat most site COCs quicker than other technologies and contain remainder within the property boundary. Trucking of excavated materials offsite would be more substantial for this alternative than other alternatives.	This technology could potentially address all site COCs but would cause major disturbance to site activities if implemented in the source areas. Potentially one of the most effective treatment technologies for the silt layer.	Retain

Abbreviations

cis -1,2-DCE = *cis* -1,2-dichloroethene
COL = constituent of concern
CUL = cleanup level
HRC = hydrogen-releasing compounds
ISCO = in situ chemical oxidation
O&M = operation and maintenance
ORC = oxygen-releasing compound
SVOCs = semivolatile organic compounds
TCE = trichloroethene
TPH = total petroleum hydrocarbon
VC = vinyl chloride
VOCs = volatile organic compounds
ZVI = zero-valent iron

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TABLE 5-5
RETAINED REMEDIATION TECHNOLOGIES
Stericycle Washougal Facility
Washougal, Washington

Potentially Applicable Soil Technology	
General Response Actions	**Remediation Technologies**
In Situ Biological Treatment	Phytoremediation
In Situ Physical/Chemical Treatment	Chemical Oxidation
	Solidification/Stabilization
In Situ Thermal Treatment	High-Temperature Volatilization
Containment	Cap/Surface Cover
Excavation and Disposal	Excavation and Off-Site Disposal

Potentially Applicable Groundwater Technology	
General Response Actions	**Remediation Technologies**
In Situ Biological Treatment	Enhanced Biodegradation with Biosparging
	Oxygen Enhancement with Hydrogen Peroxide or ORC
	Biostimulation of Reductive Dechlorination (Anaerobic)
	Bioaugmentation
	Monitored Natural Attenuation
	Phytoremediation
In Situ Physical/Chemical Treatment	Air Sparging
	Chemical Oxidation
	Thermal Treatment
	Passive/Reactive Treatment Walls
	Emulsified Zero-Valent Iron
Groundwater Extraction (Pump and Treat)	Hydraulic Control
Physical Containment	Barrier Wall
Ancillary/Support Technologies	Air stripping
	Oxidation
	Adsorption
	Deep Soil Mixing

Abbreviations
ORC = oxygen-releasing compound

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TABLE 7-1
REMEDIAL ALTERNATIVES SUMMARY
Stericycle Washougal Facility
Washougal, Washington

General Target Description	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7
Common to all alternatives for Soil and GW	Grouting of utility bedding						
	Surface cover over areas with soils with elevated concentrations of COCs						
	Inhalation Pathway Interim Measure under Building 1						
	Verification of GW remediation progress and effectiveness through GW monitoring						
	Long Term or Temporary Institutional Controls						
GW-Shallow Source Areas	MNA in former tank farm area (VOCs, metals)	ISB in former tank farm area primarily targeting silt layer, MA (VOCs, metals)	DSM with ZVI of shallow zone and silt layer, MA (VOCs, 1,4-dioxane, metals)	ERH of shallow zone and silt layer, MA (VOCs, 1,4-dioxane, metals)	PRB with ZVI above and within silt layer, MA (VOCs, metals)	ISB in former tank farm area primarily targeting silt layer, MA (VOCs, metals)	ISCO in former tank farm area primarily targeting silt layer, MA (VOCs, 1,4-dioxane, metals)
	MNA near MC-14 (VOCs, metals)	ISCO near MC-14, MA (VOCs, 1,4-dioxane, metals)	ISCO near MC-14 , MA (VOCs, 1,4-dioxane, metals)	ERH near MC-14, MA (VOCs, 1,4-dioxane, metals)	ISCO near MC-14, MA (VOCs, 1,4-dioxane, metals)	ISCO near MC-14 , MA (VOCs, 1,4-dioxane, metals)	ISCO near MC-14 , MA (VOCs, 1,4-dioxane, metals)
GW-Shallow Downgradient	MNA						
GW-Lower Aquifer Former Tank Farm Area and North Fence line (near MC-118D) Source Area	MNA (VOCs, metals)	ISB in silt/lower aquifer, MA (VOCs, metals)	DSM with ZVI/clay of silt, targeted ISCO in silt/lower aquifer, MA (VOCs, 1,4-dioxane, metals)	ERH in silt/lower aquifer, MA (VOCs, 1,4-dioxane, metals)	PRB with ZVI of silt/lower aquifer, MA (VOCs, metals)	ISB in silt/lower aquifer, hydraulic control, MA (VOCs, 1,4-dioxane, metals)	ISCO in silt/lower aquifer, MA (VOCs, 1,4-dioxane, metals)
GW-Lower Aquifer Downgradient (Including MC-15D Area)	MNA (VOCs, metals)	ISB, MA (VOCs, metals)	ISB, MA (VOCs, metals)	ISB, MA (VOCs, metals)	PRB with ZVI, MA (VOCs, metals)	ISB and hydraulic control, MA (VOCs, 1,4-dioxane, metals)	ISB, MA (VOCs, metals)
Comparison of Alternative Timing							
	Alternative 1	**Alternative 2**	**Alternative 3**	**Alternative 4**	**Alternative 5**	**Alternative 6**	**Alternative 7**
Start of Significant COC Reduction (years)	10+	1	1	1	1	1	1
Active Remediation Duration (years) [1]	30	3 to 5	1	1	3 to 10+	3 to 5	1
Restoration Time Frame (years)	30 +	15	10	10	10	15	10

Notes
1. Active remediation indicates the expected duration of accelerated degradation rates, except in the case of MNA which has no active component, a passive timeframe was used.

Abbreviations:
COC= Contaminant of Concern
MNA= Monitored Natural Attenuation
VOCs = Volitale Organic Compounds
ISCO= In-Situ Chemical Oxidation
ZVI= Zero Valent Iron
DSM= Deep Soil Mixing
MA= Monitored Attenuation
ERH= Electrical Resistive Heating
ISB= In-situ Bioremediation
GW= Groundwater

TABLE 7-2
EVALUATION OF REMEDIAL ALTERNATIVES
Stericycle Washougal Facility
Washougal, Washington

Standards/Criteria[2]	Alternative Rating[1]						
	A-1	A-2	A-3	A-4	A-5	A-6	A-7
	Cap/Surface Cover and MNA	**ISB, Targeted ISCO, and MA**	**Deep Soil Mixing, Targeted ISCO, ISB downgradient, and MA**	**Electrical Resistive Heating, ISB downgradient, and MA**	**ZVI PRB, Targeted ISCO, and MA**	**ISB, Targeted ISCO, ISB downgradient, Hydraulic Control, and MA**	**Full Scale ISCO, ISB downgradient, and MA**
Protectiveness and Risk Reduction	4	8	9	8	8	8	8
Permanence	5	8	9	10	8	8	7
Long-term Effectiveness	4	8	10	10	8	9	7
Management of Short-Term Risks	9	8	6	4	8	5	6
Technical and Administrative Implementability	10	8	2	3	7	5	6
Public Concern	4	8	6	5	7	6	6
Benefit Score Total[2]	**36**	**48**	**42**	**40**	**46**	**41**	**40**
Cost (estimated)	$2,742,000	$2,532,000	$3,688,000	$5,034,000	$2,447,000	$3,722,000	$2,963,000
Cost/Benefit	$76,167	$52,750	$87,810	$125,850	$53,196	$90,780	$74,075
Cost/Benefit Rank	4	1	5	7	2	6	3
Restoration Time Frame (years)	30 +	15	10	10	10	15	10
Start of Signifcant COC Reduction (years)	10 +	1	1	1	1	1	1

Notes

1. Alternatives are rated from 10 to 1, with a rating of 10 indicating the highest or most favorable performance for that criterion.
2. In accordance with EPA guidance for each criterion and the MTCA regulations, all standards and/or criteria are considered equal; no weighting is given to any individual criterion.

Abbreviations

MNA = monitored natural attenuation
ISCO = in situ chemical oxidation
MA= Monitored Attenuation
ISB= In-Situ Bioremediation
EPA = U.S. Environmental Protection Agency
MTCA = Model Toxics Control Act
ZVI = Zero Valent Iron

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TABLE 7-3
REMEDIAL ALTERNATIVE EVALUATION DETAILS
Stericycle Washougal Facility
Washougal, Washington

Alternative Number	A-1		A-2		A-3		A-4	
Remedial Components	**Cap/Surface Cover and MNA**		**ISB, Targeted ISCO, and MA**		**Deep Soil Mixing, Targeted ISCO, ISB downgradient, and MA**		**Electrical Resistive Heating, ISB downgradient, and MA**	
MTCA Criteria - subcriteria	Notes	Score	Notes	Score	Notes	Score	Notes	Score
Protectiveness- Degree existing risks reduced	+ Capping of exposed soils reduces onsite exposure, starting risk is low (relatively low concentrations of COCs, no NAPL onsite) + Relatively low concentrations above CULs in soil and GW which would be reduced eventually through passive treatment + GW monitoring will detect if the potential threat to receptors increases, more active measures can be implemented. - Potential risk to receptors in shallow GW above CULs for many years - Potential risk to receptors in deep GW above CULs for many years - Longer term low level risk than all other alternatives	4	+ Capping of exposed soils reduces onsite exposure, starting risk is low (relatively low concentrations of COCs, no NAPL onsite) + Onsite GW actively treated to below CULs + Biggest potential offsite risks to GW reduced in Year 1 + Additional years (3-5 years) treatment of GW desorbing from fine grained units - Some CULs likely to exceed in GW for 3-5 years - Moderately aggressive for GW cleanup when compared to DSM or ERH	8	+ Capping of exposed soils reduces onsite exposure, starting risk is low (relatively low concentrations of COCs, no NAPL onsite) + Onsite GW actively treated to below CULs + Tied for highest potential for treatment of all soil and GW COCs of all alternatives - Some CULs likely to exceed in GW for 1-3 years - Pilot testing is required to confirm viability in lower permeability soils	10	+ Capping of exposed soils reduces onsite exposure, starting risk is low (relatively low concentrations of COCs, no NAPL onsite) + Onsite GW actively treated to below CULs + Tied for highest potential for treatment of all soil and GW COCs of all alternatives - Some CULs likely to exceed in GW for 1-3 years	10
Protectiveness- Time until reduced risk	+ Soils capped in year 1 - Only slow incremental reductions in risk every year for 30 years for GW	3	+ Soils capped in year 1 + Majority of GW cleaned up in year 1, with remainder in 3-5 years - Some CULs likely to exceed in GW for 3-5 years	8	+ Soils and GW treatment complete in year 1 - Some CULs likely to exceed in GW for 1-3 years	10	+ Soils and GW treatment complete in year 1 - Some CULs likely to exceed in GW for 1-3 years	10
Protectiveness- Time to cleanup standards	- Longest time of all alternatives	1	+ Majority of GW cleaned up in year 1, with remainder in 3-5 years. + Treatment of downgradient GW will reduce time to CULs - Some CULs likely to exceed in GW for 3-5 years	8	+ Soils and GW treatment complete in year 1 + Treatment of downgradient GW will reduce time to CULs - Some CULs likely to exceed in GW for 1-3 years	10	+ Soils and GW treatment complete in year 1 + Treatment of downgradient GW will reduce time to CULs - Some CULs likely to exceed in GW for 1-3 years	10

TABLE 7-3
REMEDIAL ALTERNATIVE EVALUATION DETAILS
Stericycle Washougal Facility
Washougal, Washington

Alternative Number	A-1		A-2		A-3		A-4	
Remedial Components	**Cap/Surface Cover and MNA**		**ISB, Targeted ISCO, and MA**		**Deep Soil Mixing, Targeted ISCO, ISB downgradient, and MA**		**Electrical Resistive Heating, ISB downgradient, and MA**	
MTCA Criteria - subcriteria	Notes	Score	Notes	Score	Notes	Score	Notes	Score
Protectiveness- Onsite risks resulting from implementation	+ Reduced risk- only GW monitoring + No NAPL onsite, relatively low concentrations above CULs - While risk is low, GW monitoring for decades more than other alternatives	6	+ Reduced risk- low amount of high risk work above ground (small amount of corrosive chemical mixing) + Shorter GW monitoring, reduced chance of exposure to soils during future construction + No NAPL onsite, reduced number of COCs above CULs - Short term mobilization of COCs from ISB/ISCO - Additional management of potential exposure to ISCO treatment chemicals - Short term risks related to drilling and associated (small amount of) waste disposal	9	+ Majority of chemicals used for DSM are relatively low risk + Low amount high risk chemical work above ground (small amount of corrosive chemical mixing) + Shorter GW monitoring, reduced chance of exposure to soils during future construction + No NAPL onsite, reduced number of COCs above CULs - Most above ground activity resulting in highest potential for construction related risks (dust generation, silica hazard, volatilization, heavy equipment) but or a short time (< 1 year) - Highest amount of offsite waste disposal - Short term mobilization of COCs from ISB/ISCO - Additional management of potential exposure to ISCO treatment chemicals	6	+ Limited amount of treatment chemicals used for ERH + Shorter GW monitoring, reduced chance of exposure to soils during future construction + No NAPL onsite, reduced number of COCs above CULs - Highest risk construction activities (electrical, dust generation, volatilization, heavy equipment), but for a short time (~1 year) - Additional management of potential short term exposure to COCs in air and water collection and treatment systems (~1 year) - Moderate amount of offsite waste disposal	3
Protectiveness- Offsite risks resulting from implementation	+ Least amount of air, wastewater, or soil contamination transferred offsite as part of active remediation - COCs in shallow GW do reach receptors in marsh - Potential for deep GW to migrate to Columbia River eventually - Long term GW monitoring may add up to significant GHG emissions	4	+ Air- low GHG or COC emissions from remediation + Wastewater- low risk from decon water disposal + Soil- low risk from drill cuttings/decon/PPE disposal + Medium term treatment of GW source area - Potential short term mobilization of COCs from ISB/ISCO	8	+ Air- low COC emissions from remediation + Wastewater- low risk from decon water disposal + Long term low permeability in GW treatment areas from addition of bentonite to soils limiting migration of GW COCs offsite - Potential short term mobilization of COCs from ISB/ISCO - Significant amount of soil hauled for offsite disposal - Significant GHG emissions from transport of wastes - Highest dust generation and noise potential	6	+ GW capture likely to mitigate GW COC migration offsite - Potential short term and Long term mobilization of COCs from ERH possible in GW - Potential elevated GW temperatures feeding marsh - Potential for cross media transfer through air and water treatment - Moderate dust and noise generation potential - Significant GHG emissions from energy use	5

Alternative Number	A-1		A-2		A-3		A-4	
Remedial Components	Cap/Surface Cover and MNA		ISB, Targeted ISCO, and MA		Deep Soil Mixing, Targeted ISCO, ISB downgradient, and MA		Electrical Resistive Heating, ISB downgradient, and MA	
MTCA Criteria - subcriteria	Notes	Score	Notes	Score	Notes	Score	Notes	Score
Protectiveness- Improvement of the overall environmental quality	+ Least disruptive treatment alternative + Low Starting risk to receptors eventually reaching CULs with reduced risk to potential receptors + GW monitoring will detect if the potential threat to receptors increases, more active measures can be implemented. - Slowest to CULs - Highest uncertainty in time to reach CULs.	5	+ Tied for least disruptive active treatment alternative including low GHG emissions. + Reaching CULs in near future with reduced risk to potential receptors in the short term + Lower potential side effects of active remedial actions - Likely not the fastest alternative to reach CULs - Some uncertainty in time to reach CULs.	7	+ Reaching CULs in Year 1 with reduced risk to potential receptors + Lower potential side effects than most aggressive remedial actions - Potentially the highest GHG emissions	10	+ Reaching CULs in Year 1 with reduced risk to potential receptors - Some potential significant side effects (GW temperatures, solubilization of organic carbon) - Potentially the highest GHG emissions	9
	Average of Protectiveness sub-categories	3.8	Average of Protectiveness sub-categories	8.0	Average of Protectiveness sub-categories	8.7	Average of Protectiveness sub-categories	7.8
Permanence	+ Anaerobic degradation of VOCs is permanent. + Once VOCs are degraded, groundwater conditions should return to normal conditions resulting in a drop in metals concentrations. - 1,4-dioxane concentrations are not actively treated.	5	+ Anaerobic degradation of VOCs is permanent. + High concentrations of 1,4- dioxane are permanently destroyed by ISCO. + Once VOCs are degraded, groundwater conditions should return to normal conditions resulting in a drop in metals concentrations. - Low level 1,4-dioxane concentrations are passively treated.	8	+ DSM permanently destroys VOCs/metals and permanently traps any remaining COCs. + Low permeability permanently reduces groundwater flow through the treatment area. + High concentrations of 1,4- dioxane are permanently destroyed by ISCO.	9	+ ERH removes or destroys all COCs. + Once VOCs are degraded, groundwater conditions should return to normal conditions resulting in a drop in metals concentrations.	10
Long-term Effectiveness	+ Capping of exposed soils reduces onsite exposure, starting risk is low (relatively low concentrations of COCs, no NAPL onsite) + Relatively low concentrations above CULs in soil and GW which would be reduced eventually through passive treatment - Potential risk to receptors in shallow GW above CULs for many years - Potential risk to receptors in deep GW above CULs for many years - Longer term low level risk than all other alternatives	4	+ Capping of exposed soils reduces onsite exposure, starting risk is low (relatively low concentrations of COCs, no NAPL onsite) + Onsite GW actively treated to below CULs + Biggest potential offsite risks to GW reduced in Year 1 + Additional years (3-5 years) treatment of GW desorbing from fine grained units - Some CULs likely to exceed in GW for 3-5 years - Moderately aggressive for GW cleanup when compared to DSM or ERH	8	+ Capping of exposed soils reduces onsite exposure, starting risk is low (relatively low concentrations of COCs, no NAPL onsite) + Onsite GW actively treated to below CULs + Tied for highest potential for treatment of all soil and GW COCs of all alternatives - Some CULs likely to exceed in GW for 1-3 years	10	+ Capping of exposed soils reduces onsite exposure, starting risk is low (relatively low concentrations of COCs, no NAPL onsite) + Onsite GW actively treated to below CULs + Tied for highest potential for treatment of all soil and GW COCs of all alternatives - Some CULs likely to exceed in GW for 1-3 years	10

TABLE 7-3
REMEDIAL ALTERNATIVE EVALUATION DETAILS
Stericycle Washougal Facility
Washougal, Washington

Alternative Number	A-1		A-2		A-3		A-4	
Remedial Components	**Cap/Surface Cover and MNA**		**ISB, Targeted ISCO, and MA**		**Deep Soil Mixing, Targeted ISCO, ISB downgradient, and MA**		**Electrical Resistive Heating, ISB downgradient, and MA**	
MTCA Criteria - subcriteria	Notes	Score	Notes	Score	Notes	Score	Notes	Score
Management of Short-Term Risks	+ Reduced risk- only GW monitoring + No NAPL onsite, relatively low concentrations above CULs + Least amount of air, wastewater, or soil contamination transferred offsite - While risk is low, GW monitoring for decades more than other alternatives - GW in shallow water receptors to marsh	9	+ Reduced risk- low amount of high risk work above ground (small amount of corrosive chemical mixing) + No NAPL onsite, reduced number of COCs above CULs + Low offsite risks in short term - Potential short term mobilization of COCs from ISB/ISCO - Additional management of potential exposure to ISCO treatment chemicals - Short term risks related to drilling and associated (small amount of) waste disposal	8	+ Majority of chemicals used for DSM are relatively low risk + Low amount high risk chemical work above ground (small amount of corrosive chemical mixing) + No NAPL onsite, reduced number of COCs above CULs - Most above ground activity resulting in highest potential for construction related risks (dust generation, silica hazard, volatilization, heavy equipment) but or a short time (< 1 year) - Highest amount of offsite waste disposal - Potential short term mobilization of COCs from ISB/ISCO - Additional management of potential exposure to ISCO treatment chemicals	6	+ Limited amount of treatment chemicals used for ERH + No NAPL onsite, reduced number of COCs above CULs - Highest risk construction activities (electrical, dust generation, volatilization, heavy equipment), but for a short time (~1 year) - Additional management of potential short term exposure to COCs in air and water collection and treatment systems (~1 year) - Moderate amount of offsite waste disposal - Potential for increased GW temperature discharges to marsh - Potential short term mobilization of COCs from ERH possible in GW	4
Technical and Administrative Implementability	+ Least disruptive treatment alternative - Only 100% passive treatment option	10	+ Tied for least disruptive active treatment alternative including low GHG emissions. + Longer term release of substrate should mitigate risks of slow release of COCs from low permeability soils.	8	+ Physical mixing of soils most robust method to ensure treatment of COC affected soils and leaves a low permeability barrier that will reduce flow through the treatment area + Long term source of ZVI should mitigate risks of slow release of COCs from low permeability soils. - Most disruptive active treatment alternative, requiring large portions of the site to be shut down from active operations.	2	+ Several example projects with successful results in low permeability soils in the Pacific NW - Second most disruptive active treatment alternative, requiring large portions of the site to be shut down from active operations (or significant coordination off hours work.) - Requires the most additional permitting since the alternative includes offsite disposal of wastewater, air emissions, and soil disposal plus significant construction (buildings, electrical, etc.)	3

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TABLE 7-3
REMEDIAL ALTERNATIVE EVALUATION DETAILS
Stericycle Washougal Facility
Washougal, Washington

Alternative Number	A-1		A-2		A-3		A-4	
Remedial Components	Cap/Surface Cover and MNA		ISB, Targeted ISCO, and MA		Deep Soil Mixing, Targeted ISCO, ISB downgradient, and MA		Electrical Resistive Heating, ISB downgradient, and MA	
MTCA Criteria - subcriteria	Notes	Score	Notes	Score	Notes	Score	Notes	Score
Public Concern	+ Least amount of air, wastewater, or soil contamination transferred offsite as part of active remediation + GW monitoring will detect if the potential threat to receptors increases, more active measures can be implemented. - COCs in shallow GW do reach receptors in marsh - Potential for deep GW to migrate to Columbia River eventually - Long term GW monitoring may add up to significant GHG emissions	4	+ Majority of GW cleaned up in year 1, with remainder in 3-5 years. - Some CULs likely to exceed in GW for 3-5 years	8	+ Soils and GW treatment complete in year 1 + Treatment of downgradient GW will reduce time to CULs - Some CULs likely to exceed in GW for 1-3 years - Most above ground activity resulting in highest potential for construction related risks (dust generation, silica hazard, volatilization, heavy equipment) but or a short time (< 1 year) - Highest amount of offsite waste disposal and associated traffic - Short term mobilization of COCs from ISB/ISCO - Highest potential for dust and noise generation impacts to offsite	6	+ Soils and GW treatment complete in year 1 + Capture of GW onsite will blunt any potential offsite impacts of GW treatment. + Treatment of downgradient GW will reduce time to CULs - Some CULs likely to exceed in GW for 1-3 years - Highest risk construction activities (electrical, dust generation, volatilization, heavy equipment), but for a short time (~1 year) - Additional management to prevent harmful emissions from air and water collection and treatment systems (~1 year) - Moderate amount of offsite waste disposal and associated traffic - Potential for increased GW temperature discharges to marsh - Moderate potential for dust and noise generation impacts to offsite - Potential short term mobilization of COCs from ERH possible in GW	5
	Sum of Subcriteria Scores	**35.8**	**Sum of Subcriteria Scores**	**48.0**	**Sum of Subcriteria Scores**	**41.7**	**Sum of Subcriteria Scores**	**39.8**
	Ranking	6	**Ranking**	1	**Ranking**	3	**Ranking**	5

Notes
+ = Generally considered a beneficial aspect of the remedial alternative
- = Generally considered a detrimental aspect of the remedial alternative

Abbreviations

MNA = monitored natural attenuation
ISCO = in situ chemical oxidation
COC= Contaminant of Concern
VOCs = Volitale Organic Compounds
DSM= Deep Soil Mixing
MA= Monitored Attenuation
EPA = U.S. Environmental Protection Agency
MTCA = Model Toxics Control Act
ISB= In-Situ Bioremediation
CUL- Preliminary Cleanup Level
ZVI = Zero Valent Iron
ISB= In-situ Bioremediation
GW = Groundwater
GHG = Greenhouse Gas
NAPL = Non-aqueous Phase Liquid
ERH = Electrical Resistive Heating
NW = Northwest

TABLE 7-3
REMEDIAL ALTERNATIVE EVALUATION DETAILS
Stericycle Washougal Facility
Washougal, Washington

Alternative Number	A-5		A-6		A-7	
Remedial Components	**ZVI PRB, Targeted ISCO, and MA**		**ISB, Targeted ISCO, ISB downgradient, Hydraulic Control, and MA**		**Full Scale ISCO, ISB downgradient, and MA**	
MTCA Criteria - subcriteria	Notes	Score	Notes	Score	Notes	Score
Protectiveness- Degree existing risks reduced	+ Capping of exposed soils reduces onsite exposure, starting risk is low (relatively low concentrations of COCs, no NAPL onsite) + Onsite GW actively treated to below CULs + Biggest potential offsite risks to GW reduced in Year 1 + Potentially the most additional years (3-10 years) treatment of GW desorbing from fine grained units - Some CULs likely to exceed in GW for 3-5 years - Moderately aggressive for GW cleanup when compared to DSM or ERH	8	+ Capping of exposed soils reduces onsite exposure, starting risk is low (relatively low concentrations of COCs, no NAPL onsite) + Onsite GW actively treated to below CULs + Offsite GW risks aggressively reduced by capture of GW in Year 1 + Additional years (3-5 years) treatment of GW desorbing from fine grained units - Some CULs likely to exceed in GW for 3-5 years - Moderately aggressive for GW cleanup when compared to DSM or ERH	9	+ Capping of exposed soils reduces onsite exposure, starting risk is low (relatively low concentrations of COCs, no NAPL onsite) + Onsite GW actively treated to below CULs + Tied for highest potential for treatment of all soil and GW COCs of all alternatives - Majority of cleanup action depends on chemical contact in low permeability soils - Pilot testing is required to confirm viability in lower permeability soils - No additional treatment for desorbing contaminants, if treatment does not work additional injection rounds will be necessary.	8
Protectiveness- Time until reduced risk	+ Soils capped in year 1 + Majority of GW cleaned up in year 1, with remainder in 3-5 years - Some CULs likely to exceed in GW for 3-5 years	8	+ Soils capped in year 1 + Majority of GW cleaned up in year 1 (including offsite), with remainder of onsite GW reaching CULs in 3-5 years - Some CULs likely to exceed in GW for 3-5 years	9	+ Soils and GW treatment complete in year 1 - Some CULs likely to exceed in GW for 1-3 years	10
Protectiveness- Time to cleanup standards	+ Majority of GW cleaned up in year 1, with remainder in 3-5 years. + Treatment of downgradient GW will reduce time to CULs - Some CULs likely to exceed in GW for 3-5 years	8	+ Majority of GW cleaned up in year 1, with remainder in 3-5 years + Offsite GW will reach CULs faster than with ISB alone - Some CULs likely to exceed in GW for 3-5 years	9	+ Soils and GW treatment likely complete in year 1 + Treatment of downgradient GW will reduce time to CULs - Some CULs likely to exceed in GW for 1-3 years - If poor contact, then CULs may be exceeded for longer than 3 years	9

TABLE 7-3
REMEDIAL ALTERNATIVE EVALUATION DETAILS
Stericycle Washougal Facility
Washougal, Washington

Alternative Number	A-5		A-6		A-7	
Remedial Components	ZVI PRB, Targeted ISCO, and MA		ISB, Targeted ISCO, ISB downgradient, Hydraulic Control, and MA		Full Scale ISCO, ISB downgradient, and MA	
MTCA Criteria - subcriteria	Notes	Score	Notes	Score	Notes	Score
Protectiveness- Onsite risks resulting from implementation	+ Reduced risk- low amount of high risk work above ground (small amount of corrosive chemical mixing) + Shorter GW monitoring, reduced chance of exposure to soils during future construction + No NAPL onsite, reduced number of COCs above CULs - Short term mobilization of COCs from PRB/ISCO - Additional management of potential exposure to ISCO chemicals - Short term risks related to drilling and associated (small amount of) waste disposal	9	+ Moderate risk- operation of pump and treat system includes volatilization of VOCs and groundwater treatment prior to discharge + Shorter GW monitoring, reduced chance of exposure to soils during future construction + No NAPL onsite, reduced number of COCs above CULs - Short term mobilization of COCs from ISB/ISCO - Additional management of potential exposure to ISCO treatment chemicals, air, and water treatment chemicals and COCs in hydraulic capture systems (up to 3 years) - Short term risks related to drilling/trenching (dust generation, volatilization, heavy equipment) - Moderate amount of offsite waste disposal	4	+ Moderate risk- above ground work includes substantial corrosive chemical mixing + Shorter GW monitoring, reduced chance of exposure to soils during future construction + No NAPL onsite, reduced number of COCs above CULs - Short term mobilization of COCs from ISB/ISCO - Additional management of potential exposure to large amount of ISCO treatment chemicals, but for short periods of time (during injections only). - Short term risks related to drilling and associated (small amount of) waste disposal	5
Protectiveness- Offsite risks resulting from implementation	+ Air- low GHG or COC emissions from remediation + Wastewater- low risk from decon water disposal + Soil- low risk from drill cuttings/decon/PPE disposal + Longer term treatment of GW in source area - Potential short term mobilization of COCs from PRB/ISCO	9	+ GW capture likely to mitigate offsite GW releases + Medium term treatment of GW in source area - Potential short term mobilization of COCs from ISB/ISCO - Potential for cross media transfer through air and water treatment - Moderate GHG emissions from energy use - Moderate dust and noise generation potential	7	+ Air- low GHG or COC emissions from remediation + Wastewater- low risk from decon water disposal + Soil- low risk from drill cuttings/decon/PPE disposal - Potential short term mobilization of COCs from ISCO	7

TABLE 7-3
REMEDIAL ALTERNATIVE EVALUATION DETAILS
Stericycle Washougal Facility
Washougal, Washington

Alternative Number	A-5		A-6		A-7	
Remedial Components	**ZVI PRB, Targeted ISCO, and MA**		**ISB, Targeted ISCO, ISB downgradient, Hydraulic Control, and MA**		**Full Scale ISCO, ISB downgradient, and MA**	
MTCA Criteria - subcriteria	Notes	Score	Notes	Score	Notes	Score
Protectiveness- Improvement of the overall environmental quality	+ Tied for least disruptive active treatment alternative including low GHG emissions. + Reaching CULs in near future with reduced risk to potential receptors in the short term + Lower potential side effects of active remedial actions - Likely not the fastest alternative to reach CULs - Some uncertainty in time to reach CULs.	7	+ Reaching CULs in near future with reduced risk to potential receptors in the short term + Lower potential side effects of active remedial actions - Slower to onsite CULs than most aggressive options - Some uncertainty in time to reach CULs.	8	+ Reaching CULs in near future with reduced risk to potential receptors in the short term + Some potential side effects of active remedial actions - Majority of treatment only works if contact is achieved, pilot testing is needed to confirm effectiveness in lower permeability soils	6
	Average of Protectiveness sub-categories	8.2	Average of Protectiveness sub-categories	7.7	Average of Protectiveness sub-categories	7.5
Permanence	+ Chemical reduction of VOCs and metals is permanent. + High concentrations of 1,4- dioxane are permanently destroyed by ISCO. - Low level 1,4-dioxane concentrations are passively treated.	8	+ Anaerobic degradation of VOCs is permanent. + High concentrations of 1,4- dioxane are permanently destroyed by ISCO and low level 1,4-dioxane concentrations may be captured in pump and treat. + Once VOCs are degraded, groundwater conditions should return to normal conditions resulting in a drop in metals concentrations. - Low level 1,4-dioxane concentrations may remain in low permeability soils to be passively treated long-term.	8	+ ISCO of VOCs and 1,4-dioxane is permanent. - ISCO permanence is dependent on direct contact of chemicals with COCs, permanence in low permeability soils is unclear until bench/pilot scale studies are completed. - ISCO may result in side effect of metals release, unsure until bench/pilot scale studies are completed.	7
Long-term Effectiveness	+ Capping of exposed soils reduces onsite exposure, starting risk is low (relatively low concentrations of COCs, no NAPL onsite) + Onsite GW actively treated to below CULs + Biggest potential offsite risks to GW reduced in Year 1 + Potentially the most additional years (3-10 years) treatment of GW desorbing from fine grained units - Some CULs likely to exceed in GW for 3-5 years - Moderately aggressive for GW cleanup when compared to DSM or ERH	8	+ Capping of exposed soils reduces onsite exposure, starting risk is low (relatively low concentrations of COCs, no NAPL onsite) + Onsite GW actively treated to below CULs + Offsite GW risks aggressively reduced by capture of GW in Years 1 to 3 + Additional years (3-5 years) treatment of GW desorbing from fine grained units - Some CULs likely to exceed in GW for 3-5 years - Moderately aggressive for GW cleanup when compared to DSM or ERH	9	+ Capping of exposed soils reduces onsite exposure, starting risk is low (relatively low concentrations of COCs, no NAPL onsite) + Onsite GW actively treated to below CULs + Tied for highest potential for treatment of all soil and GW COCs of all alternatives - Majority of cleanup action depends on chemical contact in low permeability soils - Pilot testing is required to confirm viability in lower permeability soils - No additional treatment for desorbing contaminants, if treatment does not work additional injection rounds will be necessary.	7

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TABLE 7-3
REMEDIAL ALTERNATIVE EVALUATION DETAILS
Stericycle Washougal Facility
Washougal, Washington

Alternative Number	A-5		A-6		A-7	
Remedial Components	ZVI PRB, Targeted ISCO, and MA		ISB, Targeted ISCO, ISB downgradient, Hydraulic Control, and MA		Full Scale ISCO, ISB downgradient, and MA	
MTCA Criteria - subcriteria	Notes	Score	Notes	Score	Notes	Score
Management of Short-Term Risks	+ Reduced risk- low amount of high risk work above ground (small amount of corrosive chemical mixing) + No NAPL onsite, reduced number of COCs above CULs - Potential short term mobilization of COCs from PRB/ISCO - Additional management of potential exposure to ISCO chemicals - Short term risks related to drilling and associated (small amount of) waste disposal	8	+ Moderate risk- operation of pump and treat system includes volatilization of VOCs and groundwater treatment prior to discharge + No NAPL onsite, reduced number of COCs above CULs - Potential short term mobilization of COCs from ISB/ISCO - Additional management of potential exposure to ISCO treatment chemicals, air, and water treatment chemicals and COCs in hydraulic capture systems (up to 3 years) - Short term risks related to drilling/trenching (dust generation, volatilization, heavy equipment) - Moderate amount of offsite waste disposal	5	+ Moderate risk- above ground work includes substantial corrosive chemical mixing + No NAPL onsite, reduced number of COCs above CULs - Highest potential for short and long term mobilization of COCs from ISCO - Additional management of potential exposure to large amount of ISCO treatment chemicals, but for short periods of time (during injections only). - Short term risks related to drilling and associated (small amount of) waste disposal - Potential short term mobilization of COCs from ISB	6
Technical and Administrative Implementability	+ Tied for least disruptive active treatment alternative including low GHG emissions + Long term source of ZVI should mitigate risks of slow release of COCs from low permeability soils - Less history of successful hydraulic fracturing placement of substrate in low permeability soils than other alternatives in the Pacific NW	7	+ Hydraulic control has been proven to work at myriad example projects with successful results in low permeability soils in the Pacific NW - Third most disruptive active treatment alternative, requiring significant coordination for pipe trenching and treatment building construction - Requires the second most additional permitting since the alternative includes offsite disposal of wastewater, air emissions, and soil disposal plus significant construction (buildings, electrical, etc.)	5	+ Only slightly more disruptive than ISB/ZVI, since injections would likely require tighter spacing and more rounds of injection - ISCO implementability is dependent on direct contact of chemicals with COCs, technical performance in low permeability soils is unclear until bench/pilot scale studies are completed.	6

TABLE 7-3
REMEDIAL ALTERNATIVE EVALUATION DETAILS
Stericycle Washougal Facility
Washougal, Washington

Alternative Number	A-5		A-6		A-7	
Remedial Components	ZVI PRB, Targeted ISCO, and MA		ISB, Targeted ISCO, ISB downgradient, Hydraulic Control, and MA		Full Scale ISCO, ISB downgradient, and MA	
MTCA Criteria - subcriteria	Notes	Score	Notes	Score	Notes	Score
Public Concern	+ Majority of GW cleaned up in year 1, with remainder in 3-5 years. - Some CULs likely to exceed in GW for 3-5 years - Hydraulic fracturing for placement of ZVI in the lower permeability units which may trigger public concerns due to confusion with hydraulic fracturing for natural gas/oil exploration	7	+ Majority of GW cleaned up in year 1, with remainder in 3-5 years. + Capture of GW onsite will blunt any potential offsite impacts of GW treatment. + Offsite GW will reach CULs faster than with ISB alone - Some CULs likely to exceed in GW for 3-5 years - Additional managemetn to prevent harmful emissions from air, and water treatment system components of hydraulic capture system (up to 3 years) - Moderate amount of offsite waste disposal and associated traffic - Moderate potential for dust and noise generation impacts to offsite	6	+ Soils and GW treatment likely complete in year 1 - Short term mobilization of COCs from ISB/ISCO - ISCO may result in side effect of metals release, unsure until bench/pilot scale studies are completed. - ISCO implementability is dependent on direct contact of chemicals with COCs, technical performance in low permeability soils is unclear until bench/pilot scale studies are completed.	6
	Sum of Subcriteria Scores	**46.2**	**Sum of Subcriteria Scores**	**40.7**	**Sum of Subcriteria Scores**	**39.5**
	Ranking	1	**Ranking**	4	**Ranking**	5

Notes
+ = Generally considered a beneficial aspect of the remedial alternative
- = Generally considered a detrimental aspect of the remedial alternative

Abbreviations
MNA = monitored natural attenuation
ISCO = in situ chemical oxidation
COC= Contaminant of Concern
VOCs = Volitale Organic Compounds
DSM= Deep Soil Mixing
MA= Monitored Attenuation
EPA = U.S. Environmental Protection Agency
MTCA = Model Toxics Control Act
ISB= In-Situ Bioremediation
CUL- Preliminary Cleanup Level
ZVI = Zero Valent Iron
ISB= In-situ Bioremediation
GW = Groundwater
GHG = Greenhouse Gas
NAPL = Non-aqueous Phase Liquid
ERH = Electrical Resistive Heating
NW = Northwest

DALTON OLMSTED FUGLEVAND

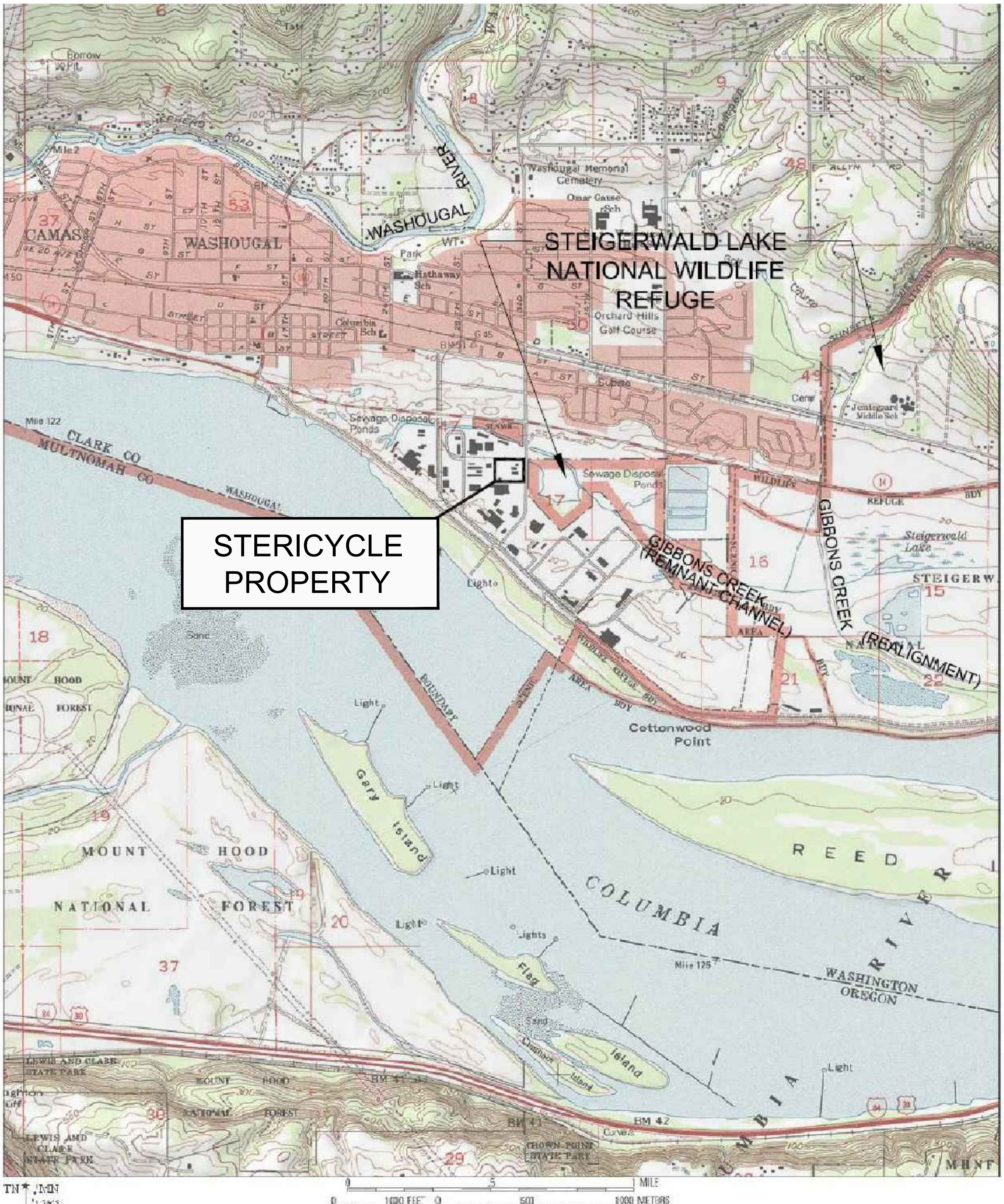
TABLE 7-4
COST ESTIMATES FOR REMEDIAL ALTERNATIVES
Stericycle Washougal Facility
Washougal, Washington

Alternatives	Initial Implementation Cost	Net Present Value Cost	Start of Significant COC Reduction (years)	Active Remediation Duration (years) [1]	Restoration Time Frame (years)
A-1: Capping and MNA	$46,600	$2,742,000	10+	30	30 +
A-2: Bioremediation and Targeted ISCO	$638,300	$2,532,000	1	3 to 5	15
A-3: Deep Soil Mixing with ZVI and Targeted ISCO	$2,283,500	$3,688,000	1	1	10
A-4: Electrical Resistive Heating	$3,549,000	$5,034,000	1	1	10
A-5: ZVI Permeable Reactive Barrier and Targeted ISCO	$971,500	$2,447,000	1	3 to 10	10
A-6: Hydraulic Control with Bioremediation and Targeted ISCO	$1,099,400	$3,722,000	1	3 to 5	15
A-7: Full Scale ISCO Treatment	$1,614,000	$2,963,000	1	1	10

Notes
1. Active remediation indicates the expected duration of accelerated degradation rates, except in the case of MNA which has no active component, a passive timeframe was used.

Abbreviations
ISCO = in situ chemical oxidation
MNA = monitored natural attenuation
ZVI = zero-valent iron

Figures



Map created with TOPO!® ©2002 National Geographic (www.nationalgeographic.com/topo)

Washougal, Washington

Stericycle - Washougal Facility
Washougal, Washington

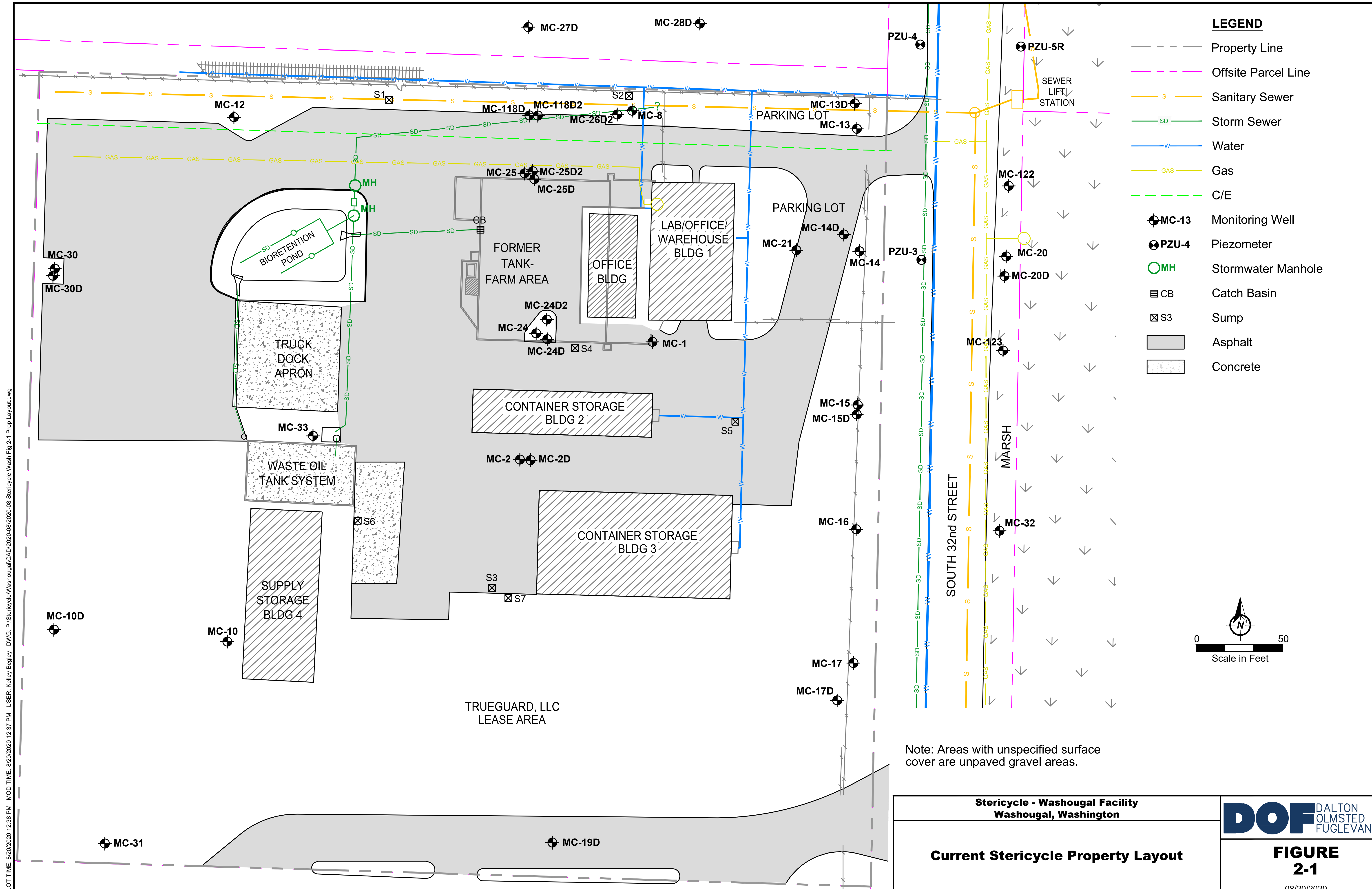
Vicinity Map

DALTON OLMSTED FUGLEVAND

FIGURE 1-1

03/27/2020

PLOT TIME: 3/26/2020 5:19 PM MOD TIME: 3/26/2020 5:18 PM USER: Kelley Begley DWG: P:\Stericycle\Washougal\CAD\2020-03\2020-03 Stericycle Wash Vic Map.dwg



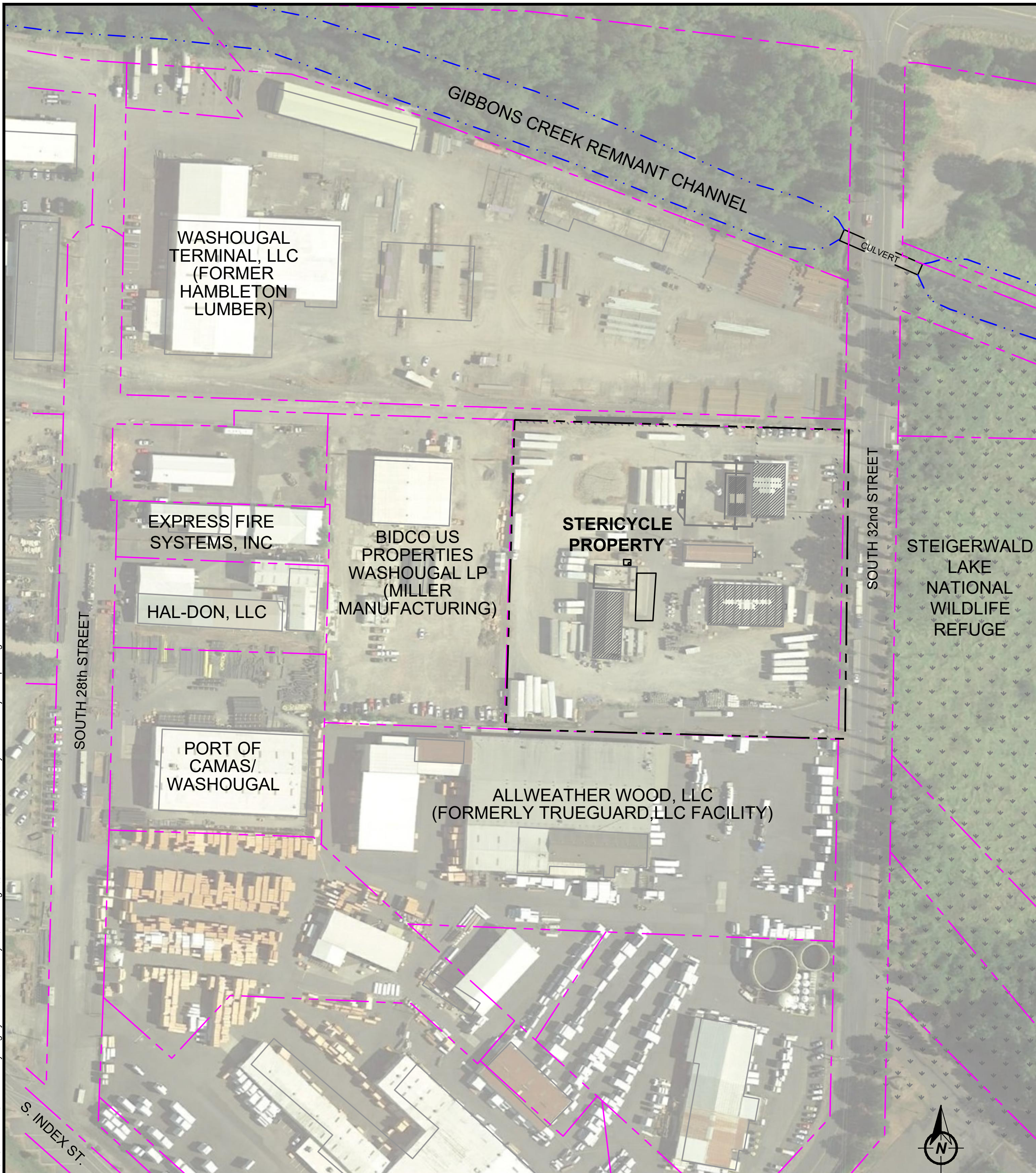
Stericycle - Washougal Facility
Washougal, Washington

Current Stericycle Property Layout

DALTON OLMSTED FUGLEVAND

FIGURE 2-1

08/20/2020



Resource: Aerial-Google Earth Pro, 7/16/18.

0 200
Scale in Feet

LEGEND

Property Line

Offsite Parcel Line

Stericycle - Washougal Facility
Washougal, Washington

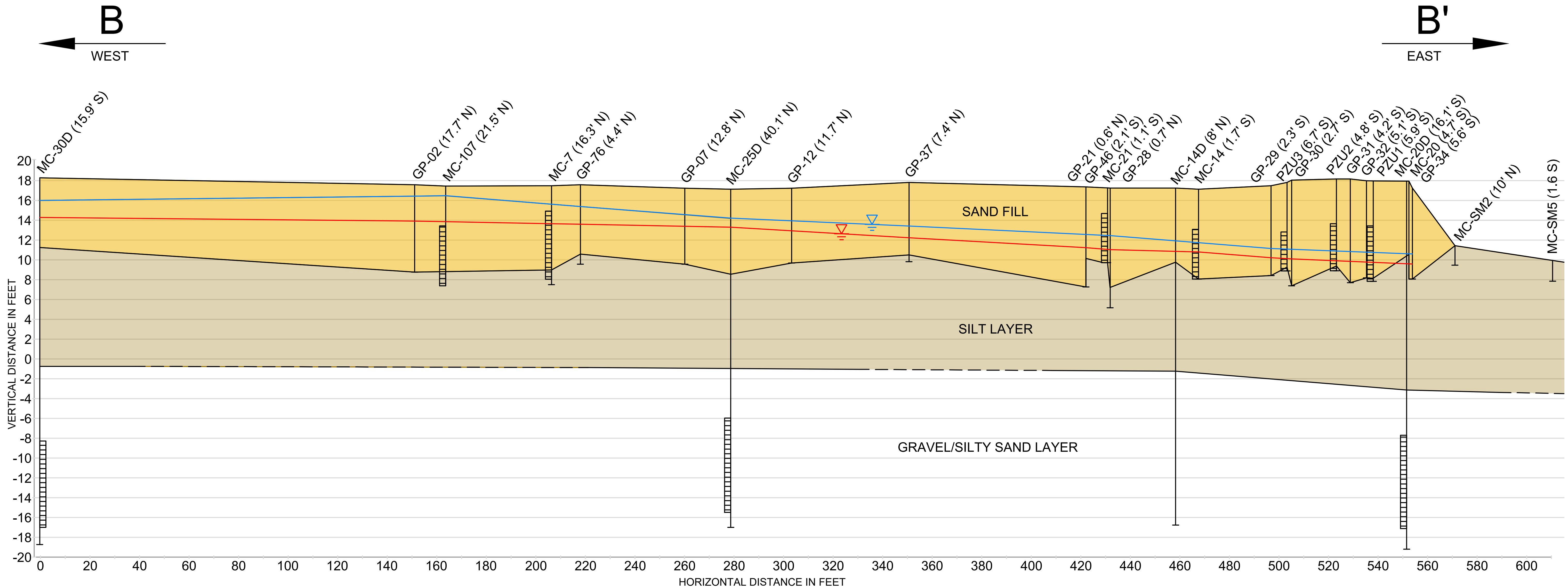
Adjacent Properties

DALTON OLMSTED FUGLEVAND

FIGURE 2-2

05/21/2020

PLOT TIME: 5/21/2020 10:43 AM MOD TIME: 5/21/2020 10:42 AM USER: Kelley Begley DWG: P:\Stericycle\Washougal\CAD\2020-05\2020-05 Stericycle Wash Adjac Props.dwg



LEGEND

MC-107 (21.5' N) — Well/Boring Identification (distance in feet and cardinal direction from cross section plane)

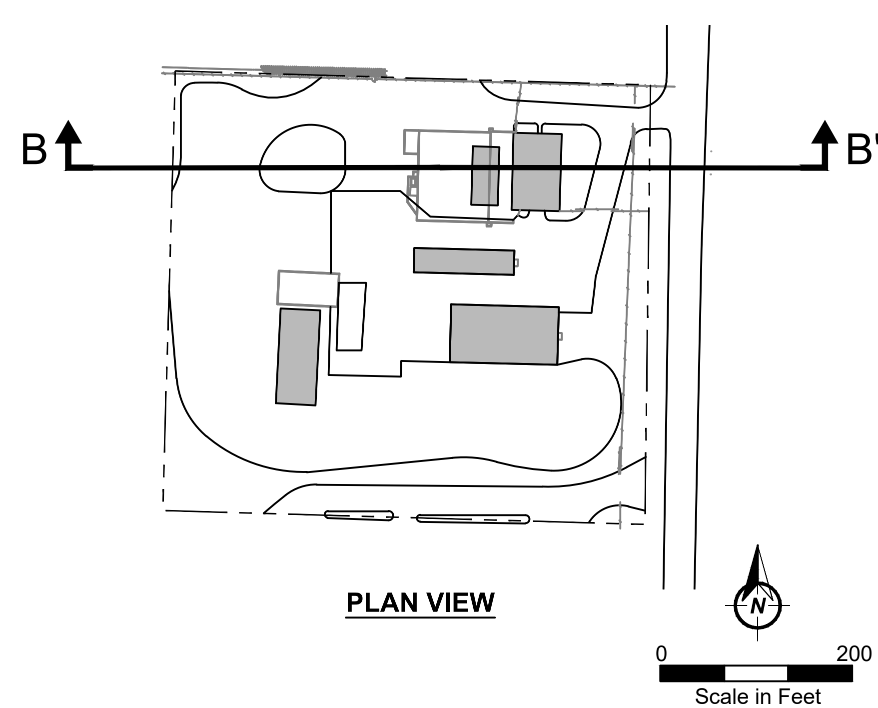
Poorly Graded Sand

Organic Soil or Silty Clay

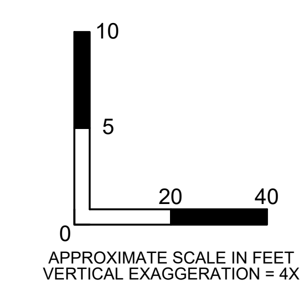
Screened Interval

2006-2009 average high water level elevation

2006-2009 average low water level elevation



PLAN VIEW



NOTES

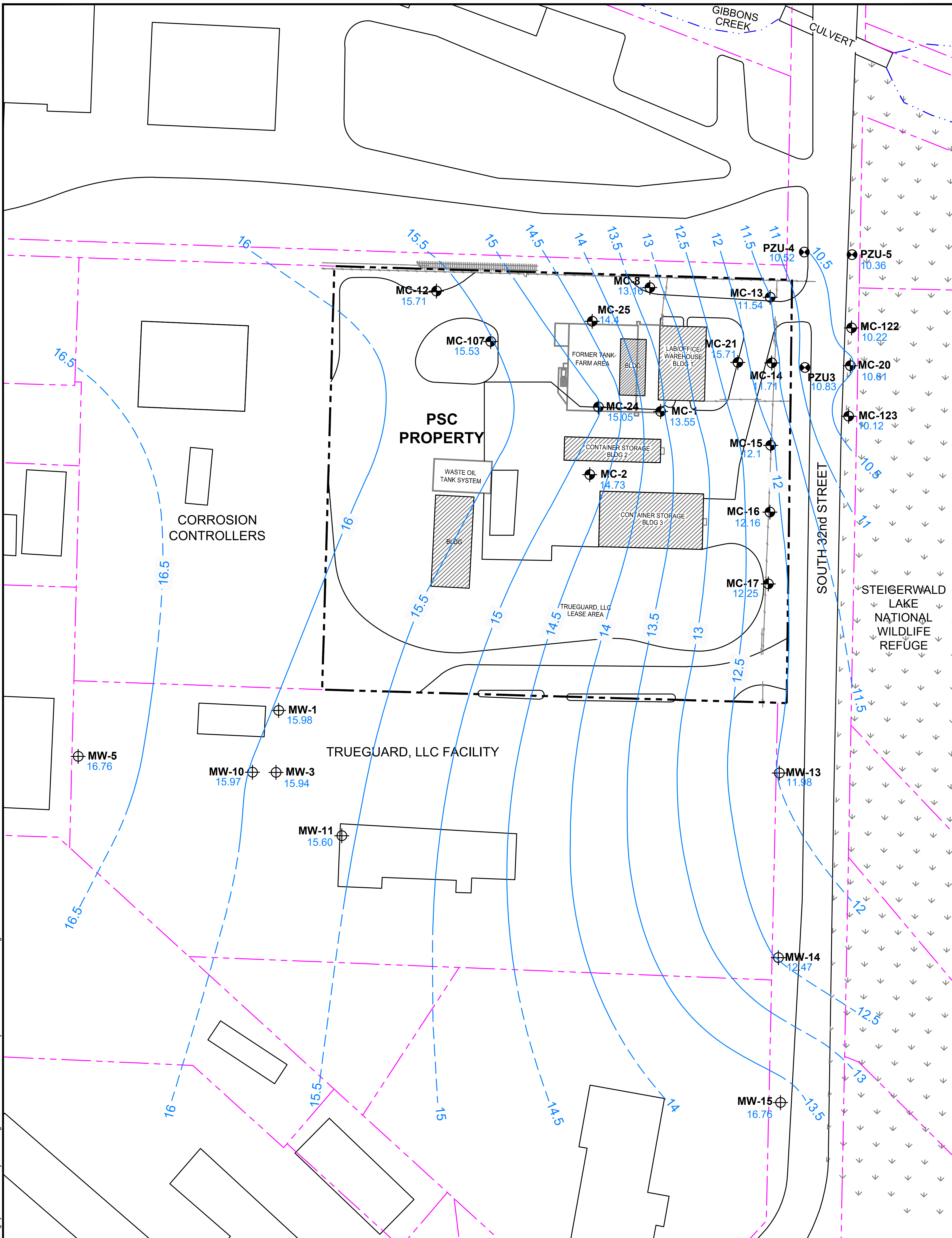
1. Contact are dashed where inferred.
2. Water levels were calculated using the average of the water level elevations from 2006-2009.
3. Original figure included as Figure 6-5 AMEC 2013 Remedial Investigation.

Stericycle - Washougal Facility
Washougal, Washington

Representative Cross Section from 2013 Remedial Investigation

FIGURE 2-3

08/19/2020



LEGEND

15 — Groundwater Elevation Contour (feet above MSL)

Property Line

Offsite Parcel Line

MC-13 11.54 — Shallow Groundwater Zone Monitoring Well

PZU-4 10.52 — Piezometer

MW-13 11.98 — Trueguard, LLC Monitoring Well

NOTES:

Groundwater elevations for Washougal Facility collected March 9, 2008.

Groundwater elevations for Trueguard, LLC Facility collected on February 28, 2008. (Maul, Foster, Alongi, 2009)

Original figure included as figure 7-1 AMEC 2013 Remedial Investigation.

N

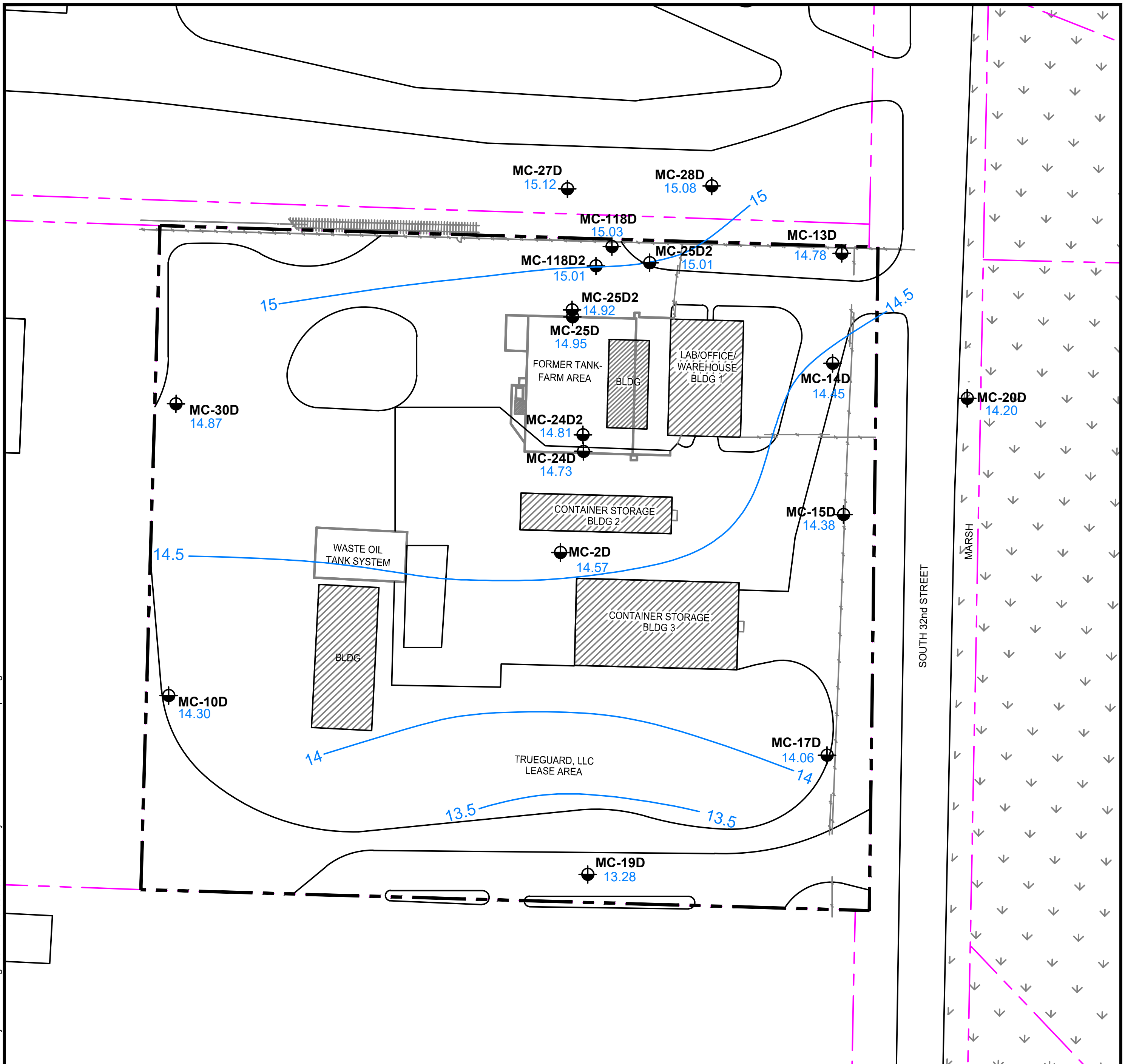
0 100
Scale in Feet

Stericycle - Washougal Facility
Washougal, Washington

Area-Wide Groundwater Elevation
Shallow Groundwater Zone
from 2013 Remedial Investigation

FIGURE 2-4

08/19/2020



LEGEND

Property Line

Offsite Parcel Line

MC-19D 13.28 — Deep Aquifer Monitoring Well with Water Level (feet)

Groundwater Elevation Contour (Interval=0.2 feet)

Approximate Flow Direction

N

0 100
Scale in Feet

Note:
Originally presented as Figure 2 in January-March 2019 Quarterly Report, dated July 15, 2019.

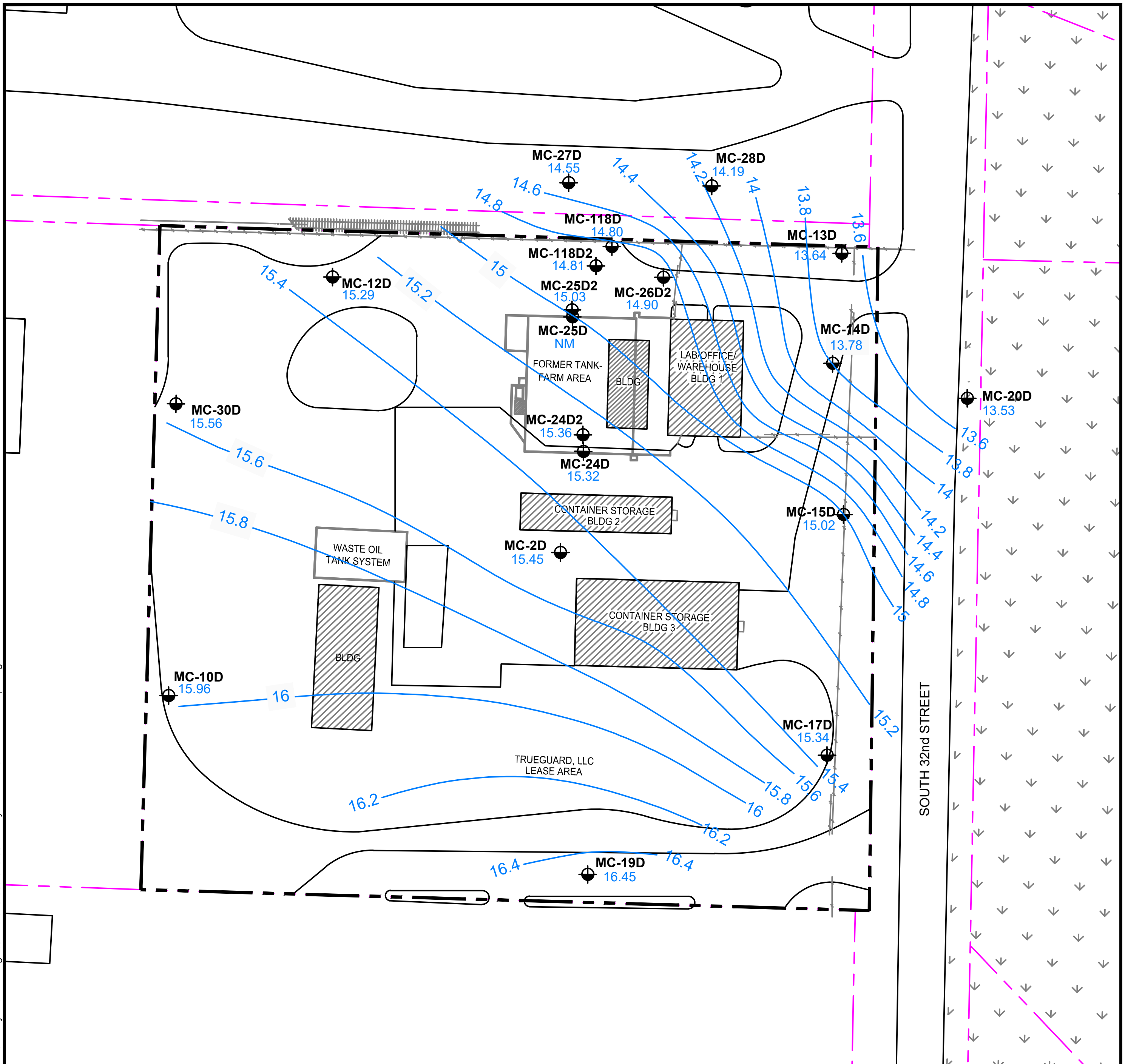
Stericycle - Washougal Facility
Washougal, Washington

Groundwater Elevations
Lower Aquifer
March 18, 2019

FIGURE 2-5

08/19/2020

PLOT TIME: 8/19/2020 2:29 PM MOD TIME: 8/19/2020 2:28 PM USER: Kelley Begley DWG: P:\Stericycle\Washougal\CAD\2020-08\2020-08 Stericycle Wash GW Elev Low Aq2.dwg



LEGEND

Property Line

Offsite Parcel Line

MC-19D 16.45 — Deep Aquifer Monitoring Well with Water Level (feet)

Groundwater Elevation Contour (Interval=0.2 feet)

Approximate Flow Direction

0 100
Scale in Feet

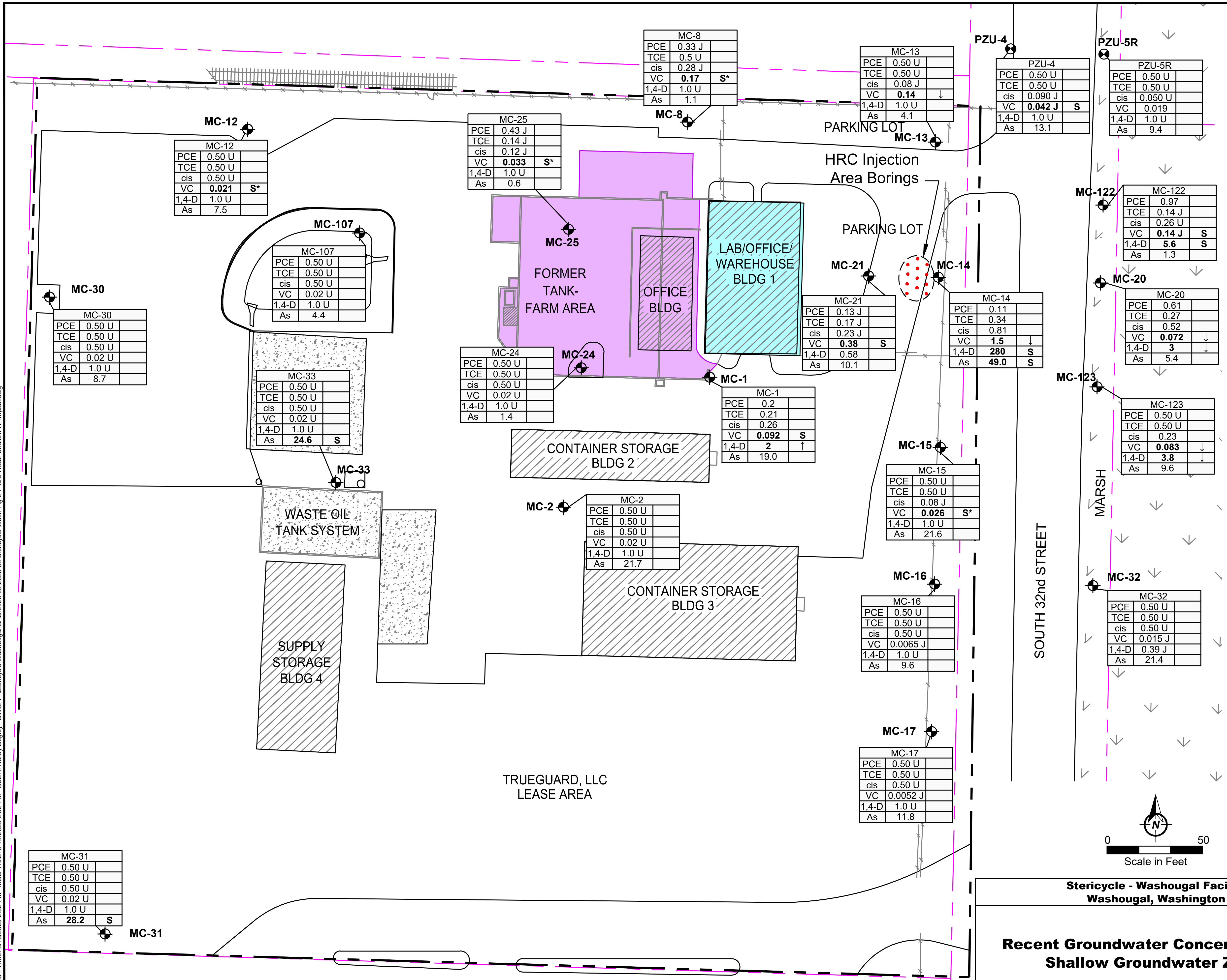
Note:
Originally presented as Figure 2 in April - June 2017 Quarterly Report, dated October 9, 2017.

Stericycle - Washougal Facility
Washougal, Washington

Groundwater Elevations
Lower Aquifer
June 19, 2017

FIGURE 2-6

08/20/2020



LEGEND

Property Line

Offsite Parcel Line

MC-13 Shallow Groundwater Zone Monitoring Well

PZU-4 Piezometer

HRC Injection Area Boring

Depressurization System-Building 1

Area of 1997 Excavation

DATABOX KEY

PCE	Tetrachloroethene
TCE	Trichloroethene
cis	cis-1,2-Dichloroethene
VC	Vinyl Chloride
1,4-D	1,4-Dioxane
As	Arsenic

Shallow CUL (ug/L)	
PCE	2.4
TCE	1
cis	16
VC	0.02
1,4-D	1
As	22.8

← Location I.D.

Highest detected concentration (ug/L)

← Average concentration (ug/L)

DATA QUALIFIERS

U= analyte was not detected at the quantitation limit indicated.

J= analyte was positively identified. Result is an estimated value.

Bold= above cleanup level.

↑= indicates an increasing concentration trend 2003 to 2019

↓= indicates a decreasing concentration

S= indicates a stable concentration

*= indicates a single anomalous detection above the cleanup level between 2Q 2018 and 1Q 2019

NOTES:

Values shown for VOCs and 1,4-Dioxane are highest detected concentrations (or highest detection limit for non-detect analytes) from four quarters of sampling (2Q2018 through 1Q2019). Values shown for arsenic are average total arsenic concentrations over four quarters of sampling.

Concentrations shown in µg/L.

Stericycle - Washougal Facility
Washougal, Washington

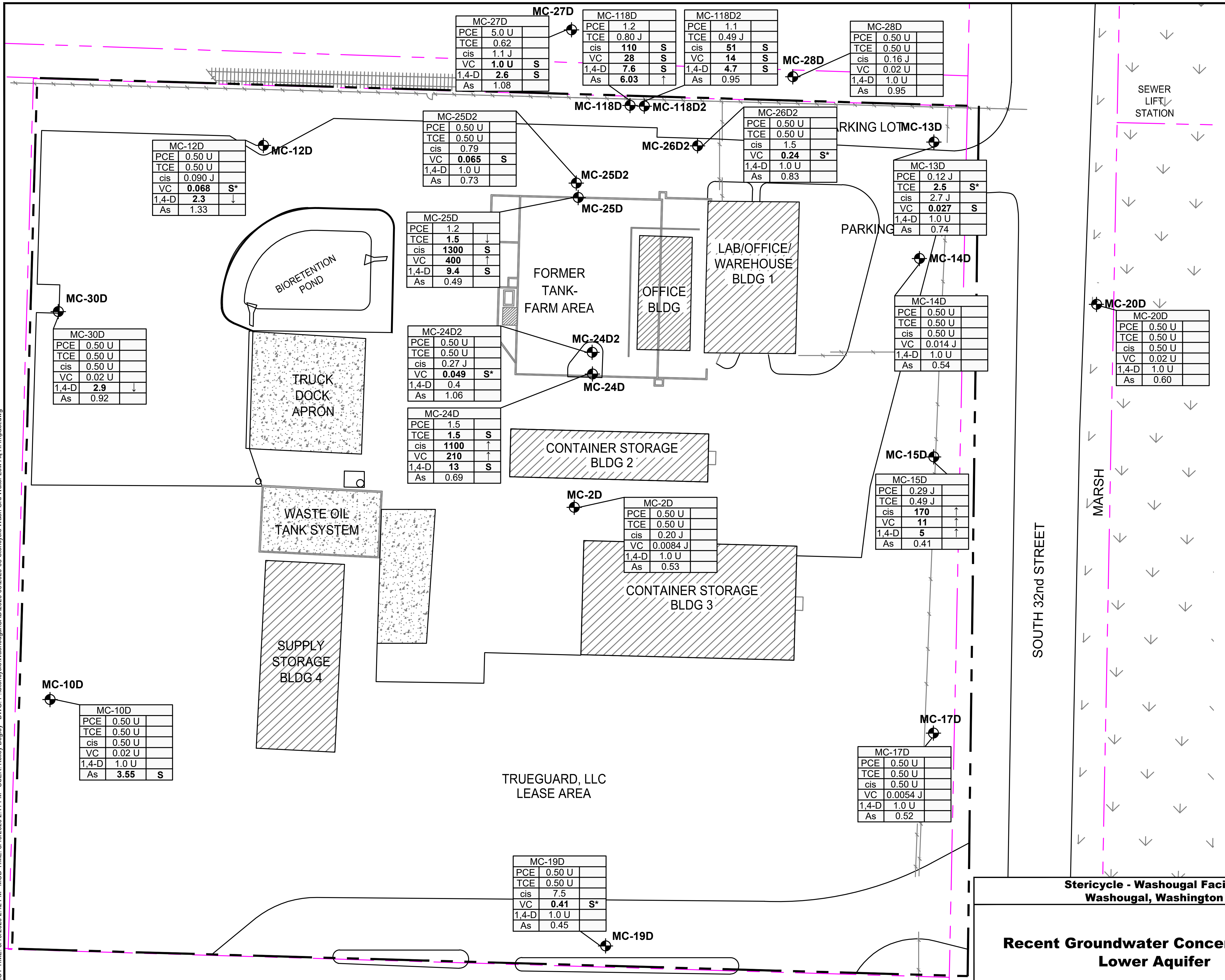
Recent Groundwater Concentrations - Shallow Groundwater Zone

DALTON OLMSTED FUGLEVAND

FIGURE 2-7

08/19/2020

PLOT TIME: 8/19/2020 2:32 PM MOD TIME: 8/19/2020 2:32 PM USER: Kelley Begley DWG: P:\Stericycle\Washougal\CAD\2020-08\2020-08 Stericycle Wash Fig 2-7 Grd Water Shallow Hi-Impact.dwg



LEGEND

Property Line

Offsite Parcel Line

MC-13D Deep Groundwater Zone Monitoring Well

DATABOX KEY

PCE	Tetrachloroethene
TCE	Trichloroethene
cis	cis-1,2-Dichloroethene
VC	Vinyl Chloride
1,4-D	1,4-Dioxane
As	Arsenic

Deep	CUL (ug/L)	
PCE	2.4	
TCE	1	
cis	16	
VC	0.02	
1,4-D	1	
As	1.42	

← Location I.D.

Highest detected concentration (ug/L)

← Average concentration (ug/L)

DATA QUALIFIERS

U= analyte was not detected at the quantitation limit indicated.

J= analyte was positively identified. Result is an estimated value.

Bold= above cleanup level.

↑= indicates an increasing concentration trend 2003 to 2019

↓= indicates a decreasing concentration

S= indicates a stable concentration

*= indicates a single anomalous detection above the cleanup level between 2Q 2018 and 1Q 2019

NOTES:

Values shown for VOCs and 1,4-Dioxane are highest detected concentrations (or highest detection limit for non-detect analytes) from four quarters of sampling (2Q2018 through 1Q2019). Values shown for arsenic are average total arsenic concentrations over four quarters of sampling.

Concentrations shown in µg/L.

N

0 50

Scale in Feet

Stericycle - Washougal Facility
Washougal, Washington

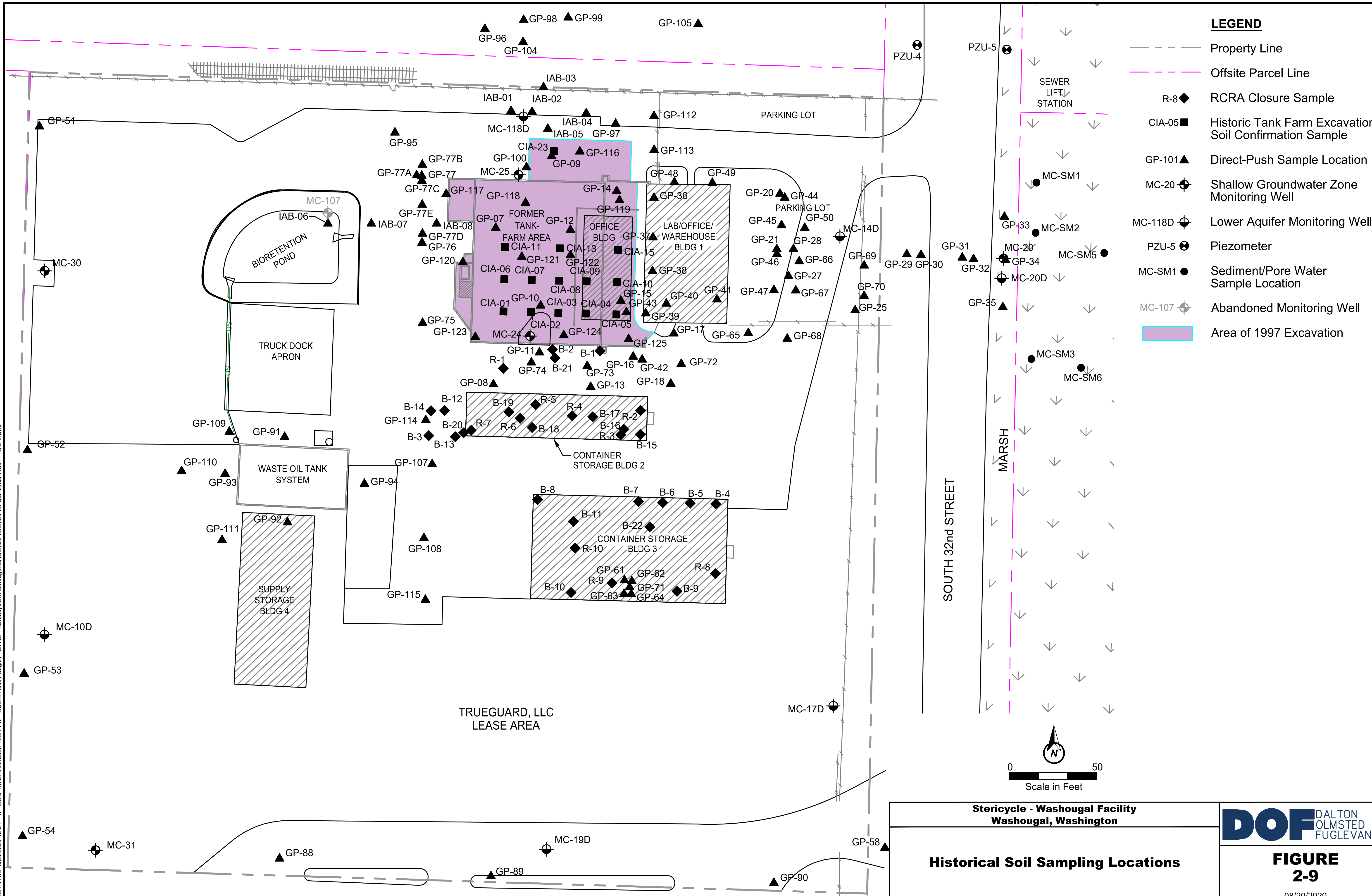
Recent Groundwater Concentrations - Lower Aquifer

DALTON OLMSTED FUGLEVAND

FIGURE 2-8

08/19/2020

PLOT TIME: 8/19/2020 2:42 PM MOD TIME: 8/19/2020 2:41 PM USER: Kelley Begley DWG: P:\Stericycle\Washougal\CAD\2020-08\2020-08 Stericycle Wash Grd Water Low Aq Hi-Impact.dwg



Stericycle - Washougal Facility
Washougal, Washington

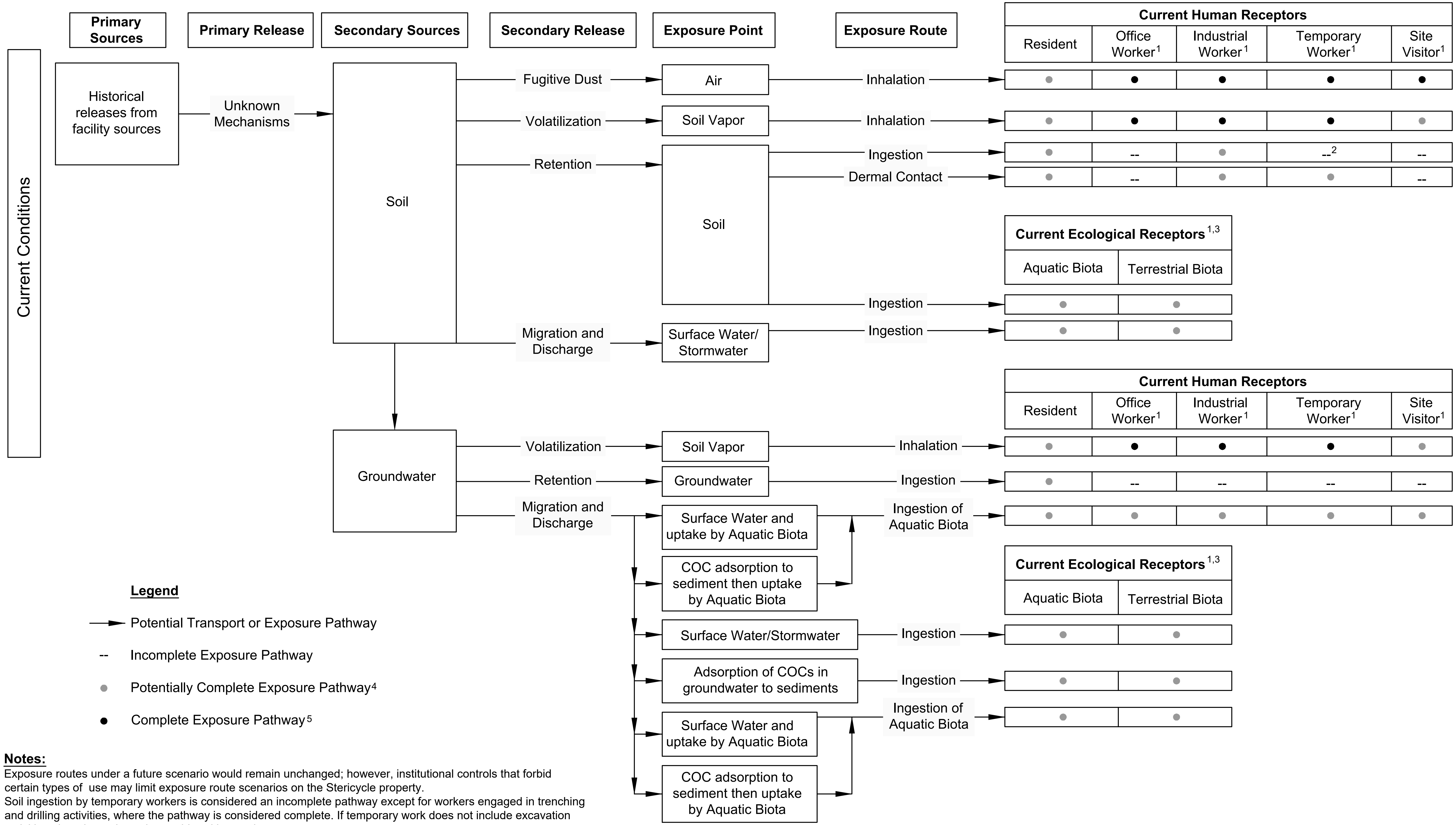
Historical Soil Sampling Locations

DALTON OLMSTED FUGLEVAND

FIGURE 2-9

08/20/2020

PLOT TIME: 8/20/2020 12:21 PM MOD TIME: 8/20/2020 12:21 PM USER: Kelley Begley DWG: P:\Stericycle\Washougal\CAD\2020-08\2020-08 Stericycle Wash FIG 2-9.dwg



Notes:

1. Exposure routes under a future scenario would remain unchanged; however, institutional controls that forbid certain types of use may limit exposure route scenarios on the Stericycle property.
2. Soil ingestion by temporary workers is considered an incomplete pathway except for workers engaged in trenching and drilling activities, where the pathway is considered complete. If temporary work does not include excavation activities, then the pathway is considered incomplete.
3. Dermal contact is not considered a complete pathway for ecological receptors. Note barium concentrations is excess of Ecological Indicator Soil Concentrations for the Protection of Terrestrial Plants and Animals (MTCA Table 749-3) are present on the property, but less than reported background. See Section 8.4 of Remedial Investigation Report (AMEC, 2013) for further detail.
4. A potentially complete exposure pathway exists when potential contamination exposure to an individual or population is considered possible but unlikely.
5. A complete exposure pathway exists when an individual or population is exposed or has the potential to be exposed to hazardous substances at or originating from the site.
6. Stormwater could potentially be impacted by soil or groundwater as noted above. There is no un-permitted stormwater discharge by the facility because they are covered by an industrial stormwater general permit.

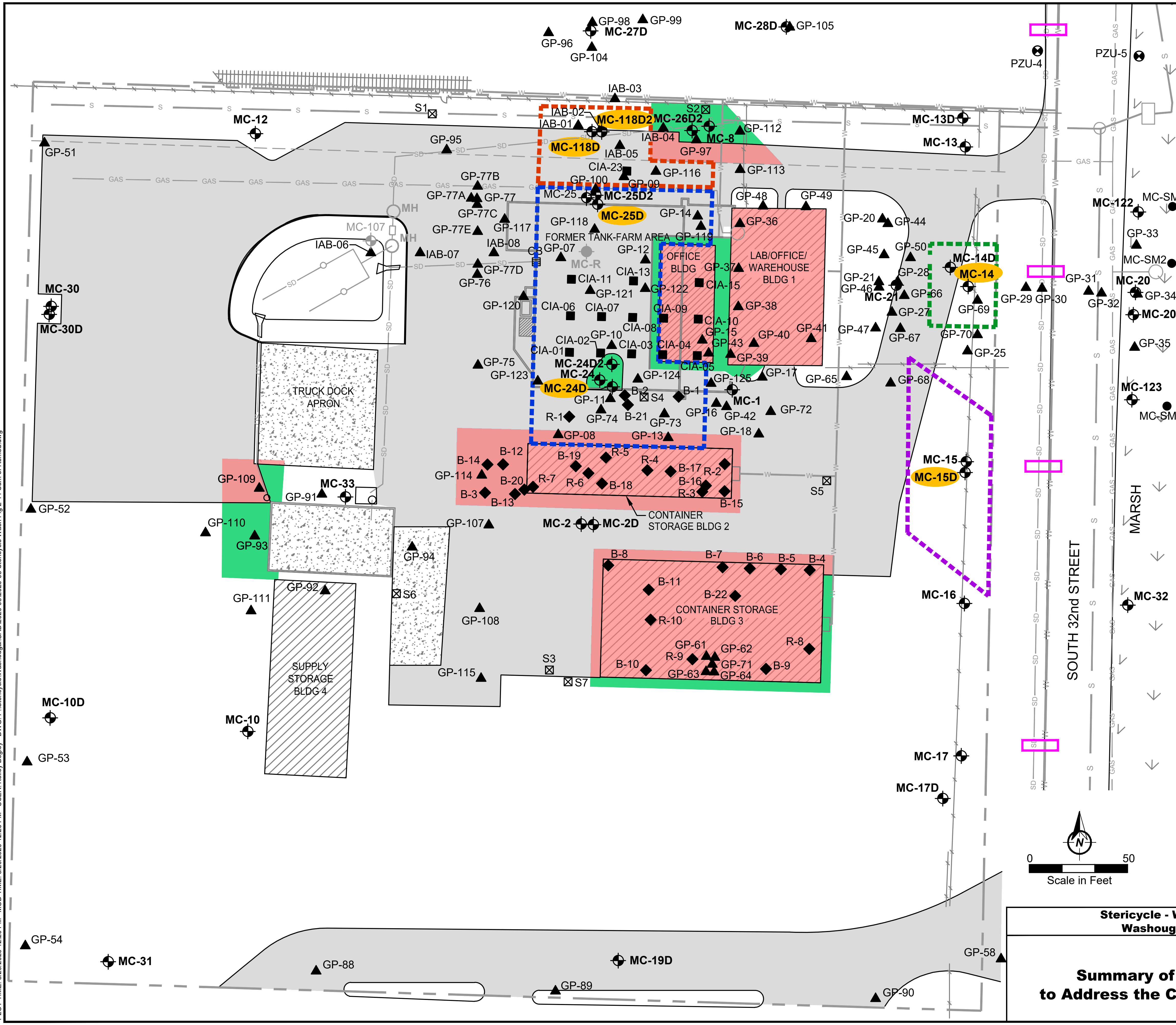
Stericycle - Washougal Facility
Washougal, Washington

Conceptual Site Model - Receptors

DOF DALTON OLMSTED FUGLEVAND

FIGURE 2-10

08/19/2020



LEGEND

- Property Line
- Sanitary Sewer
- Storm Sewer
- Water
- Gas
- C/E
- MC-13 Monitoring Well
- MC-107 Monitoring Well, Abandoned
- MC-R Recovery Monitoring Well, Abandoned
- PZU-4 Piezometer
- R-8 RCRA Closure Sample
- CIA-05 Historic Tank Farm Excavation Soil Confirmation Sample
- GP-101 Direct-Push Sample Location
- MH Stormwater Manhole
- CB Catch Basin
- S3 Sump
- Approximate Grout Location to Address Potential Groundwater Conduit (not to scale)
- Existing Capped Area to be maintained
- New Capped Area to be paved
- Downgradient Groundwater Treatment Area (Deep Aquifer)
- MC-14 Treatment Area (Shallow Zone)
- North Groundwater Treatment Area (Shallow Zone, Silt Layer, and Deep Aquifer)
- Former Tank Farm Groundwater Treatment Area (Silt Layer, and Deep Aquifer)
- Groundwater detections significantly above CULs or groundwater detections above CULs with stable or increasing trends.
- Asphalt
- Concrete

NOTE:
The effluent storm drain line was located in the field by others to a location near MC-8. The alignment is unknown beyond this location, but extends to South 32nd Street where it connects to the main line adjacent to the roadway.

Stericycle - Washougal Facility
Washougal, Washington

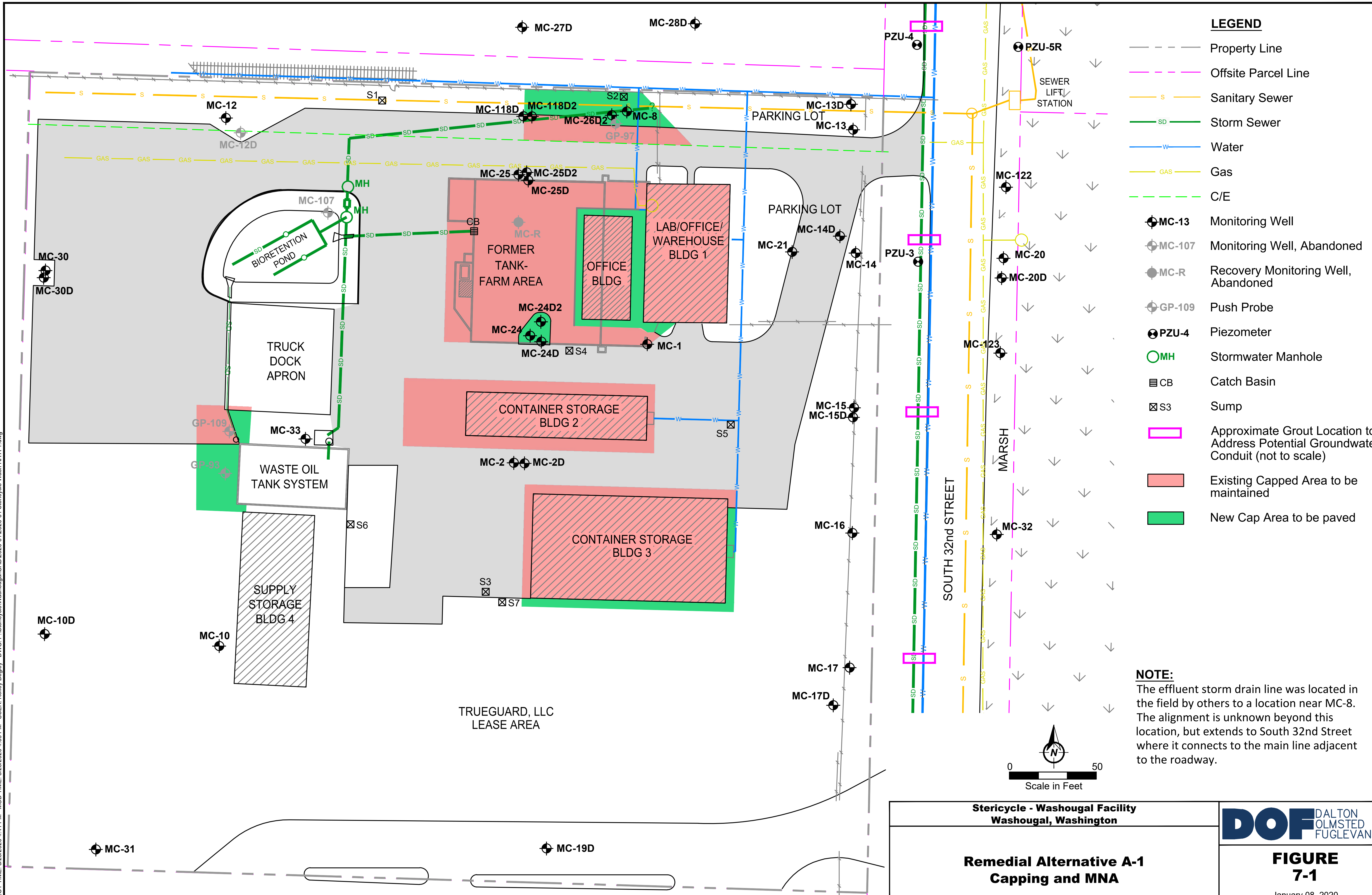
Summary of Remedial Areas to Address the Conceptual Site Model

DOF DALTON OLMSTED FUGLEVAND

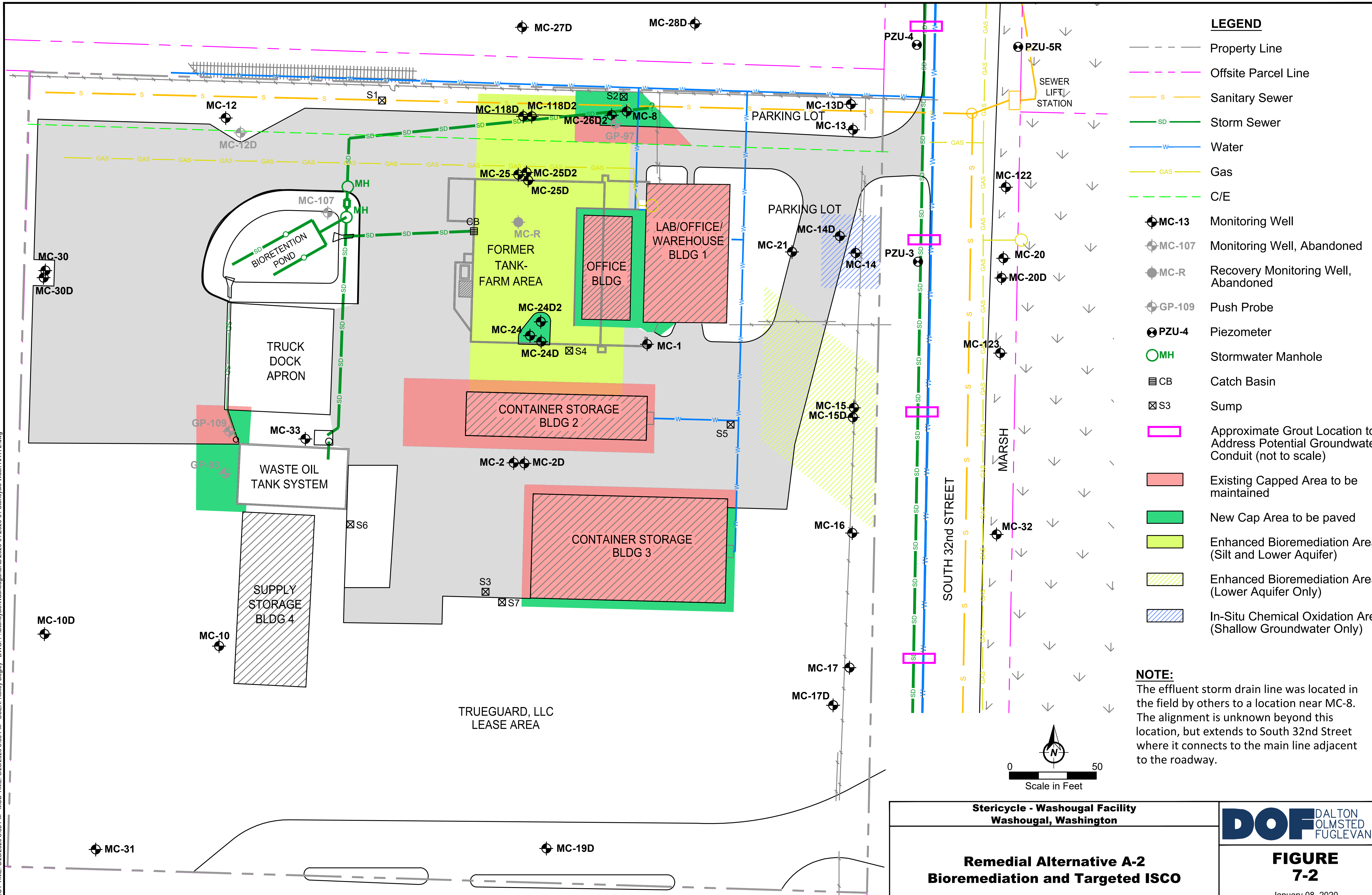
FIGURE 2-11

08/20/2020

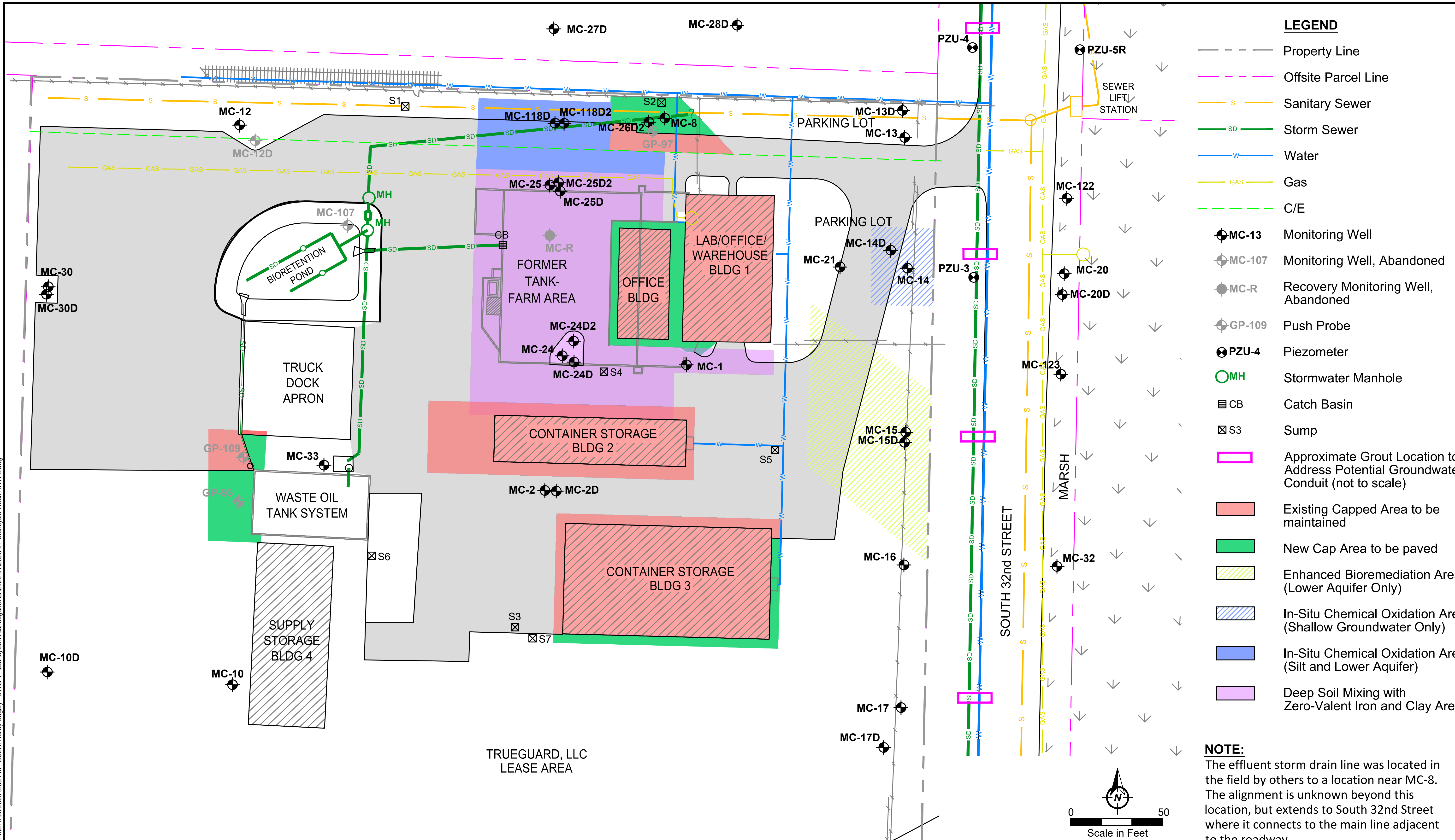
PLOT TIME: 8/20/2020 12:20 PM MOD TIME: 8/20/2020 12:20 PM USER: Kelley Begley DWG: P:\Stericycle\Washougal\CAD\2020-08\2020-08 Stericycle Wash Fig 2-11 Sum of Remed.dwg



PLOT TIME: 3/25/2020 4:41 PM MOD TIME: 3/25/2020 4:09 PM USER: Kelley Begley DWG: P:\Stericycle\Washougal\CAD\2020-01\2020-01 Stericycle Wash RA A-1.dwg



PLOT TIME: 3/25/2020 3:33 PM MOD TIME: 3/25/2020 3:30 PM USER: Kelley Begley DWG: P:\Stericycle\Washougal\CAD\2020-01\2020-01 Stericycle Wash RA A-2.dwg



NOTE:
The effluent storm drain line was located in the field by others to a location near MC-8. The alignment is unknown beyond this location, but extends to South 32nd Street where it connects to the main line adjacent to the roadway.

Stericycle - Washougal Facility
Washougal, Washington

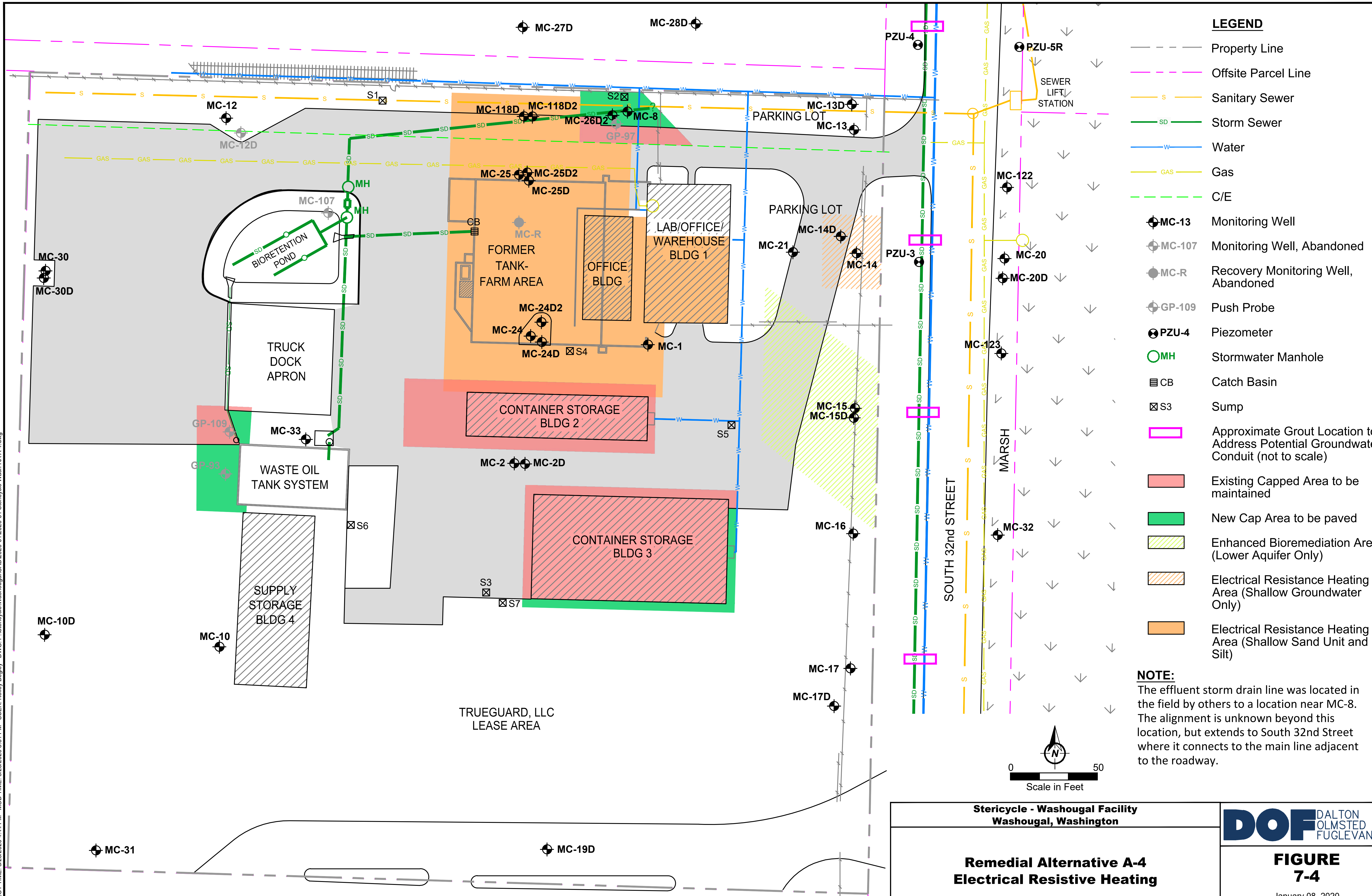
Remedial Alternative A-3
Deep Soil Mixing with
ZVI and Targeted ISCO

DALTON OLMSTED FUGLEVAND

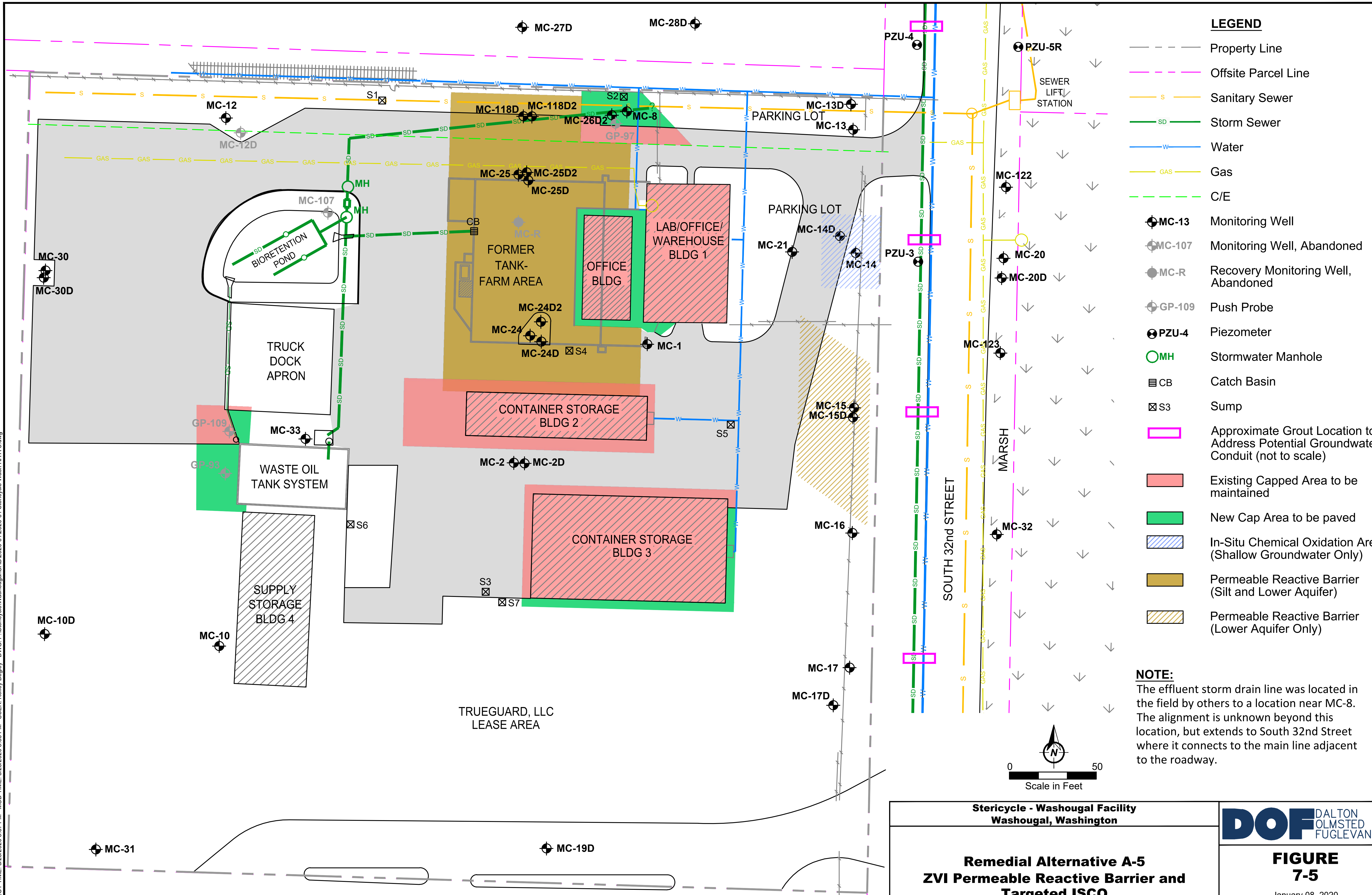
FIGURE 7-3

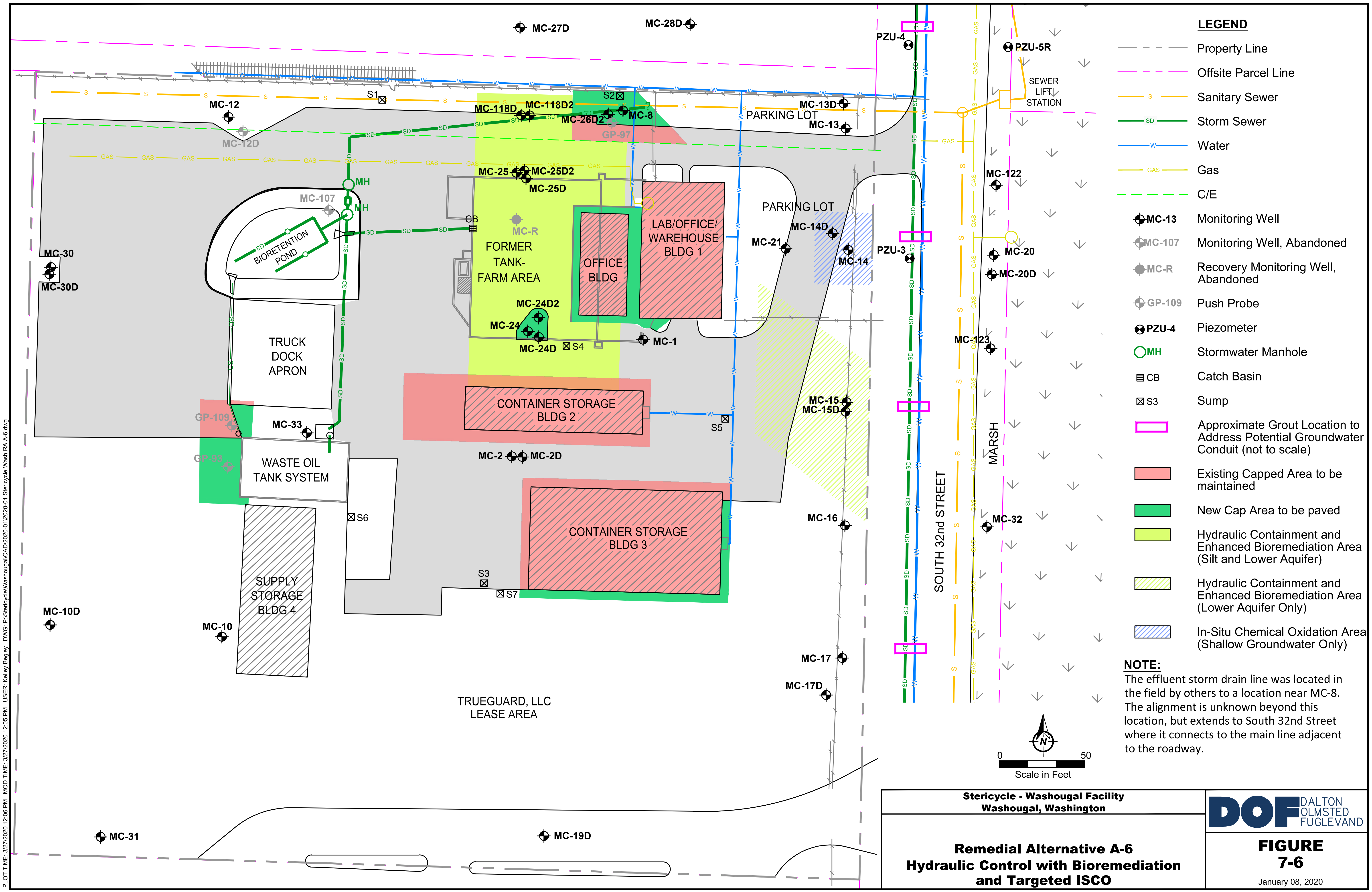
January 08, 2020

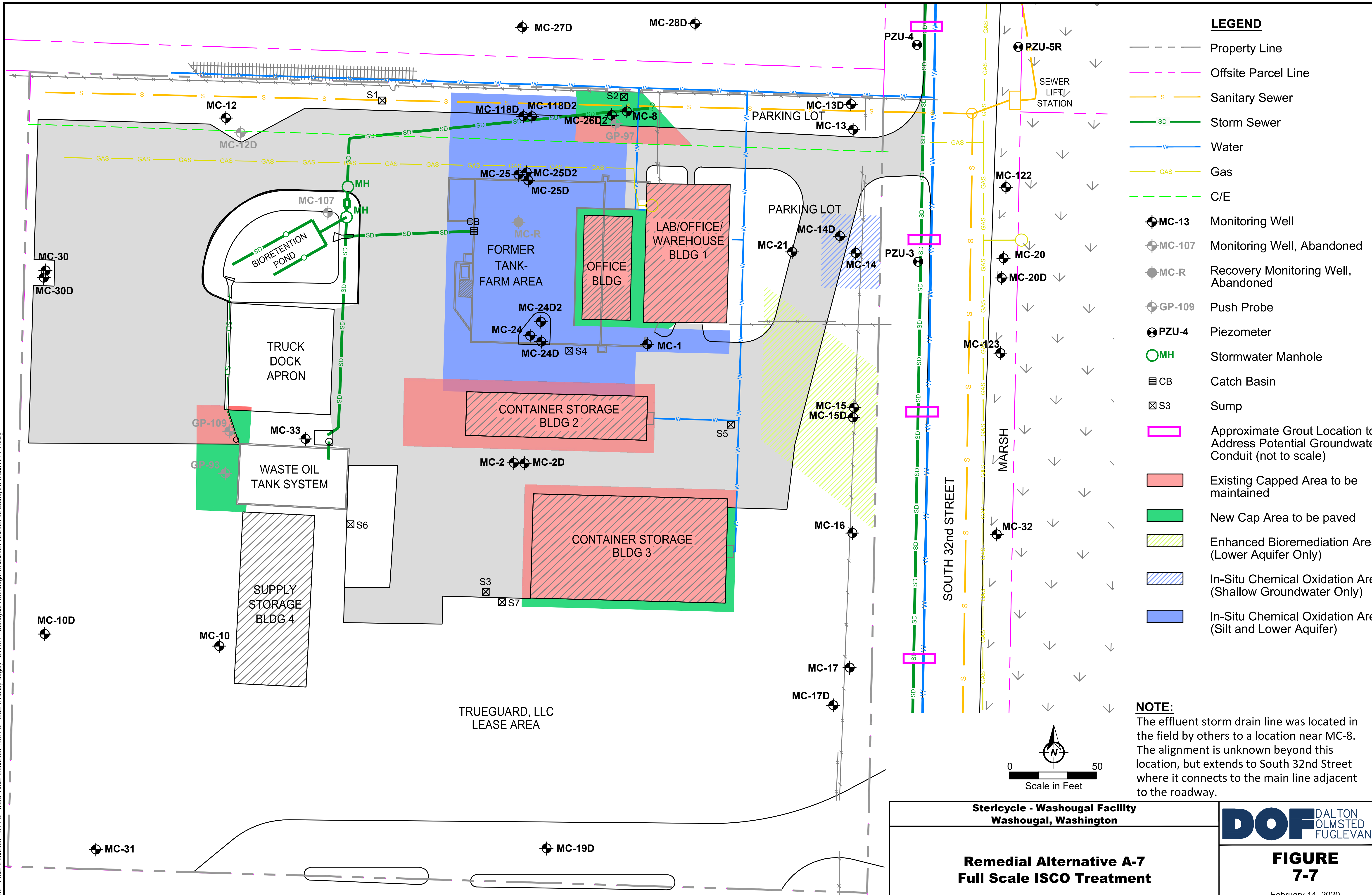
PLOT TIME: 3/25/2020 3:39 PM MOD TIME: 3/25/2020 3:38 PM USER: Kelley Begley DWG: P:\Stericycle\Washougal\CAD\2020-01\2020-01 Stericycle Wash RA A-3.dwg



MC-27D
MC-28D
PZU-4
PZU-5R
SEWER
LIFT
STATION
S1
S2
MC-12
MC-12D
MC-118D
MC-118D2
MC-26D2
MC-8
GP-97
PARKING LOT
MC-13D
MC-13
MC-122
MC-107
MH
MH
BIORETENTION
POND
MC-25
MC-25D2
MC-25D
CB
MC-R
FORMER
TANK-
FARM AREA
OFFICE
BLDG
LAB/OFFICE/
WAREHOUSE
BLDG 1
PARKING LOT
MC-14D
MC-21
MC-14
PZU-3
MC-20
MC-20D
MC-30
MC-30D
TRUCK
DOCK
APRON
MC-24D2
MC-24
MC-24D
S4
MC-1
MC-123
GP-109
MC-33
CONTAINER STORAGE
BLDG 2
S5
MC-15
MC-15D
MARSH
GP-53
WASTE OIL
TANK SYSTEM
MC-2
MC-2D
S6
CONTAINER STORAGE
BLDG 3
MC-16
MC-32
SOUTH 32nd STREET
SUPPLY
STORAGE
BLDG 4
S3
S7
MC-10D
MC-10
MC-17
MC-17D
TRUEGUARD, LLC
LEASE AREA
MC-31
MC-19D
0
50
Scale in Feet
LEGEND
Property Line
Offsite Parcel Line
Sanitary Sewer
Storm Sewer
Water
Gas
C/E
MC-13 Monitoring Well
MC-107 Monitoring Well, Abandoned
MC-R Recovery Monitoring Well, Abandoned
GP-109 Push Probe
PZU-4 Piezometer
MH Stormwater Manhole
CB Catch Basin
S3 Sump
Approximate Grout Location to Address Potential Groundwater Conduit (not to scale)
Existing Capped Area to be maintained
New Cap Area to be paved
Enhanced Bioremediation Area (Lower Aquifer Only)
Electrical Resistance Heating Area (Shallow Groundwater Only)
Electrical Resistance Heating Area (Shallow Sand Unit and Silt)
NOTE:
The effluent storm drain line was located in the field by others to a location near MC-8. The alignment is unknown beyond this location, but extends to South 32nd Street where it connects to the main line adjacent to the roadway.
Stericycle - Washougal Facility
Washougal, Washington
Remedial Alternative A-4
Electrical Resistive Heating
DALTON OLMSTED FUGLEVAND
FIGURE
7-4
January 08, 2020


MC-27D
MC-28D
PZU-4
PZU-5R
SEWER LIFT STATION
S1
S2
MC-12
MC-12D
MC-118D
MC-118D2
MC-26D2
MC-8
GP-97
MC-13D
MC-13
PARKING LOT
MC-25
MC-25D2
MC-25D
MC-107
MH
BIORETENTION POND
CB
MC-R
FORMER TANK-FARM AREA
OFFICE BLDG
LAB/OFFICE/ WAREHOUSE BLDG 1
PARKING LOT
MC-14D
MC-14
MC-21
PZU-3
MC-122
MC-20
MC-20D
MC-30
MC-30D
TRUCK DOCK APRON
MC-24D2
MC-24
MC-24D
S4
MC-1
MC-123
GP-109
MC-33
CONTAINER STORAGE BLDG 2
S5
MC-15
MC-15D
GP-53
WASTE OIL TANK SYSTEM
MC-2
MC-2D
S6
MC-16
MC-32
CONTAINER STORAGE BLDG 3
SUPPLY STORAGE BLDG 4
S3
S7
SOUTH 32nd STREET
MARSH
MC-10D
MC-10
MC-17
MC-17D
TRUEGUARD, LLC LEASE AREA
MC-31
MC-19D
0
50
Scale in Feet
LEGEND
Property Line
Offsite Parcel Line
Sanitary Sewer
Storm Sewer
Water
Gas
C/E
MC-13 Monitoring Well
MC-107 Monitoring Well, Abandoned
MC-R Recovery Monitoring Well, Abandoned
GP-109 Push Probe
PZU-4 Piezometer
MH Stormwater Manhole
CB Catch Basin
S3 Sump
Approximate Grout Location to Address Potential Groundwater Conduit (not to scale)
Existing Capped Area to be maintained
New Cap Area to be paved
In-Situ Chemical Oxidation Area (Shallow Groundwater Only)
Permeable Reactive Barrier (Silt and Lower Aquifer)
Permeable Reactive Barrier (Lower Aquifer Only)
NOTE:
The effluent storm drain line was located in the field by others to a location near MC-8. The alignment is unknown beyond this location, but extends to South 32nd Street where it connects to the main line adjacent to the roadway.
Stericycle - Washougal Facility
Washougal, Washington
Remedial Alternative A-5
ZVI Permeable Reactive Barrier and Targeted ISCO
DALTON OLMSTED FUGLEVAND
FIGURE 7-5
January 08, 2020


LEGEND
Property Line
Offsite Parcel Line
Sanitary Sewer
Storm Sewer
Water
Gas
C/E
MC-13 Monitoring Well
MC-107 Monitoring Well, Abandoned
MC-R Recovery Monitoring Well, Abandoned
GP-109 Push Probe
PZU-4 Piezometer
MH Stormwater Manhole
CB Catch Basin
S3 Sump
Approximate Grout Location to Address Potential Groundwater Conduit (not to scale)
Existing Capped Area to be maintained
New Cap Area to be paved
Hydraulic Containment and Enhanced Bioremediation Area (Silt and Lower Aquifer)
Hydraulic Containment and Enhanced Bioremediation Area (Lower Aquifer Only)
In-Situ Chemical Oxidation Area (Shallow Groundwater Only)
NOTE:
The effluent storm drain line was located in the field by others to a location near MC-8. The alignment is unknown beyond this location, but extends to South 32nd Street where it connects to the main line adjacent to the roadway.
0 50
Scale in Feet
MC-27D
MC-28D
PZU-4
PZU-5R
SEWER LIFT STATION
MC-12
MC-12D
S1
S2
MC-118D
MC-118D2
MC-26D2
MC-8
GP-97
MC-13D
MC-13
PARKING LOT
MH
MC-107
BIORETENTION POND
MC-25
MC-25D2
MC-25D
CB
MC-R
FORMER TANK-FARM AREA
OFFICE BLDG
LAB/OFFICE/ WAREHOUSE BLDG 1
PARKING LOT
MC-14D
MC-21
MC-14
PZU-3
MC-122
MC-20
MC-20D
MC-30
MC-30D
TRUCK DOCK APRON
MC-24D2
MC-24
MC-24D
S4
MC-1
MC-123
GP-109
MC-33
CONTAINER STORAGE BLDG 2
S5
MC-15
MC-15D
MARSH
GP-53
WASTE OIL TANK SYSTEM
MC-2
MC-2D
S6
MC-16
MC-32
SOUTH 32nd STREET
CONTAINER STORAGE BLDG 3
S3
S7
SUPPLY STORAGE BLDG 4
MC-10D
MC-10
MC-17
MC-17D
TRUEGUARD, LLC LEASE AREA
MC-31
MC-19D
Stericycle - Washougal Facility
Washougal, Washington
Remedial Alternative A-6
Hydraulic Control with Bioremediation and Targeted ISCO
DOF DALTON OLMSTED FUGLEVAND
FIGURE 7-6
January 08, 2020



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Appendix A

Revised Technical Memorandum: Feasibility Study – Point of Compliance and Preliminary Cleanup Level Assessment

Revised Technical Memorandum: Feasibility Study – Point of Compliance and Preliminary Cleanup Level Assessment

WASHOUGAL FACILITY

WASHOUGAL, WASHINGTON

November 12, 2019

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DALTON OLMSTED FUGLEVAND

November 12, 2019

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1.0 INTRODUCTION

This technical memorandum was prepared to summarize the outcome of discussions regarding components of the Feasibility Study (FS), currently under revision, for the Stericycle Environmental Solutions (Stericycle) Washougal, Washington facility. Washington Department of Ecology (Ecology), Ridolfi (Ecology's technical consultant), Stericycle, and Dalton, Olmsted, and Fuglevand (DOF) met on August 8, 2019. The purpose of that meeting was to discuss Stericycle's planned approach to addressing Ecology's 2019 comments on the FS, particularly with regards to the Point of Compliance and revision to site potential cleanup levels.

DOF prepared this technical memorandum on behalf of Stericycle to document information presented at that August 8, 2019 meeting and allow preliminary review of how those topics will be discussed in the revised FS. This memorandum has been revised based on comments received from Ecology in September 2019 via email (Ecology, 2019).

The approach to cleanup standards for the Washougal facility is described below including derivation of potential cleanup levels and consideration of points of compliance (POCs) established in accordance with the Model Toxic Control Act (MTCA) regulations.

Constituents of concern and preliminary cleanup levels were developed in the Remedial Investigation (RI) and draft FS (AMEC, 2013a and b). This memorandum updates that previously presented approach to cleanup levels to address comments received from Ecology and account for regulatory revisions made since the RI and Draft FS were completed. To streamline this memorandum background information and terminology defintions related to areas of the site and the conceptual site model are not repeated here and should be referenced in the RI, draft FS, and Ecology comments.

2.0 APPROACH TO CLEANUP STANDARDS

This section outlines the approach used to develop preliminary cleanup levels for the facility. The preliminary cleanup levels must be established for affected media and must be appropriate for the land use and relevant exposure pathways identified in the conceptual site model. Affected media identified through previous investigations include soil in the area of the former tank farm, including areas outside the tank farm footprint, and groundwater beneath the Stericycle property that is migrating beyond the Stericycle property boundary.

MTCA regulations require that remedial action alternatives achieve cleanup standards. MTCA regulations establish three primary components for cleanup standards:

- Cleanup levels for constituents of concern;

- The POC where these cleanup levels must be met; and
- Other regulatory requirements that apply.

MTCA regulations define three basic methods of determining cleanup levels for soil and groundwater.

- Method A – applies to "routine" sites or where few hazardous substances are involved. Method A cleanup levels have been established for unrestricted and industrial land uses.
- Method B – the "universal" method that can be applied to all media at all sites (unrestricted and industrial use). Two types of Method B cleanup levels can be used: standard (or default) cleanup levels based on standard assumptions, and modified cleanup levels that incorporate chemical-specific or site-specific information.
- Method C – a conditional cleanup level that can be used where more rigorous cleanup levels cannot be achieved. Similar to Method B, Method C comprises two types: standard and modified. Use of Method C cleanup levels requires institutional controls to ensure future protection of human health and the environment and is generally applicable only to industrial sites.

For carcinogenic constituents of concern, MTCA Method B and Method C cleanup levels are generally defined by the upper bound of the estimated lifetime cancer risk, which cannot exceed 1×10^{-6} and 1×10^{-5}, respectively, for each method, for individual carcinogens. Hazard indices for both Methods B and C cannot exceed 1.0, and the total risk for COCs under each method cannot exceed 1×10^{-5}.

Cleanup standards in MTCA Methods A, B, and C are required by RCW 70.105D.030 (2)(d) to be "*at least as stringent as all applicable state and federal laws*." These requirements are similar to the applicable, relevant and appropriate requirements (ARAR) approach of the federal Superfund law, and are described in entirety in WAC 173-340-710. In addition, the Stericycle property meets criteria established in WAC 173-340-200 and 173-340-745 for a site to be defined as an industrial property, as described in the RI. Although there is a potential for the property to be used sometime in the future for residential use (and therefore residential exposure was considered in the conceptual site model as a potentially complete exposure pathway), the property and surrounding industrial park are industrial and are expected to remain industrial for the foreseeable future, and institutional controls are anticipated to be established at the site as part of the cleanup action, restricting use of the property to industrial uses. As noted in the RI, groundwater from the Stericycle property discharges to the Steigerwald Lake National Wildlife Refuge, and since Steigerwald Marsh is not zoned as industrial, the entire "facility" or "site" cannot be viewed as industrial and cleanup levels must reflect this distinction for areas outside the industrial park.

Preliminary site-specific cleanup levels must be protective of the pathways established in the conceptual site model, including the following media exposure pathways:

- Groundwater – the groundwater-to-surface water pathway (the Shallow Groundwater Zone groundwater discharges to the Steigerwald Marsh and Gibbons Creek Remnant Channel, and the Lower Aquifer groundwater discharges to the Columbia River);
- Groundwater – indoor vapor inhalation pathway;
- Soil – industrial direct human exposure pathways (ingestion, inhalation, dermal absorption);
- Soil – indoor vapor inhalation pathway; and
- Soil – groundwater pathway (protective of a groundwater level that accounts for all groundwater-related pathways including drinking water, surface water, and vapor pathways).

Since groundwater in the Lower Aquifer is also considered a potential drinking water source, and the Shallow Aquifer appears to have some connectivity to the Lower Aquifer, these aquifers must also be considered for direct ingestion of groundwater (levels protective of drinking water).

2.1 GROUNDWATER PRELIMINARY CLEANUP LEVELS

Preliminary groundwater cleanup levels are based on a general analysis of groundwater use and the MTCA methodology for establishing cleanup levels. Final cleanup levels will be established in the Cleanup Action Plan (CAP) for use in designing the final remedy for the facility. For groundwater in the Shallow Groundwater Zone (above or in the Silt Layer) as well as for groundwater in the Lower Aquifer (in or below the Silt Layer), the preliminary cleanup level for each constituent of concern is a MTCA Method B Cleanup level selected by choosing the minimum of the following:

- **MTCA Groundwater Table Values (from CLARC [Ecology, 2019]) (Table 1)**
  - MTCA Method A levels for constituents that do not have a Method B level available;
  - MTCA standard Method B levels based on drinking water beneficial use, which include Federal Maximum Contaminant Levels (MCLs);
- **Surface Water ARARs (Table 2)**

  Several surface water criteria have changed since the RI and draft FS due to updates in EPA's National Recommended Water Quality Criteria (304[a]) in 2015 and 2016, Ecology's Water Quality Standards (WAC 173-201A) in 2016, and EPA's 2016 "Revision of Certain Federal Water Quality Criteria Applicable to Washington"

(40 CFR 131.45; formerly the Washington criteria were in 40 CFR 131.36, referred to as the National Toxics Rule, or NTR).

- Water Quality Standards for Surface Waters of the State of Washington (WAC 173-201A) – Acute and Chronic effects, Aquatic Life, Human Health (water and organism), Human Health (organism only), Freshwater;
- National Recommended Water Quality Criteria (NRWQC) (Clean Water Act §304) – Freshwater, Acute and Chronic effects, Aquatic Life and for the Protection of Human Health;
- National Toxics Rule (40 CFR 131) – Freshwater, Human Health, Consumption of Water and Organisms;

- **MTCA Surface Water Table Values (from CLARC) (Table 2)**
  - MTCA Method B Surface Water levels from Ecology's Cleanup Levels and Risk Calculation (CLARC) tables if a federal or local surface water value is not found in the above references (Ecology, 2019); and
- **Values Protective of Indoor Air (Table 3)**
  - For the Shallow Groundwater Zone only, MTCA Method B groundwater cleanup levels protective of vapor intrusion, obtained from CLARC (Ecology, 2019).

After selecting the minimum value from the MTCA Method B levels and the ARARs, preliminary cleanup levels were established for use in the FS. For some constituents, the preliminary Method B cleanup levels were revised upward in accordance with the MTCA regulations [WAC 173-340-705(6)] so that the screening levels were not lower than the practical quantitation limits (PQLs) obtained by the project laboratory. The preliminary cleanup levels established by this process are modified MTCA Method B cleanup levels. In reviewing the modified Method B cleanup levels based on analytical considerations, Ecology may consider the availability of improved analytical techniques and require their use. In accordance with WAC 173-340-707, if the PQL for a constituent was higher than the preliminary groundwater cleanup level, the cleanup level was raised to the PQL level if:

- The PQL is no greater than 10 times the method detection limit (MDL); and
- The laboratory PQL is not higher than the PQL established by the EPA.

The PQLs were obtained from the current project laboratory, Agriculture & Priority Pollutants Laboratories, Inc. (APPL) of Clovis, California, which is certified by the state of Washington. APPL performs low-level and selective ion monitoring (SIM) for VOCs and SVOCs, and analyses for PCBs, to attain PQLs below typical reporting limits. For some constituents, the APPL PQL was slightly higher than 10 times the MDL. In these cases, the value of 10 times the

MDL was used as the PQL. Applicable PQLs used for adjusting the Method B groundwater cleanup levels are provided in Table 4.

The preliminary groundwater cleanup levels are summarized in Table 5. Additional adjustments for background were considered for arsenic in accordance with WAC 173-340-705 and -706, which establish the applicability of Method B and C to determine cleanup levels for this constituent (further discussed in the RI).

Both area and natural background were considered in developing cleanup levels for arsenic. Background values were calculated using upgradient site data outside of contaminated source areas as described in the RI. These calculated values are 22.84 μg/L for the Shallow Groundwater Zone and 1.42 μg/L for the Lower Aquifer. It is difficult to ascertain if these background values should be categorized strictly as natural background values or area background values given that the site has both natural and anthropogenic (area) influences:

- Natural - The site and surrounding industrial park are built over a large marsh, resulting in naturally reducing conditions. These naturally reducing conditions are directly impacting concentrations of arsenic on the site. The arsenic concentrations show a clear and consistent trend of higher concentrations in the Shallow Groundwater Zone during the summer months (when the groundwater elevation is lowest and we observe the strongest reducing conditions) and lower concentrations in the winter months when recharge of oxygenated rainwater occurs. The natural conditions (high organic content and peat layers that promote reducing conditions) would encourage mobility of arsenic.

- Area - The site is located within a man-made industrial park, constructed on imported fill. The shallow aquifer is actually within this fill zone, but the geochemistry of this unit is strongly influenced by the methanogenic conditions produced by the underlying marsh deposits.

In 2010, the MTCA Science Advisory Board reviewed a statewide dataset of groundwater data for arsenic (San Juan, 2010). For this background study, arsenic study data were obtained from the Washington Department of Health Drinking Water Program. A total of 18,238 groundwater sample results, collected over a 10-year period (2000-2010) from 6,776 drinking water wells (depths of 10 to 2,200 feet.), were evaluated. Ecology used the “MTCAStat” statistical software to estimate background arsenic concentrations using the procedures specified in WAC 173-340-709. The review produced the following key results:

- On a statewide basis, Ecology estimated that arsenic concentrations of 10.7 μg/L represent the 90th percentile of the sampling distribution for groundwater in the State.

- High arsenic concentrations (> 25 μg/L) were detected in 12 western Washington counties (Clark, Cowlitz, Island, Jefferson, King, Lewis, Mason, Skagit, Skamania, Snohomish, Thurston, and Whatcom). The PSC Washougal facility is located in Clark County.

Stericycle's site-specific background calculation yielded results consistent with Ecology's study that indicates high arsenic concentrations are present in Clark County. Stericycle set the preliminary cleanup level for arsenic iat 22.84 µg/L for the Shallow Groundwater Zone and 1.42 µg/L for the Lower Aquifer.

The arsenic assessment and background calculation were described in Appendix O of the RI.

2.1.1 Beneficial Use of Groundwater

The designation of the highest beneficial use of groundwater in an area governs potential exposure to groundwater in that area. The designation of the highest beneficial use of groundwater in a particular area is regulated by several different agencies, including Ecology, the Washington State Department of Health (WDOH), and county and city governments. The requirements, rules, and guidance of each of these agencies are considered in the determination of the highest beneficial use of groundwater under MTCA (WAC 173-340-720). According to WAC 173-340-720, groundwater cleanup levels must be based on the highest beneficial use of groundwater, which is human ingestion, unless the criteria outlined in WAC 173-340-720(2) subsections (a) through (c) are met. Unless all of the criteria can be demonstrated, WAC 173-340-720(2) defines all groundwater as potable.

Since groundwater in the Lower Aquifer is considered a potential drinking water source, cleanup levels must be developed based on an exposure pathway that includes direct ingestion of groundwater (levels protective of drinking water). Groundwater in the Shallow Groundwater Zone of the site is not a current source of drinking water, and has a very low yield; however, the Shallow Groundwater Zone is partially connected to the Lower Aquifer groundwater, which could potentially be used as a drinking water source, and therefore drinking water is a potential exposure mechanism for both the Shallow Groundwater Zone and the Lower Aquifer.

2.2 Soil Preliminary Cleanup Levels

The Stericycle property is located in an area zoned for heavy industrial use; therefore, MTCA Method C soil cleanup levels are appropriate for use at the Stericyle property. In addition, the Stericycle property meets criteria established in WAC 173-340-200 and 173-340-745 for a site to be defined as an industrial property, as described in the RI. However, portions of the site that are east of the property, outside the industrial park, do not meet this definition since a national wildlife refuge exists in this area. Areas of the site outside the industrial park require development of more stringent cleanup levels, which would apply in these areas. MTCA Method

C industrial soil cleanup levels are based on adult occupational exposures and assume that current and future land use will be restricted to industrial purposes.

Preliminary cleanup levels for soil on the property are selected by choosing the minimum of the following MTCA cleanup levels (Table 6):

- MTCA Method C - Industrial Cleanup Level based on direct contact/ingestion obtained from the CLARC website (Ecology, 2019);
- For those constituents with no available Method C cleanup levels, MTCA Method A Industrial Soil Cleanup Levels (MTCA Table 745-1);
- Soil cleanup levels protective of the preliminary groundwater cleanup levels described in Section 2.1 [WAC 173-340-747(4)];
- EPA Regional Screening Levels (RSLs); and
- Ecological Indicator Soil Concentrations for Protective of Terrestrial Plants and Animals (MTCA Table 749-3).

Additionally, areas of the site outside the Industrial Park will be considered with regard to MTCA Method A and B – Unrestricted Cleanup Levels (and residential EPA RSLs), based on direct contact/ingestion obtained from the CLARC website (Table 7). After selecting the minimum value from the levels described above, the preliminary cleanup levels are established below. For some constituents, the preliminary cleanup levels were revised upward when compared to natural background levels and PQLs in accordance with the MTCA regulations [WAC 173-340-709 and WAC 173-340-705(6)]. The modified preliminary cleanup levels were established as follows.

- The risk-based soil cleanup level selected for each constituent was compared to the natural background concentration. If the risk-based cleanup level was less than the natural background concentration, the natural background concentration was selected for comparison to the PQL.
- If natural background concentrations were lower than the risk-based soil cleanup level, the risk-based soil cleanup level was selected for comparison to the PQL.
- If the selected natural background concentration or risk-based soil cleanup level was less than the PQL, the PQL was selected as the PCL.

Natural background levels for metals were defined by Ecology (1994) for the Clark County area. The Clark County natural background values were calculated as the 90th percentile value using Ecology's MTCA STAT program on a sample set of n = 45. Screening levels that were below the defined Clark County natural background levels were adjusted up to the applicable natural background level in accordance with the limitations set forth in WAC 173-340-706(6).

Applicable PQLs were established for soil in the same manner described in Section 2.1 for groundwater. The preliminary cleanup levels for on-property soils are listed in Table 6, and for off-property soils in Table 7.

2.3 ADJUSTMENT FOR MULTIPLE HAZARDOUS SUBSTANCES

Cleanup levels for some hazardous substances may be adjusted downward in accordance with WAC 173- 340-705(4) (multiple hazardous substances or pathways) as part of completion of the CAP and establishment of final cleanup levels for the site. Cleanup levels may be adjusted downward if the total combined excess cancer risk potential (calculated in accordance with MTCA methods) for the carcinogenic substances exceeds one in 100,000 (1 x 10-5), or if the hazard index (HI) calculated in accordance with MTCA methods exceeded 1. The HI is calculated by summing hazard quotients (HQs) for individual COCs. The cleanup levels applicable at the POC must be adjusted to meet these two total risk criteria.

3.0 POINT OF COMPLIANCE

To develop and evaluate a reasonable range of cleanup alternatives in the FS, a POC must be defined for contaminated sites. As defined in the MTCA regulations, the POC is the point or points at which cleanup levels must be attained. The POC, cleanup levels, and other applicable standards taken together define the cleanup standard. Sites that achieve the cleanup standards at the point of compliance and comply with applicable state and federal laws are presumed to be protective of human health and the environment, as approved by Ecology. The POC or multiple POCs will be used in the FS for design and evaluation of potential remedial alternatives. After approval of the FS, the proposed final POC(s) will be incorporated into the CAP and final design for the cleanup alternative selected in the FS. The basis for selecting the POC(s) for the FS is defined in the following subsections. The final POC(s) to be used for implementing the cleanup action will be determined after Ecology approval of the CAP and after completing the requirements specified in the MTCA regulations for approval by other agencies, other property owners, and the public.

3.1 REGULATORY REQUIREMENTS

The MTCA regulations specify POCs for various media that may become contaminated. MTCA defines both the standard POC (SPOC) and the less stringent conditional POC (CPOC). The SPOC applies to all soil, groundwater, air, or surface water at or adjacent to any location where releases of hazardous substances have occurred or that has been impacted by releases from the location. A CPOC is usually defined only for groundwater, air, or surface water. A CPOC typically applies to a specific location as near as possible to the source of the release. Site-specific conditions determine whether the SPOC or CPOC would be appropriate for a site.

Several requirements are specified in the MTCA regulations for establishing a CPOC, as discussed in more detail below. The most important criterion for approval of a CPOC is the practicality of attaining cleanup levels within a reasonable time frame throughout the plume. A common situation for use of a CPOC is migration of contaminated groundwater beyond the property boundary. In this case, a CPOC is most frequently established at the property boundary beyond which contaminated groundwater has migrated. However, in certain instances a CPOC may be established beyond the property boundary if Ecology and any landowners located between the source area and the CPOC approve the CPOC before it can be incorporated into a final cleanup action.

As described in the RI Report, affected media at the facility include soil and groundwater. POCs for soil and groundwater are established separately and may be different due to different regulatory requirements and potential exposure pathways associated with the two media. The regulatory requirements for POCs in soil and groundwater are summarized in Sections 3.1.1 and 3.1.2 below.

3.1.1 Soil Point of Compliance

The regulatory requirements for the soil POC are presented in the MTCA regulations, WAC 173-340-740(6). The requirements for the soil POC depend on the relevant exposure pathway. Therefore, MTCA may require different soil POCs for different COCs. The requirements specified by MTCA are as follows.

- For soil COCs whose cleanup level is based on protection of groundwater, the POC shall be in soils throughout the site.
- For soil COCs whose cleanup level is based on the vapor/inhalation pathway, the POC must be the soils throughout the site (from the ground surface to the uppermost water table).
- For soil COCs whose cleanup level is based on human exposure (i.e., the Commercial Cleanup Level defined in the RI Report), the POC must include the soils throughout the site from the ground surface to a depth of 15 feet bgs.
- For soil COCs whose cleanup level is based on ecological exposure, additional specific requirements that must be addressed are presented in WAC 173-370-7490(4).

The soil POCs defined above by MTCA would apply to soil at the surface and beneath the surface affected by releases from the Stericycle operations. However, for cleanup actions that involve containment of contamination, WAC 173-340-740(6)(f) establishes the following provisions for the cleanup to comply with the cleanup standards:

For those cleanup actions selected under this chapter that involve containment of hazardous substances, the soil CULs will typically not be met at the points of compliance specified in (b) through (e) of this subsection. In these cases, the cleanup action may be determined to comply with cleanup standards, provided:

(i) The selected remedy is permanent to the maximum extent practicable.

(ii) The cleanup is protective of human health.

(iii) The cleanup action is demonstrated to be protective of terrestrial ecological receptors.

(iv) Institutional controls are put in place … that prohibit or limit activities that could interfere with the long-term integrity of the containment system.

(v) Compliance monitoring and periodic reviews are designed to ensure the long-term integrity of the containment system.

(vi) The types, levels and amounts of hazardous substances remaining on-site and the measures that will be used to prevent migration and contact with those substances are specified in the cleanup action plan.

3.1.2 Groundwater Point of Compliance

The groundwater SPOC, as described in WAC 173-340-720(8)(b), would include all groundwater within the saturated zone beneath the Stericycle property and in any area affected by releases from the Stericycle operations. Under WAC 173-340-720(8)(c), Ecology may approve use of a CPOC if the responsible person demonstrates that it is not practicable to attain the SPOC within a reasonable restoration time frame and that all practicable methods of treatment have been used. A CPOC is essentially a vertical surface extending downward from the water table and laterally so that it spans the vertical area affected by the release (e.g., the contaminated groundwater extending beyond the boundary of the Stericycle property). Groundwater cleanup levels would apply everywhere downgradient from the CPOC; groundwater cleanup levels could be exceeded upgradient from the CPOC. Under WAC 173-340-720(8)(c), a CPOC must be as close as practicable to the source of hazardous substances and not exceed the property boundary.

The MTCA regulations favor a permanent solution for groundwater cleanup at the SPOC. If a permanent cleanup action (e.g., a cleanup action capable of attaining cleanup levels of all COCs in groundwater at the SPOC) is not selected for a site, then MTCA imposes additional requirements as described in WAC 173-340-360(2)(c)(ii). Under this section, MTCA requires treatment or removal of the sources of the release for liquid wastes, high concentration COC areas, highly mobile COCs, or COCs that cannot be reliably contained. This may include removal of light non-aqueous phase liquids through generally accepted remedial technologies. MTCA states containment may be appropriate for dense non-aqueous phase liquids after generally accepted remedial technologies have been exhausted. Groundwater containment measures are required to the maximum extent practicable to avoid lateral and vertical migration of COCs in groundwater. During development of alternatives these requirements will be addressed if a non-permanent remedy is proposed.

Under MTCA, additional requirements apply for establishing a groundwater CPOC beyond the property boundary for facilities such as the Stericycle Washougal facility that are near, but not abutting, surface water are set forth in WAC 173-340-720(8)(d)(ii).

- The CPOC must be located as close as practicable to the source of the release.
- The CPOC must not be located beyond the point or points where groundwater flows into surface water.
- The conditions specified in WAC 173-340-720(8)(d)(i) must be met.
- All affected property owners between the source of contamination and the CPOC agree in writing to the CPOC location.
- The CPOC cannot be located beyond the extent of groundwater contamination exceeding cleanup levels when Ecology approves the CPOC.

A CPOC at the property boundary may be selected for groundwater. The specific regulatory requirements that will apply for establishing a groundwater CPOC for the facility include the following.

- It is not practicable to attain the SPOC within a reasonable restoration time frame [WAC 173-340-720(8)(c)].
- The CPOC shall be as close as practicable to the source of the release [WAC 173-340-720(8)(c)].
- All practicable methods of treatment are used in the site cleanup [WAC 173-340-720(8)(c)].

The regulatory requirements in the bullet list above must be met in order to specify a groundwater CPOC for the facility.

3.2 PROPOSED POINTS OF COMPLIANCE

As defined in the MTCA regulations, the POC is the point or points at which CULs must be attained. Given the nature and extent of contamination in the source area within the site and in the groundwater downgradient from the source area, some cleanup alternatives incorporate a CPOC for groundwater. The POCs proposed for consideration in completing the FS are described in Sections 3.2.1 and 3.2.2.

3.2.1 Proposed Soil Point of Compliance

The soil POC includes soil throughout the site, as required under WAC 173-340-740(6). For remedial alternatives to be considered in the FS that rely on containment and will not meet the soil cleanup level at the POC, the requirements specified in the MTCA rules under WAC 173-340-740(6)(f) to demonstrate compliance with the soil POC will be presented in the description of the alternative.

Based on the site conditions presented in the RI, the FS assumes that soil cleanup levels will not be met at the POC and that the provisions of WAC 173-340-740(6)(f) will apply. It is not practicable to attain the preliminary cleanup levels at the POC for soil because buildings on the property limit the accessibility to some portions of the subsurface, and the presence of shallow groundwater limits the practicable depth of many technologies, including excavation. PSC conducted an interim measure to remove shallow impacted soils from the former tank farm area. This excavation was successful at removing shallow zone soils that were a significant source of COCs to soil and groundwater. However, it is not practicable to remove the impacted Silt Layer below the water table. In addition, the Silt Layer provides some protection from migration of shallow impacted groundwater to deeper, less impacted water-bearing zones. Therefore, removal of the Silt Layer may not be desirable. This will be described further in the FS.

Additional treatment methods that may be applicable are described and evaluated as part of the FS; however, the results of these treatments are uncertain. Therefore, it is unlikely that soil cleanup levels at the POC will be achieved in a reasonable time frame. Further discussion of the source area characteristics that would make complying with soil cleanup levels at the POC challenging will be discussed further in the FS.

3.2.2 Proposed Groundwater Conditional Points of Compliance

For groundwater, if a CPOC is necessary, a CPOC near the property boundary will be evaluated for areas where the effectiveness of a particular remedial alternative is uncertain.

As noted above, the CPOC must be located as close to the source area as practicable. Site characterization data confirm that COC concentrations exceeding preliminary cleanup levels in the Shallow Groundwater Zone and Lower Aquifer extend downgradient from the source area in the former tank farm. Some remedial alternatives to be considered in the FS may not attain cleanup levels throughout the site for an extended period of time, but are expected to improve groundwater quality sufficiently to decrease concentrations below cleanup levels near the Stericycle property line much faster. Since the property use is not expected to change, institutional controls could be readily implemented to support a CPOC placed near the boundary of the Stericycle property.

The CPOC shown in Figure 3-1 of the draft FS was placed to comply with the regulatory requirements of WAC 173-340-720(8)(c), as described below:

1. The impacted silt layer in the Former Tank Farm Area will serve as an ongoing source to groundwater. Due to the difficulty in removing or treating the impacted silt layer, it is not practicable to attain the standard POC for groundwater within a reasonable restoration time frame.

2. The groundwater CPOC is as close to the source area as practicable. The groundwater CPOC encompasses the area of the impacted Silt Layer in the former tank farm area and the resulting chlorinated VOC plume located on the property. It is impracticable to treat the plume without addressing the source. Because the Silt Layer will act as an ongoing source of contaminants to groundwater, the inclusion of both the source area and the plume within the groundwater CPOC boundary is appropriate.

3. Stericycle conducted an interim measure to remove shallow impacted soils from the former tank farm area to the maximum extent practicable. Although additional treatment is considered in the FS, it is unlikely that cleanup levels can be obtained at the standard POC in a reasonable time frame using practicable treatment methods.

Assuming the provisions in WAC 173-340-740(6)(f) are applicable for the Facility, Stericycle plans to comply with the requirements of this subsection as follows:

(i) Practicable, permanent treatment methods were used to remove the source area historically. Additional treatment methods that may be applicable will be described and evaluated as part of this FS and adhere to the requirements specified under WAC 173- 340-360.

(ii) Preliminary cleanup levels have been established to protect human health; in those locations where cleanup levels will not be achieved, the receptor pathways will be evaluated and suitable institutional controls will be included in the final remedy to protect human health.

(iii) The RI evaluated terrestrial ecological receptors and determined that site conditions were safe for these receptors, with the exception of on-property receptors exposed to soil. For these receptors, barium was the only constituent identified at concentrations above screening levels for terrestrial ecological receptors (MTCA Table 749-3). However, the RI demonstrated that barium concentrations are far below reported background levels for barium in the region and statewide. Therefore terrestrial ecological receptors are not expected to be at risk, and evaluation of all remedies will consider any additional harm that could be caused by a remedy.

(iv) Institutional controls that maintain the integrity of the containment system will be part of the selected final remedy.

(v) Compliance monitoring and long-term controls necessary for the remedy will be defined in the design of the final remedy.

If a CPOC is selected in the CAP, groundwater compliance monitoring will be conducted along or immediately downgradient of the CPOC. This location is consistent with the location-specific CPOC requirements cited in the MTCA regulations. The practicability of attaining an SPOC or a CPOC will be discussed in relation to the remedial alternatives to be considered in the FS.

4.0 REFERENCES

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5.0 CLOSING

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TABLE 1
GROUNDWATER-BASED PRELIMINARY CLEANUP LEVELS[1]
Stericycle Washougal Facility
Technical Memorandum (8/26/19)

Concentrations in micrograms per liter (µg/L)

Constituent	CAS Number	Groundwater, MTCA Method A Cleanup Level	Groundwater, MTCA Method B Cleanup Level, Carcinogenic	Groundwater, MTCA Method B Cleanup Level, Non-carcinogenic	Groundwater ARAR-Federal MCL[2]	Groundwater ARAR - State MCL[3]	Minimum Level
Inorganics							
Ammonia (as nitrogen)	7664-41-7	--	--	--	--	--	**--**
Arsenic, inorganic	7440-38-2	5	0.058	4.8	10	10	**0.058**
Barium	7440-39-3	--	--	3,200	2,000	2,000	**2000**
Cadmium	7440-43-9	5	--	8	5	5	**5**
Chromium	7440-47-3	50	--	--	100	100	**50**
Copper	7440-50-8	--	--	640	1,300	1,300	**640**
Cyanide	57-12-5	--	--	10	200	200	**10**
Iron	7439-89-6	--	--	11,000	--	--	**11000**
Lead	7439-92-1	15	--	--	15	15	**15**
Manganese	7439-96-5	--	--	--	--	--	**--**
Nickel	7440-02-0	--	--	320	--	100	**100**
Silver	7440-22-4	--	--	80	--	--	**80**
Vanadium	7440-62-2	--	--	80	--	--	**80**
Zinc	7440-66-6	--	--	4,800	--	--	**4800**
VOCs							
Benzene	71-43-2	5	0.8	32	5	5	**0.8**
Bromodichloromethane	75-27-4	--	0.71	160	80	80	**0.71**
Bromoform	75-25-2	--	5.5	160	80	80	**5.5**
Bromomethane	74-83-9	--	--	11	--	--	**11**
Carbon disulfide	75-15-0	--	--	800	--	--	**800**
Carbon tetrachloride	56-23-5	--	0.625	32	5	5	**0.625**
Chlorobenzene	108-90-7	--	--	160	100	100	**100**
Chloroform	67-66-3	--	1.4	80	80	80	**1.4**
Chloromethane	74-87-3	--	--	--	--	--	**--**
1,2-Dibromo-3-chloropropane	96-12-8	--	0.055	1.6	0.2	0.2	**0.055**
Dibromochloromethane	124-48-1	--	0.52	160	80	80	**0.52**
1,4-Dichlorobenzene	106-46-7	--	8.1	560	75	75	**8.1**
1,1-Dichloroethane	75-34-3	--	7.7	1,600	--	--	**7.7**
1,2-Dichloroethane	107-06-2	5	0.48	48	5	5	**0.48**
1,1-Dichloroethene	75-35-4	--	--	400	7	7	**7**
1,2-Dichloroethene (total)	540-59-0	--	--	72	--	--	**72**
cis-1,2-Dichloroethene	156-59-2	--	--	16	70	70	**16**
trans-1,2-Dichloroethene	156-60-5	--	--	160	100	100	**100**
Dichlorodifluoromethane	75-71-8	--	--	1,600	--	--	**1600**
1,2-Dichloropropane	78-87-5	--	1.2	320	5	5	**1.2**
Ethyl chloride (chloroethane)	75-00-3	--	--	--	--	--	**--**
Ethylene dibromide (EDB) (1,2-Dibromoethane)	106-93-4	0.01	0.022	72	0.05	0.05	**0.01**
Methylene chloride	75-09-2	5	22	48	5	5	**5**
Styrene	100-42-5	--	--	1,600	100	100	**100**
1,1,1,2-Tetrachloroethane	630-20-6	--	1.68	240	--	--	**1.68**
1,1,2,2-Tetrachloroethane	79-34-5	--	0.22	160	--	--	**0.22**
Tetrachloroethene	127-18-4	5	21	48	5	5	**5**

TABLE 1
GROUNDWATER-BASED PRELIMINARY CLEANUP LEVELS[1]
Stericycle Washougal Facility
Technical Memorandum (8/26/19)

Concentrations in micrograms per liter (µg/L)

Constituent	CAS Number	Groundwater, MTCA Method A Cleanup Level	Groundwater, MTCA Method B Cleanup Level, Carcinogenic	Groundwater, MTCA Method B Cleanup Level, Non-carcinogenic	Groundwater ARAR-Federal MCL[2]	Groundwater ARAR - State MCL[3]	Minimum Level
Toluene	108-88-3	1,000	--	640	1,000	1,000	**640**
1,2,4-Trichlorobenzene	120-82-1	--	1.51	80	70	70	**1.51**
1,1,1-Trichloroethane	71-55-6	200	--	16,000	200	200	**200**
1,1,2-Trichloroethane	79-00-5	--	0.77	32	5	5	**0.77**
Trichloroethene	79-01-6	5	0.54	4	5	5	**0.54**
1,2,3-Trichloropropane	96-18-4	--	0.0015	32	--	--	**0.0015**
Vinyl chloride	75-01-4	0.2	0.029	24	2	2	**0.029**
m,p-Xylene	106-42-3	--	--	1,600	--	--	**1600**
SVOCs							
2,4,6-Trichlorophenol	88-06-2	--	4	8	--	--	**4**
2-Chlorophenol	95-57-8	--	--	40	--	--	**40**
2-Methylnaphthalene	91-57-6	--	--	32	--	--	**32**
Aniline	62-53-3	--	7.7	56	--	--	**7.7**
Benzo(a)anthracene	56-55-3	--	--	--	--	--	**--**
Benzo(a)pyrene	50-32-8	0.1	0.023	4.8	0.2	0.2	**0.023**
Benzo(b)fluoranthene	205-99-2	--	--	--	--	--	**--**
Benzo(k)fluoranthene	207-08-9	--	--	--	--	--	**--**
bis(2-Chloroethyl) ether	111-44-4	--	0.04	--	--	--	**0.04**
bis(2-Ethylhexyl) phthalate	117-81-7	--	6.3	320	6	6	**6**
Chrysene	218-01-9	--	--	--	--	--	**--**
3,3'-Dichlorobenzidine	91-94-1	--	0.19	--	--	--	**0.19**
1,4-Dioxane	123-91-1	--	0.44	240	--	--	**0.44**
2,4-Dichlorophenol	120-83-2	--	--	24	--	--	**24**
2,4-Dinitrophenol	51-28-5	--	--	32	--	--	**32**
2,4-Dinitrotoluene	121-14-2	--	0.28	32	--	--	**0.28**
2,6-Dinitrotoluene	606-20-2	--	0.058	16	--	--	**0.058**
Dibenzo[a,h]anthracene	53-70-3	--	--	--	--	--	**--**
Dibenzofuran	132-64-9	--	--	16	--	--	**16**
Dinoseb	88-85-7	--	--	16	7	7	**7**
Hexachlorobenzene	118-74-1	--	0.055	13	1	1	**0.055**
Hexachlorobutadiene	87-68-3	--	0.56	8	--	--	**0.56**
Hexachlorocyclopentadiene	77-47-4	--	--	48	50	50	**48**
Hexachloroethane	67-72-1	--	1.1	5.6	--	--	**1.1**
Indeno(1,2,3-cd)pyrene	193-39-5	--	--	--	--	--	**--**
Isophorone	78-59-1	--	46.05	1,600	--	--	**46.05**
N-Nitroso-di-n-propylamine	621-64-7	--	0.013	--	--	--	**0.013**
N-Nitrosodiphenylamine	86-30-6	--	18	--	--	--	**18**
Nitrobenzene	98-95-3	--	--	16	--	--	**16**
p-Chloroaniline	106-47-8	--	0.22	32	--	--	**0.22**
Pentachlorophenol	87-86-5	--	0.22	80	1	1	**0.22**
TPH							
Gasoline	86290-81-5	800	--	--	--	--	**800**
Lube oil	NA	500	--	--	--	--	**500**

DALTON OLMSTED FUGLEVAND

TABLE 1
GROUNDWATER-BASED PRELIMINARY CLEANUP LEVELS[1]
Stericycle Washougal Facility
Technical Memorandum (8/26/19)

Concentrations in micrograms per liter (µg/L)

Constituent	CAS Number	Groundwater, MTCA Method A Cleanup Level	Groundwater, MTCA Method B Cleanup Level, Carcinogenic	Groundwater, MTCA Method B Cleanup Level, Non-carcinogenic	Groundwater ARAR-Federal MCL[2]	Groundwater ARAR - State MCL[3]	Minimum Level

Notes

1. All levels downloaded from Washington State Department of Ecology Cleanup Levels and Risk Calculations (CLARC) Web site, https://fortress.wa.gov/ecy/c
2. Federal MCL established under the Safe Drinking Water Act.
3. State MCL established under Washington Administrative Code Chapter 246-290.
4. Values for endosulfan (CAS 115-29-7) listed.

Abbreviations

-- = not available

CAS = Chemical Abstracts Service

MCL = maximum contaminant level

MTCA = Model Toxics Control Act

NA = not applicable

PCBs = polychlorinated biphenyls

SVOCs = semivolatile organic compounds

VOCs = volatile organic compounds

DALTON OLMSTED FUGLEVAND

TABLE 2
GROUNDWATER PRELIMINARY CLEANUP LEVELS – SURFACE WATER ARARS [1]
Stericycle Washougal Facility

Concentrations in micrograms per liter (µg/L)

Constituent	CAS Number	Surface Water, MTCA Method B Cleanup Level, Carcinogenic	Surface Water, MTCA Method B Cleanup Level, Non- carcinogenic	Surface Water ARAR - Aquatic Life - Fresh/Acute (WAC 173-201A)	Surface Water ARAR - Aquatic Life - Fresh/Chronic (WAC 173-201A)	Surface Water ARAR - Human Health - water & organism (WAC 173-201A)	Surface Water ARAR - Human Health - organism only (WAC 173-201A)	Surface Water ARAR - Human Health - Fresh Water - NTR (40 CFR 131)	Surface Water ARAR - Aquatic Life - Fresh/Acute (CWA §304)	Surface Water ARAR - Aquatic Life - Fresh/Chronic (CWA §304)	Surface Water ARAR - Human Health - Fresh Water (CWA §304)	Minimum Level
Inorganics												
Ammonia (as nitrogen)	7664-41-7	--	--	--	--	--	--	--	--	--	--	**--**
Arsenic, inorganic	7440-38-2	0.098	18	360	190	10	10	0.018	340	150	0.018	**0.018**
Barium	7440-39-3	--	--	--	--	--	--	--	--	--	1,000	**1000**
Cadmium	7440-43-9	--	41	3.7	1	--	--	--	1.8	0.72	--	**0.72**
Chromium	7440-47-3	--	--	--	--	--	--	--	--	--	--	**--**
Copper	7440-50-8	--	2,900	17	11	1300	--	--	--	--	1,300	**11**
Cyanide	57-12-5	--	1,600	22	5.2	19	270	9	22	5.2	4	**4**
Iron	7439-89-6	--	--	--	--	--	--	--	--	1,000	--	**1000**
Lead	7439-92-1	--	--	65	2.5	--	--	--	65	2.5	--	**2.5**
Manganese	7439-96-5	--	--	--	--	--	--	--	--	--	50	**50**
Nickel	7440-02-0	--	1,100	470	160	150	190	80	470	52	610	**52**
Silver	7440-22-4	--	26,000	3.4	--	--	--	--	3.2	--	--	**3.2**
Vanadium	7440-62-2	--	--	--	--	--	--	--	--	--	--	**--**
Zinc	7440-66-6	--	17,000	110	100	2300	2900	--	120	120	7,400	**100**
VOCs												
Benzene	71-43-2	23	2,000	--	--	0.44	1.6	--	--	--	0.58	**0.44**
Bromodichloromethane	75-27-4	28	14,000	--	--	0.77	3.6	--	--	--	0.95	**0.77**
Bromoform	75-25-2	220	14,000	--	--	5.8	27	4.6	--	--	7	**4.6**
Bromomethane	74-83-9	--	970	--	--	520	2400	--	--	--	100	**100**
Carbon disulfide	75-15-0	--	--	--	--	--	--		--	--	--	**--**
Carbon tetrachloride	56-23-5	4.9	550	--	--	0.2	0.35	--	--	--	0.4	**0.2**
Chlorobenzene	108-90-7	--	5,000	--	--	380	890	100	--	--	100	**100**
Chloroform	67-66-3	56	6,900	--	--	260	1200	100	--	--	60	**56**
Chloromethane	74-87-3	--	--	--	--	--	--	--	--	--	--	**--**
1,2-Dibromo-3-chloropropane	96-12-8	--	--	--	--	--	--	--	--	--	--	**--**
Dibromochloromethane	124-48-1	21	14,000	--	--	0.65	3	--	--	--	0.8	**0.65**
1,4-Dichlorobenzene	106-46-7	22	3300	--	--	460	580	200	--	--	300	**22**
1,1-Dichloroethane	75-34-3	--	--	--	--	--	--	--	--	--	--	**--**
1,2-Dichloroethane	107-06-2	59	13,000	--	--	9.3	120	8.9	--	--	9.9	**8.9**
1,1-Dichloroethene	75-35-4	--	23,000	--	--	1200	4100	700	--	--	300	**300**
1,2-Dichloroethene (total)	540-59-0	--	--	--	--	--	--	--	--	--	--	**--**
cis-1,2-Dichloroethene	156-59-2	--	--	--	--	--	--	--	--	--	--	**--**
trans-1,2-Dichloroethene	156-60-5	--	33,000	--	--	0.015	0.023	--	--	--	100	**0.015**
Dichlorodifluoromethane	75-71-8	--	--	--	--	--	--	--	--	--	--	**0**
1,2-Dichloropropane	78-87-5	43	25000	--	--	0.71	3.1	--	--	--	0.9	**0.71**
Ethyl chloride (chloroethane)	75-00-3	--	--	--	--	--	--	--	--	--	--	**--**
Ethylene dibromide (EDB) (1,2-Dibromoethane)	106-93-4	--	--	--	--	--	--	--	--	--	--	**--**
Methylene chloride	75-09-2	3600	17,000	--	--	16	250	10	--	--	20	**10**
Styrene	100-42-5	--	--	--	--	--	--	--	--	--	--	**--**
1,1,1,2-Tetrachloroethane	630-20-6	--	--	--	--	--	--	--	--	--	--	**--**
1,1,2,2-Tetrachloroethane	79-34-5	6.5	10,000	--	--	0.12	0.46	0.1	--	--	0.2	**0.1**
Tetrachloroethene	127-18-4	100	500	--	--	4.9	7.1	2.4	--	--	10	**2.4**
Toluene	108-88-3	--	19,000	--	--	180	410	72	--	--	57	**57**
1,2,4-Trichlorobenzene	120-82-1	2	230	--	--	0.12	0.14	0.036	--	--	0.071	**0.036**
1,1,1-Trichloroethane	71-55-6	--	930,000	--	--	47000	160000	--	--	--	10000	**10000**
1,1,2-Trichloroethane	79-00-5	25	2,300	--	--	0.44	1.8	0.35	--	--	0.55	**0.35**
Trichloroethene	79-01-6	13	120	--	--	0.38	0.86	0.3	--	--	0.6	**0.3**
1,2,3-Trichloropropane	96-18-4	--	--	--	--	--	--	--	--	--	--	**--**
Vinyl chloride	75-01-4	3.7	6,600	--	--	0.02	0.26	--	--	--	0.022	**0.02**
m,p-Xylene	106-42-3	--	--	--	--	--	--	--	--	--	--	**--**

TABLE 2
GROUNDWATER PRELIMINARY CLEANUP LEVELS – SURFACE WATER ARARS [1]
Stericycle Washougal Facility

Concentrations in micrograms per liter (µg/L)

Constituent	CAS Number	Surface Water, MTCA Method B Cleanup Level, Carcinogenic	Surface Water, MTCA Method B Cleanup Level, Non- carcinogenic	Surface Water ARAR - Aquatic Life - Fresh/Acute (WAC 173-201A)	Surface Water ARAR - Aquatic Life - Fresh/Chronic (WAC 173-201A)	Surface Water ARAR - Human Health - water & organism (WAC 173-201A)	Surface Water ARAR - Human Health - organism only (WAC 173-201A)	Surface Water ARAR - Human Health - Fresh Water - NTR (40 CFR 131)	Surface Water ARAR - Aquatic Life - Fresh/Acute (CWA §304)	Surface Water ARAR - Aquatic Life - Fresh/Chronic (CWA §304)	Surface Water ARAR - Human Health - Fresh Water (CWA §304)	Minimum Level
SVOCs												
2,4,6-Trichlorophenol	88-06-2	3.9	17	--	--	0.25	0.28	--	--	--	1.5	**0.25**
2-Chlorophenol	95-57-8	--	97	--	--	15	17	--	--	--	30	**15**
2-Methylnaphthalene	91-57-6	--	--	--	--	--	--	--	--	--	--	**--**
Aniline	62-53-3	--	--	--	--	--	--	--	--	--	--	**--**
Benzo(a)anthracene	56-55-3	--	--	--	--	0.014	0.021	0.00016	--	--	0.0012	**0.00016**
Benzo(a)pyrene	50-32-8	0.035	0.26	--	--	0.0014	0.0021	1.60E-05	--	--	0.00012	**0.000016**
Benzo(b)fluoranthene	205-99-2	--	--	--	--	0.014	0.021	0.00016	--	--	0.0012	**0.00016**
Benzo(k)fluoranthene	207-08-9	--	--	--	--	0.014	0.21	0.0016	--	--	0.012	**0.0016**
bis(2-Chloroethyl) ether	111-44-4	0.85	--	--	--	0.02	0.06	--	--	--	0.03	**0.02**
bis(2-Ethylhexyl) phthalate	117-81-7	3.6	400	--	--	0.23	0.25	0.045	--	--	0.32	**0.045**
Chrysene	218-01-9	--	--	--	--	1.4	2.1	0.016	--	--	0.12	**0.016**
3,3'-Dichlorobenzidine	91-94-1	0.046	--	--	--	0.0031	0.0033	--	--	--	0.049	**0.0031**
1,4-Dioxane	123-91-1	--	--	--	--	--	--	--	--	--	--	**--**
2,4-Dichlorophenol	120-83-2	--	190	--	--	25	34	10	--	--	10	**10**
2,4-Dinitrophenol	51-28-5	--	3,500	--	--	60	610	30	--	--	10	**10**
2,4-Dinitrotoluene	121-14-2	5.5	1,400	--	--	0.039	0.18	--	--	--	0.049	**0.039**
2,6-Dinitrotoluene	606-20-2	--	--	--	--	--	--	--	--	--	--	**--**
Dibenzo[a,h]anthracene	53-70-3	--	--	--	--	0.0014	0.0021	1.60E-05	--	--	0.00012	**0.000016**
Dibenzofuran	132-64-9	--	--	--	--	--	--	--	--	--	--	**--**
Dinoseb	88-85-7	--	--	--	--	--	--	--	--	--	--	**--**
Hexachlorobenzene	118-74-1	0.00047	0.24	--	--	0.000051	0.000052	5.00E-06	--	--	0.000079	**0.000005**
Hexachlorobutadiene	87-68-3	30	930	--	--	0.69	4.1	0.01	--	--	0.01	**0.01**
Hexachlorocyclopentadiene	77-47-4	--	3,600	--	--	150	630	1	--	--	4	**1**
Hexachloroethane	67-72-1	1.9	21	--	--	0.11	0.13	0.02	--	--	0.1	**0.02**
Indeno(1,2,3-cd)pyrene	193-39-5	--	--	--	--	0.014	0.021	0.00016	--	--	0.0012	**0.00016**
Isophorone	78-59-1	1,600	120,000	--	--	27	110	--	--	--	34	**27**
N-Nitroso-di-n-propylamine	621-64-7	0.82	--	--	--	0.0044	0.058	--	--	--	0.005	**0.0044**
N-Nitrosodiphenylamine	86-30-6	9.7	--	--	--	0.62	0.69	--	--	--	3.3	**0.62**
Nitrobenzene	98-95-3	--	1,800	--	--	55	320	30	--	--	10	**10**
p-Chloroaniline	106-47-8	--	--	--	--	--	--	--	--	--	--	**--**
Pentachlorophenol	87-86-5	1.5	1,200	20	13	0.046	0.1	0.002	19	15	0.03	**0.002**
TPH												
Gasoline	86290-81-5	--	--	--	--	--	--	--	--	--	--	**--**
Lube oil	NA	--	--	--	--	--	--	--	--	--	--	**--**

Notes

1. All levels downloaded from Washington State Department of Ecology, Cleanup Levels and Risk Calculations (CLARC) Web site, https://fortress.wa.gov/ecy/clarc/CLARCHome.aspx.
2. Values for endosulfan (CAS 115-29-7) listed.
3. Value found in 40 C.F.R. 131.36

Abbreviations

-- = not available
ARAR = applicable or relevant and appropriate requirement
CAS = Chemical Abstracts Service
CFR = Code of Federal Regulations
CWA = Clean Water Act
MTCA = Model Toxics Control Act
NA = not applicable
NTR = National Toxics Rule
PCBs = polychlorinated biphenyls
PQL = practical quantitation limit
SVOCs = semivolatile organic compounds
TPH = total petroleum hydrocarbons
VOCs = volatile organic compounds
WAC = Washington Adminstrative Code

TABLE 3
GROUNDWATER PRELIMINARY CLEANUP LEVELS - VAPOR INTRUSION
Stericycle Washougal Facility

Concentrations in micrograms per liter (µg/L)

Chemical Name	CAS #	Groundwater Screening Level Method B Noncancer	Groundwater Screening Level Method B Cancer	Minimum Level
benzene	71-43-2	100	2.4	**2.4**
bromodichloromethane	75-27-4	--	1.8	**1.8**
bromoform	75-25-2	--	200	**200**
bromomethane	74-83-9	13	--	**13**
carbon disulfide	75-15-0	400	--	**400**
carbon tetrachloride	56-23-5	62	0.56	**0.56**
chlorobenzene	108-90-7	290	--	**290**
chloroform	67-66-3	490	1.2	**1.2**
chloromethane	74-87-3	150	--	**150**
dichlorobenzene;1,4-	106-46-7	7900	4.9	**4.9**
dichlorodifluoromethane	75-71-8	5.6	--	**5.6**
dichloroethane;1,1-	75-34-3	--	11	**11**
dichloroethane;1,2-	107-06-2	140	4.2	**4.2**
dichloroethylene;1,1-	75-35-4	130	--	**130**
dichloropropane;1,2-	78-87-5	28	10	**10**
ethylene dibromide (EDB)	106-93-4	270	0.27	**0.27**
methylene chloride	75-09-2	4800	4400	**4400**
styrene	100-42-5	8200	--	**8200**
tetrachloroethane;1,1,1,2-	630-20-6	--	7.4	**7.4**
tetrachloroethane;1,1,2,2-	79-34-5	--	6.2	**6.2**
tetrachloroethylene	127-18-4	46	24	**24**
toluene	108-88-3	15000	--	**15000**
trichlorobenzene;1,2,4-	120-82-1	39	--	**39**
trichloroethane;1,1,1-	71-55-6	5500	--	**5500**
trichloroethane;1,1,2-	79-00-5	4.6	7.9	**4.6**
trichloroethylene	79-01-6	3.8	1.5	**1.5**
vinyl chloride	75-01-4	57	0.35	**0.35**
xylenes	1330-20-7	330	--	**330**

TABLE 4
GROUNDWATER PRACTICAL QUANTITATION LIMITS
Stericycle Washougal Facility
Technical Memorandum (8/26/19)

Concentrations in micrograms per liter (µg/L)

Constituent	CAS Number	Lab PQL
Inorganics		
Ammonia (as nitrogen)	7664-41-7	--
Arsenic, inorganic	7440-38-2	5
Barium	7440-39-3	3
Cadmium	7440-43-9	1
Chromium	7440-47-3	10
Copper	7440-50-8	2
Cyanide	57-12-5	10
Iron	7439-89-6	40
Lead	7439-92-1	3
Manganese	7439-96-5	3.5
Nickel	7440-02-0	3
Silver	7440-22-4	5
Vanadium	7440-62-2	6
Zinc	7440-66-6	20
VOCs		
Benzene	71-43-2	1
Bromodichloromethane	75-27-4	1
Bromoform	75-25-2	1
Bromomethane	74-83-9	2
Carbon disulfide	75-15-0	1
Carbon tetrachloride	56-23-5	1
Chlorobenzene	108-90-7	1
Chloroform	67-66-3	1
Chloromethane	74-87-3	1
1,2-Dibromo-3-chloropropane	96-12-8	2
Dibromochloromethane	124-48-1	1
1,4-Dichlorobenzene	106-46-7	1
1,1-Dichloroethane	75-34-3	1
1,2-Dichloroethane	107-06-2	1
1,1-Dichloroethene	75-35-4	1
1,2-Dichloroethene (total)	540-59-0	1
cis-1,2-Dichloroethene	156-59-2	1
trans-1,2-Dichloroethene	156-60-5	1
Dichlorodifluoromethane	75-71-8	1
1,2-Dichloropropane	78-87-5	1
Ethyl chloride (chloroethane)	75-00-3	1
Ethylene dibromide (EDB) (1,2-Dibromoethane)	106-93-4	1
Methylene chloride	75-09-2	5
Styrene	100-42-5	1
1,1,1,2-Tetrachloroethane	630-20-6	1
1,1,2,2-Tetrachloroethane	79-34-5	1
Tetrachloroethene	127-18-4	1
Toluene	108-88-3	1
1,2,4-Trichlorobenzene	120-82-1	1
1,1,1-Trichloroethane	71-55-6	1
1,1,2-Trichloroethane	79-00-5	1
Trichloroethene	79-01-6	1
1,2,3-Trichloropropane	96-18-4	2
Vinyl chloride	75-01-4	0.02
m,p-Xylene	106-42-3	2
SVOCs		
2,4,6-Trichlorophenol	88-06-2	10
2-Chlorophenol	95-57-8	10
2-Methylnaphthalene	91-57-6	0.2
Aniline	62-53-3	--
Benzo(a)anthracene	56-55-3	0.2
Benzo(a)pyrene	50-32-8	0.2

TABLE 4
GROUNDWATER PRACTICAL QUANTITATION LIMITS
Stericycle Washougal Facility
Technical Memorandum (8/26/19)

Concentrations in micrograms per liter (µg/L)

Constituent	CAS Number	Lab PQL
Benzo(b)fluoranthene	205-99-2	0.2
Benzo(k)fluoranthene	207-08-9	0.2
bis(2-Chloroethyl) ether	111-44-4	10
bis(2-Ethylhexyl) phthalate	117-81-7	20
Chrysene	218-01-9	0.2
3,3'-Dichlorobenzidine	91-94-1	10
1,4-Dioxane	123-91-1	1
2,4-Dichlorophenol	120-83-2	10
2,4-Dinitrophenol	51-28-5	20
2,4-Dinitrotoluene	121-14-2	0.5
2,6-Dinitrotoluene	606-20-2	0.5
Dibenzo[a,h]anthracene	53-70-3	0.2
Dibenzofuran	132-64-9	20
Dinoseb	88-85-7	--
Hexachlorobenzene	118-74-1	0.05
Hexachlorobutadiene	87-68-3	1
Hexachlorocyclopentadiene	77-47-4	--
Hexachloroethane	67-72-1	10
Indeno(1,2,3-cd)pyrene	193-39-5	0.2
Isophorone	78-59-1	10
N-Nitroso-di-n-propylamine	621-64-7	10
N-Nitrosodiphenylamine	86-30-6	10
Nitrobenzene	98-95-3	0.5
p-Chloroaniline	106-47-8	10
Pentachlorophenol	87-86-5	20
TPH		
Gasoline	86290-81-5	20
Lube oil	NA	100

<u>Abbreviations</u>

-- = not available
CAS = Chemical Abstracts Service
PQL = practical quantitation limit
SVOCs = semivolatile organic compounds
TPH = total petroleum hydrocarbons
VOCs = volatile organic compounds

TABLE 5
GROUNDWATER PRELIMINARY CLEANUP LEVELS
Stericycle Washougal Facility
Technical Memorandum (8/26/19)

Concentrations in micrograms per liter (µg/L)

Constituent	CAS Number	Lab PQL	Minimum Shallow Criteria (Tables 1,2&3)	Minimum Lower Criteria (Tables 1&2)	Shallow Groundwater Preliminary Cleanup Level	Lower Aquifer Groundwater Preliminary Cleanup Level
Inorganics						
Ammonia (as nitrogen)	7664-41-7	--	--	--		**--**
Arsenic, inorganic	7440-38-2	5	0.018	0.018	**22.84**	**1.42**
Barium	7440-39-3	3	1000	1000	**1000**	**1000**
Cadmium	7440-43-9	1	0.72	0.72	**1**	**1**
Chromium	7440-47-3	10	50	50	**50**	**50**
Copper	7440-50-8	2	11	11	**11**	**11**
Cyanide	57-12-5	10	4	4	**10**	**10**
Iron	7439-89-6	40	1000	1000	**1000**	**1000**
Lead	7439-92-1	3	2.5	2.5	**3**	**3**
Manganese	7439-96-5	3.5	50	50	**50**	**50**
Nickel	7440-02-0	3	52	52	**52**	**52**
Silver	7440-22-4	5	3.2	3.2	**5**	**5**
Vanadium	7440-62-2	6	80	80	**80**	**80**
Zinc	7440-66-6	20	100	100	**100**	**100**
VOCs						
Benzene	71-43-2	1	0.44	0.44	**1**	**1**
Bromodichloromethane	75-27-4	1	0.71	0.71	**1**	**1**
Bromoform	75-25-2	1	4.6	4.6	**4.6**	**4.6**
Bromomethane	74-83-9	2	11	11	**11**	**11**
Carbon disulfide	75-15-0	1	400	800	**400**	**800**
Carbon tetrachloride	56-23-5	1	0.2	0.2	**1**	**1**
Chlorobenzene	108-90-7	1	100	100	**100**	**100**
Chloroform	67-66-3	1	1.2	1.4	**1.2**	**1.4**
Chloromethane	74-87-3	1	150	--	**150**	**--**
1,2-Dibromo-3-chloropropane	96-12-8	2	0.055	0.055	**2**	**2**
Dibromochloromethane	124-48-1	1	0.52	0.52	**1**	**1**
1,4-Dichlorobenzene	106-46-7	1	4.9	8.1	**4.9**	**8.1**
1,1-Dichloroethane	75-34-3	1	7.7	7.7	**7.7**	**7.7**
1,2-Dichloroethane	107-06-2	1	0.48	0.48	**1**	**1**
1,1-Dichloroethene	75-35-4	1	7	7	**7**	**7**
1,2-Dichloroethene (total)	540-59-0	1	72	72	**72**	**72**
cis-1,2-Dichloroethene	156-59-2	1	16	16	**16**	**16**
trans-1,2-Dichloroethene	156-60-5	1	0.015	0.015	**1**	**1**
Dichlorodifluoromethane	75-71-8	1	5.6	--	**5.6**	**--**
1,2-Dichloropropane	78-87-5	1	0.71	0.71	**1**	**1**
Ethyl chloride (chloroethane)	75-00-3	1	--	--	**--**	**--**
Ethylene dibromide (EDB) (1,2-Dibromoethane)	106-93-4	1	0.01	0.01	**1**	**1**
Methylene chloride	75-09-2	5	5	5	**5**	**5**
Styrene	100-42-5	1	100	100	**100**	**100**
1,1,1,2-Tetrachloroethane	630-20-6	1	1.68	1.68	**1.68**	**1.68**
1,1,2,2-Tetrachloroethane	79-34-5	1	0.1	0.1	**1**	**1**
Tetrachloroethene	127-18-4	1	2.4	2.4	**2.4**	**2.4**
Toluene	108-88-3	1	57	57	**57**	**57**
1,2,4-Trichlorobenzene	120-82-1	1	0.036	0.036	**1**	**1**
1,1,1-Trichloroethane	71-55-6	1	200	200	**200**	**200**
1,1,2-Trichloroethane	79-00-5	1	0.35	0.35	**1**	**1**
Trichloroethene	79-01-6	1	0.3	0.3	**1**	**1**
1,2,3-Trichloropropane	96-18-4	2	0.0015	0.0015	**2**	**2**
Vinyl chloride	75-01-4	0.02	0.02	0.02	**0.02**	**0.02**
m,p-Xylene	106-42-3	2	330	1600	**330**	**1600**
SVOCs						
2,4,6-Trichlorophenol	88-06-2	10	0.25	0.25	**10**	**10**
2-Chlorophenol	95-57-8	10	15	15	**15**	**15**

TABLE 5
GROUNDWATER PRELIMINARY CLEANUP LEVELS
Stericycle Washougal Facility
Technical Memorandum (8/26/19)

Concentrations in micrograms per liter (µg/L)

Constituent	CAS Number	Lab PQL	Minimum Shallow Criteria (Tables 1,2&3)	Minimum Lower Criteria (Tables 1&2)	Shallow Groundwater Preliminary Cleanup Level	Lower Aquifer Groundwater Preliminary Cleanup Level
2-Methylnaphthalene	91-57-6	0.2	32	32	**32**	**32**
Aniline	62-53-3	--	7.7	7.7	**7.7**	**7.7**
Benzo(a)anthracene	56-55-3	0.2	0.00016	0.00016	**0.2**	**0.2**
Benzo(a)pyrene	50-32-8	0.2	0.000016	0.000016	**0.2**	**0.2**
Benzo(b)fluoranthene	205-99-2	0.2	0.00016	0.00016	**0.2**	**0.2**
Benzo(k)fluoranthene	207-08-9	0.2	0.0016	0.0016	**0.2**	**0.2**
bis(2-Chloroethyl) ether	111-44-4	10	0.02	0.02	**10**	**10**
bis(2-Ethylhexyl) phthalate	117-81-7	20	0.045	0.045	**20**	**20**
Chrysene	218-01-9	0.2	0.016	0.016	**0.2**	**0.2**
3,3'-Dichlorobenzidine	91-94-1	10	0.0031	0.0031	**10**	**10**
1,4-Dioxane	123-91-1	1	0.44	0.44	**1**	**1**
2,4-Dichlorophenol	120-83-2	10	10	10	**10**	**10**
2,4-Dinitrophenol	51-28-5	20	10	10	**20**	**20**
2,4-Dinitrotoluene	121-14-2	0.5	0.039	0.039	**0.5**	**0.5**
2,6-Dinitrotoluene	606-20-2	0.5	0.058	0.058	**0.5**	**0.5**
Dibenzo[a,h]anthracene	53-70-3	0.2	0.000016	0.000016	**0.2**	**0.2**
Dibenzofuran	132-64-9	20	16	16	**20**	**20**
Dinoseb	88-85-7	--	7	7	**7**	**7**
Hexachlorobenzene	118-74-1	0.05	0.000005	0.000005	**0.05**	**0.05**
Hexachlorobutadiene	87-68-3	1	0.01	0.01	**1**	**1**
Hexachlorocyclopentadiene	77-47-4	--	1	1	**1**	**1**
Hexachloroethane	67-72-1	10	0.02	0.02	**10**	**10**
Indeno(1,2,3-cd)pyrene	193-39-5	0.2	0.00016	0.00016	**0.2**	**0.2**
Isophorone	78-59-1	10	27	27	**27**	**27**
N-Nitroso-di-n-propylamine	621-64-7	10	0.0044	0.0044	**10**	**10**
N-Nitrosodiphenylamine	86-30-6	10	0.62	0.62	**10**	**10**
Nitrobenzene	98-95-3	0.5	10	10	**10**	**10**
p-Chloroaniline	106-47-8	10	0.22	0.22	**10**	**10**
Pentachlorophenol	87-86-5	20	0.002	0.002	**20**	**20**
TPH						
Gasoline	86290-81-5	20	800	800	**800**	**800**
Lube oil	NA	100	500	500	**500**	**500**

<u>Abbreviations</u>

-- = not available
CAS = Chemical Abstracts Service
PQL = practical quantitation limit
SVOCs = semivolatile organic compounds
TPH = total petroleum hydrocarbons
VOCs = volatile organic compounds

TABLE 6

SOIL PRELIMINARY CLEANUP LEVELS FOR STERICYCLE PROPERTY SOILS [1]

Stericycle Washougal Facility

Concentrations are in milligrams per kilogram (mg/kg)

Constituent	CAS Number	Terrestrial MTCA Table 749-3	Soil, MTCA Method A Cleanup Level, Industrial	Soil, MTCA Method C Cleanup Level, Carcinogenic[2]	Soil, MTCA Method C Cleanup Level, Non-carcinogenic[2]	EPA Regional Screening Levels[3] (Industrial)	Soil Cleanup Level Protective of Groundwater[4,8]	Minimum Screening Level	Clark County Natural Background Level[5]	PQL	Stericycle-Property Soil Preliminary Cleanup Level[7]
Inorganics											
Barium	7440-39-3	500	--	--	700,000	220,000	824	500	--	0.25	500
Cadmium	7440-43-9a	4	2	--	3,500	980	0.138	0.138	1.1	0.1	1.1
Chromium (total)	7440-47-3	42	--	--	--	--	1,000	42	27	0.5	42
Copper	7440-50-8	50	--	--	140,000	47,000	4.88	4.88	34	2.5	34
Cyanide	57-12-5	--	--	--	2,200	150	--	150	--	--	--
Lead	7439-92-1	50	1,000	--	--	800	600	50	24	0.1	50
Mercury	7439-97-6	0.1	2	--	--	46	***	0.1	0.04	0.1	0.1
Nickel	7440-02-0	30	--	--	70,000	22,000	67.8	30	21	0.35	30
Selenium and compounds	7782-49-2	0.3	--	--	18,000	5,800	5.2	0.3	--	0.5	0.5
Silver	7440-22-4	2	--	--	18,000	5,800	0.85	0.85	--	0.1	0.85
Thallium, soluble salts	7440-28-0	1	--	--	35	12	0.23	0.23	--	0.1	0.23
Vanadium	7440-62-2	2	--	--	18,000	5,800	1600	2	--	0.5	2
Zinc	7440-66-6	86	--	--	1,100,000	350,000	124	86	96	2.5	96
PCBs/Pesticides											
Aldrin	309-00-2	0.1	--	7.7	110	0.18	***	0.1	--	0.005	0.1
delta-BHC	319-86-8	--	--	--	--	--	***	--	--	0.005	--
4,4'-DDD	72-54-8	0.75 [16]	--	550	110	9.6	***	9.6	--	0.005	9.6
4,4'-DDT	50-29-3	0.75 [16]	4	390	1,800	8.5	***	8.5	--	0.005	8.5
Dieldrin	60-57-1	0.07	--	8.2	180	0.14	***	0.07	--	0.005	0.07
Endrin	72-20-8	0.2	--	--	1,100	250	***	0.2	--	0.005	0.2
Heptachlor	76-44-8	0.4 [18]	--	29	1,800	0.63	***	0.63	--	0.005	0.63
Heptachlor epoxide	1024-57-3	0.4 [18]	--	14	46	0.33	***	0.33	--	0.005	0.33
Lindane	58-89-9	--	0.01	12	1,100	2.5	***	2.5	--	--	--
Toxaphene	8001-35-2	--	--	120	320	2.1	***	2.1	--	0.1	2.1
Polychlorinated biphenyls, total[9]	1336-36-3	40	10	66	--	0.94	***	0.94	--	0.05	0.94
SVOCs											
Acetophenone	98-86-2	--	--	--	350,000	120,000	***	120000	--	0.33	120000
Benzidine	92-87-5	--	--	0.57	11,000	0.01	--	0.01	--	--	--
Benzo(a)anthracene	56-55-3	--	--	--	--	21	1.43	1.43	--	0.005	1.43
Benzo(a)pyrene	50-32-8	12	2	130	110	2.1	3.88	2.1	--	0.005	2.1
Benzo(b)fluoranthene	205-99-2	--	--	--	--	21	4.92	4.92	--	0.005	4.92
Benzo(k)fluoranthene	207-08-9	--	--	--	--	210	4.92	4.92	--	0.005	4.92
p-Chloroaniline (4-chloroaniline)	106-47-8	--	--	660	14,000	11	0.0012	0.0012	--	0.33	0.33
bis(2-Chloroethyl) ether	111-44-4	--	--	120	--	1	0.0552	0.0552	--	0.33	0.33
2-Chloronaphthalene	91-58-7	--	--	--	280,000	60,000	***	60000	--	0.33	60000
2-Chlorophenol	95-57-8	--	--	--	18,000	5,800	0.177	0.177	--	0.33	0.33
Chrysene	218-01-9	--	--	--	--	2100	1.59	1.59	--	0.005	1.59
3,3'-Dichlorobenzidine	91-94-1	--	--	290	--	5.1	0.185	0.185	--	0.66	0.66
2,4-Dichlorophenol	120-83-2	--	--	--	11,000	2,500	0.0694	0.0694	--	0.33	0.33
Dibenzo[a,h]anthracene	53-70-3	--	--	--	--	2.1	7.16	2.1	--	0.005	2.1
Dibenzofuran	132-64-9	0.000002 [15]	--	--	3,500	1,000	--	1000	--	0.66	1000

TABLE 6

SOIL PRELIMINARY CLEANUP LEVELS FOR STERICYCLE PROPERTY SOILS [1]

Stericycle Washougal Facility

Concentrations are in milligrams per kilogram (mg/kg)

Constituent	CAS Number	Terrestrial MTCA Table 749-3	Soil, MTCA Method A Cleanup Level, Industrial	Soil, MTCA Method C Cleanup Level, Carcinogenic[2]	Soil, MTCA Method C Cleanup Level, Non-carcinogenic[2]	EPA Regional Screening Levels[3] (Industrial)	Soil Cleanup Level Protective of Groundwater[4,8]	Minimum Screening Level	Clark County Natural Background Level[5]	PQL	Stericycle-Property Soil Preliminary Cleanup Level[7]
2,4-Dimethylphenol	105-67-9	--	--	--	70,000	16,000	***	16000	--	0.33	16000
2,4-Dinitrophenol	51-28-5	20	--	--	7,000	1,600	0.08	0.08	--	--	--
2,4-Dinitrotoluene	121-14-2	--	--	420	7,000	7.4	0.00296	0.00296	--	0.1	0.1
2,6-Dinitrotoluene	606-20-2	--	--	88	1,100	1.5	0.00892	0.00892	--	0.1	0.1
1,4-Dioxane	123-91-1	--	--	1,300	110,000	24	--	24	--	--	--
bis(2-Ethylhexyl) phthalate	117-81-7	--	--	9,400	70,000	160	44.5	44.5	--	0.66	44.5
Hexachlorobenzene	118-74-1	17	--	82	2,800	0.96	0.082	0.082	--	0.05	0.082
Hexachlorobutadiene	87-68-3	--	--	1,700	3,500	5.3	1.08	1.08	--	0.01	1.08
Hexachloroethane	67-72-1	--	--	3,300	2,500	8.0	***	8	--	0.33	8
Indeno(1,2,3-cd)pyrene	193-39-5	--	--	--	--	21	13.9	13.9	--	0.005	13.9
Isophorone	78-59-1	--	--	140,000.00	700,000	2,400	0.133	0.133	--	0.33	0.33
4-Methylphenol	106-44-5	--	--	--	350,000	82,000	--	82000	--	0.33	82000
N-Nitroso-di-n-propylamine	621-64-7	--	--	19	--	0.33	0.0448	0.0448	--	0.33	0.33
N-Nitrosodiphenylamine	86-30-6	20	--	27,000.00	--	470	0.298	0.298	--	0.33	0.33
Nitrobenzene	98-95-3	40	--	--	7,000	22	0.0638	0.0638	--	0.1	0.1
Pentachlorophenol	87-86-5	3	--	330	18,000	4.0	0.317	0.317	--	0.66	0.66
2,4,6-Trichlorophenol	88-06-2	10	--	12,000	3,500	210	0.116	0.116	--	0.33	0.33
TPH											
Gasoline	86290-81-5	100	30/100	--	--	--	--	100	--	1	100
Lube Oil		--	2,000	--	--	--	--	2,000	--	10	2000
VOCs											
Acetone	67-64-1	--	--	--	3,200,000	670,000	29	29	--	0.01	29
Acrolein	107-02-8	--	--	--	1,800	0.6	***	0.6	--	0.02	0.6
Acrylonitrile	107-13-1	--	--	240	140000	1.1	***	1.1	--	0.05	1.1
Benzene	71-43-2	--	0.03	2,400.00	14,000	5.1	0.00564	0.00564	--	0.005	0.00564
Bromodichloromethane	75-27-4	--	--	2,100.00	70,000	1.3	0.00521	0.00521	--	0.005	0.00521
Bromoform	75-25-2	--	--	17,000.00	70,000	86	0.0302	0.0302	--	0.005	0.0302
Bromomethane	74-83-9	--	--	--	4,900	30	0.0509	0.0509	--	0.005	0.0509
Carbon disulfide	75-15-0	--	--	--	350,000	3,500	2.83	2.83	--	0.005	2.83
Carbon tetrachloride	56-23-5	--	--	1,900	14,000	2.9	0.00921	0.00921	--	0.005	0.00921
Chlorobenzene	108-90-7	40	--	--	70,000	1,300	0.874	0.874	--	0.005	0.874
Chloroform	67-66-3	--	--	4200	35,000	1.4	0.00638	0.00638	--	0.005	0.00638
Chloromethane	74-87-3	--	--	--	--	460	--	460	--	0.005	460
2-Chlorotoluene	95-49-8	--	--	--	70,000	23,000	--	23000	--	0.005	23000
1,2-Dibromo-3-chloropropane	96-12-8	--	--	160	700	0.064	--	0.064	--	0.01	0.064
Dibromochloromethane	124-48-1	--	--	1,600.00	70,000	39	0.00532	0.00532	--	0.005	0.00532
1,4-Dichlorobenzene	106-46-7	20	--	24000	250000	11	0.0808	0.0808	--	0.005	0.0808
Dichlorodifluoromethane	75-71-8	--	--	--	700,000	370	--	370	--	0.01	370
1,2-Dichloroethane	107-06-2	--	--	1,400.00	21,000	2.0	0.00483	0.00483	--	0.005	0.005
1,1-Dichloroethene	75-35-4	--	--	23000	700,000	1,000	0.0501	0.0501	--	0.005	0.0501
cis-1,2-Dichloroethene	156-59-2	--	--	--	7,000	2,300	0.08	0.08	--	0.01	0.08
trans-1,2-Dichloroethene	156-60-5	--	--	--	70,000	2,300	0.00543	0.00543	--	0.005	0.00543

DALTON OLMSTED FUGLEVAND

TABLE 6

SOIL PRELIMINARY CLEANUP LEVELS FOR STERICYCLE PROPERTY SOILS [1]

Stericycle Washougal Facility

Concentrations are in milligrams per kilogram (mg/kg)

Constituent	CAS Number	Terrestrial MTCA Table 749-3	Soil, MTCA Method A Cleanup Level, Industrial	Soil, MTCA Method C Cleanup Level, Carcinogenic[2]	Soil, MTCA Method C Cleanup Level, Non-carcinogenic[2]	EPA Regional Screening Levels[3] (Industrial)	Soil Cleanup Level Protective of Groundwater[4,8]	Minimum Screening Level	Clark County Natural Background Level[5]	PQL	Stericycle-Property Soil Preliminary Cleanup Level[7]
Ethyl chloride (chloroethane)	75-00-3	--	--	--	--	57,000	--	57000	--	0.005	57000
Ethylbenzene	100-41-4	--	6	--	350,000	25	5.9	5.9	--	0.005	5.9
Ethylene dibromide (EDB) (1,2-Dibromoethane)	106-93-4	--	0.005	6.6	32,000	0.16	--	0.16	--	0.005	0.16
4-Methyl-2-butanone (4-Methyl-2-pentanone)	108-10-1	--	--	--	280,000	140,000	***	140000	--	0.01	140000
Methylene chloride	75-09-2	--	0.02	66,000	21,000	1000	0.0218	0.0218	--	0.02	0.0218
Styrene	100-42-5	300	--	--	700,000	35,000	2.24	2.24	--	0.005	2.24
1,1,2,2-Tetrachloroethane	79-34-5	--	--	660	70,000	2.7	0.0056	0.0056	--	0.005	0.0056
Tetrachloroethene	127-18-4	--	0.05	63,000	21,000	100	0.0255	0.0255	--	0.005	0.0255
1,1,1-Trichloroethane	71-55-6	--	2	--	7,000,000	36,000	1.58	1.58	--	0.005	1.58
1,1,2-Trichloroethane	79-00-5	--	--	2,300.00	14,000	5.0	0.00556	0.00556	--	0.005	0.00556
Trichloroethene	79-01-6	--	0.03	2,800	1,800	6.0	0.00661	0.00661	--	0.005	0.00661
1,2,3-Trichloropropane	96-18-4	--	--	4.4	14,000	0.11	--	0.11	--	0.02	0.11
1,2,4-Trimethylbenzene	95-63-6	--	--	--	35,000	1800	--	1800	--	0.005	1800
1,3,5-Trimethylbenzene	108-67-8	--	--	--	35,000	1,500	--	1500	--	0.005	1500
Toluene	108-88-3	200	7	--	280,000	47,000	0.414	0.414	--	0.005	0.414
Vinyl chloride	75-01-4	--	--	88	11,000	1.7	0.000126	0.000126	--	0.005	0.005
m,p-Xylene[10]	106-42-3	--	9	--	700,000	2,400	3.02	3.02	--	0.01	3.02

Notes

1. All levels downloaded from Washington State Department of Ecology Cleanup Levels and Risk Calculations (CLARC) website
2. Direct contact (ingestion only), industrial land use.
3. EPA Regional Screening Levels reviewed in 2019.
4. The calculations for soil cleanup levels protective of groundwater followed methods used in the RI.
5. 90th percentile natural background levels from the 1994 Washington State Department of Ecology *Natural Background Soil Metals Concentrations in Washington State.*
6. Applicable PQL updated in 2019.
7. Preliminary cleanup level was selected based on criteria described in text. In some cases, the screening level was adjusted up to the PQL or natural background.
8. For soil COCs that are not groundwater COCs (and did not have a calculated preliminary groundwater cleanup level) the default soil cleanup level protecive of groundwater from CLARC was applied

Abbreviations

-- = not available

*** = Not calculated for COCs not detected in groundwater at concentrations greater than the cleanup level in the last 10 years and, consistent with the empirical demonstration method for deriving soil concentrations for groundwater prote

CAS = Chemical Abstracts Service

EPA = US Environmental Protection Agency

MTCA = Model Toxics Control Act

PCBs = polychlorinated biphenyls

PQL = practical qnantitation limit

SVOCs = semivolatile organic compounds

TPH = total petroleum hydrocarbons

VOCs = volatile organic compounds

TABLE 7

SOIL PRELIMINARY CLEANUP LEVELS FOR OFF-PROPERTY SOILS [1]
Stericycle Washougal Facility

Concentrations are in milligrams per kilogram (mg/kg)

Constituent	CAS Number	Terrestrial MTCA Table 749-3	Soil, MTCA Method A Cleanup Level, Unrestricted Use	Soil, MTCA Method B Cleanup Level Carcinogenic	Soil, MTCA Method B Cleanup Level Non-Carcinogenic	Soil, MTCA Method C Cleanup Level, Carcinogenic[2]	Soil, MTCA Method C Cleanup Level, Non-carcinogenic[2]	EPA Regional Screening Levels[3] (Residential)	EPA Regional Screening Levels[3] (Industrial)	Soil Cleanup Level Protective of Groundwater[4,8]	Minimum Screening Level	Clark County Natural Background Level[5]	PQL	Off-Property Soil Preliminary Cleanup Level[7]
Inorganics														
Barium	7440-39-3	500	--	--	16,000	--	700,000	15,000	220,000	824	500	--	0.25	500
Cadmium	7440-43-9a	4	2	--	80	--	3,500	71	980	0.138	0.138	1.1	0.1	1.1
Chromium (total)	7440-47-3	42	--	--	--	--	--	--	--	1,000	42	27	0.5	42
Copper	7440-50-8	50	--	--	3,200	--	140,000	3,100	47,000	4.88	4.88	34	2.5	34
Cyanide	57-12-5	--	--	--	50	--	2,200	23	150	--	23	--	--	--
Lead	7439-92-1	50	250	--	--	--	--	400	800	600	50	24	0.1	50
Mercury	7439-97-6	0.1	2	--	--	--	--	11	46	***	0.1	0.04	0.1	0.1
Nickel	7440-02-0	30	--	--	1,600	--	70,000	1,500	22,000	67.8	30	21	0.35	30
Selenium and compounds	7782-49-2	0.3	--	--	400	--	18,000	390	5,800	5.2	0.3	--	0.5	0.5
Silver	7440-22-4	2	--	--	400	--	18,000	390	5,800	0.85	0.85	--	0.1	0.85
Thallium, soluble salts	7440-28-0	1	--	--	0.8	--	35	0.78	12	0.23	0.23	--	0.1	0.23
Vanadium	7440-62-2	2	--	--	400	--	18,000	390	5,800	1600	2	--	0.5	2
Zinc	7440-66-6	86	--	--	24,000	--	1,100,000	23,000	350,000	124	86	96	2.5	96
PCBs/Pesticides														
Aldrin	309-00-2	0.1	--	0.059	2.4	7.7	110	0.039	0.18	***	0.039	--	0.005	0.039
delta-BHC	319-86-8	--	--	--	--	--	--	--	--	***	--	--	0.005	--
4,4'-DDD	72-54-8	0.75 [16]	--	4.2	2.4	550	110	1.9	9.6	***	1.9	--	0.005	1.9
4,4'-DDT	50-29-3	0.75 [16]	3	2.9	40	390	1,800	1.9	8.5	***	1.9	--	0.005	1.9
Dieldrin	60-57-1	0.07	--	0.063	4	8.2	180	0.034	0.14	***	0.034	--	0.005	0.034
Endrin	72-20-8	0.2	--	--	24	--	1,100	19	250	***	0.2	--	0.005	0.2
Heptachlor	76-44-8	0.4 [18]	--	0.22	40	29	1,800	0.13	0.63	***	0.13	--	0.005	0.13
Heptachlor epoxide	1024-57-3	0.4 [18]	--	0.11	1	14	46	0.07	0.33	***	0.07	--	0.005	0.07
Lindane	58-89-9	--	0.01	0.91	24	12	1,100	0.57	2.5	***	0.57	--	--	--
Toxaphene	8001-35-2	--	--	0.91	7.2	120	320	0.49	2.1	***	0.49	--	0.1	0.49
Polychlorinated biphenyls, total[9]	1336-36-3	40	1	0.5	--	66	--	0.23	0.94	***	0.23	--	0.05	0.23
SVOCs														
Acetophenone	98-86-2	--	--	--	8,000	--	350,000	7,800	120,000	***	7800	--	0.33	7800
Benzidine	92-87-5	--	--	0.0043	240	0.57	11,000	0.00053	0.01	--	0.00053	--	--	--
Benzo(a)anthracene	56-55-3	--	--	--	--	--	--	1.1	21	1.43	1.1	--	0.005	1.1
Benzo(a)pyrene	50-32-8	12	0.1	0.19	24	130	110	0.11	2.1	3.88	0.11	--	0.005	0.11
Benzo(b)fluoranthene	205-99-2	--	--	--	--	--	--	1.1	21	4.92	1.1	--	0.005	1.1
Benzo(k)fluoranthene	207-08-9	--	--	--	--	--	--	11	210	4.92	4.92	--	0.005	4.92
p-Chloroaniline (4-chloroaniline)	106-47-8	--	--	5	320	660	14,000	2.7	11	0.0012	0.0012	--	0.33	0.33
bis(2-Chloroethyl) ether	111-44-4	--	--	0.91	--	120	--	0.23	1	0.0552	0.0552	--	0.33	0.33
2-Chloronaphthalene	91-58-7	--	--	--	6,400	--	280,000	4,800	60,000	***	4800	--	0.33	4800
2-Chlorophenol	95-57-8	--	--	--	400	--	18,000	390	5,800	0.177	0.177	--	0.33	0.33
Chrysene	218-01-9	--	--	--	--	--	--	110	2100	1.59	1.59	--	0.005	1.59
3,3'-Dichlorobenzidine	91-94-1	--	--	2.2	--	290	--	1.2	5.1	0.185	0.185	--	0.66	0.66
2,4-Dichlorophenol	120-83-2	--	--	--	240	--	11,000	190	2,500	0.0694	0.0694	--	0.33	0.33
Dibenzo[a,h]anthracene	53-70-3	--	--	--	--	--	--	0.11	2.1	7.16	0.11	--	0.005	0.11
Dibenzofuran	132-64-9	0.000002 [15]	--	--	80	--	3,500	73	1,000	--	73	--	0.66	73
2,4-Dimethylphenol	105-67-9	--	--	--	1,600	--	70,000	1,300	16,000	***	1300	--	0.33	1300
2,4-Dinitrophenol	51-28-5	20	--	--	160	--	7,000	130	1,600	0.08	0.08	--	--	--
2,4-Dinitrotoluene	121-14-2	--	--	3.2	160	420	7,000	1.7	7.4	0.00296	0.00296	--	0.1	0.1
2,6-Dinitrotoluene	606-20-2	--	--	0.67	24	88	1,100	0.36	1.5	0.00892	0.00892	--	0.1	0.1
1,4-Dioxane	123-91-1	--	--	10	2,400	1,300	110,000	5.3	24	--	5.3	--	--	--
bis(2-Ethylhexyl) phthalate	117-81-7	--	--	71	1,600	9,400	70,000	39	160	44.5	39	--	0.66	39

DALTON OLMSTED FUGLEVAND

TABLE 7

SOIL PRELIMINARY CLEANUP LEVELS FOR OFF-PROPERTY SOILS [1]
Stericycle Washougal Facility

Concentrations are in milligrams per kilogram (mg/kg)

Constituent	CAS Number	Terrestrial MTCA Table 749-3	Soil, MTCA Method A Cleanup Level, Unrestricted Use	Soil, MTCA Method B Cleanup Level Carcinogenic	Soil, MTCA Method B Cleanup Level Non-Carcinogenic	Soil, MTCA Method C Cleanup Level, Carcinogenic[2]	Soil, MTCA Method C Cleanup Level, Non-carcinogenic[2]	EPA Regional Screening Levels[3] (Residential)	EPA Regional Screening Levels[3] (Industrial)	Soil Cleanup Level Protective of Groundwater[4,8]	Minimum Screening Level	Clark County Natural Background Level[5]	PQL	Off-Property Soil Preliminary Cleanup Level[7]
Hexachlorobenzene	118-74-1	17	--	0.63	64	82	2,800	0.21	0.96	0.082	0.082	--	0.05	0.082
Hexachlorobutadiene	87-68-3	--	--	13	80	1,700	3,500	1.2	5.3	1.08	1.08	--	0.01	1.08
Hexachloroethane	67-72-1	--	--	25	56	3,300	2,500	1.8	8.0	***	1.8	--	0.33	1.8
Indeno(1,2,3-cd)pyrene	193-39-5	--	--	--	--	--	--	1.1	21	13.9	1.1	--	0.005	1.1
Isophorone	78-59-1	--	--	1,100	16,000	140,000.00	700,000	570	2,400	0.133	0.133	--	0.33	0.33
4-Methylphenol	106-44-5	--	--	--	8000	--	350,000	6,300	82,000	--	6300	--	0.33	6300
N-Nitroso-di-n-propylamine	621-64-7	--	--	0.14	--	19	--	0.078	0.33	0.0448	0.0448	--	0.33	0.33
N-Nitrosodiphenylamine	86-30-6	20	--	200	--	27,000.00	--	110	470	0.298	0.298	--	0.33	0.33
Nitrobenzene	98-95-3	40	--	--	160	--	7,000	5.1	22	0.0638	0.0638	--	0.1	0.1
Pentachlorophenol	87-86-5	3	--	2.5	400	330	18,000	1.0	4.0	0.317	0.317	--	0.66	0.66
2,4,6-Trichlorophenol	88-06-2	10	--	91	80	12,000	3,500	49	210	0.116	0.116	--	0.33	0.33
TPH														
Gasoline	86290-81-5	100	30/100	--	--	--	--	--	--	--	100	--	1	100
Lube Oil		--	2,000	--	--	--	--	--	--	--	2,000	--	10	2000
VOCs														
Acetone	67-64-1	--	--	--	72,000	--	3,200,000	61,000	670,000	29	29	--	0.01	29
Acrolein	107-02-8	--	--	--	40	--	1,800	0.14	0.6	***	0.14	--	0.02	0.14
Acrylonitrile	107-13-1	--	--	1.9	3200	240	140000	0.25	1.1	***	0.25	--	0.05	0.25
Benzene	71-43-2	--	0.03	18	320	2,400.00	14,000	1.2	5.1	0.00564	0.00564	--	0.005	0.00564
Bromodichloromethane	75-27-4	--	--	16	1,600	2,100.00	70,000	0.29	1.3	0.00521	0.00521	--	0.005	0.00521
Bromoform	75-25-2	--	--	130	1,600	17,000.00	70,000	19	86	0.0302	0.0302	--	0.005	0.0302
Bromomethane	74-83-9	--	--	--	110	--	4,900	7	30	0.0509	0.0509	--	0.005	0.0509
Carbon disulfide	75-15-0	--	--	--	8,000	--	350,000	770	3,500	2.83	2.83	--	0.005	2.83
Carbon tetrachloride	56-23-5	--	--	14	320	1,900	14,000	0.65	2.9	0.00921	0.00921	--	0.005	0.00921
Chlorobenzene	108-90-7	40	--	--	1,600	--	70,000	280	1,300	0.874	0.874	--	0.005	0.874
Chloroform	67-66-3	--	--	32	800	4200	35,000	0.32	1.4	0.00638	0.00638	--	0.005	0.00638
Chloromethane	74-87-3	--	--	--	--	--	--	110	460	--	110	--	0.005	110
2-Chlorotoluene	95-49-8	--	--	--	1,600	--	70,000	1,600	23,000	--	1600	--	0.005	1600
1,2-Dibromo-3-chloropropane	96-12-8	--	--	1.3	16	160	700	0.0053	0.064	--	0.0053	--	0.01	0.01
Dibromochloromethane	124-48-1	--	--	12	1,600	1,600.00	70,000	8.3	39	0.00532	0.00532	--	0.005	0.00532
1,4-Dichlorobenzene	106-46-7	20	--	190	5600	24000	250000	2.6	11	0.0808	0.0808	--	0.005	0.0808
Dichlorodifluoromethane	75-71-8	--	--	--	16,000	--	700,000	87	370	--	87	--	0.01	87
1,2-Dichloroethane	107-06-2	--	--	11	480	1,400.00	21,000	0.46	2.0	0.00483	0.00483	--	0.005	0.005
1,1-Dichloroethene	75-35-4	--	--	--	4,000	23000	700,000	230	1,000	0.0501	0.0501	--	0.005	0.0501
cis-1,2-Dichloroethene	156-59-2	--	--	--	160	--	7,000	160	2,300	0.08	0.08	--	0.01	0.08
trans-1,2-Dichloroethene	156-60-5	--	--	--	1,600	--	70,000	160	2,300	0.00543	0.00543	--	0.005	0.00543
Ethyl chloride (chloroethane)	75-00-3	--	--	--	--	--	--	14000	57,000	--	14000	--	0.005	14000
Ethylbenzene	100-41-4	--	6	--	8,000	--	350,000	5.8	25	5.9	5.8	--	0.005	5.8
Ethylene dibromide (EDB) (1,2-Dibromoethane)	106-93-4	--	0.005	0.5	720	6.6	32,000	0.036	0.16	--	0.036	--	0.005	0.036
4-Methyl-2-butanone (4-Methyl-2-pentanone)	108-10-1	--	--	--	6,400	--	280,000	33,000	140,000	***	6400	--	0.01	6400
Methylene chloride	75-09-2	--	0.02	50	4,800	66,000	21,000	57	1000	0.0218	0.0218	--	0.02	0.0218
Styrene	100-42-5	300	--	--	16,000	--	700,000	6,000	35,000	2.24	2.24	--	0.005	2.24
1,1,2,2-Tetrachloroethane	79-34-5	--	--	5	1,600	660	70,000	0.6	2.7	0.0056	0.0056	--	0.005	0.0056
Tetrachloroethene	127-18-4	--	0.05	480	480	63,000	21,000	24	100	0.0255	0.0255	--	0.005	0.0255
1,1,1-Trichloroethane	71-55-6	--	2	--	160,000	--	7,000,000	8,100	36,000	1.58	1.58	--	0.005	1.58
1,1,2-Trichloroethane	79-00-5	--	--	18	320	2,300.00	14,000	1.1	5.0	0.00556	0.00556	--	0.005	0.00556
Trichloroethene	79-01-6	--	0.03	12	40	2,800	1,800	0.9	6.0	0.00661	0.00661	--	0.005	0.00661

DOF DALTON OLMSTED FUGLEVAND

TABLE 7

SOIL PRELIMINARY CLEANUP LEVELS FOR OFF-PROPERTY SOILS [1]
Stericycle Washougal Facility

Concentrations are in milligrams per kilogram (mg/kg)

Constituent	CAS Number	Terrestrial MTCA Table 749-3	Soil, MTCA Method A Cleanup Level, Unrestricted Use	Soil, MTCA Method B Cleanup Level Carcinogenic	Soil, MTCA Method B Cleanup Level Non-Carcinogenic	Soil, MTCA Method C Cleanup Level, Carcinogenic[2]	Soil, MTCA Method C Cleanup Level, Non-carcinogenic[2]	EPA Regional Screening Levels[3] (Residential)	EPA Regional Screening Levels[3] (Industrial)	Soil Cleanup Level Protective of Groundwater[4,8]	Minimum Screening Level	Clark County Natural Background Level[5]	PQL	Off-Property Soil Preliminary Cleanup Level[7]
1,2,3-Trichloropropane	96-18-4	--	--	0.033	320	4.4	14,000	0.0051	0.11	--	0.0051	--	0.02	0.02
1,2,4-Trimethylbenzene	95-63-6	--	--	--	800	--	35,000	300	1800	--	300	--	0.005	300
1,3,5-Trimethylbenzene	108-67-8	--	--	--	800	--	35,000	270	1,500	--	270	--	0.005	270
Toluene	108-88-3	200	7	--	6,400	--	280,000	4,900	47,000	0.414	0.414	--	0.005	0.414
Vinyl chloride	75-01-4	--	--	0.67	240	88	11,000	0.059	1.7	0.000126	0.000126	--	0.005	0.005
m,p-Xylene[10]	106-42-3	--	9	--	16,000	--	700,000	560	2,400	3.02	3.02	--	0.01	3.02

Notes

1. All levels downloaded from Washington State Department of Ecology Cleanup Levels and Risk Calculations (CLARC) website
2. Direct contact (ingestion only), industrial land use.
3. EPA Regional Screening Levels reviewed in 2019.
4. The calculations for soil cleanup levels protective of groundwater followed methods used in the RI.
5. 90th percentile natural background levels from the 1994 Washington State Department of Ecology *Natural Background Soil Metals Concentrations in Washington State.*
6. Applicable PQL updated in 2019.
7. Preliminary cleanup level was selected based on criteria described in text. In some cases, the screening level was adjusted up to the PQL or natural background.
8. For soil COCs that are not groundwater COCs (and did not have a calculated preliminary groundwater cleanup level) the default soil cleanup level protecive of groundwater from CLARC was applied

Abbreviations

-- = not available
*** = Not calculated for COCs not detected in groundwater at concentrations greater than the cleanup level in the last 10 years and, consistent with the empirical demonstration method for deriving soil concentrations for groundwater protection in WAC 173-340-747(3)(f)
CAS = Chemical Abstracts Service
EPA = US Environmental Protection Agency
MTCA = Model Toxics Control Act
PCBs = polychlorinated biphenyls
PQL = practical qnantitation limit
SVOCs = semivolatile organic compounds
TPH = total petroleum hydrocarbons
VOCs = volatile organic compounds

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Appendix B

Technical Memorandum: Feasibility Study – Nature and Extent of Contamination Update

Technical Memorandum:
Feasibility Study – Nature and Extent of Contamination Update

WASHOUGAL FACILITY

WASHOUGAL, WASHINGTON

September 24, 2019

Prepared by:

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September 24, 2019

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DALTON OLMSTED FUGLEVAND

September 24, 2019

1.0 INTRODUCTION

This technical memorandum was prepared to summarize information presented during discussions regarding components of the Feasibility Study (FS), currently under revision, for the Stericycle Environmental Solutions (Stericycle) Washougal, Washington facility. Washington Department of Ecology (Ecology), Ridolfi (Ecology's technical consultant), Stericycle, and Dalton, Olmsted, and Fuglevand (DOF) met on September 5, 2019. The purpose of that meeting was to discuss Stericycle's planned approach to addressing Ecology's 2019 comments on the FS, particularly with regards to the updated nature and extent of contamination, screening of technologies, and remedial alternatives.

DOF prepared this technical memorandum on behalf of Stericycle to document information presented at that September 5, 2019 meeting and subsequently expanded on based on Ecology's requests for additional assessment of areas of the site to be considered in the revised FS. The updated nature and extent of contamination summary are described below.

This memorandum updates previously presented information developed in the Remedial Investigation (RI) and draft FS (AMEC, 2013a and b) to address comments received from Ecology and account for monitoring conducted since the RI and Draft FS were completed, as well as updates to cleanup levels. To streamline this memorandum background information and terminology definitions related to areas of the site and the conceptual site model are not repeated here and should be referenced in the RI, draft FS, and Ecology comments.

2.0 NATURE AND EXTENT OF CONTAMINATION

The distribution of COCs in soil and groundwater at the Site was reviewed in detail in the RI and summarized in the draft FS. COCs at the Site are highly varied in nature and broadly distributed over the entire Site and to a maximum depth of approximately 40 feet bgs, with the water table at 4 to 6 feet below ground surface (bgs), and occasionally shallower. Because VOCs and metals are more widespread around the property and tend to occur in the same locations where elevated levels of other COC groups are found, these groups were designated as indicators of areas of contamination for a broad range of constituents at the facility and to highlight the spatial distribution of COCs.

Elevated levels of COCs were identified in the RI and draft FS as posing a risk in the following primary areas:

- Former Tank Farm Area,
- East of the Former Tank Farm Area,

- North of the Former Tank Farm Area,
- Buildings 2 and 3, and
- Waste Oil Tank Area.

Data from these areas, including data collected since completion of the 2013 draft FS were reviewed to prepare the updated sections below.

2.1 Previous Interim Measures

Previous interim measures have removed much of the contamination from the former tank farm source area, provided information for future designs, and addressed immediate threats to indoor air quality at Building 1. Previous interim measures at the Facility were detailed in the RI and are listed below for reference with locations shown in Figure 1.

- A recovery well (MC-R) operated beginning in 1987 to recover dense nonaqueous-phase liquid (DNAPL) in the area of the former solvent distillation processing area of the tank farm. This interim measure removed approximately 60 gallons of solvent and 18,000 gallons of contaminated groundwater.
- An interim action soil excavation was conducted in September and October 1997 in the former tank farm area. The excavation led to removal of most of the contaminated soil in the source area. Complete source area removal was not possible due to the proximity of Building 1 and the silt layer. COC-impacted silt was left in place below the water table, and soils were not removed immediately adjacent to and underneath Building 1.
- An indoor air inhalation pathway interim measure (IPIM) was implemented to prevent the risk of exposure for workers in Building 1 to VOCs. The IPIM decreases the pressure below the building slab such that pressure inside the building is higher than the pressure in the subsurface. Any flow of air between the building and the slab is forced downward out of the building and into the slab, thereby preventing any volatile constituents that may be present in soil from migrating into the building. It continues to operate.
- A pilot test to assess the effectiveness of using hydrogen-releasing compound (HRC) for enhanced bioremediation of groundwater was conducted in shallow groundwater downgradient of Building 1 in the early 2000s. It provided inconclusive results.

2.2 Soil

No new soil data have been collected at the Site since the RI and draft FS were completed. The 1997 interim action removed contaminated soil from the area of the Site where the most significant contamination was found, but as noted above, the presence of Building 1 made excavation east of the former tank farm infeasible at that time and a building-specific interim measure (the IPIM) was installed instead.

Two other smaller source areas were identified at the Site where soil contamination is the primary concern: the former container storage areas at Building 2 and Building 3, and the area west of the waste oil tank system around GP-109. Soil immediately underneath Buildings 2 and 3 exceeded the cleanup levels for cyanide, PCE, and TCE, but the absence of exceedances for these COCs in groundwater nearby indicates a limited extent of affected soil.

2.3 GROUNDWATER

As presented in the RI, in groundwater, the primary COCs are similar to soil with the same VOCs consistently present, along with chlorinated ethenes, 1,4-dioxane, arsenic, and a few other inorganic COCs. Chlorinated ethenes are the primary VOCs detected above preliminary cleanup levels in groundwater and are considered indicators of contamination at the Site. Although several COC source areas exist on the Stericycle property, the main source area contributing to groundwater impacts is the former tank farm area (Figure 1). This was an area of known releases of chlorinated solvents to the subsurface and has been the focus of considerable investigation and a major soil excavation interim action in 1997. Groundwater flow directions presented in Stericycle's historical quarterly progress reports were reviewed and summarized in Table 1 for context.

2.3.1 Groundwater Trends

As part of preparing the revised FS, groundwater trends for the primary COCs were updated to include more recent data and revised preliminary cleanup levels from the Technical Memorandum: Feasibility Study – Point of Compliance and Preliminary Cleanup Level Assessment (DOF, 2019). These trends are included as Attachment A[1] for the wells routinely monitored at the site in both the Shallow Groundwater Zone and the Lower Aquifer. Table 1 provides a summary of the information shown in these trends.

In general, a COC plume in the Shallow Groundwater Zone follows groundwater flow to the east of the former tank farm area. In the Lower Aquifer, the pattern is less conclusive, but generally the highest detected concentrations of COCs are found below the former tank farm area with lesser impacts observed to the north and southeast. Although 1,4-dioxane and chlorinated VOCs both presumably originated in the former tank farm area, virtually no trace of 1,4-dioxane remains in the vicinity of the former tank farm area except in the Lower Aquifer, where concentrations slightly exceed the preliminary cleanup level. Since 1,4-dioxane has less affinity to sorb to soils, it is likely that the 1,4-dioxane plume moved farther downgradient than the VOC

[1] Note that trends have been updated since Stericycle's September 5, 2019 meeting with Ecology and DOF where they were originally shared. The version provided with this memo includes data for well MC-31 (which was previously missing) and data from the recently conducted second quarter 2019 monitoring event.

plume. Hence, the highest concentrations of 1,4-dioxane are currently measured near the eastern boundary of the property.

Review of the long-term trends in 1,4-dioxane illustrate that at higher concentration wells the concentrations in the Shallow Groundwater Zone go up when the water table is highest, during periods when more of the sandy unit above the silt layer is saturated, making it more readily accessible for treatment. Notably, the highest concentrations remain localized near well MC-14 in the Shallow Groundwater Zone and wells downgradient of this area (MC-20, MC-123) have declined to levels near or below the preliminary cleanup level.

Review of the long-term trends in VOCs show that degradation of chlorinated VOCs has continued and most wells in the Shallow Groundwater Zone currently show concentrations nearing or already below preliminary cleanup levels. The decreasing trends in the Shallow Groundwater Zone lend uncertainty as to how much VOC contaminant mass may remain underlying Building 1. The soil data collected for the RI is useful in identifying sources of contamination and areas where it may be suspected that contaminants may remain for some time. However, for remedy design purposes, additional information to inform current concentrations of COCs, particularly VOCs that have been demonstrated to be naturally degrading at the Site, would be beneficial. To meet this objective, Stericycle and Ecology have discussed collecting additional soil gas data from beneath Building 1 via the existing soil gas monitoring ports installed during the RI as part of investigation and implementation of the IPIM. Stericycle plans to conduct this sampling in late 2019 to allow for use in the draft cleanup action plan.

COC concentrations in groundwater in the Lower Aquifer are generally low outside of the former tank farm with a few exceptions as described below where COCs have migrated at lower levels, primarily to areas north and southeast of the tank farm.

Groundwater in the Lower Aquifer immediately below the Silt Layer continues to show exceedances of preliminary cleanup levels within the Stericycle property for chlorinated solvents and their breakdown products. These exceedances represent relatively low levels for both PCE and TCE (<5 micrograms per liter [µg/L]), but higher levels for the chlorinated daughter products (200-400 µg/L for VC and 1,000-1,500 µg/L for *cis*-1,2-DCE). Concentrations of all of the chlorinated ethenes in former tank farm area wells MC-24D and MC-25D show stable or declining PCE and TCE, and increasing *cis*-1,2-DCE and VC, similar to the degradation pattern observed elsewhere at the Site. The deeper Lower Aquifer paired wells (MC-24D2 and MC-25D2) show concentrations that have leveled off and remained low for several years. Wells outside of the former tank farm show generally low levels of chlorinated VOCs with occasional elevated concentrations, though much lower than observed in the former tank farm area. The exception to this is well MC-15D. This well has shown low levels of PCE and TCE (less than 1 ug/L) but an increase in degradation compounds *cis*-1,2-DCE and VC. The low levels of parent compound VOCs and the lack of historical concentrations of elevated VOCs in the paired shallow well MC-15 indicate the source of contamination detected at MC-15D is likely the upgradient residual former tank farm contamination (see Table 1).

Lower Aquifer trends in 1,4-dioxane concentrations show variable but generally steady concentrations above the preliminary cleanup level in the same area that chlorinated VOCs are found at MC-24D, MC-25D, and MC-118D (5-15 µg/L), slightly lower concentrations at MC-27D and MC-30D (1-3 µg/L), and a declining trend at well MC-12D where concentrations historically were above the preliminary cleanup level. Other wells remain steady and generally low or non-detect for 1,4-dioxane with the exception of MC-15D which, similar to VC and *cis*-1,2-DCE, shows a rising trends in the 2-5 µg/L concentration range.

In general, the highest concentrations of inorganic constituents (arsenic, zinc, copper, cadmium, chromium, manganese, nickel, and vanadium) in the Shallow Groundwater Zone have been found in samples collected at points located in identified source areas, including the waste oil tank area, north of the former tank farm area, and east of Building 1. While some metals were likely released due to facility operations, several metals present at elevated concentrations in groundwater appear to be related to changes in groundwater geochemistry caused by releases of organic constituents.

Anaerobic conditions likely existed in the former marsh prior to industrial activities owing to the high organic content of native sediments. Aerobic microbial breakdown of the released organic constituents further depleted the groundwater of dissolved oxygen. The organic Silt Layer is likely to still be creating reducing conditions in the Shallow Groundwater Zone with the strongest reducing conditions occurring during the drier summer season, as is evidenced by the low dissolved oxygen content in wells and relatively high arsenic levels found throughout the Site that do not appear to be related to any release from Facility operations. As such, arsenic concentrations are considered primarily a background issue associated with reducing geochemical conditions at the Site.

2.3.2 Current Concentrations

Recent concentrations of primary COCs in groundwater are shown on Figure 1 for the Shallow Groundwater Zone and on Figure 2 for the Lower Aquifer. The intent of these figures is to visually show source areas at the Site that appear to be contributing most significantly to groundwater contamination and driving risk. Additional figures showing isoconcentration contour maps for key COCs and detailed investigation results were provided in the RI (AMEC, 2013).

Current concentrations of COCs in groundwater at the Site do not indicate the presence of DNAPL in the subsurface. DNAPL was not encountered during the 1997 excavation interim measure or subsequent investigations in the source area in the former tank farm area. Residual chlorinated and nonchlorinated organic COCs are present in groundwater and adsorbed in the Silt Layer. These COCs adsorbed to the Silt Layer represent a long-term, continuing secondary source of COCs to groundwater but appear to no longer be heavily affecting the Shallow Groundwater Zone.

2.3.3 Cyanide

As discussed in the RI, cyanide has been detected in soil at concentrations below preliminary cleanup levels developed for all pathways except groundwater protection. To assess potential impacts of cyanide to groundwater, cyanide was included in the list of analytes at wells MC-15, MC-16, and MC-17 as part of quarterly groundwater monitoring during the fourth quarter 2013 and first quarter 2014. The results of this investigation are summarized in Table 2. Cyanide was not detected in any of the samples.

3.0 REFERENCES

AMEC, 2013a, Final Remedial Investigation Report, PSC Washougal Facility, September.

AMEC, 2013b, Final Feasibility Study Report, PSC Washougal Facility, December.

DOF, 2019, Technical Memorandum: Feasibility Study – Point of Compliance and Preliminary Cleanup Level Assessment, August.

5.0 CLOSING

The services described in this report were performed consistent with generally accepted professional consulting principles and practices. No other warranty, expressed or implied, is made. This report is solely for the use and information of our client unless otherwise noted. Any reliance on this report by a third party is at such party's sole risk.

TABLE 1
GROUNDWATER FLOW DIRECTION SUMMARY
Stericycle Washougal Facility
Washougal, Washington

	GW Flow Direction	
Qtr	**Shallow**	**Lower Aquifer**
3Q 2014	E-NE	SW-S
3Q 2015	E-NE	S
4Q 2015	E-NE	SE
1Q 2016	E-NE	E
2Q 2016	E-NE	SE
3Q 2016	E-NE	S
4Q 2016	E-NE	SE-S
1Q 2017	E-NE	NE
2Q 2017	E-NE	NE
3Q 2017	E-NE	SE-S
4Q 2017	E-NE	SE-S
1Q 2018	E-NE	SE
2Q 2018	E-NE	SE
3Q 2018	E-NE	S
4Q 2018	E-NE	S

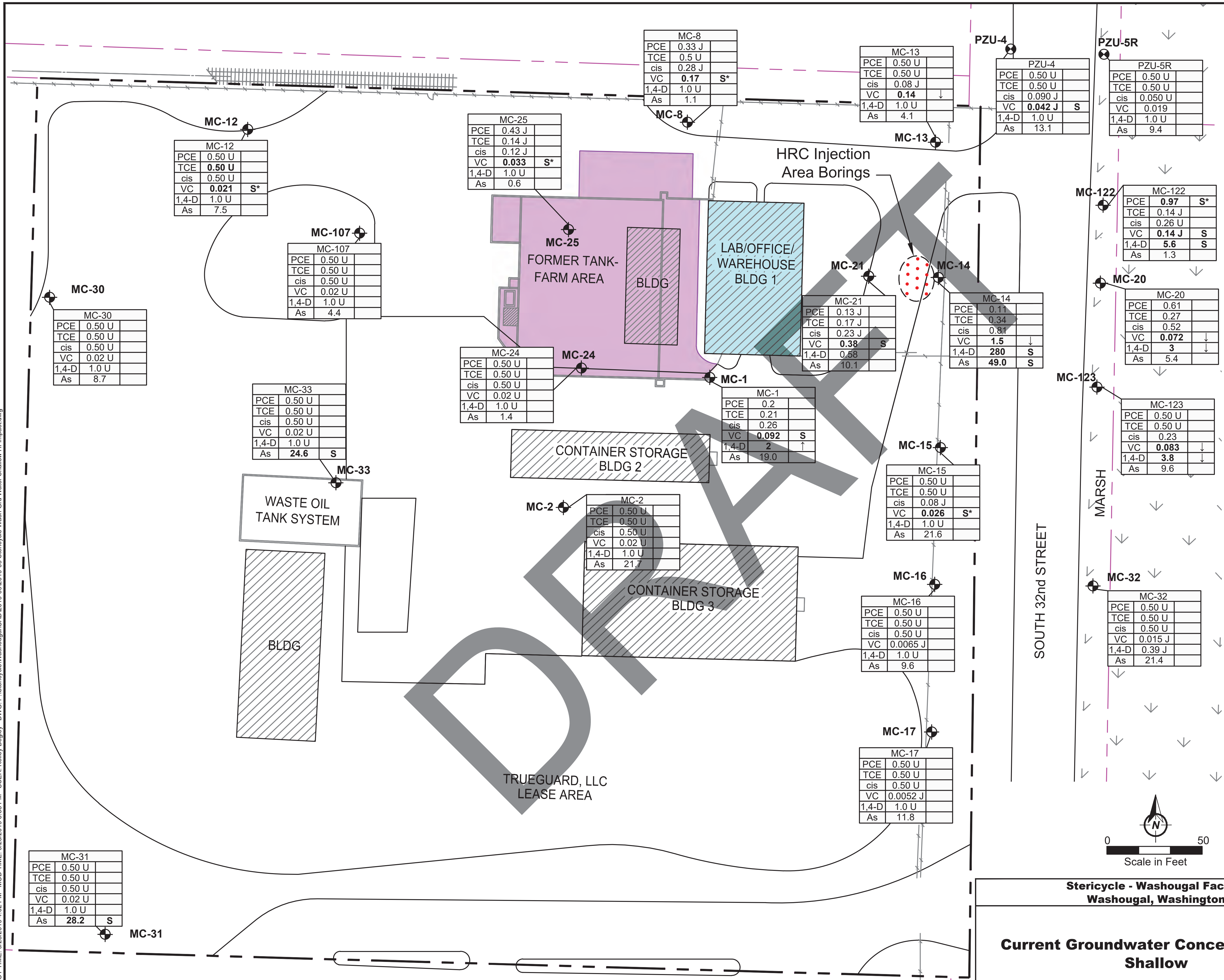
TABLE 2
SUMMARY OF CYANIDE CONCENTRATIONS

Stericycle Washougal Facility

Washougal, Washington

Concentrations are in micrograms per liter (mg/L)

Well	2Q 2004	2Q 2009	4Q 2013	1Q 2014	2Q 2014
MC-14	< 0.01	< 0.003	--	--	< 0.003
MC-15	--	--	< 0.003	< 0.003	--
MC-16	--	--	< 0.003	< 0.003	--
MC-17	--	--	< 0.003	< 0.003	--



LEGEND

- Property Line
- Offsite Parcel Line
- MC-13 Shallow Groundwater Zone Monitoring Well
- PZU-4 Piezometer
- HRC Injection Area Boring
- Depressurization System-Building 1
- Area of 1997 Excavation

DATABOX KEY

PCE	Tetrachloroethene
TCE	Trichloroethene
cis	cis-1,2-Dichloroethene
VC	Vinyl Chloride
1,4-D	1,4-Dioxane
As	Arsenic

Shallow CUL (ug/L)		← Location I.D.
PCE	0.69	Highest detected concentration (ug/L)
TCE	0.38	
cis	16	
VC	0.02	
1,4-D	1	
As	22.8	← Average concentration (ug/L)

DATA QUALIFIERS

U= analyte was not detected at the quantitation limit indicated.
J= analyte was positively identified. Result is an estimated value.
Bold= above cleanup level.
↑= indicates an increasing concentration trend 2003 to 2019
↓= indicates a decreasing concentration
S= indicates a stable concentration
*= indicates a single anomalous detection above the cleanup level between 2Q 2018 and 1Q 2019

NOTES:

Values shown for VOCs are highest detected concentrations (or highest detection limit for non-detect analytes) from four quarters of sampling (2Q2018 through 1Q2019). Values shown for arsenic are average total arsenic concentrations over four quarters of sampling.

Concentrations shown in µg/L.

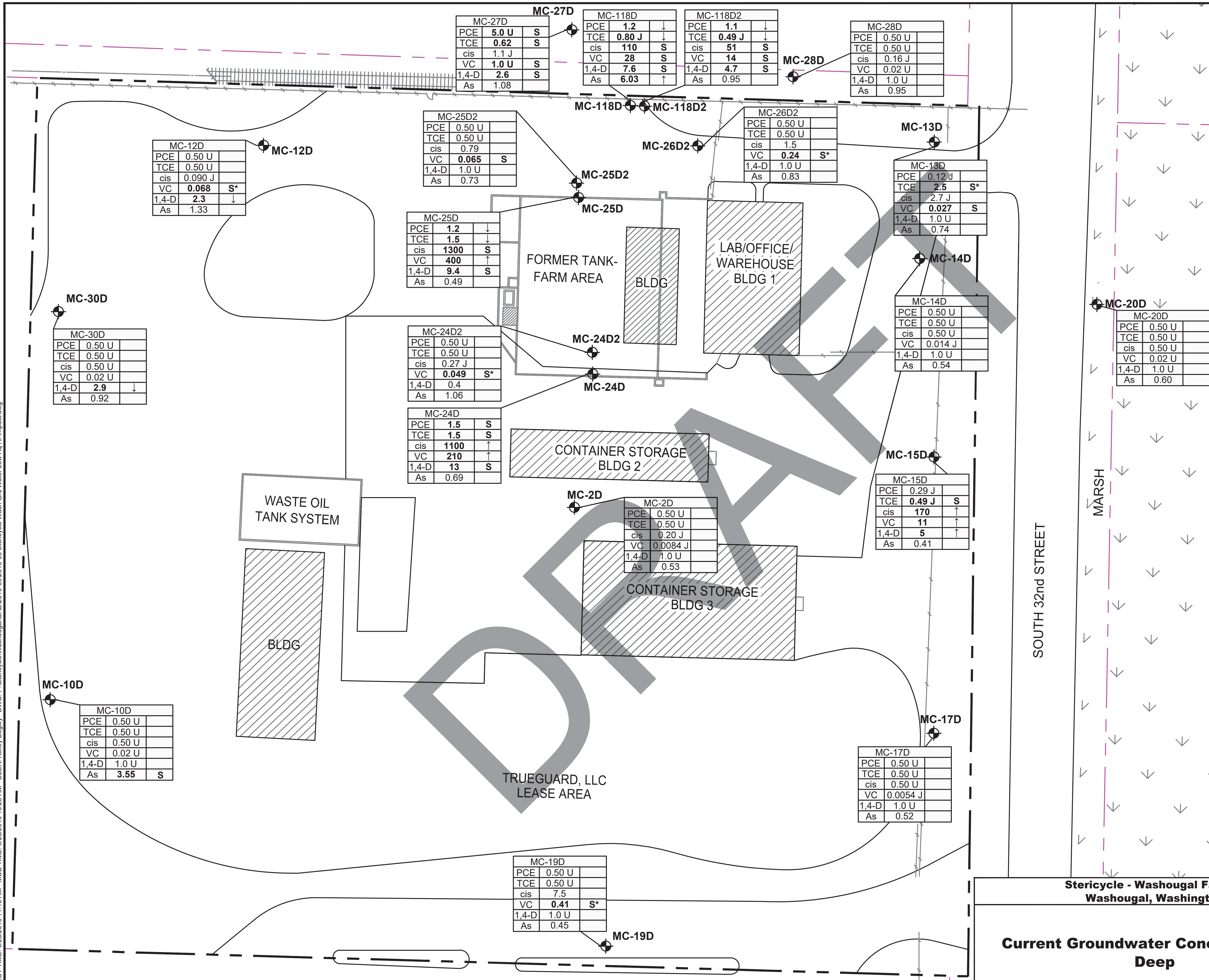
Stericycle - Washougal Facility
Washougal, Washington

Current Groundwater Concentrations - Shallow

DALTON OLMSTED FUGLEVAND

FIGURE 1

September 23, 2019



MC-27D		
PCE	**5.0 U**	**S**
TCE	**0.62**	**S**
cis	1.1 J	
VC	**1.0 U**	**S**
1,4-D	**2.6**	**S**
As	1.08	

MC-118D		
PCE	**1.2**	↓
TCE	**0.80 J**	↓
cis	**110**	**S**
VC	**28**	**S**
1,4-D	**7.6**	**S**
As	**6.03**	↑

MC-118D2		
PCE	**1.1**	↓
TCE	**0.49 J**	↓
cis	**51**	**S**
VC	**14**	**S**
1,4-D	**4.7**	**S**
As	0.95	

MC-28D		
PCE	0.50 U	
TCE	0.50 U	
cis	0.16 J	
VC	0.02 U	
1,4-D	1.0 U	
As	0.95	

MC-12D		
PCE	0.50 U	
TCE	0.50 U	
cis	0.090 J	
VC	**0.068**	**S***
1,4-D	**2.3**	↓
As	1.33	

MC-25D2		
PCE	0.50 U	
TCE	0.50 U	
cis	0.79	
VC	**0.065**	**S**
1,4-D	1.0 U	
As	0.73	

MC-26D2		
PCE	0.50 U	
TCE	0.50 U	
cis	1.5	
VC	**0.24**	**S***
1,4-D	1.0 U	
As	0.83	

MC-13D		
PCE	0.12 J	
TCE	**2.5**	**S***
cis	2.7 J	
VC	**0.027**	**S**
1,4-D	1.0 U	
As	0.74	

MC-25D		
PCE	**1.2**	↓
TCE	**1.5**	↓
cis	**1300**	**S**
VC	**400**	↑
1,4-D	**9.4**	**S**
As	0.49	

MC-30D		
PCE	0.50 U	
TCE	0.50 U	
cis	0.50 U	
VC	0.02 U	
1,4-D	**2.9**	↓
As	0.92	

MC-24D2		
PCE	0.50 U	
TCE	0.50 U	
cis	0.27 J	
VC	**0.049**	**S***
1,4-D	0.4	
As	1.06	

MC-14D		
PCE	0.50 U	
TCE	0.50 U	
cis	0.50 U	
VC	0.014 J	
1,4-D	1.0 U	
As	0.54	

MC-20D		
PCE	0.50 U	
TCE	0.50 U	
cis	0.50 U	
VC	0.02 U	
1,4-D	1.0 U	
As	0.60	

MC-24D		
PCE	**1.5**	**S**
TCE	**1.5**	**S**
cis	**1100**	↑
VC	**210**	↑
1,4-D	**13**	**S**
As	0.69	

MC-15D		
PCE	0.29 J	
TCE	**0.49 J**	**S**
cis	**170**	↑
VC	**11**	↑
1,4-D	**5**	↑
As	0.41	

MC-2D		
PCE	0.50 U	
TCE	0.50 U	
cis	0.20 J	
VC	0.0084 J	
1,4-D	1.0 U	
As	0.53	

MC-10D		
PCE	0.50 U	
TCE	0.50 U	
cis	0.50 U	
VC	0.02 U	
1,4-D	1.0 U	
As	**3.55**	**S**

MC-17D		
PCE	0.50 U	
TCE	0.50 U	
cis	0.50 U	
VC	0.0054 J	
1,4-D	1.0 U	
As	0.52	

MC-19D		
PCE	0.50 U	
TCE	0.50 U	
cis	7.5	
VC	**0.41**	**S***
1,4-D	1.0 U	
As	0.45	

LEGEND

Property Line

Offsite Parcel Line

MC-13 Shallow Groundwater Zone Monitoring Well

DATABOX KEY

PCE Tetrachloroethene

TCE Trichloroethene

cis cis-1,2-Dichloroethene

VC Vinyl Chloride

1,4-D 1,4-Dioxane

As Arsenic

Deep CUL (ug/L)	
PCE	0.69
TCE	0.38
cis	16
VC	0.02
1,4-D	1
As	22.8

← Location I.D.

Highest detected concentration (ug/L)

← Average concentration (ug/L)

DATA QUALIFIERS

U= analyte was not detected at the quantitation limit indicated.

J= analyte was positively identified. Result is an estimated value.

Bold= above cleanup level.

↑= indicates an increasing concentration trend 2003 to 2019

↓= indicates a decreasing concentration

S= indicates a stable concentration

*= indicates a single anomalous detection above the cleanup level between 2Q 2018 and 1Q 2019

NOTES:

Values shown for VOCs are highest detected concentrations (or highest detection limit for non-detect analytes) from four quarters of sampling (2Q2018 through 1Q2019). Values shown for arsenic are average total arsenic concentrations over four quarters of sampling.

Concentrations shown in µg/L.

N

0 50

Scale in Feet

Stericycle - Washougal Facility
Washougal, Washington

DALTON OLMSTED FUGLEVAND

Current Groundwater Concentrations - Deep

FIGURE 2

September 23, 2019

PLOT TIME: 9/23/2019 11:18 AM MOD TIME: 9/23/2019 10:25 AM USER: Kelley Begley DWG: P:\Stericycle\Washougal\CAD\2019-09\2019-09 Stericycle Wash Grd Water Low Aq Hi-Impact.dwg

Appendix C

Revised Technical Memorandum: Feasibility Study – Technology Screening

Revised Technical Memorandum:
Feasibility Study – Technology Screening

WASHOUGAL FACILITY

WASHOUGAL, WASHINGTON

November 12, 2019

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TABLES

1.0 INTRODUCTION

This revised technical memorandum was prepared to summarize information presented during discussions regarding components of the Feasibility Study (FS), currently under revision, for the Stericycle Environmental Solutions (Stericycle) Washougal, Washington facility. Washington Department of Ecology (Ecology), Ridolfi (Ecology's technical consultant), Stericycle, and Dalton, Olmsted, and Fuglevand (DOF) met on September 5, 2019. The purpose of that meeting was to discuss Stericycle's planned approach to addressing Ecology's 2019 comments on the 2013 FS (AMEC, 2013), particularly concerning the updated nature and extent of contamination, screening of technologies, and remedial alternatives.

DOF prepared this technical memorandum on behalf of Stericycle to document information presented at that September 5, 2019 meeting and subsequently expanded on, based on Ecology's requests for additional technology review in the revised FS. This memorandum updates previously presented information about potential remedial technologies developed in the 2013 FS to address comments received from Ecology and account for more recently developed technologies. This includes consideration of comments received from Ecology on a draft version of this memo in October 2019 (Ecology, 2019).

2.0 DEVELOPMENT OF REMEDIAL ALTERNATIVES

WAC 173-340-360 describes the minimum requirements and procedures for selecting cleanup actions under the Model Toxics Control Act (MTCA). Cleanup actions selected under MTCA must meet "threshold requirements" outlined in WAC 173-340-360(2)(a) of:

- Protecting human health and the environment;
- Complying with cleanup standards;
- Complying with applicable state and federal laws; and
- Providing for compliance monitoring.

In addition, cleanup shall adhere to "other requirements" outlined in WAC 173-340-360(2)(b):

- Using permanent solutions to the maximum extent practicable.
- Providing for a reasonable restoration time frame.
- Considering public concerns.

Additional cleanup action requirements are addressed in the remaining portions of WAC 173-340-360(2)(c through h).

Potentially applicable remediation technologies are considered in the revised FS to address the exposure pathways associated with concentrations of COCs in soil and groundwater. A wide range of potentially applicable technologies were selected for evaluation relative to the specific remediation considerations for the site. If appropriate for the site conditions, technologies will be assessed in different combinations as remedial alternatives that will satisfy the MTCA criteria described above. This memorandum includes information about newly identified technologies and additional detail regarding potential applicability of various technologies at the site.

Often a disproportionate cost analysis is conducted as part of an FS to aid in evaluating permanence of a potential clean action. WAC 173-340-360(f) outlines evaluation criteria to be used in such an analysis. These criteria provide a helpful framework for evaluating technologies against site-specific conditions and have therefore been incorporated in the screening summarized in this memo. Cost is one of the seven criteria under the DCA framework, but was not used as a basis for retention or rejection of a technology in Tables 5-2 and 5-4.

After the technology screening presented in this memorandum has been approved, technology combinations will be identified as separate cleanup action alternatives for consideration at the site. Alternatives will carefully consider the requirements of WAC 173-340-360 noted above.

3.0 POTENTIALLY APPLICABLE REMEDIAL TECHNOLOGIES

This section presents the potentially applicable remediation technologies considered in the revised FS. Technologies were re-evaluated based on updated state of practice since the 2013 FS was submitted. Several technologies are now included that had not been previously evaluated in the 2013 FS. Because the revised FS is intended to be a focused FS, only those technologies that show the greatest potential to satisfy the site remediation objectives were retained for development of remedial alternatives. A summary of the remediation technologies considered for the revised FS for soil and groundwater are provided in Tables 5-1 and 5-3, respectively. The results of the technology screening are presented in Table 5-2 for soil and in Table 5-4 for groundwater. A list of the retained technologies for both soil and groundwater is presented in Table 5-5. Table numbering used in the 2013 FS was preserved in this memorandum to make comparisons easier for review.

3.1 TECHNOLOGY SCREENING CRITERIA

The technologies described in Tables 5-1, 5-2, 5-3, and 5-4 were screened to identify those technologies best suited for potential use in developing remedial alternatives for the site. The applicability of each technology was considered in light of:

- Remediation objectives presented in Section 4.2 of the 2013 FS;
- Updated data on technology performance (with heavier weight given to peer reviewed and government agency provided literature, as well as data regarding implementation of technologies performed under similar geologic and hydrologic conditions); and
- Physical site characteristics.

Potential remediation technologies were originally screened in the 2013 FS based on the following four screening criteria:

1. **Technology Development Status** (bench, pilot, or full scale): This criterion refers to the level of development for the technology in addressing the COCs observed at the site. Technologies with full-scale implementation are favored over less developed technologies, such as those that have shown limited effectiveness at treating the COCs observed at the site or that are still in early stages of development (such as technologies only tested in bench-scale or pilot studies).
2. **Performance Record:** This criterion refers to the technology's record of successfully attaining the remediation objectives established for the technology in prior implementations for projects with similar site conditions. Factors to evaluate include ability to achieve cleanup levels, the time required to meet the cleanup levels, and the ability to meet the cleanup levels without the potential for future re-contamination (i.e., mobilization of contaminants). Technologies successfully implemented in a variety of environmental and geologic settings (especially environments similar to the site) are favored over technologies with a more restricted application record.
3. **Contaminants Addressed:** This criterion refers to the constituents the technology is capable of addressing. Only technologies demonstrated capable of addressing the specific constituents in the specific media of interest (soil or groundwater) are retained for the FS.
4. **Implementability within the Constraints of the Site:** This criterion refers to the ability to be implemented including consideration of whether the alternative is technically possible, availability of necessary off-site facilities, services and materials, administrative and regulatory requirements, scheduling, size, complexity. Monitoring requirements, access for construction operations and monitoring, and integration with existing facility operations and other current and potential remedial actions. Technologies requiring minimal access and simpler permitting are favored over technologies requiring extensive permitting or access to numerous locations. Technologies that require significant infrastructure (permanent wells, extensive piping runs, public and private easements, and access agreements) might be difficult to implement due to the associated logistical and administrative challenges; it is possible that in select cases some of these technologies might not be practicably implementable. Technologies that support and build on the documented natural degradation of VOCs are favored over those technologies that arrest or interrupt this natural degradation. However, technologies that arrest or interrupt natural degradation are not discounted if they achieve cleanup levels.

In the 2013 FS, Tables 5-1 and 5-3 provided information on criteria 1, 2, and 3 above, with

Tables 5-2 and 5-4 providing details on criteria #4 and a summary of why the technology was retained or rejected. The attached revised Tables 5-1, 5-2, and 5-3 are similarly setup, with updates based on changes in information available on technology, or site conditions, since the 2013 FS was submitted. New technologies added for consideration after the 2013 FS submittal are noted.

A review of the nature and extent of soil contamination was completed as part of the revised FS. No new soil data has been collected and no new interim measures have been performed that would change the conclusions of the 2013 FS for soil. The source areas for soil noted in the 2013 FS were the area around the former tank farm and Building 1, the soil under the former container storage areas at Building 2 and Building 3, and west of the waste oil tank system around GP-109. In contrast, additional groundwater data has been collected quarterly since the 2013 FS, allowing for development of long term trends that provide insight on the nature and extent of site contaminants (DOF, 2019). Groundwater monitoring data in shallow wells around Building 1 indicate predominantly decreasing concentration trends. The decreasing trends coupled with seasonally high groundwater that is only a few feet from the surface leaves uncertainty as to how much VOC contaminant mass may remain underlying Building 1. Stericycle plans to conduct soil gas sampling underneath Building 1 to further evaluate current concentrations of VOCs in this area. For purposes of technology identification and screening the conditions are assumed to potentially require treatment and therefore details on the soil technology screening approach remain unchanged, aside from new technologies added into the review.

Significant revisions to Table 5-4 (groundwater technology screening summary) were made due to the complexity of site use, physical conditions, long term COC trends, and the range of COCs still of concern in groundwater. Additional columns were added to Table 5-4 to clarify the site specific concerns of each groundwater technology. The technologies were evaluated against protectiveness, permanence, cost, effectiveness over the long-term, management of short term risks, and technical and administrative implementability. These criteria are typically used for disproportionate cost analysis of alternatives (WAC 173-340-360(f)), but in response to questions raised in Ecology's review of the 2013 FS, they have been used to provide a helpful framework for evaluating technologies against site-specific conditions. Table 5-4 also includes a brief summary of the reasons each technology was rejected or accepted.

4.0 REVISED FS NEXT STEPS

Once the retained technologies for soil and groundwater are approved by Ecology, Stericycle will update the FS Section 5 text (which covers detailed descriptions of remedial technologies), and Section 6 FS text regarding Remedial Alternative Evaluation Criteria. The remedial alternatives provided in Section 7 of the 2013 FS (Development and Evaluation of Remedial

Alternatives) will be re-evaluated to see if new technologies warrant addition, or if there are different combinations of technologies that should be compared in the revised FS to provide improvements in protectiveness, permanence, cost, effectiveness over the long-term, management of short term risks, and/or technical and administrative implementability.

Draft remedial alternatives will be provided to Ecology for review, and once agreed upon, a revised FS Section 7 will be prepared. Once Section 7 is approved, the full revised FS will be submitted for Ecology review.

5.0 REFERENCES

AMEC, 2013, Final Feasibility Study Report, PSC Washougal Facility, December.

DOF, 2019, Technical Memorandum: Feasibility Study – Nature and Extent of Contamination Update, September.

Ecology, 2019, Email RE: Stericycle Washougal FS Technology Screening, from Kaia Petersen, Ecology, to Tasya Gray, DOF, October 28.

6.0 CLOSING

The services described in this report were performed consistent with generally accepted professional consulting principles and practices. No other warranty, expressed or implied, is made. This report is solely for the use and information of our client unless otherwise noted. Any reliance on this report by a third party is at such party's sole risk.

TABLE 5-1
SUMMARY OF REMEDIATION TECHNOLOGIES CONSIDERED FOR SOIL
Stericycle Washougal Facility
Washougal, Washington

Technology Characteristics							
General Response Actions	**Remediation Technologies**	**Section**	**Technology Description**	**Technology Development Status**	**General Performance Record**	**Site Areas Addressed**	**Site Contaminants Addressed**
In Situ Biological Treatment	Bioventing	5.2.1.1	Oxygen is delivered to contaminated unsaturated soils by forced air movement (either extraction or injection of air) to increase oxygen concentrations and stimulate biodegradation.	Full-Scale	Performs well for nonhalogenated organic compounds in moist soils that biodegrade aerobically (such as BTEX). Low effectiveness for halogenated organics. Ineffective on PCBs, inorganics, and in dry soils	Upper Sand Unit east of Building 1 and in the former tank farm area.	TPH Constituents and VC.
	Enhanced Bioremediation	5.2.1.2	The activity of naturally occurring microbes is stimulated by circulating water-based solutions through contaminated soils to enhance in situ biological degradation of organic contaminants. Nutrients, oxygen, or other amendments may be used to enhance bioremediation and contaminant desorption from subsurface materials.	Full-Scale	Anaerobic bioremediation has been moderately effective on halogenated VOCs. Aerobic bioremediation has been moderately effective for VC, SVOCs and effective for TPH. Ineffective on inorganics and PCBs.	Areas located beneath the former fuel farm area and Building 1 (Upper and Lower Aquifer Units).	Halogenated VOCs (ethenes and TCP), SVOCs, TPH (BTEX).
	Phytoremediation	5.2.1.X	Broadly defined as the use of vegetation to address in situ biological degradation, sequestration, or capture of contaminants.	Full-Scale	Typical organic contaminants, such as petroleum hydrocarbons, gas condensates, crude oil, chlorinated compounds, pesticides, and explosive compounds, can be addressed using plant-based methods. Phytotechnologies also can be applied to typical inorganic contaminants, such as heavy metals, metalloids, radioactive materials, and salts (ITRC 2009).	Areas outside of containment located along the east fence line (possible source for 1,4-dioxane) and the area west of the waste oil tank system.	Halogenated VOCs, SVOCs, TPH, metals, and 1,4-dioxane.
In Situ Physical/Chemical Treatment	Chemical Oxidation	5.2.1.3	Oxidation chemically converts hazardous contaminants to nonhazardous or less toxic compounds that are more stable, less mobile, and/or inert. The oxidizing agents most commonly used are ozone, hydrogen peroxide, persulfate, or permanganate. Reaction occurs only in aqueous solution.	Full-Scale	Technology demonstrated to be effective under certain site conditions. Ineffective for most inorganics, but would be effective for cyanide.	Areas located beneath the former fuel farm area and Building 1 (Upper and Lower Aquifer Units).	Halogenated and nonhalogenated VOCs and SVOCs, TPH compounds, and 1,4-dioxane.
	Soil Flushing	5.2.1.4	Water, or water containing an additive to enhance contaminant solubility, is applied to the soil or injected into the groundwater to raise the water table into the contaminated soil zone. Contaminants are leached into the groundwater, which is then extracted and treated.	Full-Scale	Poor performance record. Few sites have been successfully remediated using this technology.	Vadose zone soil areas located beneath the former fuel farm area and east of Building 1.	Some inorganics and some organics, depending on site and constituent conditions and additive used (i.e. metals with chelatants, solvents with cosolvents, etc.).

TABLE 5-1
SUMMARY OF REMEDIATION TECHNOLOGIES CONSIDERED FOR SOIL
Stericycle Washougal Facility
Washougal, Washington

Technology Characteristics							
General Response Actions	**Remediation Technologies**	**Section**	**Technology Description**	**Technology Development Status**	**General Performance Record**	**Site Areas Addressed**	**Site Contaminants Addressed**
In Situ Physical/Chemical Treatment (cont.)	Soil Vapor Extraction	5.2.1.5	Removes volatile constituents from the vadose zone. Using a blower, a vacuum is applied to wells screened in the vadose zone, and the volatiles are entrained in the extracted air and removed with the soil vapor. Off gases are generally treated to control emissions using thermal destruction or adsorption technologies.	Full-Scale	Proven reliable and effective technology for VOCs. Not effective for SVOCs, PCBs, and inorganics.	Vadose zone soil areas on site around the former tank farm area and Building 1 .	Halogenated VOCs and TPH Constituents.
	Solidification/ Stabilization	5.2.1.6	Contaminants are physically bound or enclosed within a stabilized mass (solidification), or chemical reactions are induced between the stabilizing agent and contaminants either to reduce their mobility (stabilization) or to treat contaminated soil in situ (deep soil mixing).	Full-Scale	Several different field methods are used for this generalized approach. Stabilization reagents can be effective. Complete mixing can be difficult. Can be combined with variants such as deep soil mixing employing treatment technologies (e.g. zero-valent iron) to treat various COCs.	Vadose zone soil and silt around the former fuel tank area and around Building 1.	Metals and if deep soil mixing with ZVI is used; organics.
In Situ Thermal Treatment	High-Temperature Volatilization	5.2.1.7	Steam, electrical energy, or soil heaters are injected below the contaminated zone to heat contaminated soil. The heating enhances the release of contaminants from the soil matrix. Some VOCs and SVOCs are stripped from the contaminated zone and brought to the surface through soil vapor extraction.	Full-Scale	Performance of steam injection and stripping is highly variable and site specific. Installation of soil heaters will result in uneven heating and may desiccate soils. **Electrical resistive heating would be the most effective technology** but may require excess energy and time to adequately treat the target VOCs and SVOCs.	All primary impacted soil areas around the former fuel tank area and beneath/around Building 1.	VOCs, SVOCs, may treat cyanide
Containment	Cap/Surface Cover	5.2.1.8	Surface caps constructed of asphalt concrete, Portland cement concrete, or flexible membrane liners prevent direct exposure to soil contaminants, control erosion, and reduce infiltration of storm water into the subsurface, reducing the leaching of COCs to groundwater.	Full-Scale	Proven effective for preventing surface exposure to buried waste and for reducing infiltration of surface water through waste, limiting leaching of COCs to groundwater.	All impacted soil areas around the former fuel tank area, building 2 and building 3, and west of the waste oil tank system.	VOCs, SVOCs, TPH, inorganics
Ex Situ Biological Treatment (assumes excavation)	Biopiles	5.2.2.1	Excavated soils are mixed with soil amendments and placed on a treatment area that includes leachate collection systems and some form of aeration to support bioremediation of organic constituents in excavated soils. Moisture, heat, nutrients, oxygen, and pH can be controlled to enhance biodegradation.	Full-Scale	Effective for nonhalogenated VOCs and TPH. Less effective on halogenated VOCs and poor effectiveness on PCBs. **Ineffective for inorganics.**	Vadose zone soil areas around the former tank farm area and east of Building 1 with **BTEX.**	TPH (BTEX)
Ex Situ Physical/Chemical Treatment (assumes excavation)	Soil Washing	5.2.2.2	Contaminants sorbed onto fine soil particles are separated from bulk soil in an aqueous-based system on the basis of particle size. The wash water may be augmented with a basic leaching agent, surfactant, pH adjustment, or chelating agent to help remove organics and heavy metals.	Full-Scale	Not widely commercially applied in the United States. Technology sometimes has difficulties treating complex mixtures of organics and inorganics.	Vadose zone soil areas around the former tank farm area and east of Building 1.	VOCs, SVOCs, inorganics, TPH

TABLE 5-1
SUMMARY OF REMEDIATION TECHNOLOGIES CONSIDERED FOR SOIL
Stericycle Washougal Facility
Washougal, Washington

Technology Characteristics							
General Response Actions	**Remediation Technologies**	**Section**	**Technology Description**	**Technology Development Status**	**General Performance Record**	**Site Areas Addressed**	**Site Contaminants Addressed**
Ex Situ Physical/Chemical Treatment (assumes excavation)	Solidification/ Stabilization	5.2.2.3	Contaminants are physically bound or enclosed within a stabilized mass (solidification), or chemical reactions are induced between the stabilizing agent and contaminants to reduce their mobility (stabilization).	Full-Scale	Generally effective for inorganics. Mature technology with documented performance record. Poor effectiveness for organics.	Vadose zone and silt soils in and around the former tank farm area.	Inorganics
Ex Situ Thermal Treatment (assumes excavation)	Thermal Desorption	5.2.2.4	Wastes are heated to volatilize water and organic contaminants. A carrier gas or vacuum system transports volatilized water and organics to the gas treatment system.	Full-Scale	Proven effective at low temperature for TPH and VOCs; at high temperature, effective for SVOCs, PAHs, and PCBs. Proven and commercial off-the-shelf technology offered by multiple vendors. Not effective for inorganics.	Vadose zone and silt soils in and around the former tank farm area and east of Building 1.	VOCs, SVOCs, TPH
Excavation/Disposal	Excavation and Off- Site Disposal	5.2.2.5	Wastes exceeding site remedial goals are excavated and transported off site to an appropriate hazardous waste land disposal facility.	Full-Scale	Proven effective for all site COCs.	Vadose zone and silt soils in and around the former tank farm area and east of Building 1.	VOCs, SVOCs, TPH, inorganics

Notes
X indicates a new technology added to the table after submittal of the 2013 Feasibility Study

Abbreviations
SVOCs = semivolatile organic compounds
RCRA = Resource Conservation and Recovery Act
COCs = constituents of concern
RI/FS = Remedial Investigation and Feasibility Study
PAHs = polycyclic aromatic hydrocarbon
TPH = total petroleum hydrocarbons
PCBs = polychlorinated biphenyls
VOCs = volatile organic compounds

TABLE 5-2
REMEDIATION TECHNOLOGY SCREENING FOR SOIL
Stericycle Washougal Facility
Washougal, Washington

Technology Characteristics					
General Response Actions	**Remediation Technologies**	**Section**	**Site-Specific Issues Affecting Technology or Implementation**	**Rationale for Retention or Rejection**	**Screening Result**
In Situ Biological Treatment	Bioventing	5.2.1.1	Effectiveness of in situ degradation of halogenated VOCs and SVOCs is low. Technology is ineffective on inorganics and pesticides. Technology will leave a lot of mass of non-halogenated VOCs in subsurface that are buried in silts.	Low effectiveness on high-molecular-weight organic COCs (SVOCs) and halogenated VOCs, and ineffective for inorganics. Would not likely achieve CULs in source areas or at CPOCs for organic VOCs.	Reject
	Enhanced Bioremediation	5.2.1.2	In situ degradation of VOCs (chlorinated and non-chlorinated) is only moderately effective. Ineffective for other site COCs. Would require a system of numerous injection points to distribute bioremediation fluids to the subsurface across a large area, some of which is under existing buildings. Sequential anaerobic/aerobic treatment would be needed to address most of the organic COCs. Would be very difficult to apply substrate to unsaturated soils.	Only moderately effective on halogenated organics and SVOCs and likely would not obtain CULs in contaminant source areas but would likely meet CULs at CPOCs. Likely ineffective on inorganics and pesticides. Very long treatment time likely. Very high cost to implement for soils compared to other technologies, such as chemical oxidation, given uncertainty in performance, multiple injections required, and monitoring requirements.	Reject
	Phytoremediation	5.2.1.X	Only viable in non-containment areas. Would require irrigation systems for the dry season. Soil amendments may be necessary to ensure rapid and sustained growth	Environmentally-friendly “green” and low-tech remedial technology. Operation and maintenance costs are typically lower than those required for traditional remedies (such as soil vapor extraction), because the remedy is generally resilient and self-repairing. Plants can improve site aesthetics (visual appearance and noise).	Retain
In Situ Physical/Chemical Treatment	Chemical Oxidation	5.2.1.3	Handling of oxidant chemicals during remediation presents a safety concern. Chemical oxidant demand of soil can consume large quantities of oxidant (pilot test recommended). Establishing effective oxidant delivery system for even vadose zone distribution difficult. Oxidants can mobilize some metals. This technology may require multiple injection rounds and it may be difficult to implement under Building 1.	Treats all key COCs; remediation time frame is relatively short and depending on the treatment area, may achieve stringent CULs aside from silt source area given difficulty to distribute oxidant in low-permeability soils.	Retain
	Soil Flushing	5.2.1.4	Requires recovery of water (hydraulic capture) and surfactant and separation facilities. Recovered water requires treatment, disposal, and management of treatment residuals. Site would require different surfactants to treat all COCs. Large injection galleries or trenches would require extensive disruption of facility operations. Implementation under Building 1 would be difficult.	Technology is not proven effective. Requires extensive and complex fluids delivery system and recovered fluids treatment system. Technology would not meet cleanup levels and would not remove sufficient mass from source areas to meet CULs at CPOCs.	Reject

TABLE 5-2
REMEDIATION TECHNOLOGY SCREENING FOR SOIL
Stericycle Washougal Facility
Washougal, Washington

Technology Characteristics					
General Response Actions	**Remediation Technologies**	**Section**	**Site-Specific Issues Affecting Technology or Implementation**	**Rationale for Retention or Rejection**	**Screening Result**
In Situ Physical/Chemical Treatment (cont.)	Soil Vapor Extraction	5.2.1.5	Limited vadose zone at Stericycle facility; most contaminants are trapped in the Silt Layer below water table. Contamination in a large percentage of the vadose zone is likely due to smear effects of seasonal water table. Thus, the lower end of the vadose zone is likely to be recontaminated regularly.	The contaminant distribution and hydrogeology at the site are likely to lead to low mass removal and limited effectiveness using this technology. Technology will not meet cleanup levels in vadose zone soils or remove enough mass to meet CPOC CULs.	Reject
In Situ Physical/Chemical Treatment (cont.)	Solidification/ Stabilization	5.2.1.6	Increases in soil volume due to stabilization or solidification reagents ("bulk up" or "fluff") can be significant. Excess soil may require disposal as hazardous waste. Presence of solidified material could affect future site development by creating structural challenges for new buildings. Combining containment and treatment with additives would still not address all COCs.	Deep soil mixing with zero-valent iron has been identified as a potential field method that would remediate organics and reduce COC contact with groundwater, thereby limiting migration of COCs from the PSC property. Deep soil mixing with ZVI is not anticipated to meet stringent CULs in source areas but rather at CPOC.	Retain
In Situ Thermal Treatment	High-Temperature Volatilization	5.2.1.7	Effectiveness can be hindered by high organic carbon content or high moisture content (e.g., soil in the capillary fringe). Would require extensive network of steam distribution points or electrodes to heat soil effectively. For steam injection, significant volumes of water are added to the subsurface, which may flush contaminants from unsaturated soil to groundwater. Volatilization of contaminants may prevent inhalation risk for workers.	ERH is one of the **most effective** treatment technologies in silt formations and may achieve CULs in the source areas and the other target areas. Has been retained for use in soils and groundwater.	Retain
Containment	Cap/Surface Cover	5.2.1.8	The site is a patch-work of different coverings. Would require patching or paving areas of risk to prevent offsite migration or worker exposure.	Would be effective in preventing exposure of workers at the facility to contaminated soils. Would not meet CULs nor reduce any mass of COCs.	Retain
Ex Situ Biological Treatment (assumes excavation)	Biopiles	5.2.2.1	Would require extensive site excavation and soil management and removal of existing concrete cover. Extensive shoring and supporting systems would be required for excavations near existing structures. Some impacted soils would likely remain in place due to the presence of existing structures/buildings. Emission control measures (e.g., tenting site) would likely be required during excavation. Treatability tests required to assess feasibility. RCRA treatment permit would likely be required.	Unproven effectiveness on halogenated VOCs. Ineffective on inorganics. Large excavation would disrupt existing facility cover. Increased worker and public exposure risk associated with excavation and treatment process. Contaminated soils that would be left in place would be above CULs in treatment areas and at CPOCs.	Reject

TABLE 5-2
REMEDIATION TECHNOLOGY SCREENING FOR SOIL
Stericycle Washougal Facility
Washougal, Washington

Technology Characteristics					
General Response Actions	**Remediation Technologies**	**Section**	**Site-Specific Issues Affecting Technology or Implementation**	**Rationale for Retention or Rejection**	**Screening Result**
Ex Situ Physical/Chemical Treatment (assumes excavation)	Soil Washing	5.2.2.2	Would require extensive site excavation, soil management, and removal of existing concrete cover. Extensive shoring and support systems would be required for excavations near existing structures. Some impacted soils would likely remain in place due to the presence of existing structures/buildings. Emission control measures (e.g., tenting site) would likely be required during excavation. Worker and public exposure to impacted soils is significantly increased by this approach. Treatability tests would be required to assess feasibility. Produces wash water and soil residuals, which would require further treatment and off-site disposal. Significant concentrations of humus (natural organics) or clay in soil can disrupt process. RCRA treatment permit would likely be required.	Soil washing may not be effective for complex mixture of organics and inorganics. Extensive shoring and supporting systems would be required for excavations near existing structures. Worker and public exposure risks associated with excavation and treatment process. Contaminated soils that would be left in place would be above CULs in treatment areas and at CPOCs.	Reject
Ex Situ Physical/Chemical Treatment (assumes excavation) (cont.)	Solidification/ Stabilization	5.2.2.3	Would require excavation and soil management. Extensive shoring and support systems would be required for excavations near existing structures. Some impacted soils would likely remain in place due to the presence of existing structures/buildings. Emission control measures (e.g., tenting site) would likely be required during excavation. Treatability tests would be required to assess feasibility. Can result in significant increases in soil volume ("bulk up") that would likely result in off-site disposal of excess material. Because organic wastes would be encapsulated but not destroyed, long-term management of wastes would be required. RCRA treatment permit would likely be required.	Extensive shoring and support systems would be required for excavations near existing structures. Volume increase (bulk up) would result in excess material requiring off-site disposal. Post-treatment waste left on the property would remain a long-term management issue. Not proven effective for organics. Increased worker and public exposure risk associated with excavation and treatment process. Contaminated soils that would be left in place would be above CULs in treatment areas and at CPOCs.	Reject
Ex Situ Thermal Treatment (assumes excavation)	Thermal Desorption	5.2.2.4	Would require excavation and soil management. Extensive shoring and support systems would be required for excavations near existing structures. Some impacted soils would likely remain in place due to the presence of existing structures/buildings. Emission control measures (e.g., tenting site) would likely be required during excavation. Worker and public exposure to impacted soils is significantly increased by this approach. Treatability tests would be required to assess feasibility. Requires large working area for setup of equipment. High soil moisture can increase costs due to extended soil drying. Emissions from thermal desorption must be captured and treated prior to discharge to the atmosphere. RCRA treatment permit would likely be required.	Large excavation and treatment footprint would disrupt existing facility operations. High temperature desorption would address high molecular weight organics (SVOCs), but would also potentially create emissions containing metals. Increased worker and public exposure risk associated with excavation. Contaminated soils that would be left in place would be above CULs in treatment areas and at CPOCs.	Reject

TABLE 5-2
REMEDIATION TECHNOLOGY SCREENING FOR SOIL
Stericycle Washougal Facility
Washougal, Washington

Technology Characteristics					
General Response Actions	**Remediation Technologies**	**Section**	**Site-Specific Issues Affecting Technology or Implementation**	**Rationale for Retention or Rejection**	**Screening Result**
Excavation/Disposal	Excavation and Off-Site Disposal	5.2.2.5	Would require extensive site excavation and soil management. Extensive shoring and support systems would be required for excavations near existing structures. Some impacted soils would likely remain in place due to the presence of existing structures/buildings.	Capable of addressing all contaminants in vadose zone soil. Least administratively, logistically, and technically complex ex situ remediation technology. Potentially applicable to hot spots where other technologies are difficult to implement or expensive. Contaminated soils that would be left in place would be above CULs in excavated areas and at CPOCs.	Retain

Notes
X indicates a new technology added to the table after submittal of the 2013 Feasibility Study

Abbreviations
COCs = constituents of concern
CUL = cleanup level
CPOC = conditional point of compliance
ERH = electrical resistance heating
RCRA = Resource Conservation and Recovery Act
SVOCs = semivolatile organic compounds
VOCs = volatile organic compounds
ZVI = zero-valent iron

TABLE 5-3
SUMMARY OF REMEDIATION TECHNOLOGIES CONSIDERED FOR GROUNDWATER
Stericycle Washougal Facility
Washougal, Washington

Technology Characteristics							
General Response Actions	**Remediation Technologies**	**Section**	**Technology Description**	**Technology Development Status**	**General Performance Record**	**Site Area Addressed**	**Site Contaminants Addressed**
In Situ Biological Treatment	Enhanced Biodegradation with Biosparging	5.3.1	Air and nutrients, if needed, are injected into the saturated zone to increase oxygen levels and promote aerobic biological activity. Air is delivered using a compressor and vertical or horizontal injection wells.	Full-Scale	Performs well for organic compounds that biodegrade aerobically. Not effective for inorganics or chlorinated VOCs. Primarily used at petroleum-impacted sites.	Shallow groundwater and Deep Aquifer around the former tank farm area, along the northern property line and east of Building 1.	VC, TPH (BTEX)
	Oxygen Enhancement with Hydrogen Peroxide or ORC	5.3.2	Oxygen is added to the saturated zone by adding chemicals such as hydrogen peroxide or ORC®. The increased oxygen levels promote aerobic biological activity. Hydrogen peroxide or ORC solutions can be injected into the aquifer or introduced through slow release mechanisms placed in wells.	Full-Scale	Has been effectively used at TPH sites. Performance is similar to but less effective than biosparging.	Shallow groundwater and Lower Aquifer around the former tank farm area and along the northern property line.	VC, TPH (BTEX)
	Co-Metabolic Treatment	5.3.3	Chloroethenes and 1,4-dioxane are organically degraded by aerobic co-metabolism with alkane substrates, such as ethane, by indigenous microbes. Oxygen and the alkane substrate can be added through passive diffusion or through groundwater circulation system.	Full-Scale	Has been effective for degradation of chlorinated solvents and 1,4-dioxane.	Shallow groundwater and Lower Aquifer around the former tank farm area, the northern property line, and east of Building 1.	PCE, TCE, *cis* -1,2-DCE, VC, TPH, 1,4-dioxane
	Biostimulation of Reductive Dechlorination (Anaerobic)	5.3.4	A carbohydrate (e.g., molasses, sodium lactate) is injected into the affected groundwater to serve as an electron donor for indigenous organisms to enhance reductive dechlorination. A carbohydrate solution is distributed with injection wells, direct-push probes, or groundwater recirculation systems.	Full-Scale	Proven effective under proper conditions for degradation of chlorinated solvents.	Shallow groundwater and Lower Aquifer around the former tank farm area and along the northern property line.	PCE, TCE, *cis* -1,2-DCE, and VC
	Bioaugmentation	5.3.5	Injection of specialty, nonindigenous microbes to enhance biodegradation. Microorganisms are commercially available for both aerobic and anaerobic degradation of chlorinated organics and petroleum hydrocarbons.	Full-Scale	Has been effective for biodegradation of chlorinated solvents. Requires application of specific microbial seed (*Dehalococcoides*). May require repeated application.	Shallow groundwater and Lower Aquifer around the former tank farm area and along the northern property line.	PCE, TCE, *cis* -1,2-DCE, and VC
	Monitored Natural Attenuation	5.3.6	Intrinsic attenuation of groundwater constituents via the natural processes of biodegradation (aerobic and/or anaerobic), adsorption, and dilution. This passive technology relies on natural conditions within impacted groundwater.	Full-Scale	Has been proven effective at sites with appropriate conditions.	All areas of site in the Shallow and Lower Aquifer Groundwater Zones with appropriate conditions.	chlorinated VOCs, and 1,4-dioxane

TABLE 5-3
SUMMARY OF REMEDIATION TECHNOLOGIES CONSIDERED FOR GROUNDWATER
Stericycle Washougal Facility
Washougal, Washington

Technology Characteristics							
General Response Actions	Remediation Technologies	Section	Technology Description	Technology Development Status	General Performance Record	Site Area Addressed	Site Contaminants Addressed
In Situ Physical/Chemical Treatment	Phytoremediation	5.3.7	Dense plants and trees can supply nutrients to promote microbial growth that reduce contaminant concentrations in groundwater, or plants can directly uptake contaminants in groundwater. New implementation technology allows for treatment depths of more than 50 feet below ground surface and has shown effective hydraulic control.	Full-Scale	Has been proven effective at sites with appropriate conditions.	As a potential contingent remedy for groundwater zones along the northeast and east sides of the site.	VOCs (both chlorinated and non- chlorinated), TPH, SVOCs, metals, 1,4-dioxane.
In Situ Physical/Chemical Treatment	Carbon Augmentation	5.3.X	Colloidal activated carbon is injected into the saturate zone with an organic stabilizer to sequester and reduce contaminant concentrations. The activated carbon disperses through the subsurface during injection and dispersion continues over time with groundwater flow.	Full Scale	Has been proven effective at sites with appropriate conditions. Effectively used for chlorinated VOCs and TPH. Not effective for inorganics.	Shallow groundwater and Lower Aquifer around the former tank farm area, along the northern property line, and underneath and east of Building 1.	PCE, TCE, cis -1,2-DCE, non- chlorinated VOCs, SVOCs (including 1,4- dioxane), TPH, pesticides
In Situ Physical/Chemical Treatment	Air Sparging	5.3.8	Air is injected into the saturated zone to volatilize organic compounds or oxygenate aquifer to promote precipitation of metals. An air compressor is used to supply air to the saturated zone typically through air sparge wells. Similar to biosparging, but does not rely on biodegradation.	Full-Scale	Has been effectively used at non-chlorinated VOC-impacted sites. Difficult to implement for deep groundwater.	Shallow groundwater and Lower Aquifer around the former tank farm area and along the northern property line.	VC, TPH, SVOCs, metals
In Situ Physical/Chemical Treatment	Chemical Oxidation-Active	5.3.9X	An oxidizing chemical (permanganate, hydrogen peroxide, Fenton's Reagent, RegenOx) is actively injected through wells or via direct-push technology to the groundwater to chemically oxidize contaminants. Pilot test would be required	Full-Scale	Can be effective depending on oxidant demand of native material, tightness of formation, and number of injections. Not effective for most metals.	Shallow groundwater and Lower Aquifer around the former tank farm area, along the northern property line, and underneath and east of Building 1.	VOCs (both chlorinated and non- chlorinated), SVOCs (including 1,4-dioxane), TPH, pesticides
In Situ Physical/Chemical Treatment	Chemical Oxidation-Passive	5.3.9X	An oxidizing chemical (potassium permanganate, sodium persulfate) is suspended in a monitoring on an inert media to passively release chemical oxidizer for treatment of contaminants. Pilot test would be required	Full-Scale	Can be effective depending on oxidant demand of native material, tightness of formation, and number of injections. Not effective for most metals and 1,4-dioxane.	Shallow groundwater and Lower Aquifer around the former tank farm area, along the northern property line, and underneath and east of Building 1.	VOCs (both chlorinated and non- chlorinated), TPH
In Situ Physical/Chemical Treatment	Thermal Treatment	5.3.10	Temperature in the saturated zone is increased by injecting steam or applying an electrical current. The increased temperature volatilizes organic compounds, which would be collected from the vadose zone using SVE.	Full-Scale	Mixed performance record with improved performance in silts compared to other technologies. Some applications have been effective, while others have been unsuccessful in attaining cleanup objectives. Not effective for inorganics, can release metals.	Shallow Groundwater Zone, Silt Layer, and Lower Aquifer around the former tank farm area, along the northern property line, and underneath and east of Building 1.	VOCs (both chlorinated and non- chlorinated), TPH, SVOCs (including 1,4- dioxane), and metals

TABLE 5-3
SUMMARY OF REMEDIATION TECHNOLOGIES CONSIDERED FOR GROUNDWATER
Stericycle Washougal Facility
Washougal, Washington

Technology Characteristics							
General Response Actions	**Remediation Technologies**	**Section**	**Technology Description**	**Technology Development Status**	**General Performance Record**	**Site Area Addressed**	**Site Contaminants Addressed**
In Situ Physical/Chemical Treatment (cont.)	In-Well Stripping	5.3.11	Air is injected into a double-screened well, lifting the water in the well and forcing it out the upper screen. Simultaneously, additional water is drawn in the lower screen. Volatile compounds are transferred to the vapor phase and removed by vapor extraction. Groundwater in radius of influence is aerated.	Full-Scale	Mixed performance record. Some applications have been very effective, while others have been unsuccessful in attaining cleanup objectives.	Shallow Groundwater Zone and Lower Aquifer around the former fuel tank area.	VC, non-chlorinated VOCs, TPH
	Passive/Reactive Treatment Walls	5.3.12	Contaminant concentrations in groundwater are reduced as the groundwater flows through the permeable reactive barrier containing zero-valent iron.	Full-Scale	Has been effectively used to reduce chlorinated VOC and metals concentrations in groundwater.	Shallow Groundwater Zone and Lower Aquifer to the east of Building 1.	chlorinated VOCs, some metals
Groundwater Extraction and Treatment (Pump and Treat)	Hydraulic Control	5.3.13	Groundwater extraction wells are installed to create a hydraulic gradient to control contaminant migration. Extracted water is then treated and discharged.	Full-Scale	Has been effectively used to control contaminant migration. Is a long-duration technology. Cannot attain cleanup levels.	Shallow Groundwater Zone and Lower Aquifer around the former tank farm area and east of Building 1.	VOCs (both chlorinated and non-chlorinated), SVOCs (including 1,4-dioxane), TPH, metals
	Mass Reduction	5.3.13	Groundwater extraction wells are installed in source areas to aggressively remove contaminated groundwater, thereby reducing contaminant mass. Extracted water is then treated and discharged.	Full-Scale	Has been effectively used to remove contaminants. Is a long- duration technology.	Same as Hydraulic Control Technology.	VOCs (both chlorinated and non-chlorinated), SVOCs (including 1,4-dioxane), TPH, metals
	Dynamic Groundwater Recirculation (DGR)	5.3.X	DGR creates dynamic groundwater flow conditions that enhances the natural flushing processes occurring within an impacted area.	Full-Scale	Has been proven effective in homogeneous aquifers to remove COCs in solution.	Shallow Groundwater Zone and the Lower Aquifer in the vicinity of the former tank farm, along the northern property line, underneath Building 1 and to the east of Building 1.	VOCs (both chlorinated and non-chlorinated), SVOCs (including 1,4-dioxane), TPH, metals
In Situ Physical/Chemical Treatment	Emulsified Zero-Valent Iron	5.3.14	Zero-valent iron emulsified in vegetable oil and surfactant is injected into groundwater. Zero-valent iron causes abiotic reductive dechlorination, and vegetable oil and surfactant act as long-term electron donors for biotic reductive dechlorination.	Full-Scale	Has been effectively used to reduce chlorinated VOCs and metals concentrations in groundwater.	Shallow Groundwater Zone and the Lower Aquifer in the vicinity of the former tank farm, along the northern property line, underneath Building 1 and to the east of Building 1.	chlorinated VOCs, Arsenic

TABLE 5-3
SUMMARY OF REMEDIATION TECHNOLOGIES CONSIDERED FOR GROUNDWATER
Stericycle Washougal Facility
Washougal, Washington

Technology Characteristics							
General Response Actions	**Remediation Technologies**	**Section**	**Technology Description**	**Technology Development Status**	**General Performance Record**	**Site Area Addressed**	**Site Contaminants Addressed**
In Situ Physical/Chemical Treatment (cont.)	Surfactant-Enhanced Aquifer Remediation (SEAR)	5.3.15	Surfactants are injected to increase the solubility and mobility of organic contaminants, including NAPLs. Surfactants and contaminants are then recovered with conventional pump-and-treat methods. The surfactants are separated from the groundwater and contaminants and reinjected.	Full-Scale	Has been used to enhance recovery of chlorinated VOCs and DNAPL. Limited full-scale applications.	Shallow Groundwater Zone and the Lower Aquifer in the vicinity of the former tank farm, along the northern property line, underneath Building 1 and to the east of Building 1.	chlorinated VOCs, SVOCs, TPH
	Co-Solvent Flooding	5.3.16	Co-solvents, typically alcohols, are injected to enhance dissolution and recovery of DNAPL components. Co-solvent and dissolved- phase organics are recovered with conventional groundwater extraction methods.	Full-Scale	Has been used to enhance recovery of DNAPL. Limited prior full-scale applications.	Shallow Groundwater Zone and Lower Aquifer in the vicinity of the former tank farm source areas.	chlorinated VOCs, SVOCs
Physical Containment	Barrier Wall	5.3.17	Placement of a barrier wall that physically restricts flow of groundwater or grouting/cementing potential COC migration conduits. The barrier wall must be keyed into lower confining unit for total containment.	Full-Scale	Has been effectively used to contain contaminated groundwater. Cannot attain cleanup levels as sole remedial technology.	Barrier wall used to border the former tank farm in the Shallow Groundwater Zone and the Lower Aquifer.	VOCs (both chlorinated and non-chlorinated), SVOCs (including 1,4-dioxane), TPH, metals
Ancillary/Support Technologies	Air Stripping	5.3.28	This technology is used in conjunction with pump- and-treat systems. Extracted groundwater is passed downward against a stream of rising air. The countercurrent stream of air strips VOCs from the water. Contaminants in the air stream are then removed or treated by oxidation or adsorption technologies.	Full-Scale	Has been effectively used to remove VOCs (both chlorinated and non-chlorinated) from groundwater.	Same as Hydraulic Control Technology.	VOCs (both chlorinated and non-chlorinated), metals
	Oxidation	5.3.X	This technology can be used in conjunction with pump-and-treat systems. Extracted groundwater is augmented with an oxidant, such as hydrogen peroxide or potassium permanganate, to degrade COCs.	Full-Scale	Has been effectively used to remove chlorinated and non-chlorinated VOCs and 1,4-dioxane from groundwater	Same as Hydraulic Control Technology.	VOCs (both chlorinated and non-chlorinated), 1,4-dioxane, metals
	Adsorption	5.3.19	This technology is used in conjunction with pump- and-treat systems. Extracted groundwater or VOC- containing air is passed through vessels containing granular activated carbon. Organic compounds with an affinity for carbon are transferred from the aqueous or vapor phase to the solid phase by sorption to the carbon. Treated carbon products are available to address VOCs such as VC that have a low affinity for conventional carbon.	Full-Scale	Has been effectively used to remove chlorinated and non-chlorinated VOCs, 1,4-dioxane, and metals from groundwater	Same as Hydraulic Control Technology.	VOCs (both chlorinated and non-chlorinated), SVOCs (including 1,4-dioxane), TPH, metals

TABLE 5-3
SUMMARY OF REMEDIATION TECHNOLOGIES CONSIDERED FOR GROUNDWATER
Stericycle Washougal Facility
Washougal, Washington

Technology Characteristics							
General Response Actions	**Remediation Technologies**	**Section**	**Technology Description**	**Technology Development Status**	**General Performance Record**	**Site Area Addressed**	**Site Contaminants Addressed**
Ancillary/Support Technologies (cont.)	Deep Soil Mixing	5.3.20	This technology is used in conjunction with several other technologies above. An auger is used to drill down into the soil, and a substrate (sand, clay, or cement) is injected as the auger goes down and is then pulled back up. Different additives can be combined with different substrates in order to accomplish a variety of objectives. It can be used as a delivery method for in situ chemical oxidation or in situ enhanced bioremediation. It can also be used to install passive reactive barriers or to help build physical containment.	Full-Scale	Has been effectively used to treat chlorinated and non-chlorinated VOCs, SVOCs (including 1,4-dioxane), and TPH in groundwater or to contain metals, TPH, chlorinated and non-chlorinated VOCs, SVOCs, and metals.	Shallow Groundwater Zone and Silt Layer around the former tank farm area. Addressing Silt Layer addresses Lower Aquifer.	VOCs (both chlorinated and non-chlorinated), SVOCs (including 1,4-dioxane), TPH, metals

Notes

X indicates a new technology added to the table after submittal of the 2013 Feasibility Study

Abbreviations

cis -1,2-DCE = *cis* -1,2-dichloroethene
BTEX = benzene, toluene, ethylbenzene, and xylenes
DNAPL = dense nonaqueous-phase liquids
SVE = soil vapor extraction
SVOCs = semivolatile organic compounds
TCE = trichloroethene
NAPL = nonaqueous phase liquids
ORC = oxygen-releasing compound
PCE = tetrachloroethane
TPH = total petroleum hydrocarbon
VC = vinyl chloride
VOCs = volatile organic compounds

TABLE 5-4
REMEDIATION TECHNOLOGY SCREENING FOR GROUNDWATER
Stericycle Washougal Facility
Washougal, Washington

General Response Actions	Remediation Technologies	Section	Site-Specific Issues Affecting Technology or Implementation							Rationale for Retention or Rejection	Screening Result
			Protectiveness	Permanence	Cost	Effectiveness over long-term	Management of short-term Risks	Technical and Administrative Implementability	Consideration of Public Concerns		
In Situ Biological Treatment	Enhanced Biodegradation with Biosparging	5.3.1	Addresses vinyl chloride (VC), but inhibits the degradation of other chlorinated VOCs. Potentially exacerbates the vapor intrusion pathway by volatilizing VOCs in groundwater.	Inhibits degradation of chlorinated VOCs with the exception of VC. Technology ineffective in silts and does not address 1,4-dioxane.	Higher implementation costs due to active industrial facility, large number of wells, large chemical oxygen demand (due to anaerobic conditions and metals), long-term run time (high O&M) and longer term groundwater monitoring costs necessary to effectively treat the silt layer.	The aquifer is reducing, so the effects of air on the aquifer chemistry will be limited to while the system is active. Technology does not address chlorinated VOCs with the exception of VC and does not treat 1,4-dioxane.	Since this is an active facility with enclosed buildings, this technology increases risk to human health due to the potential for increased volatilization of chlorinated VOCs (which could be mitigated with operation of an SVE system.)	Since this is an active facility with high traffic and chlorinated mass trapped in silts, the implementation options are limited and more technically challenging. High groundwater at the facility makes operation of an SVE system in conjunction with air sparge potentially infeasible.	Technology is unlikely to migrate off site to neighboring properties, through utilities, or to the marsh, so public concern should be minimal.	This technology will not work for all site COCs and would cause major disturbance to site activities if implemented in the source areas. However, if implemented in select locations and for specific COCs onsite (in conjunction with other technologies), it could speed the remedial time frame while adding minimal additional risks.	Retain
	Oxygen Enhancement with Hydrogen Peroxide or ORC	5.3.2	Potentially addresses all the contaminants, but may inhibit the anaerobic degradation of other chlorinated VOCs and release additional metals.	Inhibits degradation of chlorinated VOCs with the exception of VC. Technology may be ineffective in silts.	Higher implementation costs due to active industrial facility, multiple injection rounds, large chemical oxygen demand (due to anaerobic conditions and metals), and large number of wells necessary to implement the technology in silt layer. If effective, may reduce long-term groundwater monitoring costs.	The aquifer is reducing and the majority of mass for chlorinated VOCs is trapped in the silt layer, so its unlikely oxygen addition will last long-term to treat the secondary source release from the silt layer.	Some short-term risks due to chemicals exposure possible for personnel implementing technology, typically managed with proper use of PPE.	Distribution of substrate in silts would require tighter spacing of wells and repeat injections. Implementation on an active high traffic industrial facility would require coordination of work (off hours work potentially).	Technology is unlikely to migrate off site to neighboring properties, through utilities, or to the marsh, but metals may be released to groundwater as part of treatment. Bench testing should be utilized to reduce potential for metals release.	This technology will not work for all site COCs and would cause major disturbance to site activities if implemented in the source areas. However, if implemented in select locations and for specific COCs onsite (in conjunction with other technologies), it could speed the remedial time frame while adding minimal additional risks.	Retain
	Co-Metabolic Treatment	5.3.3	Effective treatment for 1,4-dioxane and some chlorinated VOCs, but does not address metals.	Effective treatment for 1,4-dioxane and chlorinated VOCs, but does not address metals and may be ineffective in silts.	Higher implementation costs due to active industrial facility, large number of wells, long-term run time (high O&M), and longer term groundwater monitoring costs necessary to effectively treat the silt layer.	Technology will work with existing reducing conditions, but substrate injection would need to continue long-term for co-metabolic effectiveness to address secondary source in silt layer.	Active facility with enclosed buildings increases risk to human health due to use of fuels (such as propane) as substrate.	Since this is an active facility with high traffic, enclosed buildings, and chlorinated mass trapped in silts, the implementation options are limited and more technically challenging.	Technology is unlikely to migrate off site to neighboring properties or to the marsh, but some substrates like propane could potentially build up and migrate through utilities.	This technology will not work for all site COCs and would cause major disturbance to site activities if implemented in the source areas. Not likely to be as effective as biostimulation given the site conditions and data supporting ongoing anaerobic degradation. In addition, it poses significant additional safety concerns.	Reject
	Biostimulation of Reductive Dechlorination (Anaerobic)	5.3.4	Technology addresses chlorinated VOCs, but does not address metals or 1,4-dioxane.	Technology is longer lasting than oxidation substrates and permanently destroys chlorinated VOCs, but does not address metals or 1,4-dioxane.	Lower implementation costs than other technologies, even with multiple injections of substrate (as typically required for effective treatment in silts.) However, this is balanced by longer term groundwater monitoring costs which may increase overall project cost.	Technology is longer lasting than oxidation substrates and permanently destroys chlorinated VOCs, but does not address metals or 1,4-dioxane.	Minimal short-term risks possible to personnel implementing technology.	Distribution of substrate in silts would require tighter spacing of wells and repeat injections. Implementation on an active high traffic industrial facility would require coordination of work (off hours work potentially), but since substrates last longer in-situ than oxidation substrates, the total disruption to facility operations is likely lower.	Substrate is unlikely to migrate off site through utilities, neighboring properties, or to the marsh, but overdosing could lead to excess methane generation or metals release to groundwater. Bench testing should be utilized to reduce potential for overdosing.	This technology will not work for all site COCs but would cause minimal disturbance to site activities if implemented in the source areas. Potentially the most cost effective treatment for chlorinated VOCs, and once those are remediated may also allow metals concentrations to return to background levels.	Retain
	Bioaugmentation	5.3.5	Addresses chlorinated VOCs, but does not address metals or 1,4-dioxane. Typically used in concert with biostimulation.	Addresses chlorinated VOCs, but does not address metals or 1,4-dioxane. Typically used in concert with biostimulation.	Given the demonstrated decline in chlorinated VOCs onsite, bioaugmentation is unnecessary and would only add additional cost to biostimulation costs. Multiple injections of nonindigenous organisms are typically required, increasing technology cost.	Nonindigenous organisms are unlikely to out-compete local organisms, likely requiring ongoing injections for long-term effectiveness.	Minimal short-term risks possible to personnel implementing technology.	Distribution of nonindigenous organisms in silts is difficult and implementation on an active industrial facility would present the same challenges as for biostimulation. However, more frequent injections would be likely increasing disruption to facility operations.	Technology is unlikely to migrate off site through utilities, neighboring properties, or to the marsh, but typically used in concert with biostimulation so public concern should be equivalent to biostimulation concerns.	This technology will not work for all site COCs but would cause minimal disturbance to site activities if implemented in the source areas. This is likely unnecessary given the demonstrated ongoing degradation of chlorinated VOCs, but is retained as a potential supplement to biostimulation if site groundwater conditions change.	Retain
	Monitored Natural Attenuation	5.3.6	Potentially addresses all the contaminants, but is the slowest technology and metals may persist.	Technology would likely eventually attain CULs for chlorinated VOCs and 1,4-dioxane but metals may persist.	Implementation costs are minimal. Long-term groundwater monitoring costs could be substantial depending on remedial time frame.	Technology potentially addresses all contaminants but likely to have a longer timeline than active treatment options.	Minimal short-term risks possible to personnel implementing long-term monitoring.	Minimal impacts on facility operations, facility has demonstrated ability to perform long-term groundwater monitoring and results show effective degradation in areas where source removal has been completed.	Observations of natural attenuation shows constituents migrating off site, but a shrinking/receding plume in the shallow aquifer. Concerns with long-term migration in the lower aquifer may require additional offsite wells (if technology not combined with other remedial actions.)	This technology will not work for all site COCs but would cause minimal disturbance to site activities if implemented in the source areas. Natural attenuation has been documented to be actively occurring at the site. May be used in conjunction with other technologies as a polishing step to reach site CULs.	Retain

TABLE 5-4
REMEDIATION TECHNOLOGY SCREENING FOR GROUNDWATER
Stericycle Washougal Facility
Washougal, Washington

General Response Actions	Remediation Technologies	Section	Site-Specific Issues Affecting Technology or Implementation							Rationale for Retention or Rejection	Screening Result
			Protectiveness	Permanence	Cost	Effectiveness over long-term	Management of short-term Risks	Technical and Administrative Implementability	Consideration of Public Concerns		
In Situ Physical/Chemical Treatment	Phytoremediation	5.3.7	Potentially addresses site COCs.	Technology would likely eventually attain CULs for the site COCs.	Implementation costs would be substantial to institute for all source areas. Most of the source area is paved or covered with buildings, making installation incompatible with facility operations. High cost due to the need for large diameter conductor casing being used to allow for mass reduction in the lower aquifer. However, implementation costs could be minimized with use in specific areas of the facility. Long-term groundwater monitoring costs could be substantial depending on remedial time frame.	Several studies have shown good long-term effectiveness for COC destruction and hydraulic control. Could be used in conjunction with other active technologies for polishing on remaining mass at CPOC.	Minimal short-term risks possible to personnel implementing technology.	Technology cannot be used in active areas (buildings, paved areas, high traffic areas, equipment storage areas) of the industrial facility due to interference with operations, but could be used along CPOC as polishing following implementation of other technologies.	Generally considered a benefit to the public (low energy use, carbon neutral, and aesthetically pleasing). Technology does not pose concerns to off site features.	This technology could potentially address all site COCs but would cause major disturbance to site activities if implemented in the source areas. However, if implemented in select locations (should other remedies partly work), it could speed the remedial time frame while adding minimal additional risks.	Retain
	Carbon Augmentation	5.3.X	Technology addresses most chlorinated VOCs but ineffective for 1,4-dioxane and metals.	Technology would sequester chlorinated VOCs and may provide carbon source for biodegradation of COC mass. May exacerbate release of metals as a carbon source.	Higher implementation costs due to active industrial facility, multiple injection rounds, new proprietary technology (nano carbon), and large number of wells necessary to implement the technology in silt layer. If effective, may reduce long-term groundwater monitoring costs.	Technology relies on contact with constituents and good distribution within the subsurface (which is difficult in silt) to treat chlorinated VOCs. Ineffective for 1,4-dioxane and may exacerbate release of metals.	Minimal short-term risks possible to personnel implementing technology.	Distribution of substrate in silts would require tight spacing of wells and likely overlapping injections. Implementation on an active high traffic industrial facility would require coordination of work (off hours work potentially), but since substrates last longer than oxidation or biostimulation substrates, repeat rounds likely to be unnecessary.	Substrate is unlikely to migrate off site through utilities, neighboring properties, or to the marsh, but long-term carbon source could result in metals release to groundwater.	This technology will not work for all site COCs (may exacerbate metals) and would cause major disturbance to site activities if implemented in the source areas. Not likely to be as effective as biostimulation given the site conditions.	Reject
	Air Sparging	5.3.8	Active, natural, biological anaerobic degradation of chlorinated VOCs would be inhibited by the addition of oxygen (with the exception of VC). Ineffective for 1,4-dioxane treatment. Possibly effective for treatment of metals.	Likely to hinder anaerobic degradation processes for chlorinated solvents. May help sequester metals in the short-term, but reducing conditions in the aquifer may re-dissolve metals in the long-term. Could be used following primary treatment for removal of vinyl chloride.	Higher implementation costs due to active industrial facility, large number of wells, large chemical oxygen demand (due to anaerobic conditions and metals), long-term run time (high O&M) and longer term groundwater monitoring costs necessary to effectively treat the silt layer.	The aquifer is reducing, so the effects of air on the aquifer chemistry may be limited to while the system is active (precipitated metals may re-dissolve). Technology does not address chlorinated VOCs without being used in combination with SVE and does not treat 1,4-dioxane.	Since this is an active facility with enclosed buildings, this technology increases risk to human health due to the potential for increased volatilization of chlorinated VOCs (which could be mitigated with operation of an SVE system or strategic design of lower flow air sparging wells away from enclosed buildings).	Implementation at higher flow rates adjacent to Building 1 would likely overwhelm the existing inhalation pathway interim measure venting system. Associated SVE would be necessary if installed adjacent to Building 1 to prevent migration. However, implementation farther away from Building 1 at lower flow rates may be possible (with confirmation measurements taken at Building 1). Implementation oflow flow rate (without SVE) along the northeast and eastern property lines would be feasible in the shallow and deep aquifer.	Technology is unlikely to migrate contaminants off site to neighboring properties or to the marsh. This technology has led to volatiles building up in utility corridors, but implementation at a lower flow rate as a contingent remedy for polishing metals and only low VOC concentrations (or no VOCs) could limit public concern.	This technology will not work for all site COCs and would cause major disturbance to site activities if implemented in the source areas. However, if implemented in select locations and for specific COCs onsite (should other remedies partly work), it could speed the remedial time frame while adding minimal additional risks.	Retain
	Chemical Oxidation-Active	5.3.9X	Potentially treats all key COCs with a relatively short timeframe, may release metals.	Technology permanently destroys chlorinated VOCs and 1,4-dioxane, assuming effective contact.	Higher implementation costs due to active industrial facility, multiple injection rounds, large chemical oxygen demand (due to anaerobic conditions and metals), and large number of wells necessary to implement the technology in silt layer. If effective, may reduce long-term groundwater monitoring costs.	Technology relies on contact with constituents and distribution within the silt is difficult, but removes all COCs for source areas and CPOC.	Injection substrate is reactive and poses short-term risks to implementation personnel, typically managed with proper use of PPE and secondary containment.	Implementable in shallow and lower aquifer to treat all key COCs. Would be difficult to implement in the silt.	Technology is unlikely to migrate off site to neighboring properties, through utilities, or to the marsh, but metals may be released to groundwater as part of treatment. Bench testing should be utilized to reduce potential for metals release.	This technology could potentially address all site COCs but would cause significant disturbance to site activities if implemented in the source areas. However, if implemented in select locations, it could speed the remedial time frame while adding minimal additional risks.	Retain
	Chemical Oxidation-Passive	5.3.9X	Potentially treats chlorinated VOCs, unlikely to degrade 1,4-dioxane, and may release metals.	Technology permanently destroys chlorinated VOCs, assuming effective contact.	Lower implementation costs than active ISCO, but likely large chemical oxygen demand (due to anaerobic conditions and metals) and large number of wells necessary to implement the technology to address long-term release from the silt layer. If effective, may reduce long-term groundwater monitoring costs.	Technology is longer lasting than active oxidation and permanently destroys chlorinated VOCs, but does not address metals or 1,4-dioxane.	Significant but limited short-term risks related to handling of passive ISCO chemicals and installation of new wells, typically managed with proper use of PPE.	Implementable in shallow and lower aquifer to treat all key COCs. Would be difficult to implement in the silt.	Technology is unlikely to migrate off site to neighboring properties, through utilities, or to the marsh, but metals may be released to groundwater as part of treatment. Bench testing should be utilized to reduce potential for metals release.	This technology will not work for all site COCs (may exacerbate metals) and would cause major disturbance to site activities if implemented in the source areas. Not likely to be as effective as active oxidation given the site conditions.	Reject

TABLE 5-4
REMEDIATION TECHNOLOGY SCREENING FOR GROUNDWATER
Stericycle Washougal Facility
Washougal, Washington

General Response Actions	Remediation Technologies	Section	Site-Specific Issues Affecting Technology or Implementation							Rationale for Retention or Rejection	Screening Result
			Protectiveness	Permanence	Cost	Effectiveness over long-term	Management of short-term Risks	Technical and Administrative Implementability	Consideration of Public Concerns		
In Situ Physical/Chemical Treatment (cont.)	Thermal Treatment	5.3.10	Potentially addresses site COCs.	Technology degrades or removes site COCs.	Implementation costs would be substantial to institute for all source areas. Most of the source area is paved high traffic area or covered with buildings, making installation more complicated. Lower aquifer is connected to adjacent waterbodies, likely increasing water production and heating costs. Long-term groundwater monitoring costs could be substantially reduced.	Could achieve CULs in relatively short timeframe, may release dissolved carbon (which would aid in biodegradation of chlorinated VOCs), but could exacerbate metals release to groundwater.	Installation of heating elements or steam injection points pose a risk for contact with COC impacted groundwater. Operation of the system could impact utilities in the vicinity dependent on material type.	Implementation and ongoing operations and maintenance of an thermal treatment system on an active industrial facility would be difficult. High groundwater at the facility makes operation of an SVE system in conjunction with heating difficult. Buildings are present over the source area complicating installation. Lower aquifer connection to adjacent water bodies may increase water production and heating costs.	Technology is unlikely to directly affect off site property (neighboring properties or the marsh), but plastic utility lines would need to be replaced in the upper treatment zone. Heated groundwater has the potential to migrate off site and into the marsh for a short time. Dissolving of entrained carbon could release metals to groundwater.	This technology could potentially address all site COCs but would cause significant disturbance to site activities if implemented in the source areas and could potentially exacerbate release of metals. Potentially one of the most effective treatment technologies for the silt layer.	Retain
	In-Well Stripping	5.3.11	Addresses vinyl chloride (VC), but inhibits the degradation of other chlorinated VOCs. Potentially exacerbates the vapor intrusion pathway by volatilizing VOCs in groundwater.	Inhibits degradation of chlorinated VOCs with the exception of VC. Technology ineffective in silts and does not address 1,4-dioxane.	Higher implementation costs due to active industrial facility, large number of wells, large chemical oxygen demand (due to anaerobic conditions and metals), likelihood of iron precipitation and/or biological fouling. Long-term operation and maintenance would be costly due to the within the stripping wells.	The aquifer is reducing, so the effects of air on the aquifer chemistry will be limited to while the system is active. Technology does not address chlorinated VOCs with the exception of VC and does not treat 1,4-dioxane.	Since this is an active facility with enclosed buildings, this technology increases risk to human health due to the potential for increased volatilization of chlorinated VOCs (which could be mitigated with operation of an SVE system.)	Since this is an active facility with high traffic and chlorinated mass trapped in silts, the implementation options are limited and more technically challenging. High groundwater at the facility makes operation of an SVE system in conjunction with air sparge potentially infeasible.	Technology is unlikely to migrate off site to neighboring properties, through utilities, or to the marsh, so public concern should be minimal.	This technology has a mixed performance record, would not address all site COCs, and could inhibit the ongoing active anaerobic biodegradation. Not likely to be as effective as active chemical oxidation or traditional air sparging given the site conditions.	Reject
	Passive/Reactive Treatment Walls	5.3.12	Substrate such as zero valent iron (ZVI) would address chlorinated VOCs and metals but would not treat 1,4-dioxane.	Technology could reduce mass in the short-term and provide long-term passive treatment of chlorinated VOCs and metals.	Implementation costs could range widely depending on type of installation (low cost for widely spaced injections, higher cost for slurry wall or tightly spaced injections). However, implementation costs could be minimized with use in specific target zones (in sandy aquifer only). Bench or pilot testing likely necessary to accurately estimate costs. Could reduce long-term groundwater monitoring costs.	Technology could passively treat secondary source from silt until source has been degraded to below the CULs. Would need to be used in conjunction with other technologies for 1,4-dioxane.	Minimal short-term risks possible to personnel implementing technology.	Injections within the source area above and below the silt layer, within the sand units, would allow for even distribution of substrate during construction of the passive treatment barriers.	Technology will utilize substrate which will remain in the injection area and is unlikely to migrate off site through utilities, neighboring properties, or to the marsh, so public concern should be minimal.	This technology will not work for all site COCs and would cause major disturbance to site activities if implemented in the source areas. However, if implemented in select locations and for specific COCs onsite (in conjunction with other technologies), it could speed the remedial time frame while adding minimal additional risks.	Retain
Groundwater Extraction and Treatment (Pump and Treat)	Hydraulic Control	5.3.13	Could further reduce the footprint or speed up the reduction of the groundwater plume in the shallow and lower aquifer and potentially addresses all the contaminants.	Ex-situ treatment of COCs would be necessary to remove COC mass. long-term operation would be necessary to continually protect from release of COCs from silt.	Implementation costs may be significant to achieve control in the lower aquifer (given the connection to nearby surface water bodies). Long-term operations and maintenance costs would be high due to the long duration of operation necessary to continue capture of the ongoing slow release of COCs from the silt (and likelihood of iron precipitation and/or biological fouling.)	Could effectively contain COC's onsite, but due to entrainment of COC's in silts likely long-term operation required for lower aquifer. Long-term operation of the hydraulic control system would cause the restoration timeframe to increase significantly compared to other active treatment technologies.	System installation would require trenching for installation of conveyance piping in and around the source area as well as ex-situ management of contaminated groundwater increasing the potential for worker exposure to COCs.	Implementation and ongoing operations and maintenance of a hydraulic control system on an active industrial facility would be difficult compared to a vacant site, but not as disruptive as excavation, thermal, or deep soil mixing. Water is likely to flow from the more permeable layers of the aquifer (which are connected to adjacent water bodies or are impacted by seasonal high water) not from the suspected source area (the silt layer).	Technology would keep site COCs within the property boundary, so is unlikely to cause public concern and likely to be seen as generally beneficial.	This technology could capture all site COCs, but is unlikely to speed up the remedial time frame. The shallow aquifer contamination is shrinking in the majority of locations and the lower aquifer is permeable with the majority of COCs resulting from a long term secondary source. Other permanent remedial technologies are implementable with reduced restoration timeframe or are less disruptive to site activities compared to this technology.	Reject

TABLE 5-4
REMEDIATION TECHNOLOGY SCREENING FOR GROUNDWATER
Stericycle Washougal Facility
Washougal, Washington

General Response Actions	Remediation Technologies	Section	Site-Specific Issues Affecting Technology or Implementation: Protectiveness	Permanence	Cost	Effectiveness over long-term	Management of short-term Risks	Technical and Administrative Implementability	Consideration of Public Concerns	Rationale for Retention or Rejection	Screening Result
Groundwater Extraction and Treatment (Pump and Treat) (cont.)	Mass Reduction	5.3.13	Would remove COCs from higher permeability units (sand) but would be ineffective at extracting mass from the silt layer (source area).	Technology unlikely to significantly speed up mass removal from silt layer. Unlikely to significantly speed up attainment of CUL within source area or at CPOC.	Implementation costs may be significant to achieve control in the lower aquifer (given the connection to nearby surface water bodies). Long-term operations and maintenance costs would be high due to the long duration of operation necessary to continue capture of the ongoing slow release of COCs from the silt (and likelihood of iron precipitation and/or biological fouling.)	Minimal long-term effectiveness due to inability for technology to address COCs within the silt.	System installation would require trenching for installation of conveyance piping in and around the source area as well as ex-situ management of contaminated groundwater increasing the potential for worker exposure to COCs.	Implementation and ongoing operations and maintenance of a mass reduction system on an active industrial facility would be difficult compared to a vacant site, but not as hard as other technologies. Water is likely to flow from the more permeable layers of the aquifer (which are connected to adjacent water bodies or are impacted by seasonal high water) not from the suspected source area (the silt layer).	Technology would keep site COCs within the property boundary, so is unlikely to cause public concern and likely to be seen as generally beneficial.	This technology could capture all site COCs, but is unlikely to speed up the remedial time frame. Other permanent remedial technologies are implementable with reduced restoration timeframe compared to this technology.	Reject
	Dynamic Groundwater Recirculation (DGR)	5.3.X	Would remove COCs from higher permeability units (sand) but would be ineffective at extracting mass from the silt layer (source area).	Technology unlikely to significantly speed up mass removal from silt layer. Unlikely to significantly speed up attainment of CUL within source area or at CPOC.	High long-term operation and maintenance costs due to the technologies inability to attain CULs within the source area.	Minimal long-term effectiveness due to inability for technology to address COCs within the silt.	System installation would require trenching for installation of conveyance piping in and around the source area increasing the potential for worker exposure to COCs.	Installation of groundwater extraction wells and conveyance piping in the former tank farm (source area) would cause large disruptions to facility operations and structures limit the available locations for placement of wells.	Technology would keep site COCs within the property boundary, so is unlikely to cause public concern and likely to be seen as generally beneficial.	This technology could capture all site COCs, but is unlikely to speed up the remedial time frame. Other permanent remedial technologies are implementable with reduced restoration timeframe compared to this technology.	Reject
In Situ Physical/Chemical Treatment	Emulsified Zero-Valent Iron	5.3.14	Technology would address chlorinated VOCs and metals in shallow and lower aquifer, but would not address 1,4-dioxane.	Distribution of injected material is difficult in silts, but can be completed in shallow and lower aquifer above and below silts. Technology does not address 1,4-dioxane.	Implementation costs could range widely depending on type of installation (low cost for widely spaced injections, higher cost for slurry wall or tightly spaced injections). However, implementation costs could be minimized with use in specific target zones (in sandy aquifer only). Bench or pilot testing likely necessary to accurately estimate costs. Could reduce long-term groundwater monitoring costs.	Technology addresses chlorinated VOCs and metals, but does not address 1,4-dioxane.	Minimal short-term risks possible to personnel implementing technology.	Implementable in shallow and lower aquifer to treat chlorinated VOCs and metals. Would be difficult to implement in the silt and does not address 1,4-dioxane.	Technology will utilize substrate which will remain in the injection area and is unlikely to migrate off site through utilities or to the marsh, so is unlikely to cause public concern and likely to be seen as generally beneficial.	This technology will not work for all site COCs but may cause less disturbance to site activities if implemented in the source areas than other technologies. If implemented for specific COCs onsite (in conjunction with other technologies), it could speed the remedial time frame while adding minimal additional risks.	Retain
	Solvent-Enhanced Aquifer Remediation (SEAR)	5.3.15	Injection of surfactant would improve mobility of chlorinated VOCs followed by pump-and-treat extraction to remove mobile chlorinated VOCs in solution. Technology would not address metals or 1,4-dioxane.	Technology unlikely to significantly speed up mass removal from silt layer. Unlikely to significantly speed up attainment of CUL within source area or at CPOC. Technology would not address metals or 1, 4-dioxane.	Implementation costs may be significant to achieve control in the lower aquifer (given the connection to nearby surface water bodies). Long-term operations and maintenance costs would be high due to the long duration of operation necessary to continue capture of the ongoing slow release of COCs from the silt (and likelihood of iron precipitation and/or biological fouling.)	Technology addresses chlorinated VOCs in sands and some of the silt, but does not address metals or 1,4-dioxane. Injections of surfactants could create preferential pathways for groundwater flow potentially mobilizing COCs (and surfactants) outside the radius of influence from extraction wells.	System installation would require trenching for installation of conveyance piping in and around the source area as well as ex-situ management of contaminated groundwater increasing the potential for worker exposure to COCs.	Implementation and ongoing operations and maintenance of the system on an active industrial facility would be difficult compared to a vacant site. High groundwater extraction rates paired with high seasonal groundwater at the facility would increase water production and management costs. Technology depends on contact with COCs in the silt and distribution in the silt will be difficult.	Technology is designed to keep site COCs within the property boundary, but may inadvertently mobilize site COCs and surfactants outside the property boundary, so there would be higher public concern than for standard hydraulic mass removal.	This technology will not work for all site COCs (may exacerbate metals) and poses significant additional concerns with potential migration of contaminants offsite.	Reject

TABLE 5-4
REMEDIATION TECHNOLOGY SCREENING FOR GROUNDWATER
Stericycle Washougal Facility
Washougal, Washington

General Response Actions	Remediation Technologies	Section	Site-Specific Issues Affecting Technology or Implementation							Rationale for Retention or Rejection	Screening Result
			Protectiveness	Permanence	Cost	Effectiveness over long-term	Management of short-term Risks	Technical and Administrative Implementability	Consideration of Public Concerns		
In Situ Physical/Chemical Treatment (cont.)	Co-Solvent Flooding	5.3.16	Injection of solvents, typically ethanol or propanol, would improve mobility of chlorinated VOCs followed by pump-and-treat extraction to remove mobile chlorinated VOCs in solution. Technology would not address metals or 1,4-dioxane.	Technology unlikely to significantly speed up mass removal from silt layer. Unlikely to significantly speed up attainment of CUL within source area or at CPOC. Technology would not address metals or 1, 4-dioxane.	Implementation costs may be significant to achieve control in the lower aquifer (given the connection to nearby surface water bodies). Long-term operations and maintenance costs would be high due to the long duration of operation necessary to continue capture of the ongoing slow release of COCs from the silt (and likelihood of iron precipitation and/or biological fouling.)	Technology addresses chlorinated VOCs in sands and some of the silt, but does not address metals or 1,4-dioxane. Injections of solvents could create preferential pathways for groundwater flow potentially mobilizing COCs (and surfactants) outside the radius of influence from extraction wells. In addition, additional carbon source could exacerbate metals release to groundwater.	Injection of solvents , typically ethanol or propanol, pose an elevated risk to operators of the system and facility staff. Installation of the treatment system for injection of solvents and extraction of COCs pose a higher risk to installation personnel.	Implementation and ongoing operations and maintenance of the system on an active industrial facility would be difficult compared to a vacant site. High groundwater extraction rates paired with high seasonal groundwater at the facility would increase water production and management costs. Technology depends on contact with COCs in the silt and distribution in the silt will be difficult.	Technology is designed to keep site COCs within the property boundary, but may inadvertently mobilize site COCs and solvents outside the property boundary, so there would be higher public concern than for standard hydraulic mass removal.	This technology will not work for all site COCs (may exacerbate metals) and poses significant additional concerns with potential migration of contaminants offsite.	Reject
Physical Containment	Barrier Wall	5.3.17	Installation of a barrier wall would limit mobility of all COCs remaining on site, but would not reduce COC concentrations and may slow attenuation and degradation of contaminants.	The technology would completely reduce the mobility of the site COCs. The volume and toxicity of the COCs would not be addressed through this technology.	High implementation cost compared to most other alternatives to construct a barrier wall for both the shallow and lower aquifers. Long-term costs are minimal and technology could reduce long-term groundwater monitoring costs when used in conjunction with hydraulic control.	Technology potentially addresses all contaminants but likely to have a longer timeline than active treatment options.	Increased short-term risk during implementation due to displacement of large volumes of soil and potentially groundwater. Typically managed with proper use of PPE and secondary containment.	Implementation on an active industrial facility would be difficult compared to a vacant site.	A barrier wall would stop off site migration of COCs, so is unlikely to cause public concern and likely to be seen as generally beneficial.	This technology could work to capture all site COCs, but would not speed up the remedial time frame. However, it could be used in conjunction with other technologies to minimize disturbance to site activities if implemented strategically.	Retain
Ancillary/Support Technologies	Air Stripping	5.3.18	Technology addresses chlorinated VOCs and metals but not 1,4-dioxane.	Technology would remove VOCs, but effluent vapor would be treated through catalytic oxidation or adsorption. Technology does not address 1,4-dioxane and may only temporarily stabilize metals.	Minimal implementation costs when compared to installation of a pump-and-treat system. Long-term cost to operate an air stripper is relatively minimal during operation of the pump-and-treat system, but iron precipitation would likely cause significant fouling, increasing long-term maintenance costs.	Technology addresses chlorinated VOCs, but does not address 1,4-dioxane and may only temporarily stabilize metals.	Increased short-term risk during operation of the air stripper due to volatilization of VOCs . Maintenance of the air stripper and wastes generated pose additional short-term risks. Typically managed with proper use of PPE, vapor treatment, and secondary containment.	The addition of an air stripping system into a pump-and-treat system would further complicate implementation of hydraulic control remedies, as noted above.	Air stripping removes VOCs from groundwater and transfers them to the air phase. This technology could cause public concern related to air emissions.	Not applicable since groundwater extraction was not retained.	Reject
	Oxidation	5.3.X	Ex-situ oxidation would be effective in reducing contaminant mass for chlorinated VOCs, metals, and 1,4-dioxane.	Technology would destroy contaminant mass when used in conjunction with pump-and-treat.	Minimal implementation costs when compared to installation of a pump-and-treat system. Long-term costs can be variable, dependent on oxidant used, but high costs are expected with long-term operations and maintenance.	While this technology would treat all contaminants, reinjection of oxygenated water into the aquifer could impact existing anaerobic degradation and may lead to significant fouling.	Short-term risks are increased due to use of a pump-and-treat system as a remedial alternative and oxidants are an additional hazard to personnel. Typically managed with proper use of PPE and secondary containment.	The addition of an oxidant augmentation system into a pump-and-treat system would further complicate implementation of hydraulic control remedies, as noted above.	Effluent from a pump-and-treat system actively augmented with an oxidant could add to public concerns for a pump a treat system.	Not applicable since groundwater extraction was not retained.	Reject
	Adsorption	5.3.19	Potentially addresses site COCs.	Different adsorbent media are utilized for different contaminants. If media can be used effectively in a treatment train, would permanently remove contaminants.	Potentially high implementation costs and long term operations costs, depending on effectiveness of media and volumes of water needing treatment.	New adsorption media has been developed using resins for 1,4-dioxane and VC removal. Effectiveness is highly variable on groundwater chemistry, bench testing would be necessary to determine long term performance.	Short-term risks possible to personnel implementing technology depending on type of media utilized. Short-term risks are increased due to use of a pump-and-treat system as a remedial alternative. Typically managed with proper use of PPE and secondary containment.	The addition of adsorption units into a pump-and-treat system would further complicate implementation of a remedy, but potentially less complicated than oxidation or air stripping.	Adsorption technology is unlikely to contribute chemicals to offsite discharge, so is unlikely to cause public concern and likely to be seen as generally beneficial.	Not applicable since groundwater extraction was not retained.	Reject

TABLE 5-4
REMEDIATION TECHNOLOGY SCREENING FOR GROUNDWATER
Stericycle Washougal Facility
Washougal, Washington

General Response Actions	Remediation Technologies	Section	Site-Specific Issues Affecting Technology or Implementation							Rationale for Retention or Rejection	Screening Result
			Protectiveness	Permanence	Cost	Effectiveness over long-term	Management of short-term Risks	Technical and Administrative Implementability	Consideration of Public Concerns		
Ancillary/Support Technologies (cont.)	Deep Soil Mixing	5.3.20	Potentially addresses site COCs.	Technology oxidizes, reduces or sequesters depending on substrate used during mixing to permanently reduce COC mass.	Implementation costs would be substantial to institute for all source areas. Most of the source area is paved high traffic area or covered with buildings and this technology requires significant excavation as part of the work, making installation more complicated. Long-term monitoring costs would be less than most other alternatives as mass should be treated quickly.	Technology does not rely on flow through pore spaces for distribution, but physically mixes in treatment substrates. There is a high likelihood the technology would effectively treat all contaminants.	Increased short-term risk during implementation due to displacement of large volumes of soil and potentially groundwater as well as exposure to treatment chemicals. Typically managed with proper use of PPE and secondary containment.	Since this is an active facility with high traffic, enclosed buildings, and chlorinated mass trapped in silts, the implementation options are limited and more technically challenging. Implementation on an active high traffic industrial facility would require coordination of work (off hours work potentially).	Technology could potentially treat most site COCs quicker than other technologies and contain remainder within the property boundary. Trucking of excavated materials offsite would be more substantial for this alternative than other alternatives.	This technology could potentially address all site COCs but would cause major disturbance to site activities if implemented in the source areas. Potentially one of the most effective treatment technologies for the silt layer.	Retain

Notes
X indicates a new technology added to the table after submittal of the 2013 Feasibility Study

Abbreviations
cis -1,2-DCE = *cis* -1,2-dichloroethene
COL = constituent of concern
CPOC = conditional point of compliance
CUL = cleanup level
HRC = hydrogen-releasing compounds
ISCO = in situ chemical oxidation
O&M = operation and maintenance
ORC = oxygen-releasing compound
SVOCs = semivolatile organic compounds
TCE = trichloroethene
TPH = total petroleum hydrocarbon
VC = vinyl chloride
VOCs = volatile organic compounds
ZVI = zero-valent iron

TABLE 5-5
RETAINED REMEDIATION TECHNOLOGIES
Stericycle Washougal Facility
Washougal, Washington

Potentially Applicable Soil Technology	
General Response Actions	**Remediation Technologies**
In Situ Biological Treatment	Phytoremediation
In Situ Physical/Chemical Treatment	Chemical Oxidation
	Solidification/Stabilization
In Situ Thermal Treatment	High-Temperature Volatilization
Containment	Cap/Surface Cover
Excavation and Disposal	Excavation and Off-Site Disposal

Potentially Applicable Groundwater Technology	
General Response Actions	**Remediation Technologies**
In Situ Biological Treatment	Enhanced Biodegradation with Biosparging
	Oxygen Enhancement with Hydrogen Peroxide or ORC
	Biostimulation of Reductive Dechlorination (Anaerobic)
	Bioaugmentation
	Monitored Natural Attenuation
	Phytoremediation
In Situ Physical/Chemical Treatment	Air Sparging
	Chemical Oxidation
	Thermal Treatment
	Passive/Reactive Treatment Walls
	Emulsified Zero-Valent Iron
Physical Containment	Barrier Wall
Ancillary/Support Technologies	Deep Soil Mixing

Abbreviations
ORC = oxygen-releasing compound

Appendix D

Technical Memorandum: Feasibility Study – Remedial Alternatives

Technical Memorandum:
Feasibility Study – Remedial Alternatives

WASHOUGAL FACILITY

WASHOUGAL, WASHINGTON

January 15, 2020

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1.0 INTRODUCTION

This technical memorandum was prepared to summarize information presented during discussions regarding components of the Feasibility Study (FS), currently under revision, for the Stericycle Environmental Solutions (Stericycle) Washougal, Washington facility. Washington Department of Ecology (Ecology), Ridolfi (Ecology's technical consultant), Stericycle, and Dalton, Olmsted, and Fuglevand (DOF) met on December 18, 2019. The purpose of that meeting was to discuss Stericycle's planned approach to address Ecology's 2019 comments on the 2013 FS (AMEC, 2013a), particularly concerning revised remedial alternatives from the 2013 FS and two new proposed alternatives.

DOF prepared this technical memorandum on behalf of Stericycle to document information presented at that December 18, 2019 meeting, based on Ecology's requests for additional details related to each alternative.

1.1 Summary of Feasibility Study Revision Progress

Stericycle received comments on the 2013 FS from Ecology and Ridolfi on May 22, 2019. Ecology, Ridolfi, Stericycle and DOF met on July 10, 2019 to discuss comments and plan a path forward for FS revision. A second meeting (with the same parties) was held on August 8, 2019, to discuss revisions to preliminary cleanup levels and point of compliance. Draft tables and figures were provided showing updated nature and extent of contaminants of concern (COCs), and new remediation technologies under consideration. In order to expeditiously reach consensus on FS revisions, Stericycle agreed to provide Ecology Memoranda corresponding to sections of the 2013 FS as they were updated. The objective is to take the text, tables, and figures from these memoranda and incorporate them into a Final FS. To date, three memoranda have been submitted to Ecology:

- Feasibility Study – Point of Compliance and Preliminary Cleanup Level Assessment (DOF, 2019a)
- Feasibility Study – Nature and Extent of Contamination Update (DOF, 2019b)
- Feasibility Study – Technology Screening (DOF, 2019c)

Additional meetings and conference calls were held to discuss the memoranda in September, October, and December, 2019. Ecology provided comments to Stericycle regarding the technical memoranda. DOF subsequently prepared responses to comments and revised technical memoranda, and submitted them to Ecology in correspondence dated November 12, 2019. This fourth Technical Memoranda addresses the remaining comments regarding technology screening and revised technology screening table are included that were originally submitted as part of the third Technical Memorandum.

1.2 Conceptual Site Model Summary

Since the submittal of the 2013 FS additional groundwater monitoring has been performed in the shallow zone and deep aquifer groundwater. The general conceptual site model remains the same, however, the nature and extent of COCs has changed, building, paved areas, and utility locations have changed, and trends in COCs have become better defined. Previous memoranda have provided details on the nature and extent of COCs; a summary is provided here to aid in review of the remedial alternatives.

Site Geologic/Hydrologic Summary

- Site investigation has generally encountered sandy fill from ground surface to a depth of approximately 10 feet below ground surface (bgs), with an underlying silt layer from approximately 10 to 20 feet bgs, and below that a silty gravel material containing larger cobbles.
- The water table is typically quite shallow - approximately four feet bgs (plus or minus two feet), but the vadose zone can be flooded entirely in wet winter periods.
- Shallow groundwater consistently flows to the east, towards the neighboring marsh.
- Deep aquifer groundwater generally flows to the southeast, towards the neighboring marsh, but occasionally flows to the northeast, also towards the marsh, with eventual connection to the Columbia River which is the nearest larger surface water body, located south of the site.
- Vertical gradients can be upwards from the deep aquifer to the shallow zone or down from the shallow zone to the deep aquifer, depending on seasonal water level fluctuations in the shallow zone.
- The site is situated within an active industrial park, constructed on non-native fill sands placed over a native marshy silt. The sandy fill thins out towards the edges of the industrial park, with the native silt layer encountered closer to ground surface. The industrial park neighbors the Steigerwald Marsh, a wildlife refuge located east of the site.

Nature and Extent of COCs

- Soil
    - Source area soil excavation was performed in the 1990s to remove contamination present in the sandy fill near the center of the site. Excavation did not extend underneath Building 1 and stopped in the silt layer.
    - No new soil data has been acquired since the 2013 FS. The older data indicated VOCs present primarily in soils around and beneath Building 1, with lower concentrations present under Building 2 and Building 3. Detections of inorganic

COCs in shallow soils were above preliminary cleanup levels in areas near the northern property line (near GP-97) and west of the former waste oil tank system (near GP-93).

- Shallow groundwater results from around these buildings indicate the threat to groundwater from COCs present in soil under these buildings is limited.
- Sampling of soil vapor beneath Building 1 is planned prior to completion of the Cleanup Action Plan to assess current conditions underlying the building and the associated need for active treatment and continued operation of the inhalation pathway interim measure (IPIM).

- Groundwater
  - Groundwater has been sampled quarterly since the 2013 FS and long term trends of various COCs are being used to update the FS.
  - Shallow zone conditions
    - VOCs concentrations are generally below preliminary cleanup levels or are at low concentrations and trending down, with data indicating ongoing natural attenuation. Vinyl chloride is the main VOC of concern with the highest concentration detected at well MC-14.
    - 1,4-dioxane concentrations are highest at MC-14, and wells downgradient of this area (MC-20, MC-123) have declined to levels near or below the preliminary cleanup level. Based on trend analysis, the source appears to be primarily present in the shallow sand fill unit, not in the silt layer. Higher concentration wells show concentrations in the Shallow Groundwater Zone go up when the water table is highest, during periods when more of the sandy unit above the silt layer is saturated, making it more readily accessible for treatment.
    - Arsenic concentrations are generally below the preliminary cleanup level, with the highest concentrations at MC-14 and MC-31 and strong seasonality. Anaerobic conditions likely existed in the former marsh prior to industrial activities owing to the high organic content of native sediments. Aerobic microbial breakdown of the released organic constituents further depleted the groundwater of dissolved oxygen. The organic silt layer is likely to still be creating reducing conditions in groundwater with the strongest reducing conditions occurring during the drier summer season, as is evidenced by the low dissolved oxygen

content in wells and correlating higher arsenic levels that do not appear to be related to a release from facility operations.

- o Deep Aquifer conditions
  - The highest concentrations of VOCs remaining onsite are detected at wells in the former tank farm area. Deep aquifer wells screened immediately below the silt layer have higher concentrations than wells screened deeper, indicating the silt is acting as a probable secondary source of COCs.
  - Additional areas where VOCs have recently been detected above preliminary cleanup levels are located along the northern property line, near MC-118D, and southeast of the former tank farm, near well MC-15D. However, the concentrations in these areas are at least an order of magnitude lower than those in the former tank farm area.
  - 1,4-dioxane concentrations detected in the Deep Aquifer are much lower than in the shallow zone, with the highest concentrations detected in the former tank farm area and along the northern property line (near MC-118D).
  - Trends in concentrations of COCs in the deep aquifer show degradation in and north of the area of the former tank farm, and are increasing in the area of MC-15D, downgradient of the former tank farm.
- o Based on the long term trends in groundwater monitoring data (water levels and chemistry):
  - The shallow zone COC plumes are shrinking and treatment for 1,4-dioxane should be focused around MC-14.
  - The primary source for VOCs and 1,4-dioxane in the deep aquifer is likely from the silt layer in the former tank farm area, with a lower concentration source near the northern property line (near MC-118D).
  - Trend analysis in shallow and deep wells around MC-15D indicate that the source of increasing VOCs at MC-15D is likely the former tank farm area.

2.0 DEVELOPMENT OF REMEDIAL ALTERNATIVES

WAC 173-340-360 describes the minimum requirements and procedures for selecting cleanup actions under the Model Toxics Control Act (MTCA). Cleanup actions selected under MTCA must meet “threshold requirements” outlined in WAC 173-340-360(2)(a) of:

- Protecting human health and the environment;
- Complying with cleanup standards;
- Complying with applicable state and federal laws; and
- Providing for compliance monitoring.

In addition, cleanup shall adhere to “other requirements” outlined in WAC 173-340-360(2)(b):

- Using permanent solutions to the maximum extent practicable.
- Providing for a reasonable restoration time frame.
- Considering public concerns.

Additional cleanup action requirements are addressed in the remaining portions of WAC 173-340-360(2)(c through h), as discussed in the Technology Screening Technical Memorandum (DOF, 2019c) and associated response to comments. Revised technology screening tables are included in this memorandum (Tables 5-1 to 5-5). These tables have been revised to include hydraulic control and associated ancillary technologies.

This memorandum updates previously presented information about potential remedial alternatives developed in the 2013 FS:

- To address comments received from Ecology;
- To update alternative design based on current site conditions including the abundance of additional groundwater data gathered and trends that have become better defined since the 2013 FS submittal;
- To include evaluation of recently developed technologies; and
- To update alternative designs based on more recent and complete information on remedial technologies practicability, performance, and effectiveness.

Four remedial alternatives were developed as part of the 2013 FS (Alternatives 1 through 4) and two additional alternatives (Alternatives 5 and 6) have been developed during preparation of the revised FS, taking into account Ecology concerns voiced during FS meetings and communications. The six alternatives are:

- Alternative A-1- Capping and Monitored Natural Attenuation (MNA)
- Alternative A-2- Capping, In-Situ Bioremediation (ISB), In-Situ Chemical Oxidation (ISCO) and Monitored Attenuation (MA)
- Alternative A-3- Capping, Deep Soil Mixing, ISCO, and MA
- Alternative A-4- Capping, Electrical Resistive Heating and MA

- Alternative A-5- Capping, Permeable Reactive Barrier with zero valent iron (ZVI), and MA
- Alternative A-6- Capping, ISB, ISCO, Hydraulic Control, and MA

Not all retained remedial technologies were used to develop the alternatives, but all were considered and some were retained for use as contingent remedial technologies (biosparging, oxygen enhancement, phytoremediation, air sparging, barrier wall). The six remedial alternatives are discussed below in sections 2.2 through 2.7. Components of the cleanup action that are similar for all six alternatives are described in section 2.1.

2.1 Remedy Components Common to All Alternatives

All six remedial alternatives share several common elements, however only one element is the same across all alternatives.

- Grouting of the storm drain utility bedding.

While shallow groundwater trends indicate ongoing biodegradation has shrunk the impacted area, there is still a possibility that contaminated groundwater could migrate in the bedding of utility lines when the water table is elevated in the wet season. Grouting of the storm drain utility line is proposed in four locations along the alignment east of the property line. A four-foot cube would be excavated around the pipe within the bedding material and the material would be replaced with cementitious controlled density fill (CDF) to prevent groundwater migration along the utility alignment in the higher permeability pipe bedding material.

The four actions below are common components of each alternative, but implementation would vary based on the restoration time frame for each alternative.

- Institutional controls;
- Groundwater monitoring;
- Inhalation Pathway Interim Measure (IPIM); and
- Augmenting existing surface cover.

Institutional controls are non-engineered instruments such as administrative and legal controls that help reduce the potential for human exposure to contamination and/or protect the integrity of the remedy, i.e. development restrictions. Institutional controls would be implemented following completion of the implementation phase of the selected remedial alternative and would be negotiated with Ecology to protect human health and the environment. Given that the facility is an active industrial site and that several buildings with contamination under them are actively in use, long term institutional controls (primarily for low level soil contamination from inorganic COCs) and temporary institutional controls (for control during the remediation phase) are proposed for each alternative. Temporary institutional controls would be implemented to protect human health and the environment while remedial actions are underway. Once successful completion of remediation is confirmed, institutional controls would be removed.

Verification of groundwater remediation effectiveness would be implemented through a **groundwater monitoring** program. Duration and frequency of the program would be dependent on the selected remedial alternative and the alternative's effectiveness over time to obtain cleanup levels. Once successful completion of remediation is confirmed by groundwater monitoring, the groundwater component of the action would be deemed complete and no further groundwater monitoring would be required.

The **IPIM** was previously implemented to prevent risk of exposure to workers in Building 1 to VOCs. The IPIM system decreases pressure under the building and conveys VOCs through a stack on the roof of the building, preventing VOCs in the soil from entering the building. As part of the selected alternative, this system would be operated as long as necessary to protect human health. Sub-slab vapor monitoring is planned as part of design, to better assess the time frame for IPIM operations. If results indicate the system is no longer necessary, shut down of the IPIM and confirmation sampling would be negotiated with Ecology to provide verification that shutdown of the IPIM does not adversely impact human health and the environment.

Surface cover would be added in areas of the site that are unpaved to prevent direct contact with or surface water infiltration through soils with elevated concentrations of COCs.

2.2 Remedial Alternative A-1

Alternative A-1 would rely on surface cover, grouting of a potential groundwater conduit, and monitored natural attenuation to address soil and groundwater impacts within the site. The following elements are included (Figure 7-1).

- Grouting of the potential groundwater conduit, the utility trench under the stormwater piping to the east of the Stericycle property;
- Continued operation of the existing IPIM under Building 1;
- Augmenting existing surface cover by paving select areas of the site;
- Long-term monitoring and maintenance of the pavement cover;
- Monitored natural attenuation of groundwater downgradient of source areas;
- Groundwater monitoring is anticipated to evaluate MNA effectiveness for the duration of the restoration timeframe (at least 30 years based on extrapolation of groundwater monitoring data trends through the first half of 2019). Once groundwater monitoring indicates MNA has permanently destroyed COCs to below cleanup levels, remediation will be considered complete; and

- Institutional controls, including a deed restriction.

This alternative would utilize the natural reductive dechlorination process observed on the site through recent groundwater sampling results to obtain groundwater cleanup levels in the shallow groundwater and the deep aquifer. Chlorinated solvent concentrations in shallow groundwater have steadily decreased within the source area indicating that degradation is likely to continue.

Reductive dechlorination has been actively observed in the deep aquifer within the former source area through the decrease in tetrachloroethylene (PCE) and trichloroethylene (TCE). While increases in *cis*-1,2-dichloroethylene (*cis*-1,2-DCE) and vinyl chloride (VC) have been observed, the dehalococcoides bacteria currently degrading the PCE and TCE, are likely to eventually degrade the *cis*-1,2-DCE and VC to reach cleanup levels within the source area. Similar trends for chlorinated solvents have been observed in groundwater results from well MC-15D and the natural reductive dechlorination processes are expected to eventually obtain cleanup levels under this alternative, though timing is difficult to predict with currently available trend data. The restoration time frame for VOCs in the deep aquifer may exceed 30 years.

Concentrations of 1,4-dioxane have remained consistent in the vicinity of MC-14 in shallow groundwater and in the former tank farm area in the deep aquifer. These concentrations would be expected to slowly dissipate over time through dilution and dispersion, but the restoration timeframe could exceed 30 years based on current trend data.

2.3 Remedial Alternative A-2

Alternative A-2 would supplement the natural biodegradation processes that would occur under Alternative A-1 with (1) injection of carbohydrates in the former tank farm area, near MC-118D, and MC-15D and (2) in-situ chemical oxidation (ISCO) to accelerate destruction of 1,4-dioxane in the area around well MC-14.

The following elements are included (Figure 7-2).

- Grouting the utility trench under the stormwater piping to the east of the Stericycle property;
- Continued operation of the existing IPIM under Building 1;
- Augmenting the existing surface cover by paving select areas of the site;
- Long-term monitoring and maintenance of the pavement cover;
- Treatment near MC-14 - two rounds of ISCO injections to treat 1,4-dioxane and VOCs in shallow groundwater;

- Treatment in the former tank farm area and near the north fence line (near MC-118D) - two rounds of ISB injections utilizing carbohydrates and emulsified ZVI targeting chlorinated VOCs remaining in the silt layer and the upper portion of the deep aquifer;
- Treatment in the deep aquifer upgradient of and near MC-15D - ISB injection of carbohydrates near MC-15D to reduce risk of offsite migration of chlorinated VOCs in the upper portion of the deep aquifer;
- Monitored attenuation of the groundwater downgradient of the remediation areas;
- Groundwater monitoring would be used to evaluate ISB/ISCO effectiveness for the duration of the restoration timeframe (15 years based on vendor experience and the extrapolation of groundwater monitoring data trends once source area remediation is complete). Once groundwater monitoring indicates ISB/ISCO and MA has permanently destroyed COCs to below cleanup levels, remediation would be considered complete; and
- Institutional controls.

Prior to implementation of either ISCO or ISB, bench scale studies are proposed to confirm the appropriate substrate and dosage rates. Injection spacing design was based on typical spacing necessary for the soil types in each area and checked against spacing estimated by injection subcontractors. Further clarification of spacing will be included in the cost appendix of the FS.

ISCO would be utilized to address 1,4-dioxane concentrations in the vicinity of MC-14. Injections within the shallow groundwater would be completed with a spacing of 15-feet on center and a 10-feet depth interval (two to 12 feet bgs). To minimize metals release to the groundwater a Modified Fenton's Reagents (MFR) is proposed to treat the 1,4-dioxane concentrations per an estimate provided by In-Situ Oxidative Technologies, Inc. (ISOTEC). The area is estimated to be completed with nine injection locations.

A second ISCO injection event would be planned within a few months of the first injection to complete treatment of remaining COCs using approximately half the number of injection locations and half the initial treatment volume of hydrogen peroxide and MFR solution.

ISB injections within the former tank farm area, including the MC-118 well cluster area, would utilize an emulsified vegetable oil (EVO) and ZVI substrate to provide a carbon source for the natural bacteria and passively treat chlorinated solvents diffusing from the silt layer into the deep aquifer. Injections would be completed within the silt layer with a spacing of 15-feet on center (approximately 19 injection locations) and injections within the deep aquifer would be completed with a spacing of 25-feet on center (approximately seven injection locations). Treatment depths for the former tank farm would target the entire silt interval (10 to 18 feet bgs) and the upper 10 feet (18 to 28 feet bgs) of the deep aquifer. A second ISB injection event would be planned in the following year to polish treatment of remaining COCs using approximately half the number of injection locations and half the initial treatment volume of hydrogen peroxide and MFR solution.

ISB injections within the vicinity of MC-15D would utilize an EVO substrate to provide a carbon source for the natural bacteria to break down chlorinated solvents in the deep aquifer. Injections within the deep aquifer would be completed with a spacing of 25 feet on center, in the upper 10 feet (18 to 28 feet bgs) of the aquifer. The area is estimated to be completed with four injection locations.

2.4 Remedial Alternative A-3

Alternative A-3 would employ Deep Soil Mixing (DSM) with ZVI injection to treat the former tank farm area. This alternative would retain ISB to address chlorinated solvent concentrations around well MC-15D and ISCO near MC-14 from Alternative A-2, and also include ISCO near the northern fence line in the vicinity of MC-118D.

The following elements are included (Figure 7-3):

- Grouting the utility trench under the stormwater piping to the east of the Stericycle property;
- Continued operation of the existing IPIM under Building 1;
- Augmenting the existing surface cover by paving select areas of the site;
- Long-term monitoring and maintenance of the pavement cover;
- Treatment near MC-14 - two rounds of ISCO injections to treat the 1,4-dioxane and VOCs in the shallow groundwater;
- Treatment in the former tank farm area using DSM with ZVI;
    - Treatment along the North Fence Line (near MC-118D) using ISCO of the silt and deep aquifer;
- Treatment in the deep aquifer upgradient of and near MC-15D - ISB by injection of carbohydrates near MC-15D to reduce risk of offsite migration of chlorinated VOCs in the upper portion of the deep aquifer;
- Monitored attenuation of the groundwater downgradient of source remediation areas;
- Groundwater monitoring would be used to evaluate DSM/ISCO/ISB effectiveness for the duration of the restoration timeframe (10 years based on vendor experience and the extrapolation of groundwater monitoring data trends once source area remediation is complete). Once groundwater monitoring indicates DSM/ISCO/ISB and MA has

permanently destroyed COCs to below cleanup levels, remediation would be considered complete; and

- Institutional controls.

Prior to implementation of DSM, ISCO, or ISB, bench scale studies are proposed to confirm the appropriate substrate and dosage rates. Injection spacing design was based on typical spacing necessary for the soil types in each area and checked against spacing estimated by injection subcontractors. Further clarification of spacing will be included in the cost appendix of the FS.

ISCO would be utilized to address 1,4-dioxane concentrations in the vicinity of MC-14 and the north fence line (near MC-118D). To minimize metals release to the groundwater a MFR is proposed to treat the 1,4-dioxane concentrations per an estimate provided by In-Situ Oxidative Technologies, Inc. (ISOTEC). The area is estimated to be completed with nne injection locations.

Injections within the shallow groundwater near MC-14 would be completed the same as Alternative A-2, with a spacing of 15 feet on center and a 10 feet depth interval (two to 12 feet bgs). ISCO injections within the silt layer and deep aquifer around the MC-118D well cluster would be completed with a spacing of 10 feet on center in the silt layer (eight to 18 feet bgs) and 15 foot on center for the upper 10 feet (18 to 28 feet bgs) of the deep aquifer. An estimated 11 injections would be necessary to address the silt layer and five injections to treat the deep aquifer.

A second ISCO injection event would be planned within a few months of the first injection to complete treatment of remaining COCs using approximately half the number of injection locations and half the initial treatment volume of hydrogen peroxide and MFR solution.

DSM would require excavation of the upper five feet of soil within the proposed treatment area to allow for swell and substrate addition during DSM.

DSM would be implemented within the former tank farm area to address the chlorinated solvent source within the silt layer and upper zone of the deep aquifer. The addition of two percent by weight ZVI and one percent bentonite would treat COCs and reduce the permeability of the source soils in the former tank farm within the silt layer. Following DSM, the upper five feet of soil would need to be amended with Portland cement to stabilize the soils and allow for the area of the site to be utilized for normal facility operations.

ISB injections within the vicinity of MC-15D would utilize an EVO substrate to provide a carbon source for the natural bacteria to break down chlorinated solvents in the deep aquifer. Injections within the deep aquifer would be completed the same as in Alternative A-2, with a spacing of 25 feet on center, in the upper 10 feet (18 to 28 feet bgs) of the aquifer. The area is estimated to be completed with four injection locations.

2.5 Remedial Alternative A-4

Alternative A-4 would employ electrical resistive heating (ERH) to address source area COCs in both the vadose and saturated zone in the tank farm area and in the area downgradient around MC-14. The following elements are included (Figure 7-4):

- Grouting the utility trench under the stormwater piping to the east of the Stericycle property;
- Short term operation of the existing IPIM under Building 1;
- Augmenting the existing surface cover by paving select areas of the site;
- Long-term monitoring and maintenance of the pavement cover;
- Treatment of the former tank farm area, the north fence line area (near MC-118D) via ERH of the shallow zone, silt layer and upper portion of the deep aquifer;
- Treatment of the area under Building 1 and around well MC-14 via ERH of the shallow groundwater;
- Treatment in the deep aquifer upgradient of and near MC-15D via ISB by injection of carbohydrates to reduce risk of offsite migration of chlorinated VOCs;
- Monitored attenuation of groundwater downgradient of source area remediation area;
- Groundwater monitoring would be used to evaluate ERH/ISB effectiveness for the duration of the restoration timeframe (10 years based on vendor experience and the extrapolation of groundwater monitoring data trends once source area remediation is complete). Once groundwater monitoring indicates ERH/ISB and MA has permanently destroyed COCs to below cleanup levels, remediation would be considered complete; and
- Institutional controls.

Prior to implementation of ISB, bench scale studies are proposed to confirm the appropriate substrate and dosage rates. Injection spacing design was based on typical spacing necessary for the soil types in each area and checked against spacing estimated by injection subcontractors. Further clarification of spacing will be included in the cost appendix of the FS.

ISB injections within the vicinity of MC-15D would utilize an EVO substrate to provide a carbon source for the natural bacteria to break down chlorinated solvents in the deep aquifer. Injections within the deep aquifer would be completed the same as in Alternative A-2 with a spacing of 25 feet on center, in the upper 10 feet (18 to 28 feet bgs) of the aquifer. The area is estimated to be completed with four injection locations.

ERH would address chlorinated solvents and 1,4-dioxane within the shallow groundwater, the silt layer, and upper portion of the deep aquifer (two to 20 feet bgs) in the vicinity of the former tank farm and address 1,4-dioxane around MC-14 and Building 1 in the shallow groundwater (two to 10 feet bgs). Active heating following installation would operate for an estimated six months per a quote prepared by TRS Group, Inc. Following heating, a cool down period of approximately one year would be necessary before pre-ERH groundwater flow conditions would be expected to resumed. During this period, biodegradation would be expected to accelerate due to increased subsurface temperatures, helping to provide polishing of site COCs in the deep aquifer.

2.6 Remedial Alternative A-5

Alternative A-5 would employ a permeable reactive barrier (PRB) using ZVI to accelerate destruction of chlorinated solvents in the source area and around MC-15D, with ISCO utilized for treatment near MC-14.

The following elements are included (Figure 7-5):

- Grouting the utility trench under the stormwater piping to the east of the Stericycle property;
- Continued operation of the existing IPIM under Building 1;
- Augmenting the existing surface cover by paving select areas of the site;
- Long-term monitoring and maintenance of the pavement cover;
- Treatment near MC-14 - two rounds of ISCO injections to treat 1,4-dioxane and VOCs in shallow groundwater;
- Treatment in the former tank farm area and the north fence line (near MC-118D) via placement of PRBs by hydraulic fracturing of coarse grained ZVI using direct push methods, through the lower portion of the shallow zone (11 feet bgs) into the silt layer (10 to 20 feet bgs) and the upper portion of the deep aquifer (18 to 23 feet bgs) within the footprint of the former tank farm excavation and around the MC-118 well cluster.
- Treatment in the Deep Aquifer upgradient of and near MC-15D via placement of a PRB using hydraulic fracturing injection of fine grained ZVI through cased hole injections within the upper 10 feet of the deep aquifer (18 to 28 feet bgs) around MC-15D;
- Monitored attenuation of groundwater downgradient of remediation areas;
- Groundwater monitoring would be used to evaluate PRB/ISCO effectiveness for the duration of the restoration timeframe (10 years based on vendor experience and the extrapolation of groundwater monitoring data trends once source area remediation is complete). Once groundwater monitoring indicates PRB/ISCO and MA has permanently

destroyed COCs to below cleanup levels, remediation would be considered complete; and

- Institutional controls.

Prior to implementation of ISCO, bench scale studies are proposed to confirm the appropriate substrate and dosage rates. Injection spacing design was based on typical spacing necessary for the soil types in each area and checked against spacing estimated by injection subcontractors. Further clarification of spacing will be included in the cost appendix of the FS.

ISCO would be utilized to address 1,4-dioxane concentrations in the vicinity of MC-14, the same as in Alternative A-2. Injections within the shallow groundwater would be completed with a spacing of 15 feet on center and a 10 feet depth interval (two to 12 feet bgs). To minimize metals release to the groundwater MFR is proposed to treat the 1,4-dioxane concentrations per an estimate provided by In-Situ Oxidative Technologies, Inc. (ISOTEC). The area is estimated to be completed with nine injection locations.

A second ISCO injection event would be planned within a few months of the first injection to complete treatment of remaining COCs using approximately half the number of injection locations and half the initial treatment volume of hydrogen peroxide and MFR solution.

The source area PRB would utilize direct-push drilling methods for installation of a PRB above, within, and below the silt layer. An estimated 84 fracks placed through 21 injection locations (15-foot on center) would be necessary to install the PRB in the former tank farm and north fence line area. Fractures would occur at approximate depths of 11 to 12 feet, 15 to 16 feet, 20 feet, and 23 feet bgs. Placement of approximately 2,000 pounds of ZVI would occur with each fracture. Through installation of the source area PRB, site COCs diffusing from the silt layer into the shallow groundwater or deep aquifer would be destroyed. Prior to implementation of the former tank farm PRB, a pilot study would be necessary to determine the appropriate injection method and spacing, and volume of ZVI to be injected at each fracture.

The downgradient PRB placed around MC-15D would be installed with a different method than the source area PRB. Due to the increased depth of placement of the PRB, four-inch diameter cased borings would be installed by sonic drilling methods to a depth of 35-feet bgs. The cased borings would be installed in two rows, each containing four locations. A total of 16 fractures would be completed in the eight cased boring locations (15-foot on center) with fractures occurring at 25-feet and 28-feet bgs. Each fracture would place approximately 2,000 pounds of ZVI, similar to the source area. PRB placement around MC-15D would treat site COCs prior to migration off site along the eastern property boundary.

2.7 Remedial Alternative A-6

Alternative A-6 would supplement the remedial technologies from Alternative A-2 with short term hydraulic control.

The following elements are included (Figure 7-6):

- Grouting the utility trench under the stormwater piping to the east of the Stericycle property;
- Continued operation of the existing IPIM under Building 1;
- Augmenting the existing surface cover by paving select areas of the site;
- Long-term monitoring and maintenance of the pavement cover;
- Treatment near MC-14 via two rounds of ISCO injections to treat the 1,4-dioxane and VOCs in the shallow groundwater;
- Treatment in the former tank farm area and the north fence line area (near MC-118D) via two rounds of ISB injections utilizing carbohydrates and emulsified ZVI targeting chlorinated VOCs remaining in the silt layer and the upper portion of the deep aquifer;
- Short Term Hydraulic control of the deep aquifer;
- Treatment in the deep aquifer upgradient of and near MC-15D via ISB by injection of carbohydrates to reduce risk of offsite migration of chlorinated VOCs in the deep aquifer;
- Monitored attenuation of the groundwater downgradient of the remediation areas;
- Groundwater monitoring would be used to evaluate ISB/ISCO effectiveness for the duration of the restoration timeframe (15 years based on vendor experience and the extrapolation of groundwater monitoring data trends once source area remediation is complete). Once groundwater monitoring indicates ISB/ISCO and MA has permanently destroyed COCs to below cleanup levels, remediation would be considered complete; and
- Institutional controls.

Prior to implementation of either ISCO or ISB, bench scale studies are proposed to confirm the appropriate substrate and dosage rates. Injection spacing design was based on typical spacing necessary for the soil types in each area and checked against spacing estimated by injection subcontractors. Further clarification of spacing will be included in the cost appendix of the FS.

ISCO would be utilized to address 1,4-dioxane concentrations in the vicinity of MC-14, the same as in Alternative A-2. Injections within the shallow groundwater would be completed with a spacing of 15 feet on center and a 10 feet depth interval (two to 12 feet bgs). To reduce metals release to the groundwater MFR is proposed to treat the 1,4-dioxane concentrations per an estimate provided by ISOTEC. The area is estimated to be completed with nine injection locations.

A second ISCO injection event would be planned within a few months of the first injection to complete treatment of remaining COCs using approximately half the number of injection locations and half the initial treatment volume of hydrogen peroxide and MFR solution.

ISB injections within the former tank farm area, including the MC-118 well cluster area, would utilize EVO and ZVI substrate to provide a carbon source for the natural bacteria and passively treat chlorinated solvents diffusing from the silt layer into the deep aquifer, the same as in Alternative A-2. Injections would be completed within the silt layer with a spacing of 15 feet on center (approximately 19 injection locations), and injections within the deep aquifer would be completed with a spacing of 25 feet on center (approximately seven injection locations). Treatment depths for the former tank farm would target the entire silt interval (10 to 18 feet bgs) and the upper 10 feet (18 to 28 feet bgs) of the deep aquifer. A second ISB injection event would be planned in the following year to polish treatment of remaining COCs using approximately half the number of injection locations and half the initial treatment volume of hydrogen peroxide and MFR solution.

ISB injections within the vicinity of MC-15D would utilize an EVO substrate to provide a carbon source for the natural bacteria to break down chlorinated solvents in the deep aquifer. Injections within the deep aquifer would be completed the same as in Alternative A-2 with a spacing of 25 feet on center, in the upper 10 feet (18 to 28 feet bgs) of the aquifer. The area is estimated to be completed with four injection locations.

Hydraulic control would be implemented through installation of four groundwater extraction wells within the former tank farm and the MC-118 well cluster and installation of two groundwater extractions wells in the downgradient area around MC-15D. Each extraction well would be six-inch diameter and completed to approximately 30 feet bgs, screened within the deep aquifer (20 to 30 feet bgs). Using hydraulic conductivities calculated in the 2003 RI report (AMEC, 2013b), the average estimated combined flow from the six wells to contain the known areas of groundwater contamination would be approximately 33.5 gallons per minute, but the flow rate would vary with hydraulic conductivities across the site. It is assumed that prior to installation of the full hydraulic control system, a single extraction well would need to be installed and a pump test performed to determine site-specific groundwater extraction rates to properly size all other system components.

The hydraulic containment treatment system would need to be housed in a separate building with a containment foundation. Conveyance piping between wells, treatment, and discharge would be installed below grade to allow for reduced disturbance to facility operations. For the purposes of this FS, it is assumed the treatment system would include an air-stripper to remove VOCs from the water and vapor treatment vessels (with granular activated carbon and potassium permanganate media for VC) to adsorb and destroy the VOCs once they are transferred to vapor phase.

It is assumed that discharges could be sent to the Washougal publicly owned treatment works (POTW). The POTW confirmed they have capacity to receive the treated groundwater. However, the POTW does not accept industrial wastewater without an Ecology managed NPDES permit and does not accept groundwater by default. Additional permitting time and Ecology backing would be necessary to convince the POTW to accept the treated groundwater discharge.

3.0 REVISED FS NEXT STEPS

Once the remedial alternatives for soil and groundwater are approved by Ecology, Stericycle will update the FS Section 7 text, which covers detailed descriptions of remedial alternatives, and update costs for each alternative. The preferred remedial alternative will be presented with the implementation costs, including long-term operations and monitoring. Once the preferred remedy is approved by Ecology Stericycle will complete the FS and submit for Ecology review.

4.0 REFERENCES

AMEC, 2013a, Final Feasibility Study Report, PSC Washougal Facility, December.

AMEC, 2013b, Final Remedial Investigation Report, PSC Washougal Facility, September.

DOF, 2019a, Feasibility Study – Point of Compliance and Preliminary Cleanup Level Assessment, August.

DOF, 2019b, Feasibility Study Nature and Extent of Contamination Update, November 12 (originally issued in September).

DOF, 2019c, Revised Technical Memorandum: Feasibility Study – Technology Screening, November 12 (originally issued in October).

5.0 CLOSING

The services described in this report were performed consistent with generally accepted professional consulting principles and practices. No other warranty, expressed or implied, is made. This report is solely for the use and information of our client unless otherwise noted. Any reliance on this report by a third party is at such party’s sole risk.

TABLE 5-1
SUMMARY OF REMEDIATION TECHNOLOGIES CONSIDERED FOR SOIL
Stericycle Washougal Facility
Washougal, Washington

Technology Characteristics							
General Response Actions	Remediation Technologies	Section	Technology Description	Technology Development Status	General Performance Record	Site Areas Addressed	Site Contaminants Addressed
In Situ Biological Treatment	Bioventing	5.2.1.1	Oxygen is delivered to contaminated unsaturated soils by forced air movement (either extraction or injection of air) to increase oxygen concentrations and stimulate biodegradation.	Full-Scale	Performs well for nonhalogenated organic compounds in moist soils that biodegrade aerobically (such as BTEX). Low effectiveness for halogenated organics. Ineffective on PCBs, inorganics, and in dry soils	Upper Sand Unit east of Building 1 and in the former tank farm area.	TPH Constituents and VC.
	Enhanced Bioremediation	5.2.1.2	The activity of naturally occurring microbes is stimulated by circulating water-based solutions through contaminated soils to enhance in situ biological degradation of organic contaminants. Nutrients, oxygen, or other amendments may be used to enhance bioremediation and contaminant desorption from subsurface materials.	Full-Scale	Anaerobic bioremediation has been moderately effective on halogenated VOCs. Aerobic bioremediation has been moderately effective for VC, SVOCs and effective for TPH. Ineffective on inorganics and PCBs.	Areas located beneath the former fuel farm area and Building 1 (Upper and Lower Aquifer Units).	Halogenated VOCs (ethenes and TCP), SVOCs, TPH (BTEX).
	Phytoremediation	5.2.1.X	Broadly defined as the use of vegetation to address in situ biological degradation, sequestration, or capture of contaminants.	Full-Scale	Typical organic contaminants, such as petroleum hydrocarbons, gas condensates, crude oil, chlorinated compounds, pesticides, and explosive compounds, can be addressed using plant-based methods. Phytotechnologies also can be applied to typical inorganic contaminants, such as heavy metals, metalloids, radioactive materials, and salts (ITRC 2009).	Areas outside of containment located along the east fence line (possible source for 1,4-dioxane) and the area west of the waste oil tank system.	Halogenated VOCs, SVOCs, TPH, metals, and 1,4-dioxane.
In Situ Physical/Chemical Treatment	Chemical Oxidation	5.2.1.3	Oxidation chemically converts hazardous contaminants to nonhazardous or less toxic compounds that are more stable, less mobile, and/or inert. The oxidizing agents most commonly used are ozone, hydrogen peroxide, persulfate, or permanganate. Reaction occurs only in aqueous solution.	Full-Scale	Technology demonstrated to be effective under certain site conditions. Ineffective for most inorganics, but would be effective for cyanide.	Areas located beneath the former fuel farm area and Building 1 (Upper and Lower Aquifer Units).	Halogenated and nonhalogenated VOCs and SVOCs, TPH compounds, and 1,4-dioxane.
	Soil Flushing	5.2.1.4	Water, or water containing an additive to enhance contaminant solubility, is applied to the soil or injected into the groundwater to raise the water table into the contaminated soil zone. Contaminants are leached into the groundwater, which is then extracted and treated.	Full-Scale	Poor performance record. Few sites have been successfully remediated using this technology.	Vadose zone soil areas located beneath the former fuel farm area and east of Building 1.	Some inorganics and some organics, depending on site and constituent conditions and additive used (i.e. metals with chelatants, solvents with cosolvents, etc.).

TABLE 5-1
SUMMARY OF REMEDIATION TECHNOLOGIES CONSIDERED FOR SOIL
Stericycle Washougal Facility
Washougal, Washington

Technology Characteristics							
General Response Actions	**Remediation Technologies**	**Section**	**Technology Description**	**Technology Development Status**	**General Performance Record**	**Site Areas Addressed**	**Site Contaminants Addressed**
In Situ Physical/Chemical Treatment (cont.)	Soil Vapor Extraction	5.2.1.5	Removes volatile constituents from the vadose zone. Using a blower, a vacuum is applied to wells screened in the vadose zone, and the volatiles are entrained in the extracted air and removed with the soil vapor. Off gases are generally treated to control emissions using thermal destruction or adsorption technologies.	Full-Scale	Proven reliable and effective technology for VOCs. Not effective for SVOCs, PCBs, and inorganics.	Vadose zone soil areas on site around the former tank farm area and Building 1 .	Halogenated VOCs and TPH Constituents.
	Solidification/ Stabilization	5.2.1.6	Contaminants are physically bound or enclosed within a stabilized mass (solidification), or chemical reactions are induced between the stabilizing agent and contaminants either to reduce their mobility (stabilization) or to treat contaminated soil in situ (deep soil mixing).	Full-Scale	Several different field methods are used for this generalized approach. Stabilization reagents can be effective. Complete mixing can be difficult. Can be combined with variants such as deep soil mixing employing treatment technologies (e.g. zero-valent iron) to treat various COCs.	Vadose zone soil and silt around the former fuel tank area and around Building 1.	Metals and if deep soil mixing with ZVI is used; organics.
In Situ Thermal Treatment	High-Temperature Volatilization	5.2.1.7	Steam, electrical energy, or soil heaters are injected below the contaminated zone to heat contaminated soil. The heating enhances the release of contaminants from the soil matrix. Some VOCs and SVOCs are stripped from the contaminated zone and brought to the surface through soil vapor extraction.	Full-Scale	Performance of steam injection and stripping is highly variable and site specific. Installation of soil heaters will result in uneven heating and may desiccate soils. **Electrical resistive heating would be the most effective technology** but may require excess energy and time to adequately treat the target VOCs and SVOCs.	All primary impacted soil areas around the former fuel tank area and beneath/around Building 1.	VOCs, SVOCs, may treat cyanide
Containment	Cap/Surface Cover	5.2.1.8	Surface caps constructed of asphalt concrete, Portland cement concrete, or flexible membrane liners prevent direct exposure to soil contaminants, control erosion, and reduce infiltration of storm water into the subsurface, reducing the leaching of COCs to groundwater.	Full-Scale	Proven effective for preventing surface exposure to buried waste and for reducing infiltration of surface water through waste, limiting leaching of COCs to groundwater.	All impacted soil areas around the former fuel tank area, building 2 and building 3, and west of the waste oil tank system.	VOCs, SVOCs, TPH, inorganics
Ex Situ Biological Treatment (assumes excavation)	Biopiles	5.2.2.1	Excavated soils are mixed with soil amendments and placed on a treatment area that includes leachate collection systems and some form of aeration to support bioremediation of organic constituents in excavated soils. Moisture, heat, nutrients, oxygen, and pH can be controlled to enhance biodegradation.	Full-Scale	Effective for nonhalogenated VOCs and TPH. Less effective on halogenated VOCs and poor effectiveness on PCBs. **Ineffective for inorganics.**	Vadose zone soil areas around the former tank farm area and east of Building 1 with **BTEX.**	TPH (BTEX)
Ex Situ Physical/Chemical Treatment (assumes excavation)	Soil Washing	5.2.2.2	Contaminants sorbed onto fine soil particles are separated from bulk soil in an aqueous-based system on the basis of particle size. The wash water may be augmented with a basic leaching agent, surfactant, pH adjustment, or chelating agent to help remove organics and heavy metals.	Full-Scale	Not widely commercially applied in the United States. Technology sometimes has difficulties treating complex mixtures of organics and inorganics.	Vadose zone soil areas around the former tank farm area and east of Building 1.	VOCs, SVOCs, inorganics, TPH

TABLE 5-1
SUMMARY OF REMEDIATION TECHNOLOGIES CONSIDERED FOR SOIL
Stericycle Washougal Facility
Washougal, Washington

Technology Characteristics							
General Response Actions	**Remediation Technologies**	**Section**	**Technology Description**	**Technology Development Status**	**General Performance Record**	**Site Areas Addressed**	**Site Contaminants Addressed**
Ex Situ Physical/Chemical Treatment (assumes excavation)	Solidification/ Stabilization	5.2.2.3	Contaminants are physically bound or enclosed within a stabilized mass (solidification), or chemical reactions are induced between the stabilizing agent and contaminants to reduce their mobility (stabilization).	Full-Scale	Generally effective for inorganics. Mature technology with documented performance record. Poor effectiveness for organics.	Vadose zone and silt soils in and around the former tank farm area.	Inorganics
Ex Situ Thermal Treatment (assumes excavation)	Thermal Desorption	5.2.2.4	Wastes are heated to volatilize water and organic contaminants. A carrier gas or vacuum system transports volatilized water and organics to the gas treatment system.	Full-Scale	Proven effective at low temperature for TPH and VOCs; at high temperature, effective for SVOCs, PAHs, and PCBs. Proven and commercial off-the-shelf technology offered by multiple vendors. Not effective for inorganics.	Vadose zone and silt soils in and around the former tank farm area and east of Building 1.	VOCs, SVOCs, TPH
Excavation/Disposal	Excavation and Off- Site Disposal	5.2.2.5	Wastes exceeding site remedial goals are excavated and transported off site to an appropriate hazardous waste land disposal facility.	Full-Scale	Proven effective for all site COCs.	Vadose zone and silt soils in and around the former tank farm area and east of Building 1.	VOCs, SVOCs, TPH, inorganics

Notes
X indicates a new technology added to the table after submittal of the 2013 Feasibility Study

Abbreviations
SVOCs = semivolatile organic compounds
RCRA = Resource Conservation and Recovery Act
COCs = constituents of concern
RI/FS = Remedial Investigation and Feasibility Study
PAHs = polycyclic aromatic hydrocarbon
TPH = total petroleum hydrocarbons
PCBs = polychlorinated biphenyls
VOCs = volatile organic compounds

TABLE 5-2
REMEDIATION TECHNOLOGY SCREENING FOR SOIL
Stericycle Washougal Facility
Washougal, Washington

Technology Characteristics					
General Response Actions	**Remediation Technologies**	**Section**	**Site-Specific Issues Affecting Technology or Implementation**	**Rationale for Retention or Rejection**	**Screening Result**
In Situ Biological Treatment	Bioventing	5.2.1.1	Effectiveness of in situ degradation of halogenated VOCs and SVOCs is low. Technology is ineffective on inorganics and pesticides. Technology will leave a lot of mass of non-halogenated VOCs in subsurface that are buried in silts.	Low effectiveness on high-molecular-weight organic COCs (SVOCs) and halogenated VOCs, and ineffective for inorganics. Would not likely achieve CULs in source areas or at CPOCs for organic VOCs.	Reject
	Enhanced Bioremediation	5.2.1.2	In situ degradation of VOCs (chlorinated and non-chlorinated) is only moderately effective. Ineffective for other site COCs. Would require a system of numerous injection points to distribute bioremediation fluids to the subsurface across a large area, some of which is under existing buildings. Sequential anaerobic/aerobic treatment would be needed to address most of the organic COCs. Would be very difficult to apply substrate to unsaturated soils.	Only moderately effective on halogenated organics and SVOCs and likely would not obtain CULs in contaminant source areas but would likely meet CULs at CPOCs. Likely ineffective on inorganics and pesticides. Very long treatment time likely. Very high cost to implement for soils compared to other technologies, such as chemical oxidation, given uncertainty in performance, multiple injections required, and monitoring requirements.	Reject
	Phytoremediation	5.2.1.X	Only viable in non-containment areas. Would require irrigation systems for the dry season. Soil amendments may be necessary to ensure rapid and sustained growth	Environmentally-friendly “green” and low-tech remedial technology. Operation and maintenance costs are typically lower than those required for traditional remedies (such as soil vapor extraction), because the remedy is generally resilient and self-repairing. Plants can improve site aesthetics (visual appearance and noise).	Retain
In Situ Physical/Chemical Treatment	Chemical Oxidation	5.2.1.3	Handling of oxidant chemicals during remediation presents a safety concern. Chemical oxidant demand of soil can consume large quantities of oxidant (pilot test recommended). Establishing effective oxidant delivery system for even vadose zone distribution difficult. Oxidants can mobilize some metals. This technology may require multiple injection rounds and it may be difficult to implement under Building 1.	Treats all key COCs; remediation time frame is relatively short and depending on the treatment area, may achieve stringent CULs aside from silt source area given difficulty to distribute oxidant in low-permeability soils.	Retain
	Soil Flushing	5.2.1.4	Requires recovery of water (hydraulic capture) and surfactant and separation facilities. Recovered water requires treatment, disposal, and management of treatment residuals. Site would require different surfactants to treat all COCs. Large injection galleries or trenches would require extensive disruption of facility operations. Implementation under Building 1 would be difficult.	Technology is not proven effective. Requires extensive and complex fluids delivery system and recovered fluids treatment system. Technology would not meet cleanup levels and would not remove sufficient mass from source areas to meet CULs at CPOCs.	Reject

TABLE 5-2
REMEDIATION TECHNOLOGY SCREENING FOR SOIL
Stericycle Washougal Facility
Washougal, Washington

Technology Characteristics					
General Response Actions	**Remediation Technologies**	**Section**	**Site-Specific Issues Affecting Technology or Implementation**	**Rationale for Retention or Rejection**	**Screening Result**
In Situ Physical/Chemical Treatment (cont.)	Soil Vapor Extraction	5.2.1.5	Limited vadose zone at Stericycle facility; most contaminants are trapped in the Silt Layer below water table. Contamination in a large percentage of the vadose zone is likely due to smear effects of seasonal water table. Thus, the lower end of the vadose zone is likely to be recontaminated regularly.	The contaminant distribution and hydrogeology at the site are likely to lead to low mass removal and limited effectiveness using this technology. Technology will not meet cleanup levels in vadose zone soils or remove enough mass to meet CPOC CULs.	Reject
In Situ Physical/Chemical Treatment (cont.)	Solidification/ Stabilization	5.2.1.6	Increases in soil volume due to stabilization or solidification reagents ("bulk up" or "fluff") can be significant. Excess soil may require disposal as hazardous waste. Presence of solidified material could affect future site development by creating structural challenges for new buildings. Combining containment and treatment with additives would still not address all COCs.	Deep soil mixing with zero-valent iron has been identified as a potential field method that would remediate organics and reduce COC contact with groundwater, thereby limiting migration of COCs from the PSC property. Deep soil mixing with ZVI is not anticipated to meet stringent CULs in source areas but rather at CPOC.	Retain
In Situ Thermal Treatment	High-Temperature Volatilization	5.2.1.7	Effectiveness can be hindered by high organic carbon content or high moisture content (e.g., soil in the capillary fringe). Would require extensive network of steam distribution points or electrodes to heat soil effectively. For steam injection, significant volumes of water are added to the subsurface, which may flush contaminants from unsaturated soil to groundwater. Volatilization of contaminants may prevent inhalation risk for workers.	ERH is one of the **most effective** treatment technologies in silt formations and may achieve CULs in the source areas and the other target areas. Has been retained for use in soils and groundwater.	Retain
Containment	Cap/Surface Cover	5.2.1.8	The site is a patch-work of different coverings. Would require patching or paving areas of risk to prevent offsite migration or worker exposure.	Would be effective in preventing exposure of workers at the facility to contaminated soils. Would not meet CULs nor reduce any mass of COCs.	Retain
Ex Situ Biological Treatment (assumes excavation)	Biopiles	5.2.2.1	Would require extensive site excavation and soil management and removal of existing concrete cover. Extensive shoring and supporting systems would be required for excavations near existing structures. Some impacted soils would likely remain in place due to the presence of existing structures/buildings. Emission control measures (e.g., tenting site) would likely be required during excavation. Treatability tests required to assess feasibility. RCRA treatment permit would likely be required.	Unproven effectiveness on halogenated VOCs. Ineffective on inorganics. Large excavation would disrupt existing facility cover. Increased worker and public exposure risk associated with excavation and treatment process. Contaminated soils that would be left in place would be above CULs in treatment areas and at CPOCs.	Reject

TABLE 5-2
REMEDIATION TECHNOLOGY SCREENING FOR SOIL
Stericycle Washougal Facility
Washougal, Washington

Technology Characteristics					
General Response Actions	**Remediation Technologies**	**Section**	**Site-Specific Issues Affecting Technology or Implementation**	**Rationale for Retention or Rejection**	**Screening Result**
Ex Situ Physical/Chemical Treatment (assumes excavation)	Soil Washing	5.2.2.2	Would require extensive site excavation, soil management, and removal of existing concrete cover. Extensive shoring and support systems would be required for excavations near existing structures. Some impacted soils would likely remain in place due to the presence of existing structures/buildings. Emission control measures (e.g., tenting site) would likely be required during excavation. Worker and public exposure to impacted soils is significantly increased by this approach. Treatability tests would be required to assess feasibility. Produces wash water and soil residuals, which would require further treatment and off-site disposal. Significant concentrations of humus (natural organics) or clay in soil can disrupt process. RCRA treatment permit would likely be required.	Soil washing may not be effective for complex mixture of organics and inorganics. Extensive shoring and supporting systems would be required for excavations near existing structures. Worker and public exposure risks associated with excavation and treatment process. Contaminated soils that would be left in place would be above CULs in treatment areas and at CPOCs.	Reject
Ex Situ Physical/Chemical Treatment (assumes excavation) (cont.)	Solidification/ Stabilization	5.2.2.3	Would require excavation and soil management. Extensive shoring and support systems would be required for excavations near existing structures. Some impacted soils would likely remain in place due to the presence of existing structures/buildings. Emission control measures (e.g., tenting site) would likely be required during excavation. Treatability tests would be required to assess feasibility. Can result in significant increases in soil volume ("bulk up") that would likely result in off-site disposal of excess material. Because organic wastes would be encapsulated but not destroyed, long-term management of wastes would be required. RCRA treatment permit would likely be required.	Extensive shoring and support systems would be required for excavations near existing structures. Volume increase (bulk up) would result in excess material requiring off-site disposal. Post-treatment waste left on the property would remain a long-term management issue. Not proven effective for organics. Increased worker and public exposure risk associated with excavation and treatment process. Contaminated soils that would be left in place would be above CULs in treatment areas and at CPOCs.	Reject
Ex Situ Thermal Treatment (assumes excavation)	Thermal Desorption	5.2.2.4	Would require excavation and soil management. Extensive shoring and support systems would be required for excavations near existing structures. Some impacted soils would likely remain in place due to the presence of existing structures/buildings. Emission control measures (e.g., tenting site) would likely be required during excavation. Worker and public exposure to impacted soils is significantly increased by this approach. Treatability tests would be required to assess feasibility. Requires large working area for setup of equipment. High soil moisture can increase costs due to extended soil drying. Emissions from thermal desorption must be captured and treated prior to discharge to the atmosphere. RCRA treatment permit would likely be required.	Large excavation and treatment footprint would disrupt existing facility operations. High temperature desorption would address high molecular weight organics (SVOCs), but would also potentially create emissions containing metals. Increased worker and public exposure risk associated with excavation. Contaminated soils that would be left in place would be above CULs in treatment areas and at CPOCs.	Reject

TABLE 5-2
REMEDIATION TECHNOLOGY SCREENING FOR SOIL
Stericycle Washougal Facility
Washougal, Washington

Technology Characteristics					
General Response Actions	**Remediation Technologies**	**Section**	**Site-Specific Issues Affecting Technology or Implementation**	**Rationale for Retention or Rejection**	**Screening Result**
Excavation/Disposal	Excavation and Off-Site Disposal	5.2.2.5	Would require extensive site excavation and soil management. Extensive shoring and support systems would be required for excavations near existing structures. Some impacted soils would likely remain in place due to the presence of existing structures/buildings.	Capable of addressing all contaminants in vadose zone soil. Least administratively, logistically, and technically complex ex situ remediation technology. Potentially applicable to hot spots where other technologies are difficult to implement or expensive. Contaminated soils that would be left in place would be above CULs in excavated areas and at CPOCs.	Retain

Notes
X indicates a new technology added to the table after submittal of the 2013 Feasibility Study

Abbreviations
COCs = constituents of concern
CUL = cleanup level
CPOC = conditional point of compliance
ERH = electrical resistance heating
RCRA = Resource Conservation and Recovery Act
SVOCs = semivolatile organic compounds
VOCs = volatile organic compounds
ZVI = zero-valent iron

TABLE 5-3
SUMMARY OF REMEDIATION TECHNOLOGIES CONSIDERED FOR GROUNDWATER
Stericycle Washougal Facility
Washougal, Washington

Technology Characteristics							
General Response Actions	**Remediation Technologies**	**Section**	**Technology Description**	**Technology Development Status**	**General Performance Record**	**Site Area Addressed**	**Site Contaminants Addressed**
In Situ Biological Treatment	Enhanced Biodegradation with Biosparging	5.3.1	Air and nutrients, if needed, are injected into the saturated zone to increase oxygen levels and promote aerobic biological activity. Air is delivered using a compressor and vertical or horizontal injection wells.	Full-Scale	Performs well for organic compounds that biodegrade aerobically. Not effective for inorganics or chlorinated VOCs. Primarily used at petroleum-impacted sites.	Shallow groundwater and Deep Aquifer around the former tank farm area, along the northern property line and east of Building 1.	VC, TPH (BTEX)
	Oxygen Enhancement with Hydrogen Peroxide or ORC	5.3.2	Oxygen is added to the saturated zone by adding chemicals such as hydrogen peroxide or ORC®. The increased oxygen levels promote aerobic biological activity. Hydrogen peroxide or ORC solutions can be injected into the aquifer or introduced through slow release mechanisms placed in wells.	Full-Scale	Has been effectively used at TPH sites. Performance is similar to but less effective than biosparging.	Shallow groundwater and Lower Aquifer around the former tank farm area and along the northern property line.	VC, TPH (BTEX)
	Co-Metabolic Treatment	5.3.3	Chloroethenes and 1,4-dioxane are organically degraded by aerobic co-metabolism with alkane substrates, such as ethane, by indigenous microbes. Oxygen and the alkane substrate can be added through passive diffusion or through groundwater circulation system.	Full-Scale	Has been effective for degradation of chlorinated solvents and 1,4-dioxane.	Shallow groundwater and Lower Aquifer around the former tank farm area, the northern property line, and east of Building 1.	PCE, TCE, *cis* -1,2-DCE, VC, TPH, 1,4-dioxane
	Biostimulation of Reductive Dechlorination (Anaerobic)	5.3.4	A carbohydrate (e.g., molasses, sodium lactate) is injected into the affected groundwater to serve as an electron donor for indigenous organisms to enhance reductive dechlorination. A carbohydrate solution is distributed with injection wells, direct-push probes, or groundwater recirculation systems.	Full-Scale	Proven effective under proper conditions for degradation of chlorinated solvents.	Shallow groundwater and Lower Aquifer around the former tank farm area and along the northern property line.	PCE, TCE, *cis* -1,2-DCE, and VC
	Bioaugmentation	5.3.5	Injection of specialty, nonindigenous microbes to enhance biodegradation. Microorganisms are commercially available for both aerobic and anaerobic degradation of chlorinated organics and petroleum hydrocarbons.	Full-Scale	Has been effective for biodegradation of chlorinated solvents. Requires application of specific microbial seed (*Dehalococcoides*). May require repeated application.	Shallow groundwater and Lower Aquifer around the former tank farm area and along the northern property line.	PCE, TCE, *cis* -1,2-DCE, and VC
	Monitored Natural Attenuation	5.3.6	Intrinsic attenuation of groundwater constituents via the natural processes of biodegradation (aerobic and/or anaerobic), adsorption, and dilution. This passive technology relies on natural conditions within impacted groundwater.	Full-Scale	Has been proven effective at sites with appropriate conditions.	All areas of site in the Shallow and Lower Aquifer Groundwater Zones with appropriate conditions.	chlorinated VOCs, and 1,4-dioxane

TABLE 5-3
SUMMARY OF REMEDIATION TECHNOLOGIES CONSIDERED FOR GROUNDWATER
Stericycle Washougal Facility
Washougal, Washington

Technology Characteristics							
General Response Actions	**Remediation Technologies**	**Section**	**Technology Description**	**Technology Development Status**	**General Performance Record**	**Site Area Addressed**	**Site Contaminants Addressed**
In Situ Physical/Chemical Treatment	Phytoremediation	5.3.7	Dense plants and trees can supply nutrients to promote microbial growth that reduce contaminant concentrations in groundwater, or plants can directly uptake contaminants in groundwater. New implementation technology allows for treatment depths of more than 50 feet below ground surface and has shown effective hydraulic control.	Full-Scale	Has been proven effective at sites with appropriate conditions.	As a potential contingent remedy for groundwater zones along the northeast and east sides of the site.	VOCs (both chlorinated and non- chlorinated), TPH, SVOCs, metals, 1,4-dioxane.
	Carbon Augmentation	5.3.X	Colloidal activated carbon is injected into the saturate zone with an organic stabilizer to sequester and reduce contaminant concentrations. The activated carbon disperses through the subsurface during injection and dispersion continues over time with groundwater flow.	Full Scale	Has been proven effective at sites with appropriate conditions. Effectively used for chlorinated VOCs and TPH. Not effective for inorganics.	Shallow groundwater and Lower Aquifer around the former tank farm area, along the northern property line, and underneath and east of Building 1.	PCE, TCE, cis -1,2-DCE, non- chlorinated VOCs, SVOCs (including 1,4- dioxane), TPH, pesticides
	Air Sparging	5.3.8	Air is injected into the saturated zone to volatilize organic compounds or oxygenate aquifer to promote precipitation of metals. An air compressor is used to supply air to the saturated zone typically through air sparge wells. Similar to biosparging, but does not rely on biodegradation.	Full-Scale	Has been effectively used at non-chlorinated VOC-impacted sites. Difficult to implement for deep groundwater.	Shallow groundwater and Lower Aquifer around the former tank farm area and along the northern property line.	VC, TPH, SVOCs, metals
	Chemical Oxidation-Active	5.3.9X	An oxidizing chemical (permanganate, hydrogen peroxide, Fenton's Reagent, RegenOx) is actively injected through wells or via direct-push technology to the groundwater to chemically oxidize contaminants. Pilot test would be required	Full-Scale	Can be effective depending on oxidant demand of native material, tightness of formation, and number of injections. Not effective for most metals.	Shallow groundwater and Lower Aquifer around the former tank farm area, along the northern property line, and underneath and east of Building 1.	VOCs (both chlorinated and non- chlorinated), SVOCs (including 1,4-dioxane), TPH, pesticides
	Chemical Oxidation-Passive	5.3.9X	An oxidizing chemical (potassium permanganate, sodium persulfate) is suspended in a monitoring on an inert media to passively release chemical oxidizer for treatment of contaminants. Pilot test would be required	Full-Scale	Can be effective depending on oxidant demand of native material, tightness of formation, and number of injections. Not effective for most metals and 1,4-dioxane.	Shallow groundwater and Lower Aquifer around the former tank farm area, along the northern property line, and underneath and east of Building 1.	VOCs (both chlorinated and non- chlorinated), TPH
	Thermal Treatment	5.3.10	Temperature in the saturated zone is increased by injecting steam or applying an electrical current. The increased temperature volatilizes organic compounds, which would be collected from the vadose zone using SVE.	Full-Scale	Mixed performance record with improved performance in silts compared to other technologies. Some applications have been effective, while others have been unsuccessful in attaining cleanup objectives. Not effective for inorganics, can release metals.	Shallow Groundwater Zone, Silt Layer, and Lower Aquifer around the former tank farm area, along the northern property line, and underneath and east of Building 1.	VOCs (both chlorinated and non- chlorinated), TPH, SVOCs (including 1,4- dioxane), and metals

TABLE 5-3
SUMMARY OF REMEDIATION TECHNOLOGIES CONSIDERED FOR GROUNDWATER
Stericycle Washougal Facility
Washougal, Washington

Technology Characteristics							
General Response Actions	**Remediation Technologies**	**Section**	**Technology Description**	**Technology Development Status**	**General Performance Record**	**Site Area Addressed**	**Site Contaminants Addressed**
In Situ Physical/Chemical Treatment (cont.)	In-Well Stripping	5.3.11	Air is injected into a double-screened well, lifting the water in the well and forcing it out the upper screen. Simultaneously, additional water is drawn in the lower screen. Volatile compounds are transferred to the vapor phase and removed by vapor extraction. Groundwater in radius of influence is aerated.	Full-Scale	Mixed performance record. Some applications have been very effective, while others have been unsuccessful in attaining cleanup objectives.	Shallow Groundwater Zone and Lower Aquifer around the former fuel tank area.	VC, non-chlorinated VOCs, TPH
	Passive/Reactive Treatment Walls	5.3.12	Contaminant concentrations in groundwater are reduced as the groundwater flows through the permeable reactive barrier containing zero-valent iron.	Full-Scale	Has been effectively used to reduce chlorinated VOC and metals concentrations in groundwater.	Shallow Groundwater Zone and Lower Aquifer to the east of Building 1.	chlorinated VOCs, some metals
Groundwater Extraction and Treatment (Pump and Treat)	Hydraulic Control	5.3.13	Groundwater extraction wells are installed to create a hydraulic gradient to control contaminant migration. Extracted water is then treated and discharged.	Full-Scale	Has been effectively used to control contaminant migration. Is a long-duration technology. Cannot attain cleanup levels.	Shallow Groundwater Zone and Lower Aquifer around the former tank farm area and east of Building 1.	VOCs (both chlorinated and non-chlorinated), SVOCs (including 1,4-dioxane), TPH, metals
	Mass Reduction	5.3.13	Groundwater extraction wells are installed in source areas to aggressively remove contaminated groundwater, thereby reducing contaminant mass. Extracted water is then treated and discharged.	Full-Scale	Has been effectively used to remove contaminants. Is a long- duration technology.	Same as Hydraulic Control Technology.	VOCs (both chlorinated and non-chlorinated), SVOCs (including 1,4-dioxane), TPH, metals
	Dynamic Groundwater Recirculation (DGR)	5.3.X	DGR creates dynamic groundwater flow conditions that enhances the natural flushing processes occurring within an impacted area.	Full-Scale	Has been proven effective in homogeneous aquifers to remove COCs in solution.	Shallow Groundwater Zone and the Lower Aquifer in the vicinity of the former tank farm, along the northern property line, underneath Building 1 and to the east of Building 1.	VOCs (both chlorinated and non-chlorinated), SVOCs (including 1,4-dioxane), TPH, metals
In Situ Physical/Chemical Treatment	Emulsified Zero-Valent Iron	5.3.14	Zero-valent iron emulsified in vegetable oil and surfactant is injected into groundwater. Zero-valent iron causes abiotic reductive dechlorination, and vegetable oil and surfactant act as long-term electron donors for biotic reductive dechlorination.	Full-Scale	Has been effectively used to reduce chlorinated VOCs and metals concentrations in groundwater.	Shallow Groundwater Zone and the Lower Aquifer in the vicinity of the former tank farm, along the northern property line, underneath Building 1 and to the east of Building 1.	chlorinated VOCs, Arsenic

TABLE 5-3
SUMMARY OF REMEDIATION TECHNOLOGIES CONSIDERED FOR GROUNDWATER
Stericycle Washougal Facility
Washougal, Washington

Technology Characteristics							
General Response Actions	**Remediation Technologies**	**Section**	**Technology Description**	**Technology Development Status**	**General Performance Record**	**Site Area Addressed**	**Site Contaminants Addressed**
In Situ Physical/Chemical Treatment (cont.)	Surfactant-Enhanced Aquifer Remediation (SEAR)	5.3.15	Surfactants are injected to increase the solubility and mobility of organic contaminants, including NAPLs. Surfactants and contaminants are then recovered with conventional pump-and-treat methods. The surfactants are separated from the groundwater and contaminants and reinjected.	Full-Scale	Has been used to enhance recovery of chlorinated VOCs and DNAPL. Limited full-scale applications.	Shallow Groundwater Zone and the Lower Aquifer in the vicinity of the former tank farm, along the northern property line, underneath Building 1 and to the east of Building 1.	chlorinated VOCs, SVOCs, TPH
	Co-Solvent Flooding	5.3.16	Co-solvents, typically alcohols, are injected to enhance dissolution and recovery of DNAPL components. Co-solvent and dissolved- phase organics are recovered with conventional groundwater extraction methods.	Full-Scale	Has been used to enhance recovery of DNAPL. Limited prior full-scale applications.	Shallow Groundwater Zone and Lower Aquifer in the vicinity of the former tank farm source areas.	chlorinated VOCs, SVOCs
Physical Containment	Barrier Wall	5.3.17	Placement of a barrier wall that physically restricts flow of groundwater or grouting/cementing potential COC migration conduits. The barrier wall must be keyed into lower confining unit for total containment.	Full-Scale	Has been effectively used to contain contaminated groundwater. Cannot attain cleanup levels as sole remedial technology.	Barrier wall used to border the former tank farm in the Shallow Groundwater Zone and the Lower Aquifer.	VOCs (both chlorinated and non-chlorinated), SVOCs (including 1,4-dioxane), TPH, metals
Ancillary/Support Technologies	Air Stripping	5.3.28	This technology is used in conjunction with pump- and-treat systems. Extracted groundwater is passed downward against a stream of rising air. The countercurrent stream of air strips VOCs from the water. Contaminants in the air stream are then removed or treated by oxidation or adsorption technologies.	Full-Scale	Has been effectively used to remove VOCs (both chlorinated and non-chlorinated) from groundwater.	Same as Hydraulic Control Technology.	VOCs (both chlorinated and non-chlorinated), metals
	Oxidation	5.3.X	This technology can be used in conjunction with pump-and-treat systems. Extracted groundwater is augmented with an oxidant, such as hydrogen peroxide or potassium permanganate, to degrade COCs.	Full-Scale	Has been effectively used to remove chlorinated and non-chlorinated VOCs and 1,4-dioxane from groundwater	Same as Hydraulic Control Technology.	VOCs (both chlorinated and non-chlorinated), 1,4-dioxane, metals
	Adsorption	5.3.19	This technology is used in conjunction with pump- and-treat systems. Extracted groundwater or VOC- containing air is passed through vessels containing granular activated carbon. Organic compounds with an affinity for carbon are transferred from the aqueous or vapor phase to the solid phase by sorption to the carbon. Treated carbon products are available to address VOCs such as VC that have a low affinity for conventional carbon.	Full-Scale	Has been effectively used to remove chlorinated and non-chlorinated VOCs, 1,4-dioxane, and metals from groundwater	Same as Hydraulic Control Technology.	VOCs (both chlorinated and non-chlorinated), SVOCs (including 1,4-dioxane), TPH, metals

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TABLE 5-3
SUMMARY OF REMEDIATION TECHNOLOGIES CONSIDERED FOR GROUNDWATER
Stericycle Washougal Facility
Washougal, Washington

Technology Characteristics							
General Response Actions	**Remediation Technologies**	**Section**	**Technology Description**	**Technology Development Status**	**General Performance Record**	**Site Area Addressed**	**Site Contaminants Addressed**
Ancillary/Support Technologies (cont.)	Deep Soil Mixing	5.3.20	This technology is used in conjunction with several other technologies above. An auger is used to drill down into the soil, and a substrate (sand, clay, or cement) is injected as the auger goes down and is then pulled back up. Different additives can be combined with different substrates in order to accomplish a variety of objectives. It can be used as a delivery method for in situ chemical oxidation or in situ enhanced bioremediation. It can also be used to install passive reactive barriers or to help build physical containment.	Full-Scale	Has been effectively used to treat chlorinated and non-chlorinated VOCs, SVOCs (including 1,4-dioxane), and TPH in groundwater or to contain metals, TPH, chlorinated and non-chlorinated VOCs, SVOCs, and metals.	Shallow Groundwater Zone and Silt Layer around the former tank farm area. Addressing Silt Layer addresses Lower Aquifer.	VOCs (both chlorinated and non-chlorinated), SVOCs (including 1,4-dioxane), TPH, metals

Notes
X indicates a new technology added to the table after submittal of the 2013 Feasibility Study

Abbreviations
cis -1,2-DCE = *cis* -1,2-dichloroethene
BTEX = benzene, toluene, ethylbenzene, and xylenes
DNAPL = dense nonaqueous-phase liquids
SVE = soil vapor extraction
SVOCs = semivolatile organic compounds
TCE = trichloroethene
NAPL = nonaqueous phase liquids
ORC = oxygen-releasing compound
PCE = tetrachloroethane
TPH = total petroleum hydrocarbon
VC = vinyl chloride
VOCs = volatile organic compounds

TABLE 5-4
REMEDIATION TECHNOLOGY SCREENING FOR GROUNDWATER
Stericycle Washougal Facility
Washougal, Washington

General Response Actions	Remediation Technologies	Section	Site-Specific Issues Affecting Technology or Implementation							Rationale for Retention or Rejection	Screening Result
			Protectiveness	Permanence	Cost	Effectiveness over long-term	Management of short-term Risks	Technical and Administrative Implementability	Consideration of Public Concerns		
In Situ Biological Treatment	Enhanced Biodegradation with Biosparging	5.3.1	Addresses vinyl chloride (VC), but inhibits the degradation of other chlorinated VOCs. Potentially exacerbates the vapor intrusion pathway by volatilizing VOCs in groundwater.	Inhibits degradation of chlorinated VOCs with the exception of VC. Technology ineffective in silts and does not address 1,4-dioxane.	Higher implementation costs due to active industrial facility, large number of wells, large chemical oxygen demand (due to anaerobic conditions and metals), long-term run time (high O&M) and longer term groundwater monitoring costs necessary to effectively treat the silt layer.	The aquifer is reducing, so the effects of air on the aquifer chemistry will be limited to while the system is active. Technology does not address chlorinated VOCs with the exception of VC and does not treat 1,4-dioxane.	Since this is an active facility with enclosed buildings, this technology increases risk to human health due to the potential for increased volatilization of chlorinated VOCs (which could be mitigated with operation of an SVE system.)	Since this is an active facility with high traffic and chlorinated mass trapped in silts, the implementation options are limited and more technically challenging. High groundwater at the facility makes operation of an SVE system in conjunction with air sparge potentially infeasible.	Technology is unlikely to migrate off site to neighboring properties, through utilities, or to the marsh, so public concern should be minimal.	This technology will not work for all site COCs and would cause major disturbance to site activities if implemented in the source areas. However, if implemented in select locations and for specific COCs onsite (in conjunction with other technologies or as a contingent remedy), it could speed the remedial time frame while adding minimal additional risks.	Retain
	Oxygen Enhancement with Hydrogen Peroxide or ORC	5.3.2	Potentially addresses all the contaminants, but may inhibit the anaerobic degradation of other chlorinated VOCs and release additional metals.	Inhibits degradation of chlorinated VOCs with the exception of VC. Technology may be ineffective in silts.	Higher implementation costs due to active industrial facility, multiple injection rounds, large chemical oxygen demand (due to anaerobic conditions and metals), and large number of wells necessary to implement the technology in silt layer. If effective, may reduce long term groundwater monitoring costs.	The aquifer is reducing and the majority of mass for chlorinated VOCs is trapped in the silt layer, so its unlikely oxygen addition will last long-term to treat the secondary source release from the silt layer.	Some short-term risks due to chemicals exposure possible for personnel implementing technology, typically managed with proper use of PPE.	Distribution of substrate in silts would require tighter spacing of wells and repeat injections. Implementation on an active high traffic industrial facility would require coordination of work (off hours work potentially).	Technology is unlikely to migrate off site to neighboring properties, through utilities, or to the marsh, but metals may be released to groundwater as part of treatment. Bench testing should be utilized to reduce potential for metals release.	This technology will not work for all site COCs and would cause major disturbance to site activities if implemented in the source areas. However, if implemented in select locations and for specific COCs onsite (in conjunction with other technologies or as contingent remedy), it could speed the remedial time frame while adding minimal additional risks.	Retain
	Co-Metabolic Treatment	5.3.3	Effective treatment for 1,4-dioxane and some chlorinated VOCs, but does not address metals.	Effective treatment for 1,4-dioxane and chlorinated VOCs, but does not address metals and may be ineffective in silts.	Higher implementation costs due to active industrial facility, large number of wells, long-term run time (high O&M), and longer term groundwater monitoring costs necessary to effectively treat the silt layer.	Technology will work with existing reducing conditions, but substrate injection would need to continue long-term for co-metabolic effectiveness to address secondary source in silt layer.	Active facility with enclosed buildings increases risk to human health due to use of fuels (such as propane) as substrate.	Since this is an active facility with high traffic, enclosed buildings, and chlorinated mass trapped in silts, the implementation options are limited and more technically challenging.	Technology is unlikely to migrate off site to neighboring properties or to the marsh, but some substrates like propane could potentially build up and migrate through utilities.	This technology will not work for all site COCs and would cause major disturbance to site activities if implemented in the source areas. Not likely to be as effective as biostimulation given the site conditions and data supporting ongoing anaerobic degradation. In addition, it poses significant additional safety concerns.	Reject
	Biostimulation of Reductive Dechlorination (Anaerobic)	5.3.4	Technology addresses chlorinated VOCs, but does not address metals or 1,4-dioxane.	Technology is longer lasting than oxidation substrates and permanently destroys chlorinated VOCs, but does not address metals or 1,4-dioxane.	Lower implementation costs than other technologies, even with multiple injections of substrate (as typically required for effective treatment in silts.) However, this is balanced by longer term groundwater monitoring costs which may increase overall project cost.	Technology is longer lasting than oxidation substrates and permanently destroys chlorinated VOCs, but does not address metals or 1,4-dioxane.	Minimal short-term risks possible to personnel implementing technology.	Distribution of substrate in silts would require tighter spacing of wells and repeat injections. Implementation on an active high traffic industrial facility would require coordination of work (off hours work potentially), but since substrates last longer in-situ than oxidation substrates, the total disruption to facility operations is likely lower.	Substrate is unlikely to migrate off site through utilities, neighboring properties, or to the marsh, but overdosing could lead to excess methane generation or metals release to groundwater. Bench testing should be utilized to reduce potential for overdosing.	This technology will not work for all site COCs but would cause minimal disturbance to site activities if implemented in the source areas. Potentially the most cost effective treatment for chlorinated VOCs, and once those are remediated may also allow metals concentrations to return to background levels.	Retain
	Bioaugmentation	5.3.5	Addresses chlorinated VOCs, but does not address metals or 1,4-dioxane. Typically used in concert with biostimulation.	Addresses chlorinated VOCs, but does not address metals or 1,4-dioxane. Typically used in concert with biostimulation.	Given the demonstrated decline in chlorinated VOCs onsite, bioaugmentation is unnecessary and would only add additional cost to biostimulation costs. Multiple injections of nonindigenous organisms are typically required, increasing technology cost.	Nonindigenous organisms are unlikely to out-compete local organisms, likely requiring ongoing injections for long-term effectiveness.	Minimal short-term risks possible to personnel implementing technology.	Distribution of nonindigenous organisms in silts is difficult and implementation on an active industrial facility would present the same challenges as for biostimulation. However, more frequent injections would be likely increasing disruption to facility operations.	Technology is unlikely to migrate off site through utilities, neighboring properties, or to the marsh, but typically used in concert with biostimulation so public concern should be equivalent to biostimulation concerns.	This technology will not work for all site COCs but would cause minimal disturbance to site activities if implemented in the source areas. This is likely unnecessary given the demonstrated ongoing degradation of chlorinated VOCs, but is retained as a potential supplement to biostimulation if site groundwater conditions change.	Retain
	Monitored Natural Attenuation	5.3.6	Potentially addresses all the contaminants, but is the slowest technology and metals may persist.	Technology would likely eventually attain CULs for chlorinated VOCs and 1,4-dioxane but metals may persist.	Implementation costs are minimal. Long-term groundwater monitoring costs could be substantial depending on remedial time frame.	Technology potentially addresses all contaminants but likely to have a longer timeline than active treatment options.	Minimal short-term risks possible to personnel implementing long-term monitoring.	Minimal impacts on facility operations, facility has demonstrated ability to perform long-term groundwater monitoring and results show effective degradation in areas where source removal has been completed.	Observations of natural attenuation shows constituents migrating off site, but a shrinking/receding plume in the shallow aquifer. Concerns with long-term migration in the lower aquifer may require additional offsite wells (if technology not combined with other remedial actions.)	This technology will not work for all site COCs but would cause minimal disturbance to site activities if implemented in the source areas. Natural attenuation has been documented to be actively occurring at the site. May be used in conjunction with other technologies as a polishing step to reach site CULs.	Retain

TABLE 5-4
REMEDIATION TECHNOLOGY SCREENING FOR GROUNDWATER
Stericycle Washougal Facility
Washougal, Washington

General Response Actions	Remediation Technologies	Section	Site-Specific Issues Affecting Technology or Implementation							Rationale for Retention or Rejection	Screening Result
			Protectiveness	Permanence	Cost	Effectiveness over long-term	Management of short-term Risks	Technical and Administrative Implementability	Consideration of Public Concerns		
In Situ Physical/Chemical Treatment	Phytoremediation	5.3.7	Potentially addresses site COCs.	Technology would likely eventually attain CULs for the site COCs.	Implementation costs would be substantial to institute for all source areas. Most of the source area is paved or covered with buildings, making installation incompatible with facility operations. High cost due to the need for large diameter conductor casing being used to allow for mass reduction in the lower aquifer. However, implementation costs could be minimized with use in specific areas of the facility. Long-term groundwater monitoring costs could be substantial depending on remedial time frame.	Several studies have shown good long-term effectiveness for COC destruction and hydraulic control. Could be used in conjunction with other active technologies for polishing on remaining mass at CPOC.	Minimal short-term risks possible to personnel implementing technology.	Technology cannot be used in active areas (buildings, paved areas, high traffic areas, equipment storage areas) of the industrial facility due to interference with operations, but could be used along CPOC as polishing following implementation of other technologies.	Generally considered a benefit to the public (low energy use, carbon neutral, and aesthetically pleasing). Technology does not pose concerns to off site features.	This technology could potentially address all site COCs but would cause major disturbance to site activities if implemented in the source areas. However, if implemented in select locations (in conjunction with other technologies or as a contingent remedy), it could speed the remedial time frame while adding minimal additional risks.	Retain
	Carbon Augmentation	5.3.X	Technology addresses most chlorinated VOCs but ineffective for 1,4-dioxane and metals.	Technology would sequester chlorinated VOCs and may provide carbon source for biodegradation of COC mass. May exacerbate release of metals as a carbon source.	Higher implementation costs due to active industrial facility, multiple injection rounds, new proprietary technology (nano carbon), and large number of wells necessary to implement the technology in silt layer. If effective, may reduce long term groundwater monitoring costs.	Technology relies on contact with constituents and good distribution within the subsurface (which is difficult in silt) to treat chlorinated VOCs. Ineffective for 1,4-dioxane and may exacerbate release of metals.	Minimal short-term risks possible to personnel implementing technology.	Distribution of substrate in silts would require tight spacing of wells and likely overlapping injections. Implementation on an active high traffic industrial facility would require coordination of work (off hours work potentially), but since substrates last longer than oxidation or biostimulation substrates, repeat rounds likely to be unnecessary.	Substrate is unlikely to migrate off site through utilities, neighboring properties, or to the marsh, but long-term carbon source could result in metals release to groundwater.	This technology will not work for all site COCs (may exacerbate metals) and would cause major disturbance to site activities if implemented in the source areas. Not likely to be as effective as biostimulation given the site conditions.	Reject
	Air Sparging	5.3.8	Active, natural, biological anaerobic degradation of chlorinated VOCs would be inhibited by the addition of oxygen (with the exception of VC). Ineffective for 1,4-dioxane treatment. Possibly effective for treatment of metals.	Likely to hinder anaerobic degradation processes for chlorinated solvents. May help sequester metals in the short-term, but reducing conditions in the aquifer may re-dissolve metals in the long-term. Could be used following primary treatment for removal of vinyl chloride.	Higher implementation costs due to active industrial facility, large number of wells, large chemical oxygen demand (due to anaerobic conditions and metals), long-term run time (high O&M) and longer term groundwater monitoring costs necessary to effectively treat the silt layer.	The aquifer is reducing, so the effects of air on the aquifer chemistry may be limited to while the system is active (precipitated metals may re-dissolve). Technology does not address chlorinated VOCs without being used in combination with SVE and does not treat 1,4-dioxane.	Since this is an active facility with enclosed buildings, this technology increases risk to human health due to the potential for increased volatilization of chlorinated VOCs (which could be mitigated with operation of an SVE system or strategic design of lower flow air sparging wells away from enclosed buildings).	Implementation at higher flow rates adjacent to Building 1 would likely overwhelm the existing inhalation pathway interim measure venting system. Associated SVE would be necessary if installed adjacent to Building 1 to prevent migration. However, implementation farther away from Building 1 at lower flow rates may be possible (with confirmation measurements taken at Building 1). Implementation oflow flow rate (without SVE) along the northeast and eastern property lines would be feasible in the shallow and deep aquifer.	Technology is unlikely to migrate contaminants off site to neighboring properties or to the marsh. This technology has led to volatiles building up in utility corridors, but implementation at a lower flow rate as a contingent remedy for polishing metals and only low VOC concentrations (or no VOCs) could limit public concern.	This technology will not work for all site COCs and would cause major disturbance to site activities if implemented in the source areas. However, if implemented in select locations and for specific COCs onsite (in conjunction with other technologies or as a contingent remedy), it could speed the remedial time frame while adding minimal additional risks.	Retain
	Chemical Oxidation-Active	5.3.9X	Potentially treats all key COCs with a relatively short timeframe, may release metals.	Technology permanently destroys chlorinated VOCs and 1,4-dioxane, assuming effective contact.	Higher implementation costs due to active industrial facility, multiple injection rounds, large chemical oxygen demand (due to anaerobic conditions and metals), and large number of wells necessary to implement the technology in silt layer. If effective, may reduce long term groundwater monitoring costs.	Technology relies on contact with constituents and distribution within the silt is difficult, but removes all COCs for source areas and CPOC.	Injection substrate is reactive and poses short-term risks to implementation personnel, typically managed with proper use of PPE and secondary containment.	Implementable in shallow and lower aquifer to treat all key COCs. Would be difficult to implement in the silt.	Technology is unlikely to migrate off site to neighboring properties, through utilities, or to the marsh, but metals may be released to groundwater as part of treatment. Bench testing should be utilized to reduce potential for metals release.	This technology could potentially address all site COCs but would cause significant disturbance to site activities if implemented in the source areas. However, if implemented in select locations, it could speed the remedial time frame while adding minimal additional risks.	Retain
	Chemical Oxidation-Passive	5.3.9X	Potentially treats chlorinated VOCs, unlikely to degrade 1,4-dioxane, and may release metals.	Technology permanently destroys chlorinated VOCs, assuming effective contact.	Lower implementation costs than active ISCO, but likely large chemical oxygen demand (due to anaerobic conditions and metals) and large number of wells necessary to implement the technology to address long-term release from the silt layer. If effective, may reduce long-term groundwater monitoring costs.	Technology is longer lasting than active oxidation and permanently destroys chlorinated VOCs, but does not address metals or 1,4-dioxane.	Significant but limited short-term risks related to handling of passive ISCO chemicals and installation of new wells, typically managed with proper use of PPE.	Implementable in shallow and lower aquifer to treat all key COCs. Would be difficult to implement in the silt.	Technology is unlikely to migrate off site to neighboring properties, through utilities, or to the marsh, but metals may be released to groundwater as part of treatment. Bench testing should be utilized to reduce potential for metals release.	This technology will not work for all site COCs (may exacerbate metals) and would cause major disturbance to site activities if implemented in the source areas. Not likely to be as effective as active oxidation given the site conditions.	Reject

TABLE 5-4
REMEDIATION TECHNOLOGY SCREENING FOR GROUNDWATER
Stericycle Washougal Facility
Washougal, Washington

General Response Actions	Remediation Technologies	Section	Site-Specific Issues Affecting Technology or Implementation							Rationale for Retention or Rejection	Screening Result
			Protectiveness	Permanence	Cost	Effectiveness over long-term	Management of short-term Risks	Technical and Administrative Implementability	Consideration of Public Concerns		
In Situ Physical/Chemical Treatment (cont.)	Thermal Treatment	5.3.10	Potentially addresses site COCs.	Technology degrades or removes site COCs.	Implementation costs would be substantial to institute for all source areas. Most of the source area is paved high traffic area or covered with buildings, making installation more complicated. Lower aquifer is connected to adjacent waterbodies, likely increasing water production and heating costs. Long-term groundwater monitoring costs could be substantially reduced.	Could achieve CULs in relatively short timeframe, may release dissolved carbon (which would aid in biodegradation of chlorinated VOCs), but could exacerbate metals release to groundwater.	Installation of heating elements or steam injection points pose a risk for contact with COC impacted groundwater. Operation of the system could impact utilities in the vicinity dependent on material type.	Implementation and ongoing operations and maintenance of an thermal treatment system on an active industrial facility would be difficult. High groundwater at the facility makes operation of an SVE system in conjunction with heating difficult. Buildings are present over the source area complicating installation. Lower aquifer connection to adjacent water bodies may increase water production and heating costs.	Technology is unlikely to directly affect off site property (neighboring properties or the marsh), but plastic utility lines would need to be replaced in the upper treatment zone. Heated groundwater has the potential to migrate off site and into the marsh for a short time. Dissolving of entrained carbon could release metals to groundwater.	This technology could potentially address all site COCs but would cause significant disturbance to site activities if implemented in the source areas and could potentially exacerbate release of metals. Potentially one of the most effective treatment technologies for the silt layer.	Retain
	In-Well Stripping	5.3.11	Addresses vinyl chloride (VC), but inhibits the degradation of other chlorinated VOCs. Potentially exacerbates the vapor intrusion pathway by volatilizing VOCs in groundwater.	Inhibits degradation of chlorinated VOCs with the exception of VC. Technology ineffective in silts and does not address 1,4-dioxane.	Higher implementation costs due to active industrial facility, large number of wells, large chemical oxygen demand (due to anaerobic conditions and metals), likelihood of iron precipitation and/or biological fouling. Long-term operation and maintenance would be costly due to the within the stripping wells.	The aquifer is reducing, so the effects of air on the aquifer chemistry will be limited to while the system is active. Technology does not address chlorinated VOCs with the exception of VC and does not treat 1,4-dioxane.	Since this is an active facility with enclosed buildings, this technology increases risk to human health due to the potential for increased volatilization of chlorinated VOCs (which could be mitigated with operation of an SVE system.)	Since this is an active facility with high traffic and chlorinated mass trapped in silts, the implementation options are limited and more technically challenging. High groundwater at the facility makes operation of an SVE system in conjunction with air sparge potentially infeasible.	Technology is unlikely to migrate off site to neighboring properties, through utilities, or to the marsh, so public concern should be minimal.	This technology has a mixed performance record, would not address all site COCs, and could inhibit the ongoing active anaerobic biodegradation. Not likely to be as effective as active chemical oxidation or traditional air sparging given the site conditions.	Reject
	Passive/Reactive Treatment Walls	5.3.12	Substrate such as zero valent iron (ZVI) would address chlorinated VOCs and metals but would not treat 1,4-dioxane.	Technology could reduce mass in the short-term and provide long-term passive treatment of chlorinated VOCs and metals.	Implementation costs could range widely depending on type of installation (low cost for widely spaced injections, higher cost for slurry wall or tightly spaced injections). However, implementation costs could be minimized with use in specific target zones (in sandy aquifer only). Bench or pilot testing likely necessary to accurately estimate costs. Could reduce long-term groundwater monitoring costs.	Technology could passively treat secondary source from silt until source has been degraded to below the CULs. Would need to be used in conjunction with other technologies for 1,4-dioxane.	Minimal short-term risks possible to personnel implementing technology.	Injections within the source area above and below the silt layer, within the sand units, would allow for even distribution of substrate during construction of the passive treatment barriers.	Technology will utilize substrate which will remain in the injection area and is unlikely to migrate off site through utilities, neighboring properties, or to the marsh, so public concern should be minimal.	This technology will not work for all site COCs and would cause major disturbance to site activities if implemented in the source areas. However, if implemented in select locations and for specific COCs onsite (in conjunction with other technologies), it could speed the remedial time frame while adding minimal additional risks.	Retain
Groundwater Extraction and Treatment (Pump and Treat)	Hydraulic Control	5.3.13	Could further reduce the footprint or speed up the reduction of the groundwater plume in the shallow and lower aquifer and potentially addresses all the contaminants.	Ex-situ treatment of COCs would be necessary to remove COC mass. long-term operation would be necessary to continually protect from release of COCs from silt.	Implementation costs may be significant to achieve control in the lower aquifer (given the connection to nearby surface water bodies). Long-term operations and maintenance costs would be high due to the long duration of operation necessary to continue capture of the ongoing slow release of COCs from the silt (and likelihood of iron precipitation and/or biological fouling.)	Could effectively contain COC's onsite, but due to entrainment of COC's in silts likely long-term operation required for lower aquifer. Long-term operation of the hydraulic control system would cause the restoration timeframe to increase significantly compared to other active treatment technologies.	System installation would require trenching for installation of conveyance piping in and around the source area as well as ex-situ management of contaminated groundwater increasing the potential for worker exposure to COCs.	Implementation and ongoing operations and maintenance of a hydraulic control system on an active industrial facility would be difficult compared to a vacant site, but not as disruptive as excavation, thermal, or deep soil mixing. Water is likely to flow from the more permeable layers of the aquifer (which are connected to adjacent water bodies or are impacted by seasonal high water) not from the suspected source area (the silt layer). POTW does not accept groundwater by rule, would require additional permitting effort and Ecology request.	Technology would keep site COCs within the property boundary, so is unlikely to cause public concern and likely to be seen as generally beneficial.	This technology could capture all site COCs, but is unlikely to speed up the remedial time frame. On its own this technology would be rejected, but could provide temporary control of offsite migration in conjunction with other technologies. Other permanent remedial technologies are implementable with reduced restoration timeframe or are less disruptive to site activities compared to this technology.	Retain

TABLE 5-4
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			Protectiveness	Permanence	Cost	Effectiveness over long-term	Management of short-term Risks	Technical and Administrative Implementability	Consideration of Public Concerns		
Groundwater Extraction and Treatment (Pump and Treat) (cont.)	Mass Reduction	5.3.13	Would remove COCs from higher permeability units (sand) but would be ineffective at extracting mass from the silt layer (source area).	Technology unlikely to significantly speed up mass removal from silt layer. Unlikely to significantly speed up attainment of CUL within source area or at CPOC.	Implementation costs may be significant to achieve control in the lower aquifer (given the connection to nearby surface water bodies). Long-term operations and maintenance costs would be high due to the long duration of operation necessary to continue capture of the ongoing slow release of COCs from the silt (and likelihood of iron precipitation and/or biological fouling.)	Minimal long-term effectiveness due to inability for technology to address COCs within the silt.	System installation would require trenching for installation of conveyance piping in and around the source area as well as ex-situ management of contaminated groundwater increasing the potential for worker exposure to COCs.	Implementation and ongoing operations and maintenance of a hydraulic control system on an active industrial facility would be difficult compared to a vacant site, but not as disruptive as excavation, thermal, or deep soil mixing. Water is likely to flow from the more permeable layers of the aquifer (which are connected to adjacent water bodies or are impacted by seasonal high water) not from the suspected source area (the silt layer). POTW does not accept groundwater by rule, would require additional permitting effort and Ecology request.	Technology would keep site COCs within the property boundary, so is unlikely to cause public concern and likely to be seen as generally beneficial.	This technology could capture all site COCs, but is unlikely to speed up the remedial time frame. Other permanent remedial technologies are implementable with reduced restoration timeframe compared to this technology.	Reject
	Dynamic Groundwater Recirculation (DGR)	5.3.X	Would remove COCs from higher permeability units (sand) but would be ineffective at extracting mass from the silt layer (source area).	Technology unlikely to significantly speed up mass removal from silt layer. Unlikely to significantly speed up attainment of CUL within source area or at CPOC.	High long-term operation and maintenance costs due to the technologies inability to attain CULs within the source area.	Minimal long-term effectiveness due to inability for technology to address COCs within the silt.	System installation would require trenching for installation of conveyance piping in and around the source area increasing the potential for worker exposure to COCs.	Implementation and ongoing operations and maintenance of a hydraulic control system on an active industrial facility would be difficult compared to a vacant site, but not as disruptive as excavation, thermal, or deep soil mixing. Water is likely to flow from the more permeable layers of the aquifer (which are connected to adjacent water bodies or are impacted by seasonal high water) not from the suspected source area (the silt layer). POTW does not accept groundwater by rule, would require additional permitting effort and Ecology request.	Technology would keep site COCs within the property boundary, so is unlikely to cause public concern and likely to be seen as generally beneficial.	This technology could capture all site COCs, but is unlikely to speed up the remedial time frame. Other permanent remedial technologies are implementable with reduced restoration timeframe compared to this technology.	Reject
In Situ Physical/Chemical Treatment	Emulsified Zero-Valent Iron	5.3.14	Technology would address chlorinated VOCs and metals in shallow and lower aquifer, but would not address 1,4-dioxane.	Distribution of injected material is difficult in silts, but can be completed in shallow and lower aquifer above and below silts. Technology does not address 1,4-dioxane.	Implementation costs could range widely depending on type of installation (low cost for widely spaced injections, higher cost for slurry wall or tightly spaced injections). However, implementation costs could be minimized with use in specific target zones (in sandy aquifer only). Bench or pilot testing likely necessary to accurately estimate costs. Could reduce long-term groundwater monitoring costs.	Technology addresses chlorinated VOCs and metals, but does not address 1,4-dioxane.	Minimal short-term risks possible to personnel implementing technology.	Implementable in shallow and lower aquifer to treat chlorinated VOCs and metals. Would be difficult to implement in the silt and does not address 1,4-dioxane.	Technology will utilize substrate which will remain in the injection area and is unlikely to migrate off site through utilities or to the marsh, so is unlikely to cause public concern and likely to be seen as generally beneficial.	This technology will not work for all site COCs but may cause less disturbance to site activities if implemented in the source areas than other technologies. If implemented for specific COCs onsite (in conjunction with other technologies), it could speed the remedial time frame while adding minimal additional risks.	Retain
	Solvent-Enhanced Aquifer Remediation (SEAR)	5.3.15	Injection of surfactant would improve mobility of chlorinated VOCs followed by pump-and-treat extraction to remove mobile chlorinated VOCs in solution. Technology would not address metals or 1,4-dioxane.	Technology unlikely to significantly speed up mass removal from silt layer. Unlikely to significantly speed up attainment of CUL within source area or at CPOC. Technology would not address metals or 1, 4-dioxane.	Implementation costs may be significant to achieve control in the lower aquifer (given the connection to nearby surface water bodies). Long-term operations and maintenance costs would be high due to the long duration of operation necessary to continue capture of the ongoing slow release of COCs from the silt (and likelihood of iron precipitation and/or biological fouling.)	Technology addresses chlorinated VOCs in sands and some of the silt, but does not address metals or 1,4-dioxane. Injections of surfactants could create preferential pathways for groundwater flow potentially mobilizing COCs (and surfactants) outside the radius of influence from extraction wells.	System installation would require trenching for installation of conveyance piping in and around the source area as well as ex-situ management of contaminated groundwater increasing the potential for worker exposure to COCs.	Implementation and ongoing operations and maintenance of the system on an active industrial facility would be difficult compared to a vacant site. High groundwater extraction rates paired with high seasonal groundwater at the facility would increase water production and management costs. Technology depends on contact with COCs in the silt and distribution in the silt will be difficult.	Technology is designed to keep site COCs within the property boundary, but may inadvertently mobilize site COCs and surfactants outside the property boundary, so there would be higher public concern than for standard hydraulic mass removal.	This technology will not work for all site COCs (may exacerbate metals) and poses significant additional concerns with potential migration of contaminants offsite.	Reject

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General Response Actions	Remediation Technologies	Section	Site-Specific Issues Affecting Technology or Implementation							Rationale for Retention or Rejection	Screening Result
			Protectiveness	Permanence	Cost	Effectiveness over long-term	Management of short-term Risks	Technical and Administrative Implementability	Consideration of Public Concerns		
In Situ Physical/Chemical Treatment (cont.)	Co-Solvent Flooding	5.3.16	Injection of solvents, typically ethanol or propanol, would improve mobility of chlorinated VOCs followed by pump-and-treat extraction to remove mobile chlorinated VOCs in solution. Technology would not address metals or 1,4-dioxane.	Technology unlikely to significantly speed up mass removal from silt layer. Unlikely to significantly speed up attainment of CUL within source area or at CPOC. Technology would not address metals or 1, 4-dioxane.	Implementation costs may be significant to achieve control in the lower aquifer (given the connection to nearby surface water bodies). Long-term operations and maintenance costs would be high due to the long duration of operation necessary to continue capture of the ongoing slow release of COCs from the silt (and likelihood of iron precipitation and/or biological fouling.)	Technology addresses chlorinated VOCs in sands and some of the silt, but does not address metals or 1,4-dioxane. Injections of solvents could create preferential pathways for groundwater flow potentially mobilizing COCs (and surfactants) outside the radius of influence from extraction wells. In addition, additional carbon source could exacerbate metals release to groundwater.	Injection of solvents , typically ethanol or propanol, pose an elevated risk to operators of the system and facility staff. Installation of the treatment system for injection of solvents and extraction of COCs pose a higher risk to installation personnel.	Implementation and ongoing operations and maintenance of the system on an active industrial facility would be difficult compared to a vacant site. High groundwater extraction rates paired with high seasonal groundwater at the facility would increase water production and management costs. Technology depends on contact with COCs in the silt and distribution in the silt will be difficult.	Technology is designed to keep site COCs within the property boundary, but may inadvertently mobilize site COCs and solvents outside the property boundary, so there would be higher public concern than for standard hydraulic mass removal.	This technology will not work for all site COCs (may exacerbate metals) and poses significant additional concerns with potential migration of contaminants offsite.	Reject
Physical Containment	Barrier Wall	5.3.17	Installation of a barrier wall would limit mobility of all COCs remaining on site, but would not reduce COC concentrations and may slow attenuation and degradation of contaminants.	The technology would completely reduce the mobility of the site COCs. The volume and toxicity of the COCs would not be addressed through this technology.	High implementation cost compared to most other alternatives to construct a barrier wall for both the shallow and lower aquifers. Long-term costs are minimal and technology could reduce long-term groundwater monitoring costs when used in conjunction with hydraulic control.	Technology potentially addresses all contaminants but likely to have a longer timeline than active treatment options.	Increased short-term risk during implementation due to displacement of large volumes of soil and potentially groundwater. Typically managed with proper use of PPE and secondary containment.	Implementation on an active industrial facility would be difficult compared to a vacant site.	A barrier wall would stop off site migration of COCs, so is unlikely to cause public concern and likely to be seen as generally beneficial.	This technology could work to capture all site COCs, but would not speed up the remedial time frame. However, it could be used in conjunction with other technologies to minimize disturbance to site activities if implemented strategically.	Retain
Ancillary/Support Technologies	Air Stripping	5.3.18	Technology addresses chlorinated VOCs and metals but not 1,4-dioxane.	Technology would remove VOCs, but effluent vapor would be treated through catalytic oxidation or adsorption. Technology does not address 1,4-dioxane and may only temporarily stabilize metals.	Minimal implementation costs when compared to installation of a pump-and-treat system. Long-term cost to operate an air stripper is relatively minimal during operation of the pump-and-treat system, but iron precipitation would likely cause significant fouling, increasing long-term maintenance costs.	Technology addresses chlorinated VOCs, but does not address 1,4-dioxane and may only temporarily stabilize metals.	Increased short-term risk during operation of the air stripper due to volatilization of VOCs . Maintenance of the air stripper and wastes generated pose additional short-term risks. Typically managed with proper use of PPE, vapor treatment, and secondary containment.	The addition of an air stripping system into a pump-and-treat system would further complicate implementation of hydraulic control remedies, as noted above.	Air stripping removes VOCs from groundwater and transfers them to the air phase. This technology could cause public concern related to air emissions.	Retained since hydraulic control was retained.	Retain
	Oxidation	5.3.X	Ex-situ oxidation would be effective in reducing contaminant mass for chlorinated VOCs, metals, and 1,4-dioxane.	Technology would destroy contaminant mass when used in conjunction with pump-and-treat.	Minimal implementation costs when compared to installation of a pump-and-treat system. Long-term costs can be variable, dependent on oxidant used, but high costs are expected with long-term operations and maintenance.	While this technology would treat all contaminants, reinjection of oxygenated water into the aquifer could impact existing anaerobic degradation and may lead to significant fouling.	Short-term risks are increased due to use of a pump-and-treat system as a remedial alternative and oxidants are an additional hazard to personnel. Typically managed with proper use of PPE and secondary containment.	The addition of an oxidant augmentation system into a pump-and-treat system would further complicate implementation of hydraulic control remedies, as noted above.	Effluent from a pump-and-treat system actively augmented with an oxidant could add to public concerns for a pump a treat system.	Retained since hydraulic control was retained.	Retain
	Adsorption	5.3.19	Potentially addresses site COCs.	Different adsorbent media are utilized for different contaminants. If media can be used effectively in a treatment train, would permanently remove contaminants.	Potentially high implementation costs and long term operations costs, depending on effectiveness of media and volumes of water needing treatment.	New adsorption media has been developed using resins for 1,4-dioxane and VC removal. Effectiveness is highly variable on groundwater chemistry, bench testing would be necessary to determine long term performance.	Short-term risks possible to personnel implementing technology depending on type of media utilized. Short-term risks are increased due to use of a pump-and-treat system as a remedial alternative. Typically managed with proper use of PPE and secondary containment.	The addition of adsorption units into a pump-and-treat system would further complicate implementation of a remedy, but potentially less complicated than oxidation or air stripping.	Adsorption technology is unlikely to contribute chemicals to offsite discharge, so is unlikely to cause public concern and likely to be seen as generally beneficial.	Retained since hydraulic control was retained.	Retain

TABLE 5-4
REMEDIATION TECHNOLOGY SCREENING FOR GROUNDWATER
Stericycle Washougal Facility
Washougal, Washington

General Response Actions	Remediation Technologies	Section	Site-Specific Issues Affecting Technology or Implementation							Rationale for Retention or Rejection	Screening Result
			Protectiveness	Permanence	Cost	Effectiveness over long-term	Management of short-term Risks	Technical and Administrative Implementability	Consideration of Public Concerns		
Ancillary/Support Technologies (cont.)	Deep Soil Mixing	5.3.20	Potentially addresses site COCs.	Technology oxidizes, reduces or sequesters depending on substrate used during mixing to permanently reduce COC mass.	Implementation costs would be substantial to institute for all source areas. Most of the source area is paved high traffic area or covered with buildings and this technology requires significant excavation as part of the work, making installation more complicated. Long-term monitoring costs would be less than most other alternatives as mass should be treated quickly.	Technology does not rely on flow through pore spaces for distribution, but physically mixes in treatment substrates. There is a high likelihood the technology would effectively treat all contaminants.	Increased short-term risk during implementation due to displacement of large volumes of soil and potentially groundwater as well as exposure to treatment chemicals. Typically managed with proper use of PPE and secondary containment.	Since this is an active facility with high traffic, enclosed buildings, and chlorinated mass trapped in silts, the implementation options are limited and more technically challenging. Implementation on an active high traffic industrial facility would require coordination of work (off hours work potentially).	Technology could potentially treat most site COCs quicker than other technologies and contain remainder within the property boundary. Trucking of excavated materials offsite would be more substantial for this alternative than other alternatives.	This technology could potentially address all site COCs but would cause major disturbance to site activities if implemented in the source areas. Potentially one of the most effective treatment technologies for the silt layer.	Retain

Notes
X indicates a new technology added to the table after submittal of the 2013 Feasibility Study

Abbreviations

cis -1,2-DCE = *cis* -1,2-dichloroethene
COL = constituent of concern
CPOC = conditional point of compliance
CUL = cleanup level
HRC = hydrogen-releasing compounds
ISCO = in situ chemical oxidation
O&M = operation and maintenance
ORC = oxygen-releasing compound
SVOCs = semivolatile organic compounds
TCE = trichloroethene
TPH = total petroleum hydrocarbon
VC = vinyl chloride
VOCs = volatile organic compounds
ZVI = zero-valent iron

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TABLE 5-5
RETAINED REMEDIATION TECHNOLOGIES
Stericycle Washougal Facility
Washougal, Washington

Potentially Applicable Soil Technology	
General Response Actions	**Remediation Technologies**
In Situ Biological Treatment	Phytoremediation
In Situ Physical/Chemical Treatment	Chemical Oxidation
	Solidification/Stabilization
In Situ Thermal Treatment	High-Temperature Volatilization
Containment	Cap/Surface Cover
Excavation and Disposal	Excavation and Off-Site Disposal

Potentially Applicable Groundwater Technology	
General Response Actions	**Remediation Technologies**
In Situ Biological Treatment	Enhanced Biodegradation with Biosparging
	Oxygen Enhancement with Hydrogen Peroxide or ORC
	Biostimulation of Reductive Dechlorination (Anaerobic)
	Bioaugmentation
	Monitored Natural Attenuation
	Phytoremediation
In Situ Physical/Chemical Treatment	Air Sparging
	Chemical Oxidation
	Thermal Treatment
	Passive/Reactive Treatment Walls
	Emulsified Zero-Valent Iron
Groundwater Extraction (Pump and Treat)	Hydraulic Control
Physical Containment	Barrier Wall
Ancillary/Support Technologies	Air stripping
	Oxidation
	Adsorption
	Deep Soil Mixing

Abbreviations
ORC = oxygen-releasing compound

Table: 7-1
Feasibility Study Alternatives Summary

General Target Description	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6
Common to all alternatives for Soil and GW	Grouting of utility bedding					
	Surface cover over areas with soils with elevated concentrations of COCs					
	Inhalation Pathway Interim Measure under Building 1					
	Verification of GW remediation progress and effectiveness through GW monitoring					
	Long Term or Temporary Institutional Controls					
GW-Shallow Source Areas	MNA in former tank farm area	ISB in former tank farm area primarily targeting silt layer, MA	DSM with ZVI of shallow zone and silt layer, MA	ERH of shallow zone and silt layer, MA	PRB with ZVI above and within silt layer, MA	ISB in former tank farm area primarily targeting silt layer, MA
	MNA near MC-14	ISCO near MC-14, MA	ISCO near MC-14 , MA	ERH near MC-14, MA	ISCO near MC-14, MA	ISCO near MC-14 , MA
GW-Shallow Downgradient	MNA					
GW-Lower Aquifer Former Tank Farm Area and North Fence line (near MC-118D) Source Area	MNA	ISB in silt/lower aquifer, MA	DSM with ZVI/clay of silt, targeted ISCO in silt/lower aquifer, MA	ERH in silt/lower aquifer, MA	PRB with ZVI of silt/lower aquifer, MA	ISB in silt/lower aquifer, hydraulic control, MA
GW-Lower Aquifer Downgradient (Including MC-15D Area)	MNA	ISB, MA			PRB with ZVI, MA	ISB and hydraulic control, MA

Notes:

COC= Contaminant of Concern
DSM= Deep Soil Mixing
ERH= Electrical Resistive Heating
GW= Groundwater
ISB= In-situ Bioremediation
ISCO= In-Situ Chemical Oxidation
MA= Monitored Attenuation
MNA= Monitored Natural Attenuation
ZVI= Zero Valent Iron

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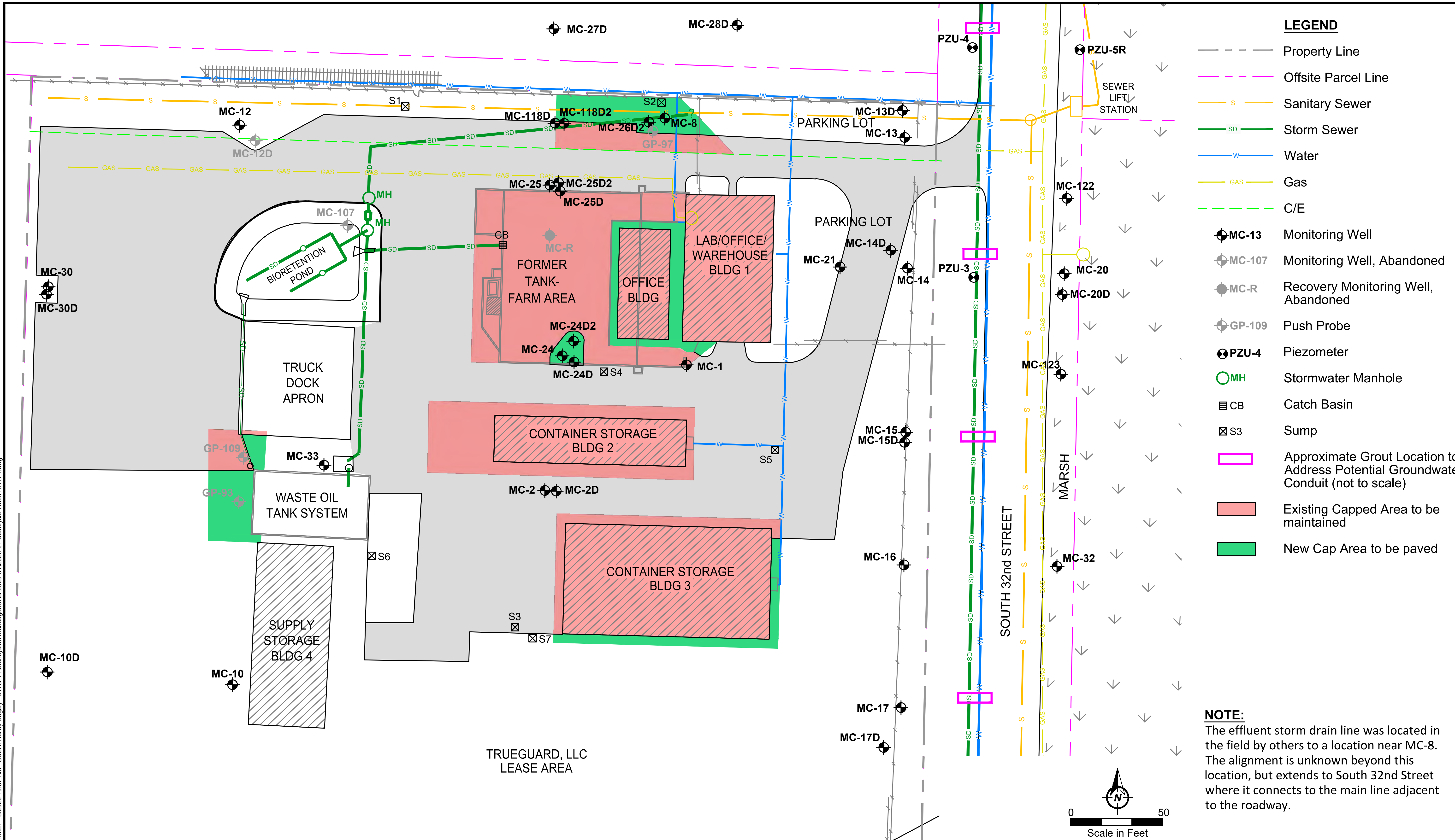

Stericycle - Washougal Facility
Washougal, Washington

Remedial Alternative A-1

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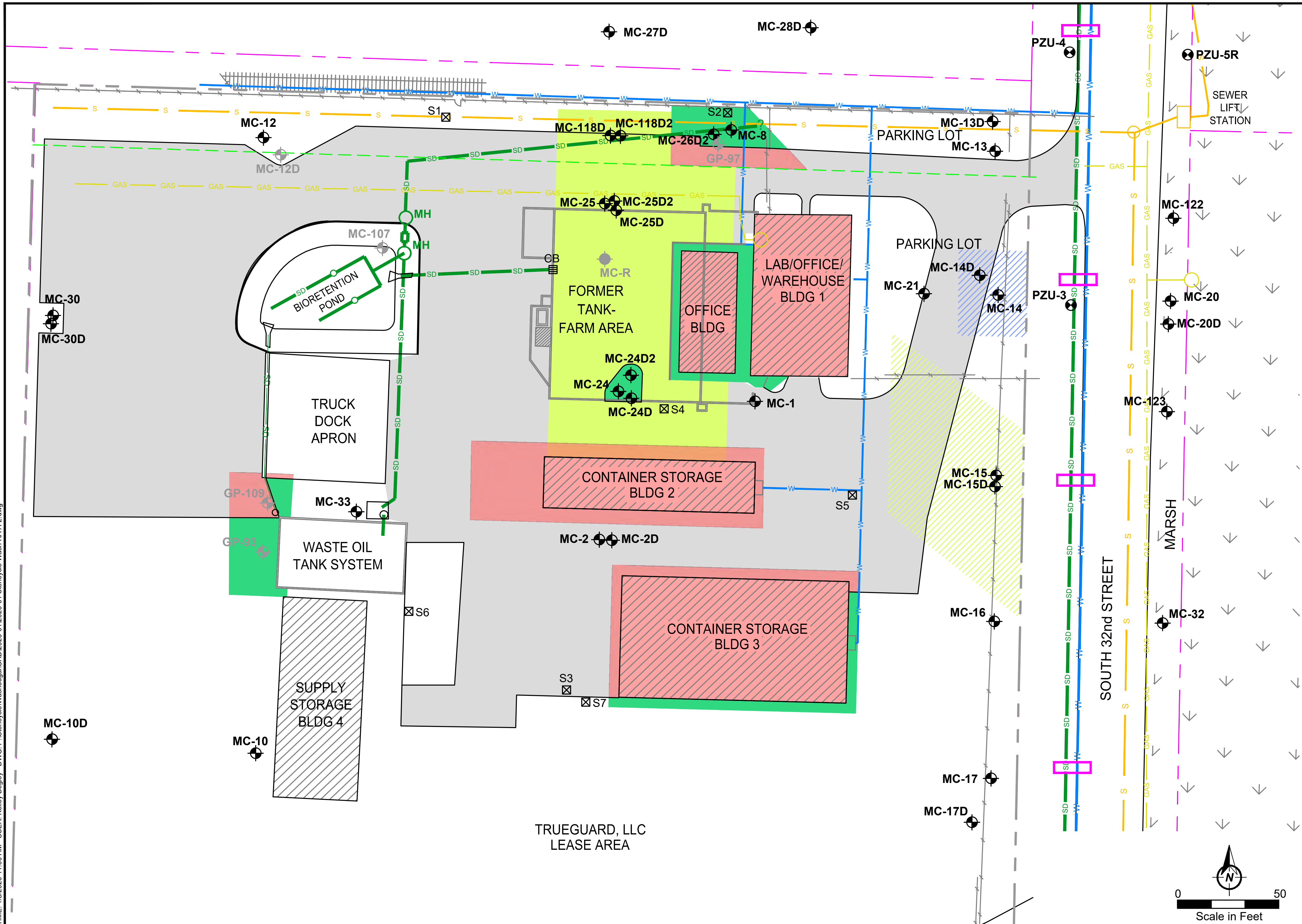
FIGURE 7-1

January 08, 2020

PLOT TIME: 1/8/2020 10:58 AM MOD TIME: 1/8/2020 10:57 AM USER: Kelley Begley DWG: P:\Stericycle\Washougal\CAD\2020-01\2020-01 Stericycle Wash RA A-1.dwg



LEGEND

- Property Line
- Offsite Parcel Line
- Sanitary Sewer
- Storm Sewer
- Water
- Gas
- C/E
- MC-13 Monitoring Well
- MC-107 Monitoring Well, Abandoned
- MC-R Recovery Monitoring Well, Abandoned
- GP-109 Push Probe
- PZU-4 Piezometer
- MH Stormwater Manhole
- CB Catch Basin
- S3 Sump
- Approximate Grout Location to Address Potential Groundwater Conduit (not to scale)
- Existing Capped Area to be maintained
- New Cap Area to be paved
- Enhanced Bioremediation Area (Silt and Lower Aquifer)
- Enhanced Bioremediation Area (Lower Aquifer Only)
- In-Situ Chemical Oxidation Area (Shallow Groundwater Only)

NOTE:
The effluent storm drain line was located in the field by others to a location near MC-8. The alignment is unknown beyond this location, but extends to South 32nd Street where it connects to the main line adjacent to the roadway.

Stericycle - Washougal Facility
Washougal, Washington

Remedial Alternative A-2

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FIGURE 7-2

January 08, 2020

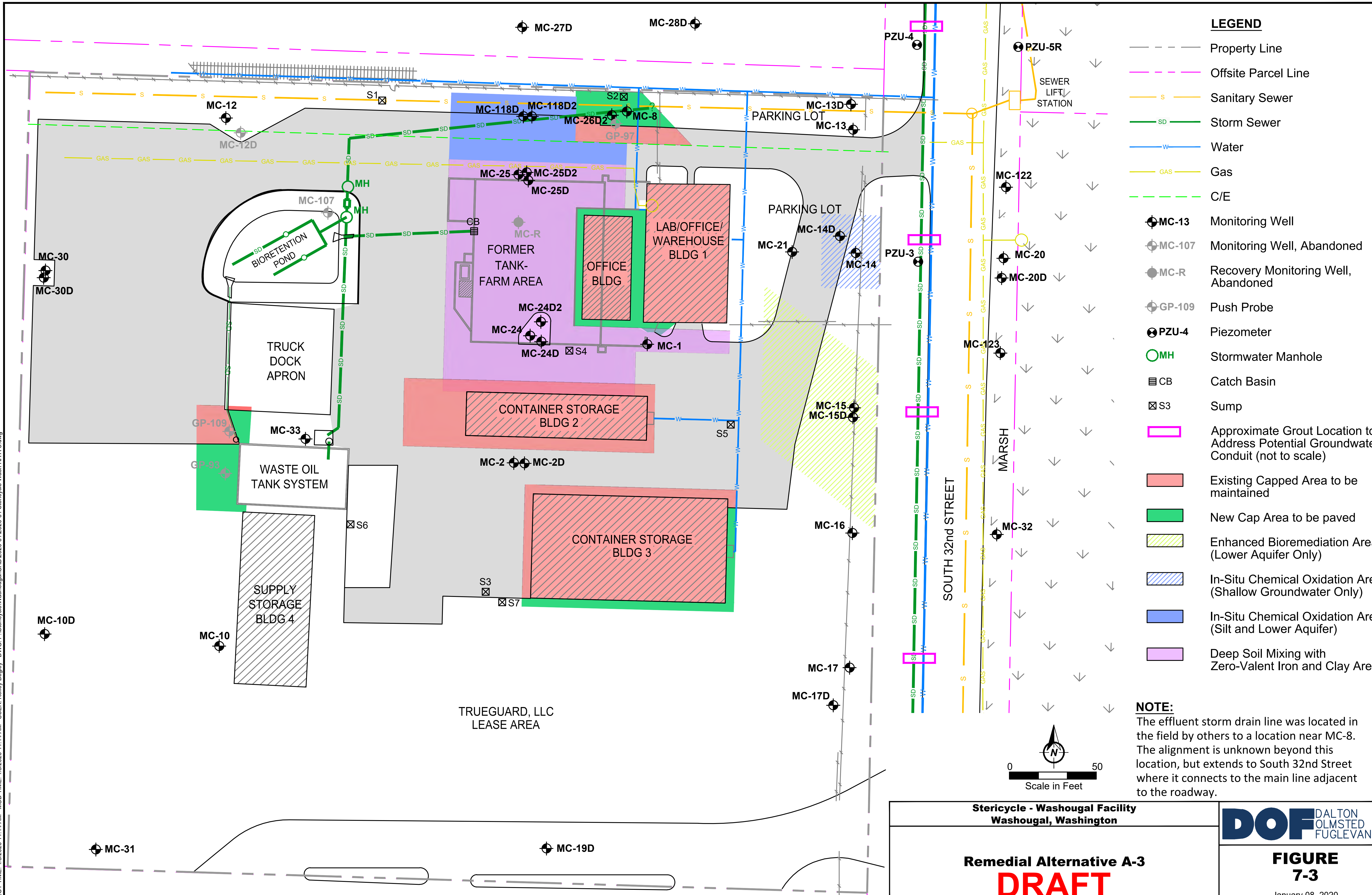
LEGEND
Property Line
Offsite Parcel Line
Sanitary Sewer
Storm Sewer
Water
Gas
C/E
MC-13 Monitoring Well
MC-107 Monitoring Well, Abandoned
MC-R Recovery Monitoring Well, Abandoned
GP-109 Push Probe
PZU-4 Piezometer
MH Stormwater Manhole
CB Catch Basin
S3 Sump
Approximate Grout Location to Address Potential Groundwater Conduit (not to scale)
Existing Capped Area to be maintained
New Cap Area to be paved
Enhanced Bioremediation Area (Lower Aquifer Only)
In-Situ Chemical Oxidation Area (Shallow Groundwater Only)
In-Situ Chemical Oxidation Area (Silt and Lower Aquifer)
Deep Soil Mixing with Zero-Valent Iron and Clay Area
MC-27D
MC-28D
PZU-4
PZU-5R
SEWER LIFT STATION
S1
S2
MC-12
MC-12D
MC-118D
MC-118D2
MC-26D2
MC-8
GP-97
MC-13D
MC-13
PARKING LOT
MC-25
MC-25D2
MC-25D
MH
MC-107
BIORETENTION POND
CB
MC-R
FORMER TANK-FARM AREA
OFFICE BLDG
LAB/OFFICE/ WAREHOUSE BLDG 1
PARKING LOT
MC-14D
MC-21
MC-14
PZU-3
MC-122
MC-20
MC-20D
MC-30
MC-30D
TRUCK DOCK APRON
MC-24D2
MC-24
MC-24D
S4
MC-1
MC-123
GP-109
MC-33
CONTAINER STORAGE BLDG 2
S5
MC-15
MC-15D
GP-53
WASTE OIL TANK SYSTEM
MC-2
MC-2D
S6
MC-16
MC-32
MARSH
SOUTH 32nd STREET
CONTAINER STORAGE BLDG 3
S3
S7
SUPPLY STORAGE BLDG 4
MC-10D
MC-10
MC-17
MC-17D
TRUEGUARD, LLC LEASE AREA
MC-31
MC-19D
0 50
Scale in Feet
N
NOTE:
The effluent storm drain line was located in the field by others to a location near MC-8. The alignment is unknown beyond this location, but extends to South 32nd Street where it connects to the main line adjacent to the roadway.
Stericycle - Washougal Facility
Washougal, Washington
Remedial Alternative A-3
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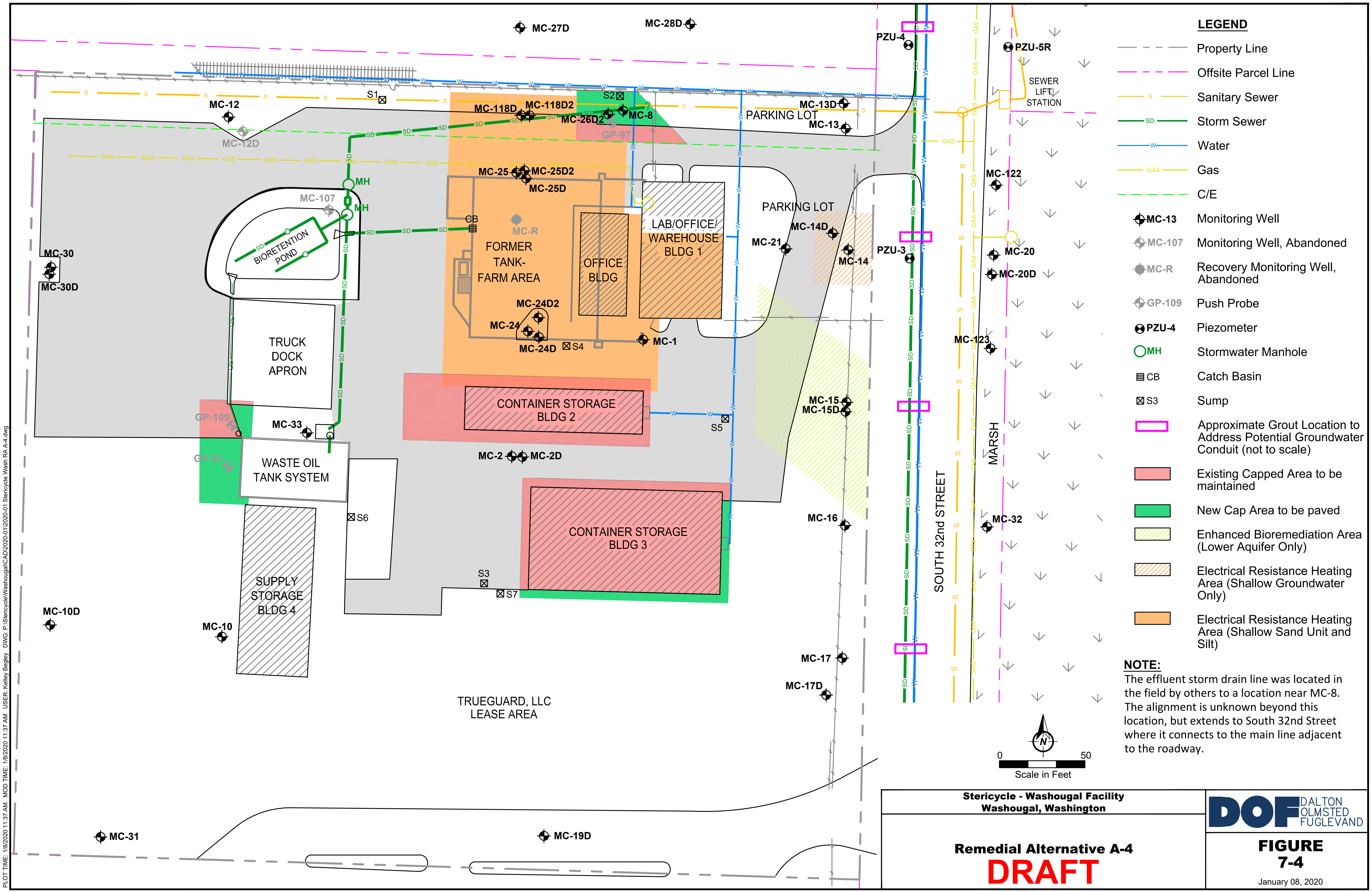
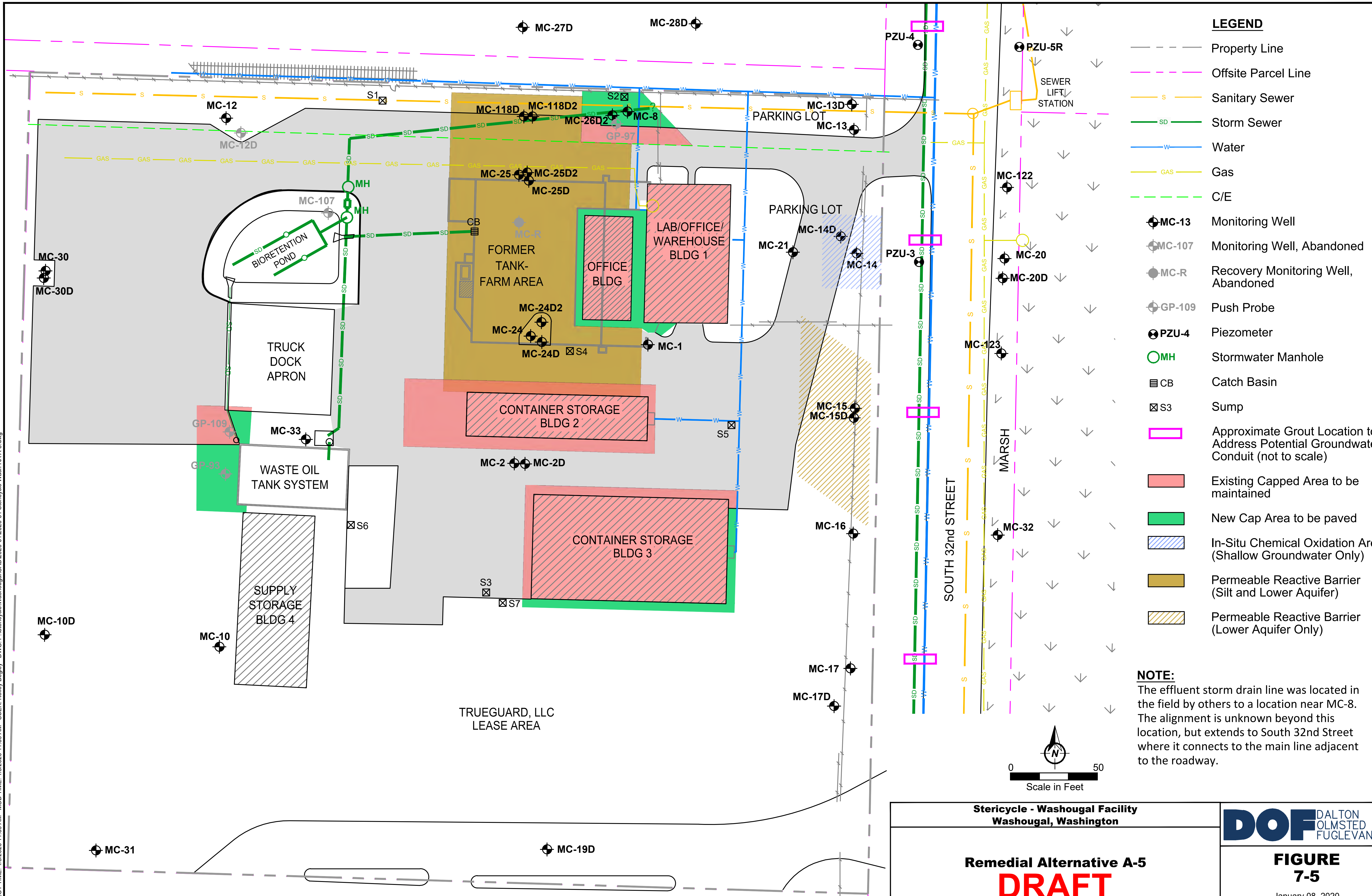
FIGURE 7-3
January 08, 2020


LEGEND
Property Line
Offsite Parcel Line
Sanitary Sewer
Storm Sewer
Water
Gas
C/E
MC-13 Monitoring Well
MC-107 Monitoring Well, Abandoned
MC-R Recovery Monitoring Well, Abandoned
GP-109 Push Probe
PZU-4 Piezometer
MH Stormwater Manhole
CB Catch Basin
S3 Sump
Approximate Grout Location to Address Potential Groundwater Conduit (not to scale)
Existing Capped Area to be maintained
New Cap Area to be paved
Enhanced Bioremediation Area (Lower Aquifer Only)
Electrical Resistance Heating Area (Shallow Groundwater Only)
Electrical Resistance Heating Area (Shallow Sand Unit and Silt)
NOTE:
The effluent storm drain line was located in the field by others to a location near MC-8. The alignment is unknown beyond this location, but extends to South 32nd Street where it connects to the main line adjacent to the roadway.
MC-27D
MC-28D
PZU-4
PZU-5R
SEWER LIFT STATION
S1
S2
MC-12
MC-12D
MC-118D
MC-118D2
MC-26D2
MC-8
GP-97
MC-13D
MC-13
PARKING LOT
MC-25
MC-25D2
MC-25D
MC-107
MH
BIORETENTION POND
CB
MC-R
FORMER TANK-FARM AREA
OFFICE BLDG
LAB/OFFICE/ WAREHOUSE BLDG 1
PARKING LOT
MC-14D
MC-14
MC-21
PZU-3
MC-122
MC-20
MC-20D
MC-30
MC-30D
TRUCK DOCK APRON
MC-24D2
MC-24
MC-24D
S4
MC-1
MC-123
GP-109
MC-33
CONTAINER STORAGE BLDG 2
S5
MC-15
MC-15D
GP-53
WASTE OIL TANK SYSTEM
MC-2
MC-2D
MARSH
SOUTH 32nd STREET
S6
CONTAINER STORAGE BLDG 3
MC-16
MC-32
SUPPLY STORAGE BLDG 4
S3
S7
MC-10D
MC-10
MC-17
MC-17D
TRUEGUARD, LLC LEASE AREA
MC-31
MC-19D
0
50
Scale in Feet
N
Stericycle - Washougal Facility
Washougal, Washington
Remedial Alternative A-4
DRAFT
DOF DALTON OLMSTED FUGLEVAND
FIGURE 7-4
January 08, 2020
PLOT TIME: 1/8/2020 11:37 AM MOD TIME: 1/8/2020 11:37 AM USER: Kelley Begley DWG: P:\Stericycle\Washougal\CAD\2020-01\2020-01 Stericycle Wash RA A-4.dwg



Stericycle - Washougal Facility
Washougal, Washington

Remedial Alternative A-5

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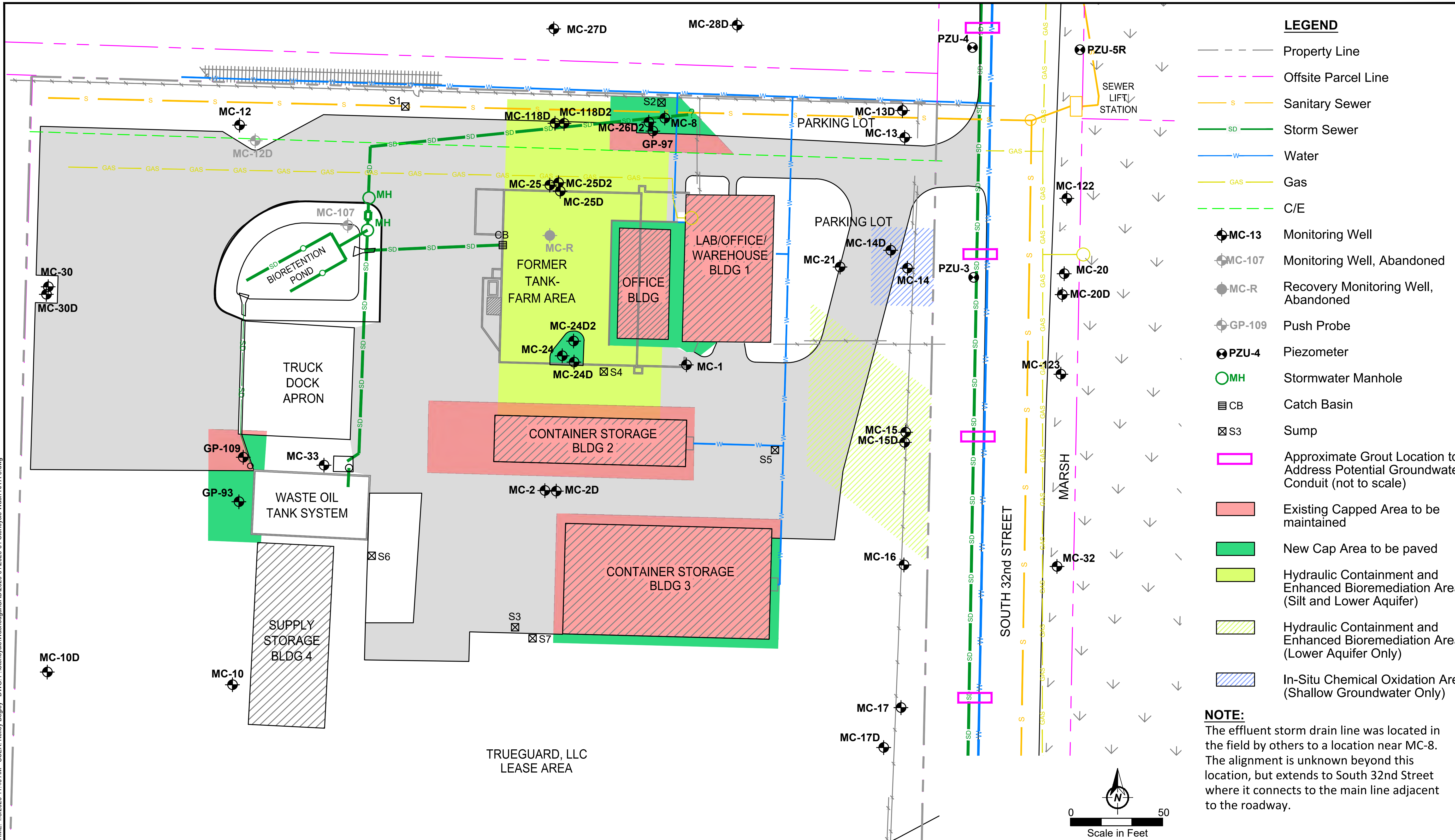
FIGURE 7-5

January 08, 2020



Stericycle - Washougal Facility
Washougal, Washington

Remedial Alternative A-6

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FIGURE 7-6

January 08, 2020

PLOT TIME: 1/8/2020 11:44 AM MOD TIME: 1/8/2020 11:40 AM USER: Kelley Begley DWG: P:\Stericycle\Washougal\CAD\2020-01\2020-01 Stericycle Wash RA A-6.dwg

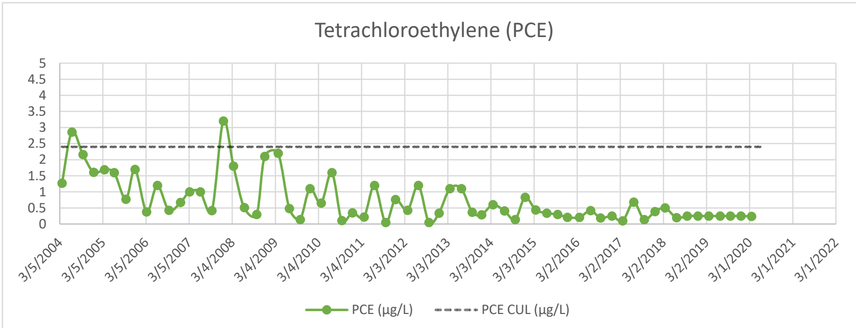
Appendix E

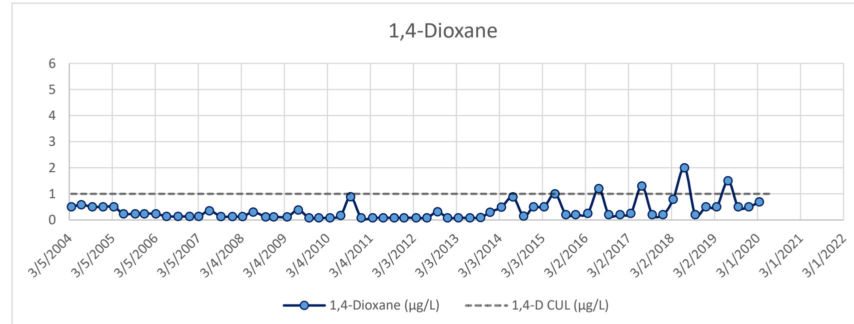
Trend Plots

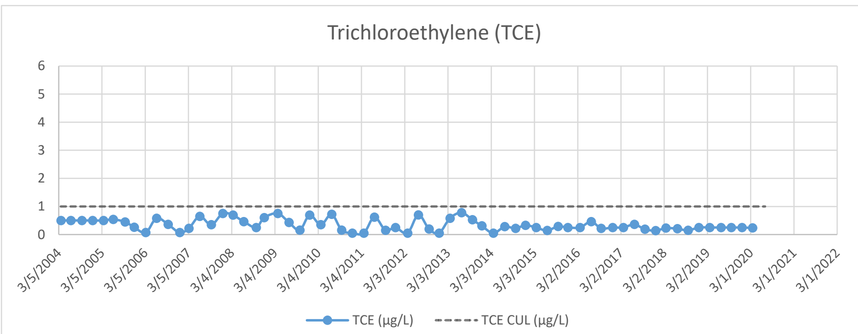
<u>Trend Plots</u>

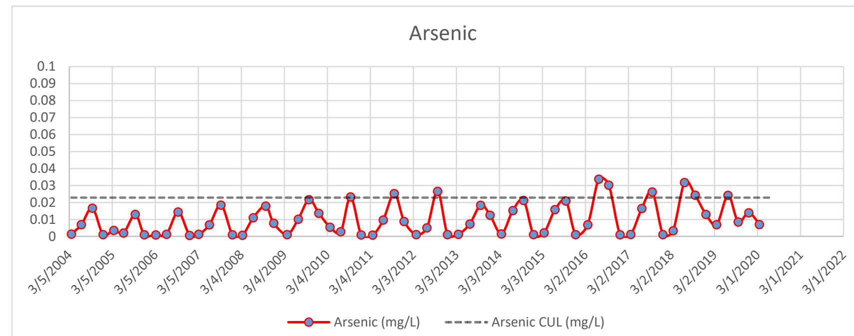
Updated August 2020 with Validated Data Through 1Q 2020

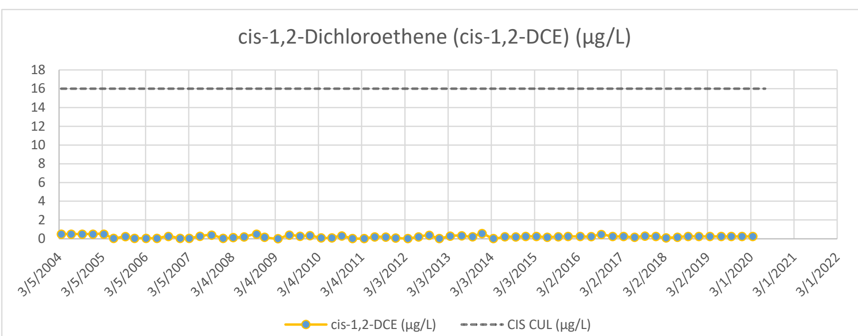
MC-1

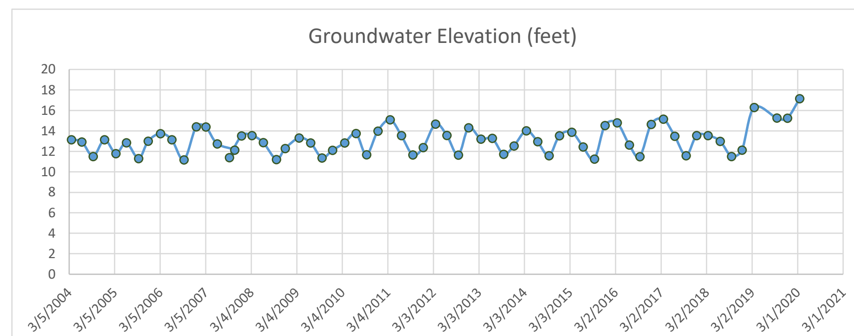

Tetrachloroethylene (PCE)
PCE (µg/L)
PCE CUL (µg/L)

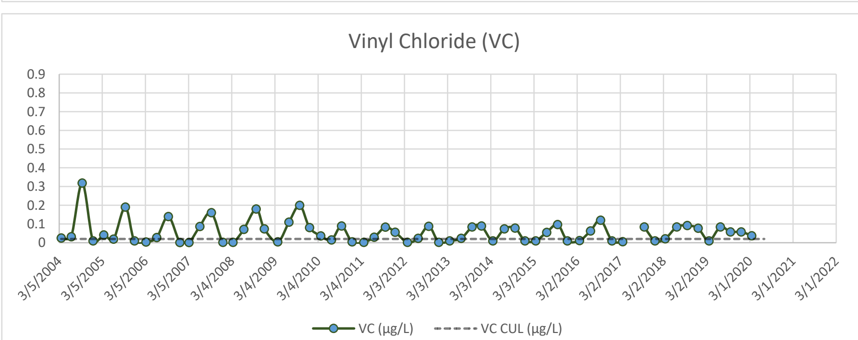

1,4-Dioxane
1,4-Dioxane (µg/L)
1,4-D CUL (µg/L)

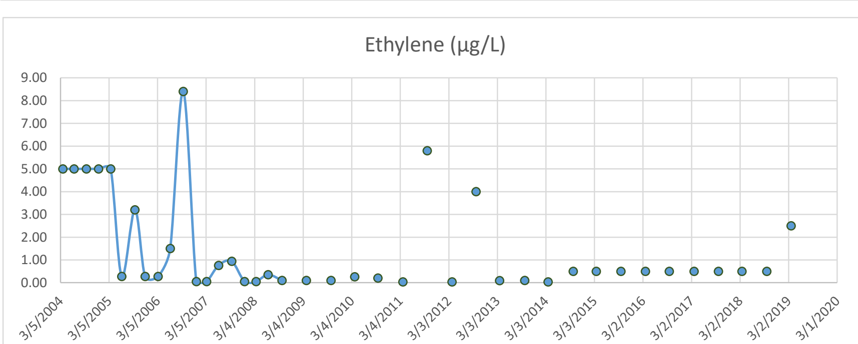

Trichloroethylene (TCE)
TCE (µg/L)
TCE CUL (µg/L)

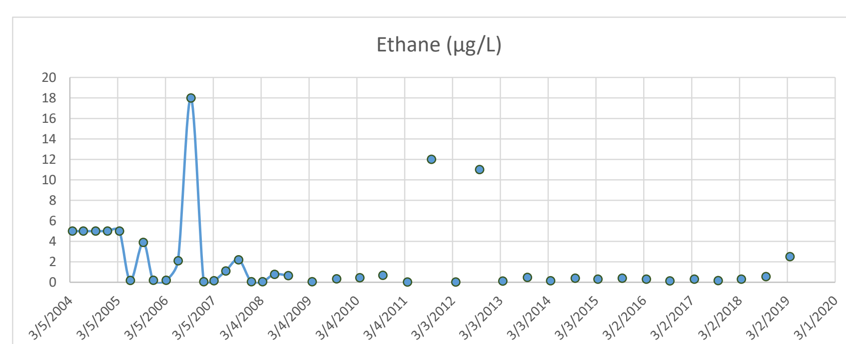

Arsenic
Arsenic (mg/L)
Arsenic CUL (mg/L)


cis-1,2-Dichloroethene (cis-1,2-DCE) (µg/L)
cis-1,2-DCE (µg/L)
CIS CUL (µg/L)

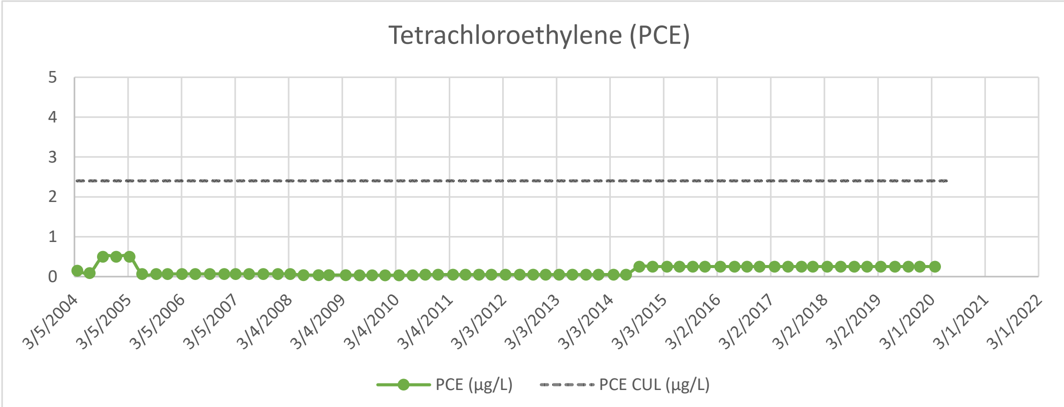

Groundwater Elevation (feet)

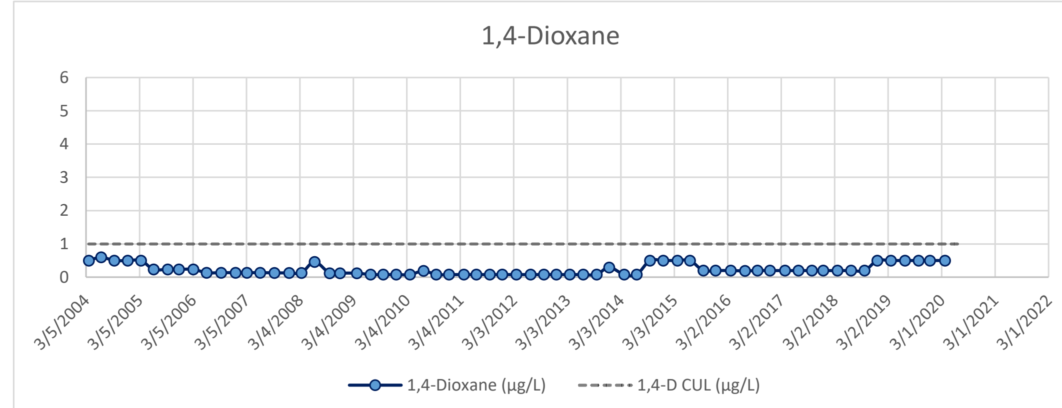

Vinyl Chloride (VC)
VC (µg/L)
VC CUL (µg/L)


Ethylene (µg/L)


Ethane (µg/L)

MC-2


Tetrachloroethylene (PCE)
0 1 2 3 4 5
3/5/2004 3/5/2005 3/5/2006 3/5/2007 3/4/2008 3/4/2009 3/4/2010 3/4/2011 3/3/2012 3/3/2013 3/3/2014 3/3/2015 3/2/2016 3/2/2017 3/2/2018 3/2/2019 3/1/2020 3/1/2021 3/1/2022
PCE (µg/L)
PCE CUL (µg/L)


1,4-Dioxane
0 1 2 3 4 5 6
3/5/2004 3/5/2005 3/5/2006 3/5/2007 3/4/2008 3/4/2009 3/4/2010 3/4/2011 3/3/2012 3/3/2013 3/3/2014 3/3/2015 3/2/2016 3/2/2017 3/2/2018 3/2/2019 3/1/2020 3/1/2021 3/1/2022
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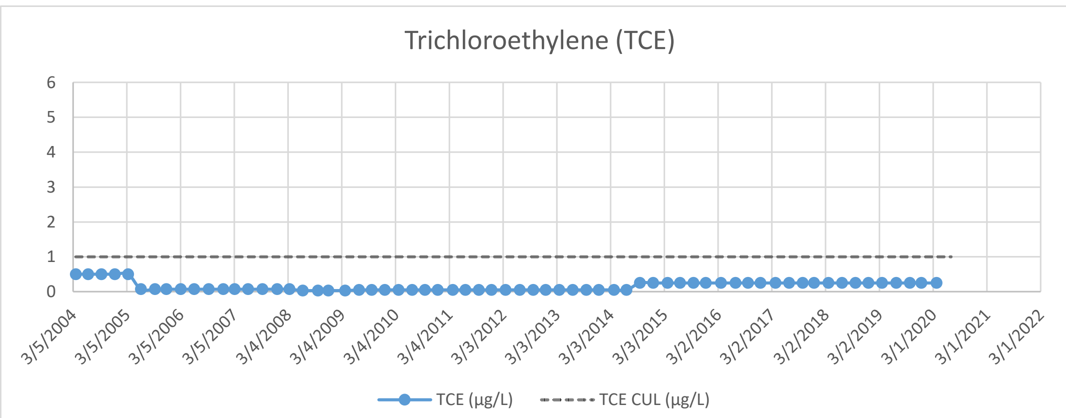
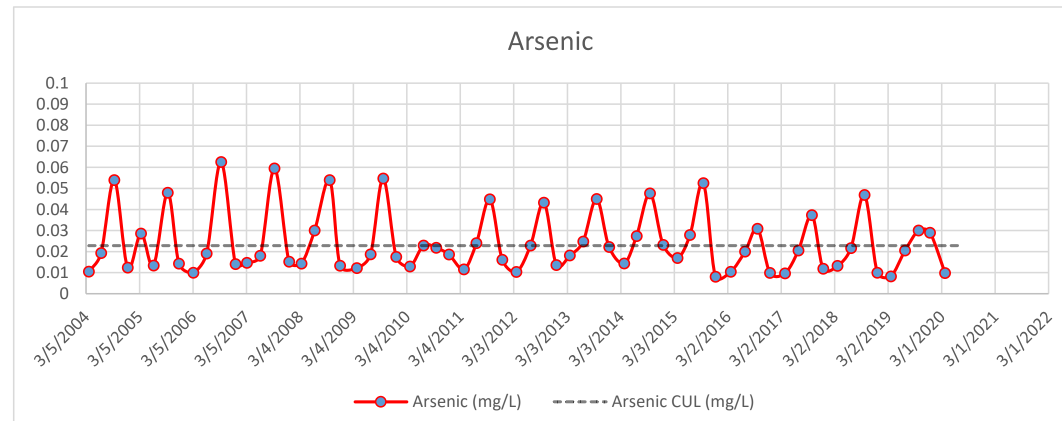
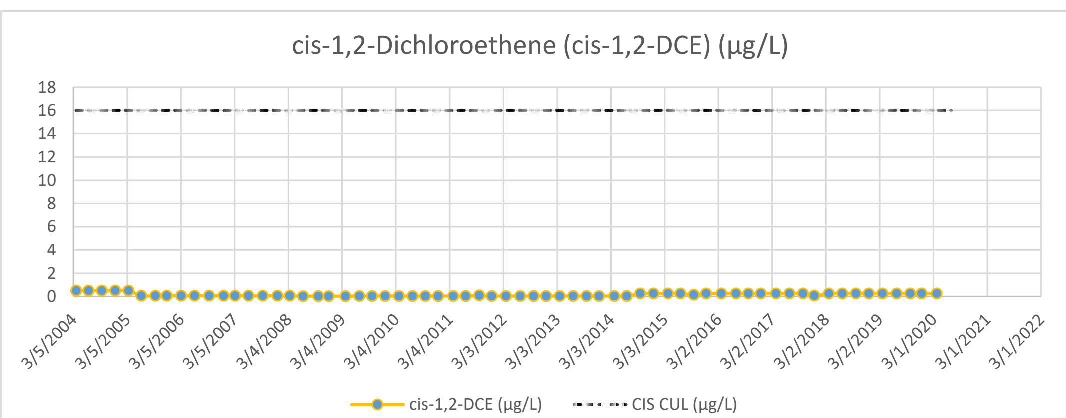
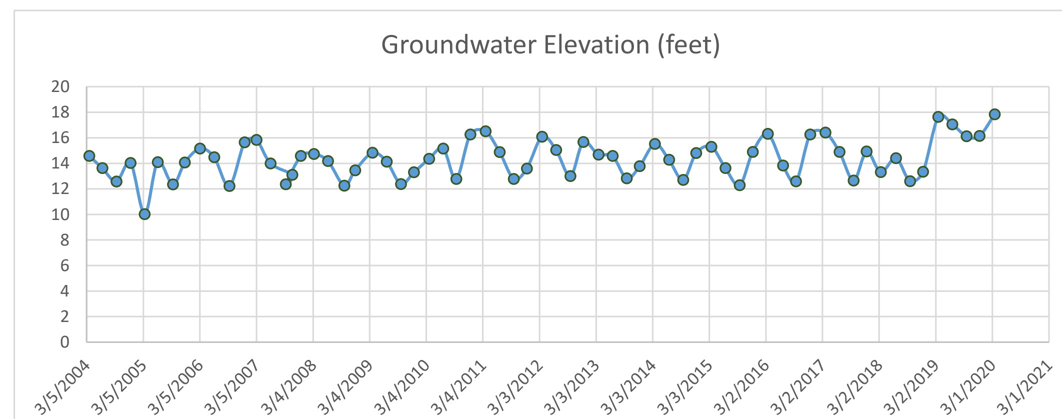
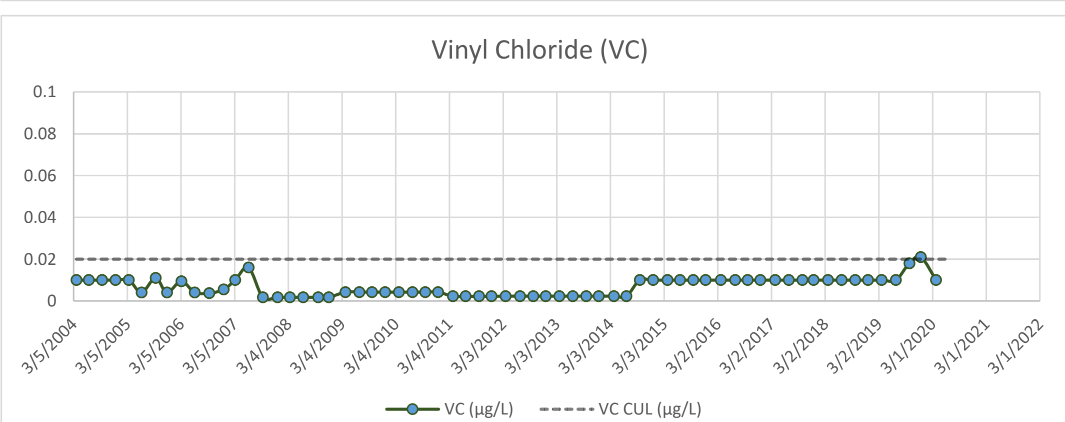
1,4-D CUL (µg/L)


Trichloroethylene (TCE)
0 1 2 3 4 5 6
3/5/2004 3/5/2005 3/5/2006 3/5/2007 3/4/2008 3/4/2009 3/4/2010 3/4/2011 3/3/2012 3/3/2013 3/3/2014 3/3/2015 3/2/2016 3/2/2017 3/2/2018 3/2/2019 3/1/2020 3/1/2021 3/1/2022
TCE (µg/L)
TCE CUL (µg/L)


Arsenic
0 0.01 0.02 0.03 0.04 0.05 0.06 0.07 0.08 0.09 0.1
3/5/2004 3/5/2005 3/5/2006 3/5/2007 3/4/2008 3/4/2009 3/4/2010 3/4/2011 3/3/2012 3/3/2013 3/3/2014 3/3/2015 3/2/2016 3/2/2017 3/2/2018 3/2/2019 3/1/2020 3/1/2021 3/1/2022
Arsenic (mg/L)
Arsenic CUL (mg/L)


cis-1,2-Dichloroethene (cis-1,2-DCE) (µg/L)
0 2 4 6 8 10 12 14 16 18
3/5/2004 3/5/2005 3/5/2006 3/5/2007 3/4/2008 3/4/2009 3/4/2010 3/4/2011 3/3/2012 3/3/2013 3/3/2014 3/3/2015 3/2/2016 3/2/2017 3/2/2018 3/2/2019 3/1/2020 3/1/2021 3/1/2022
cis-1,2-DCE (µg/L)
CIS CUL (µg/L)


Groundwater Elevation (feet)
0 2 4 6 8 10 12 14 16 18 20
3/5/2004 3/5/2005 3/5/2006 3/5/2007 3/4/2008 3/4/2009 3/4/2010 3/4/2011 3/3/2012 3/3/2013 3/3/2014 3/3/2015 3/2/2016 3/2/2017 3/2/2018 3/2/2019 3/1/2020 3/1/2021


Vinyl Chloride (VC)
0 0.02 0.04 0.06 0.08 0.1
3/5/2004 3/5/2005 3/5/2006 3/5/2007 3/4/2008 3/4/2009 3/4/2010 3/4/2011 3/3/2012 3/3/2013 3/3/2014 3/3/2015 3/2/2016 3/2/2017 3/2/2018 3/2/2019 3/1/2020 3/1/2021 3/1/2022
VC (µg/L)
VC CUL (µg/L)

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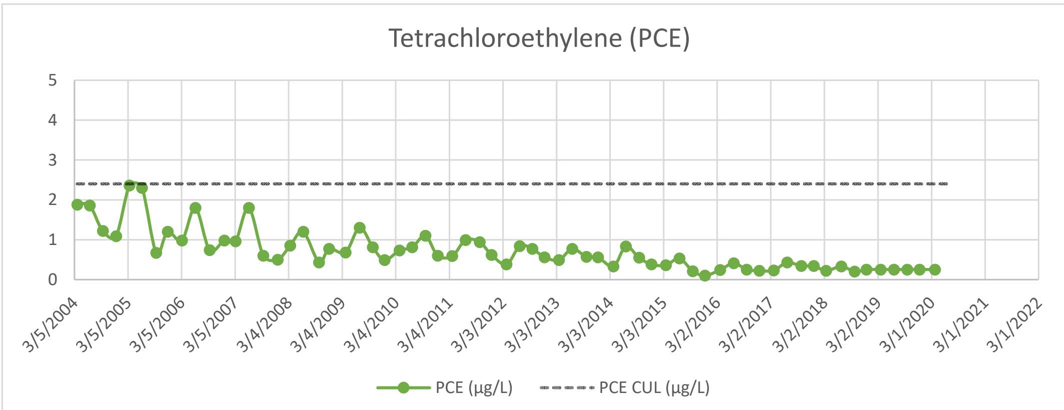
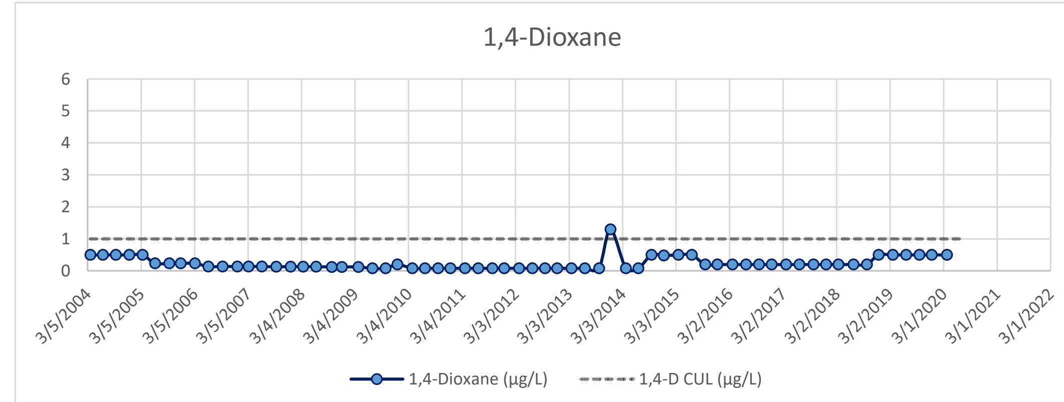
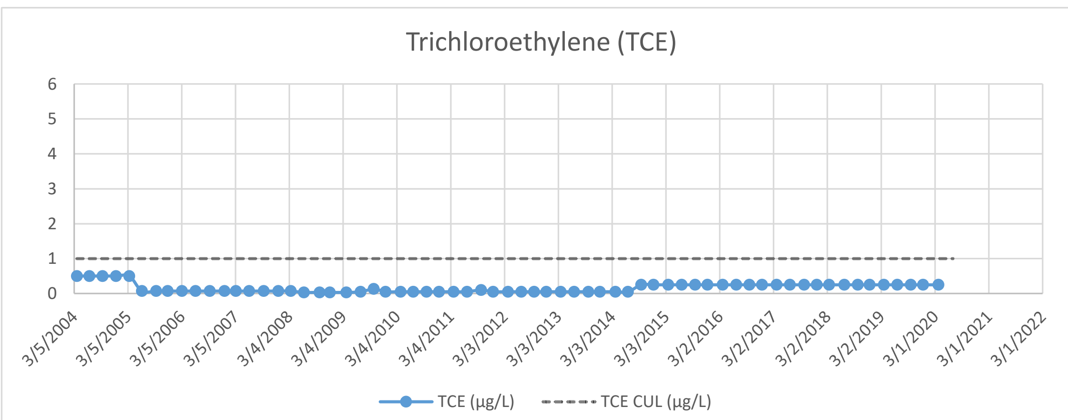
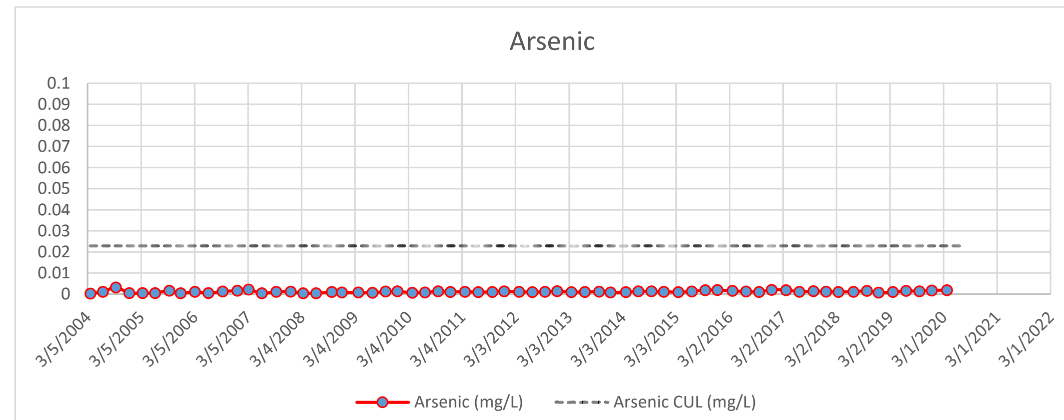
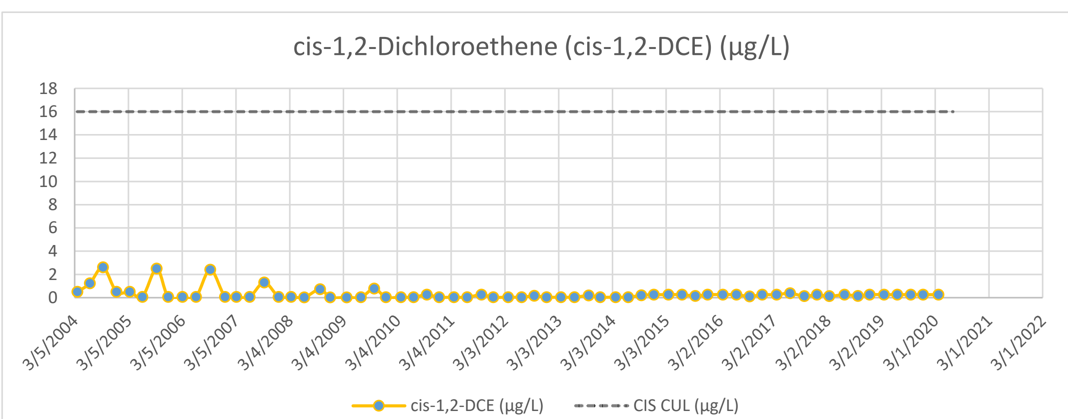
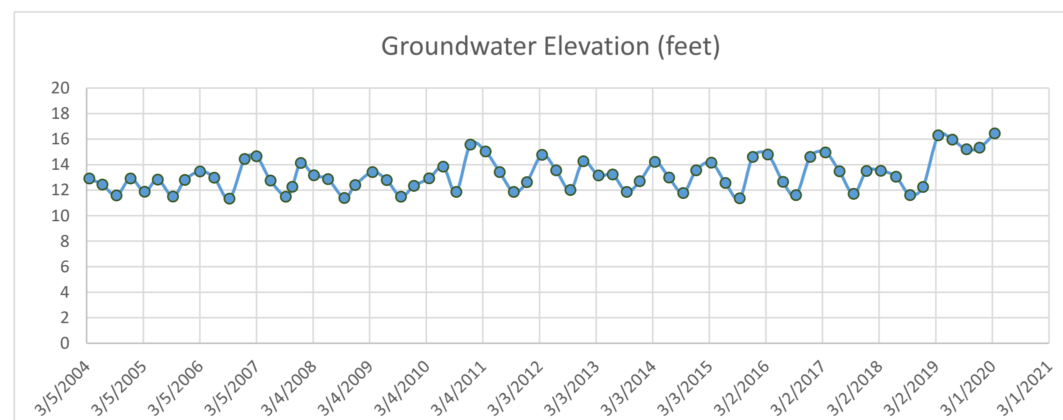

Tetrachloroethylene (PCE)
0
1
2
3
4
5
3/5/2004
3/5/2005
3/5/2006
3/5/2007
3/4/2008
3/4/2009
3/4/2010
3/4/2011
3/3/2012
3/3/2013
3/3/2014
3/3/2015
3/2/2016
3/2/2017
3/2/2018
3/2/2019
3/1/2020
3/1/2021
3/1/2022
PCE (µg/L)
PCE CUL (µg/L)

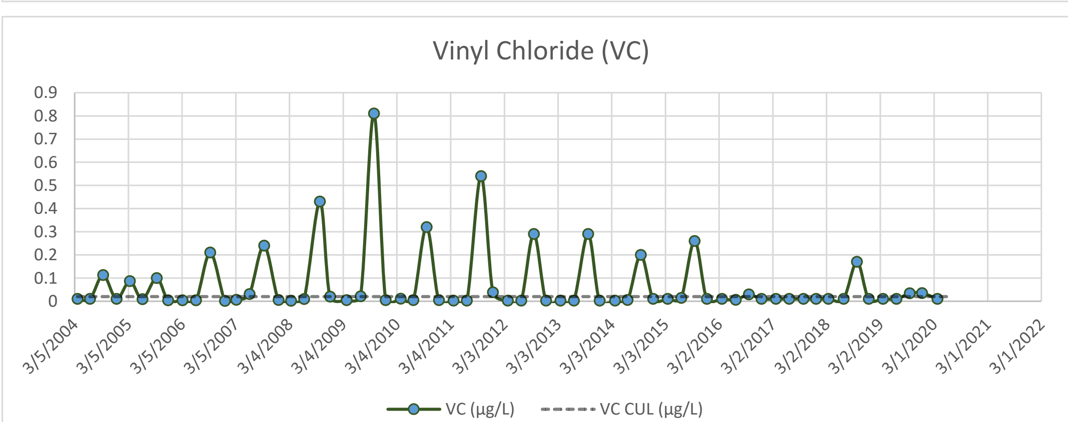

1,4-Dioxane
0
1
2
3
4
5
6
3/5/2004
3/5/2005
3/5/2006
3/5/2007
3/4/2008
3/4/2009
3/4/2010
3/4/2011
3/3/2012
3/3/2013
3/3/2014
3/3/2015
3/2/2016
3/2/2017
3/2/2018
3/2/2019
3/1/2020
3/1/2021
3/1/2022
1,4-Dioxane (µg/L)
1,4-D CUL (µg/L)


Trichloroethylene (TCE)
0
1
2
3
4
5
6
3/5/2004
3/5/2005
3/5/2006
3/5/2007
3/4/2008
3/4/2009
3/4/2010
3/4/2011
3/3/2012
3/3/2013
3/3/2014
3/3/2015
3/2/2016
3/2/2017
3/2/2018
3/2/2019
3/1/2020
3/1/2021
3/1/2022
TCE (µg/L)
TCE CUL (µg/L)


Arsenic
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.1
3/5/2004
3/5/2005
3/5/2006
3/5/2007
3/4/2008
3/4/2009
3/4/2010
3/4/2011
3/3/2012
3/3/2013
3/3/2014
3/3/2015
3/2/2016
3/2/2017
3/2/2018
3/2/2019
3/1/2020
3/1/2021
3/1/2022
Arsenic (mg/L)
Arsenic CUL (mg/L)


cis-1,2-Dichloroethene (cis-1,2-DCE) (µg/L)
0
2
4
6
8
10
12
14
16
18
3/5/2004
3/5/2005
3/5/2006
3/5/2007
3/4/2008
3/4/2009
3/4/2010
3/4/2011
3/3/2012
3/3/2013
3/3/2014
3/3/2015
3/2/2016
3/2/2017
3/2/2018
3/2/2019
3/1/2020
3/1/2021
3/1/2022
cis-1,2-DCE (µg/L)
CIS CUL (µg/L)


Groundwater Elevation (feet)
0
2
4
6
8
10
12
14
16
18
20
3/5/2004
3/5/2005
3/5/2006
3/5/2007
3/4/2008
3/4/2009
3/4/2010
3/4/2011
3/3/2012
3/3/2013
3/3/2014
3/3/2015
3/2/2016
3/2/2017
3/2/2018
3/2/2019
3/1/2020
3/1/2021


Vinyl Chloride (VC)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
3/5/2004
3/5/2005
3/5/2006
3/5/2007
3/4/2008
3/4/2009
3/4/2010
3/4/2011
3/3/2012
3/3/2013
3/3/2014
3/3/2015
3/2/2016
3/2/2017
3/2/2018
3/2/2019
3/1/2020
3/1/2021
3/1/2022
VC (µg/L)
VC CUL (µg/L)

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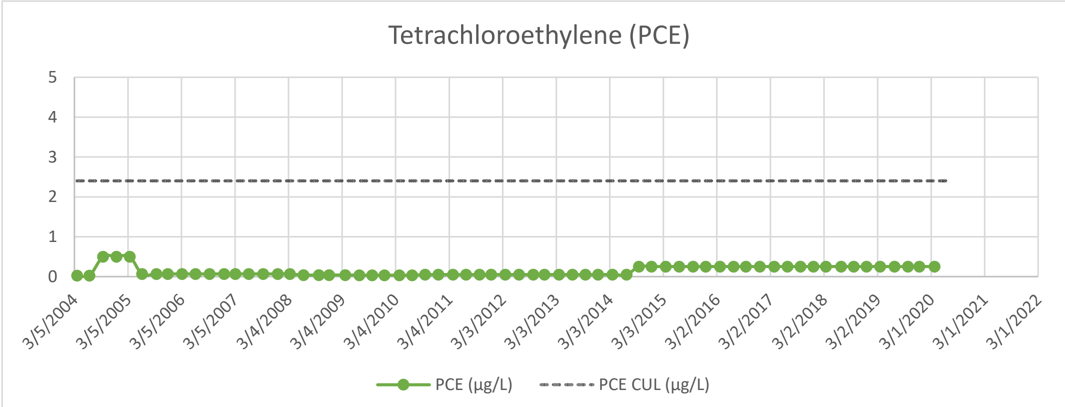
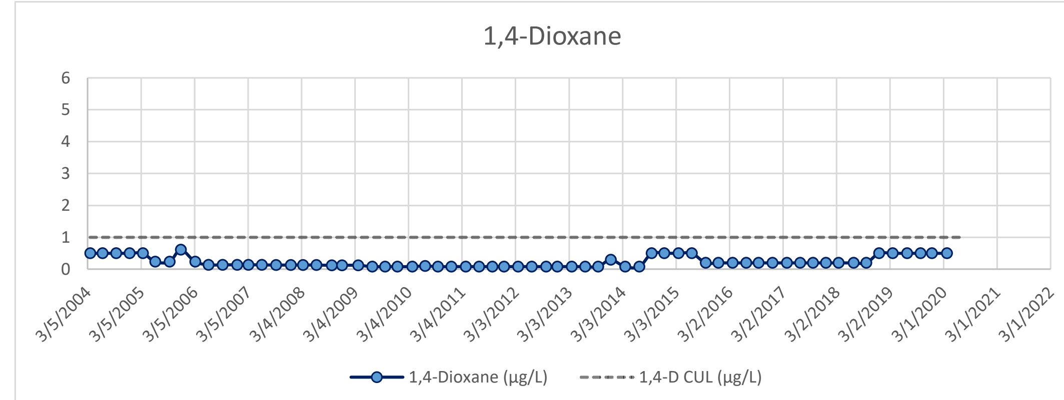
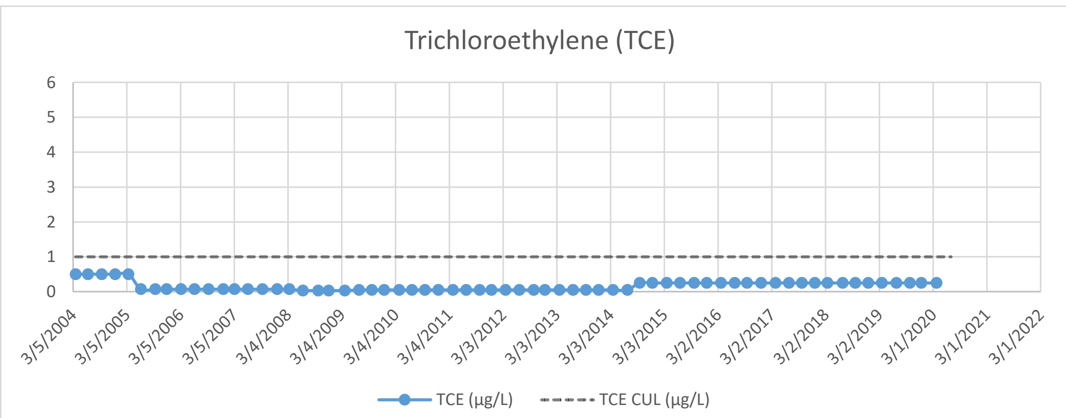
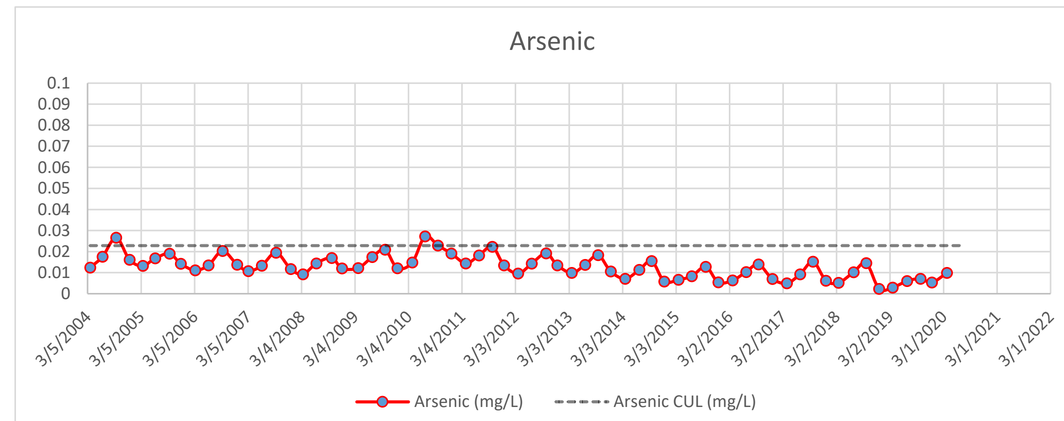
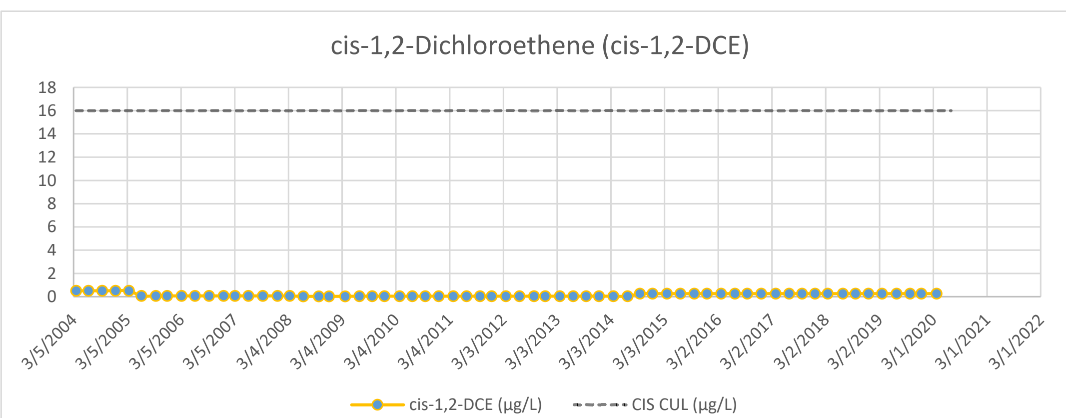
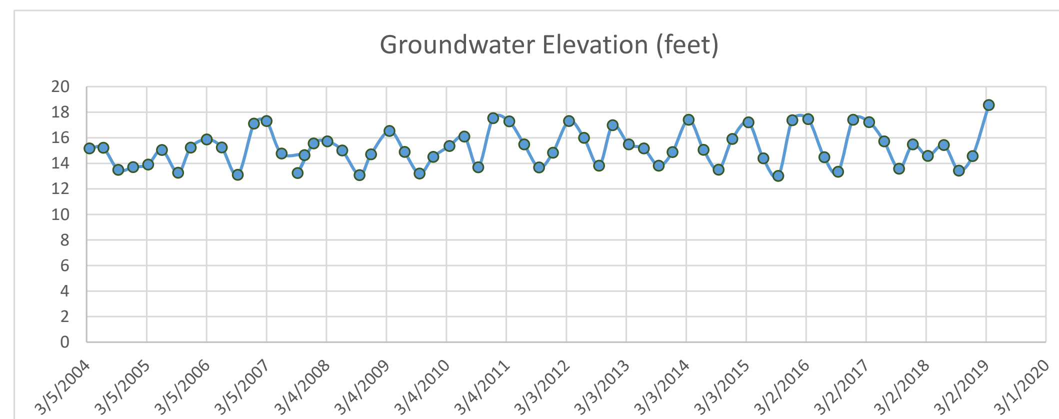

Tetrachloroethylene (PCE)
PCE (µg/L)
PCE CUL (µg/L)

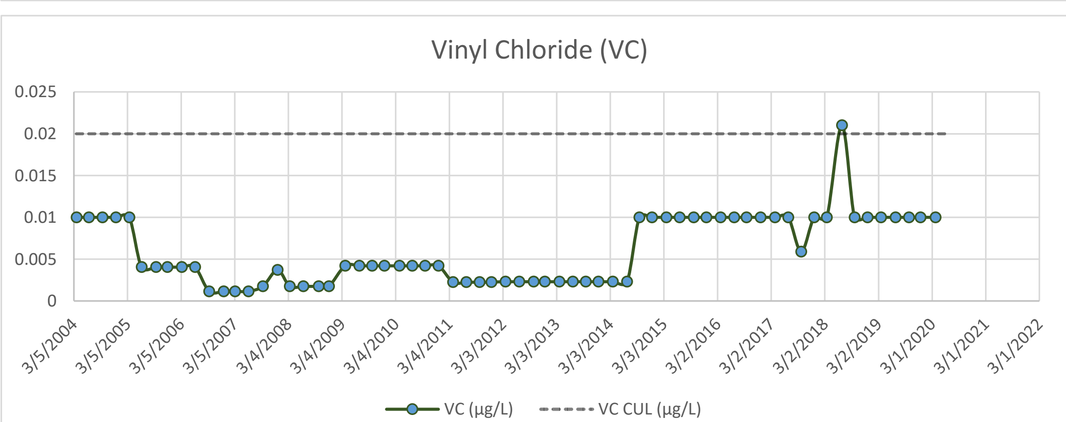

1,4-Dioxane
1,4-Dioxane (µg/L)
1,4-D CUL (µg/L)


Trichloroethylene (TCE)
TCE (µg/L)
TCE CUL (µg/L)


Arsenic
Arsenic (mg/L)
Arsenic CUL (mg/L)


cis-1,2-Dichloroethene (cis-1,2-DCE)
cis-1,2-DCE (µg/L)
CIS CUL (µg/L)


Groundwater Elevation (feet)


Vinyl Chloride (VC)
VC (µg/L)
VC CUL (µg/L)

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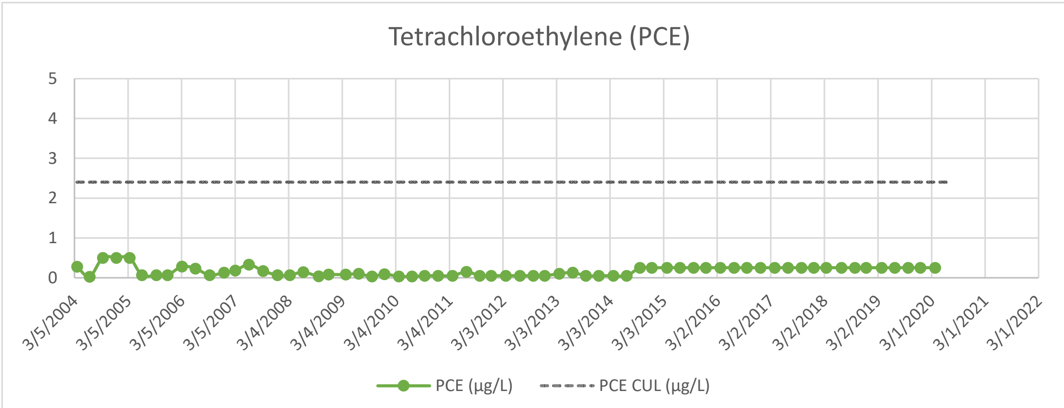
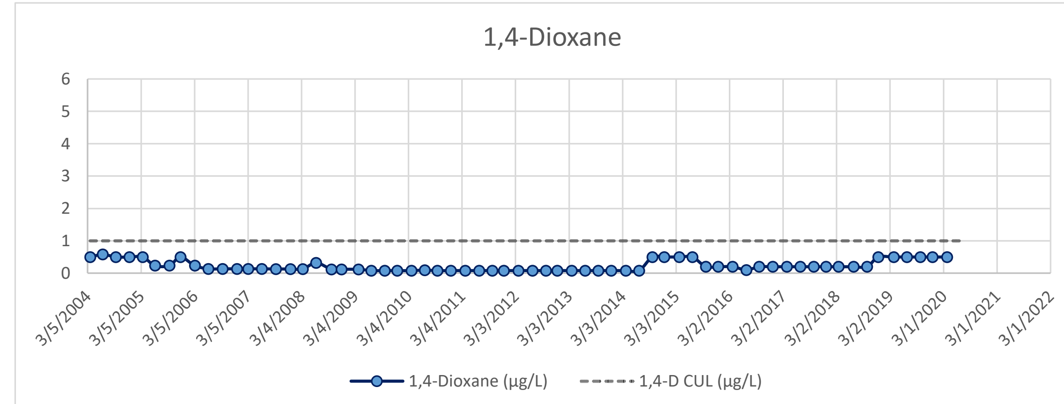
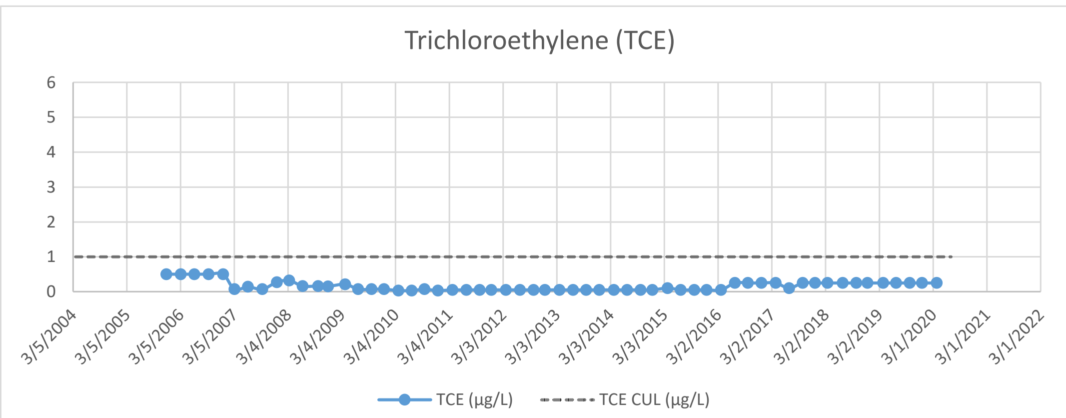
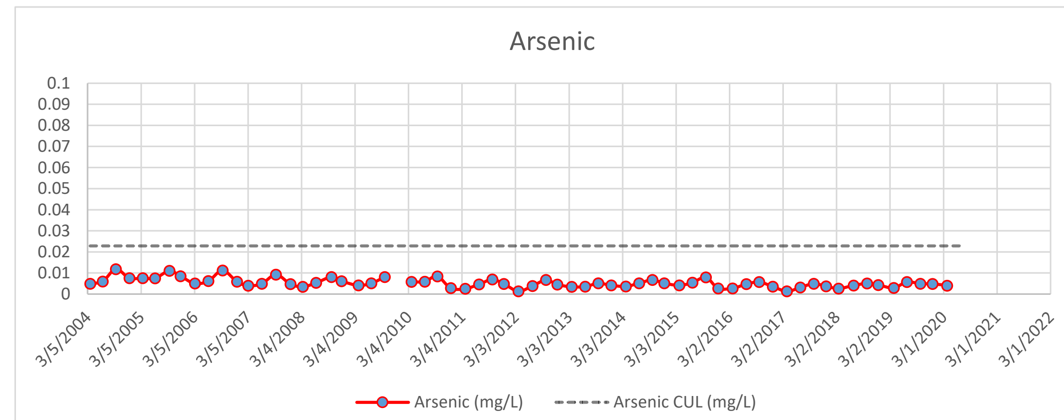
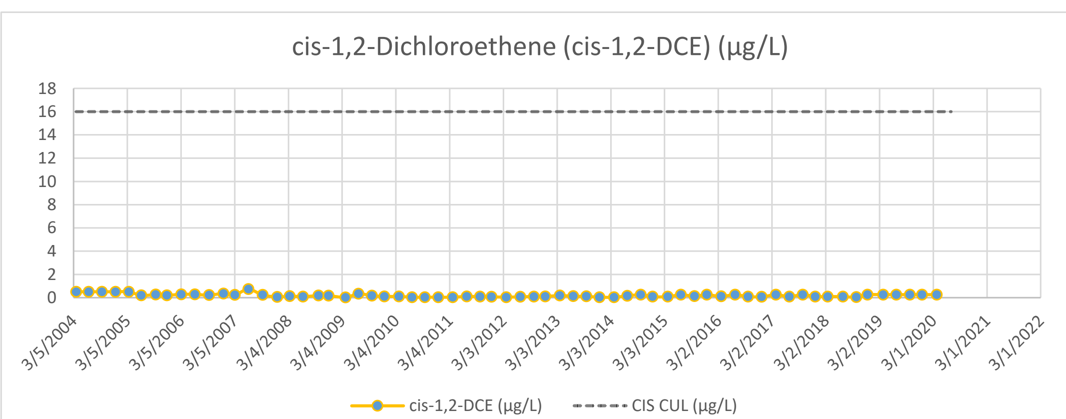
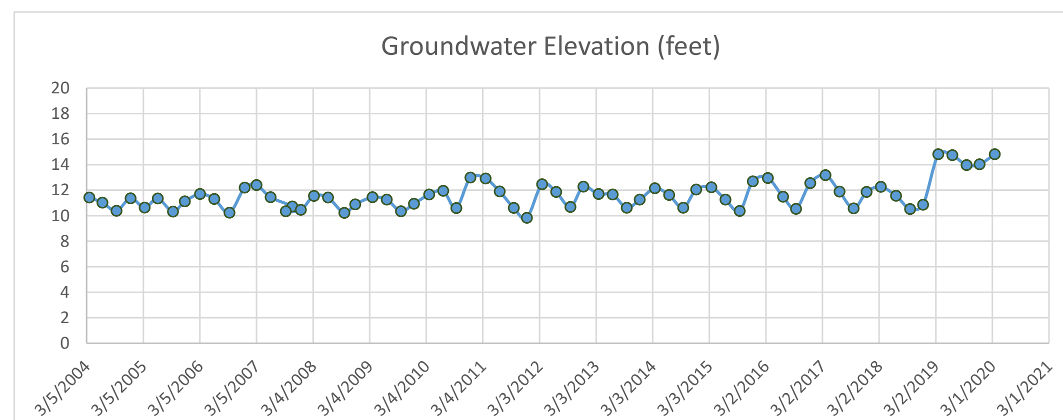

Tetrachloroethylene (PCE)
0 1 2 3 4 5
3/5/2004 3/5/2005 3/5/2006 3/5/2007 3/4/2008 3/4/2009 3/4/2010 3/4/2011 3/3/2012 3/3/2013 3/3/2014 3/3/2015 3/2/2016 3/2/2017 3/2/2018 3/2/2019 3/1/2020 3/1/2021 3/1/2022
PCE (µg/L)
PCE CUL (µg/L)

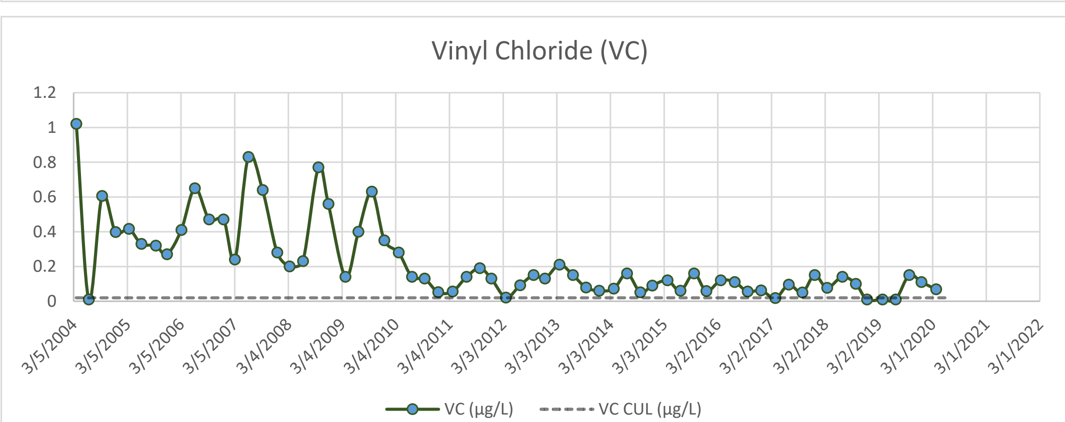

1,4-Dioxane
0 1 2 3 4 5 6
3/5/2004 3/5/2005 3/5/2006 3/5/2007 3/4/2008 3/4/2009 3/4/2010 3/4/2011 3/3/2012 3/3/2013 3/3/2014 3/3/2015 3/2/2016 3/2/2017 3/2/2018 3/2/2019 3/1/2020 3/1/2021 3/1/2022
1,4-Dioxane (µg/L)
1,4-D CUL (µg/L)


Trichloroethylene (TCE)
0 1 2 3 4 5 6
3/5/2004 3/5/2005 3/5/2006 3/5/2007 3/4/2008 3/4/2009 3/4/2010 3/4/2011 3/3/2012 3/3/2013 3/3/2014 3/3/2015 3/2/2016 3/2/2017 3/2/2018 3/2/2019 3/1/2020 3/1/2021 3/1/2022
TCE (µg/L)
TCE CUL (µg/L)

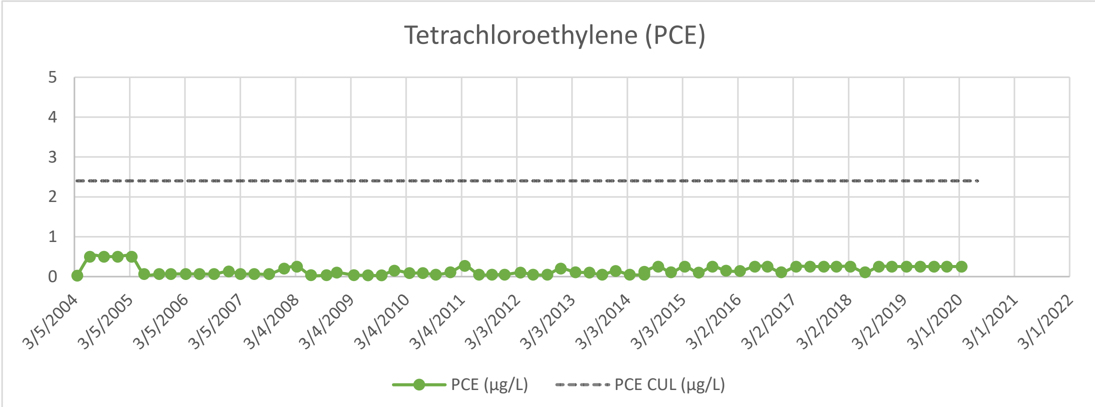

Arsenic
0 0.01 0.02 0.03 0.04 0.05 0.06 0.07 0.08 0.09 0.1
3/5/2004 3/5/2005 3/5/2006 3/5/2007 3/4/2008 3/4/2009 3/4/2010 3/4/2011 3/3/2012 3/3/2013 3/3/2014 3/3/2015 3/2/2016 3/2/2017 3/2/2018 3/2/2019 3/1/2020 3/1/2021 3/1/2022
Arsenic (mg/L)
Arsenic CUL (mg/L)

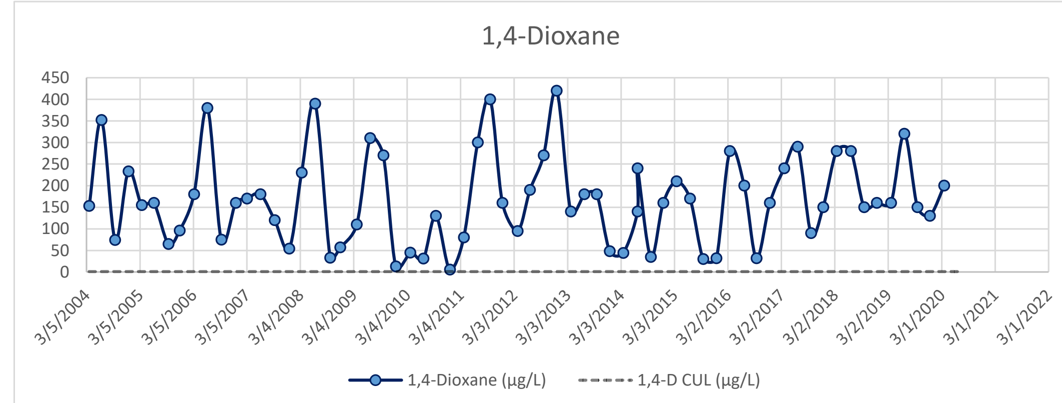

cis-1,2-Dichloroethene (cis-1,2-DCE) (µg/L)
0 2 4 6 8 10 12 14 16 18
3/5/2004 3/5/2005 3/5/2006 3/5/2007 3/4/2008 3/4/2009 3/4/2010 3/4/2011 3/3/2012 3/3/2013 3/3/2014 3/3/2015 3/2/2016 3/2/2017 3/2/2018 3/2/2019 3/1/2020 3/1/2021 3/1/2022
cis-1,2-DCE (µg/L)
CIS CUL (µg/L)

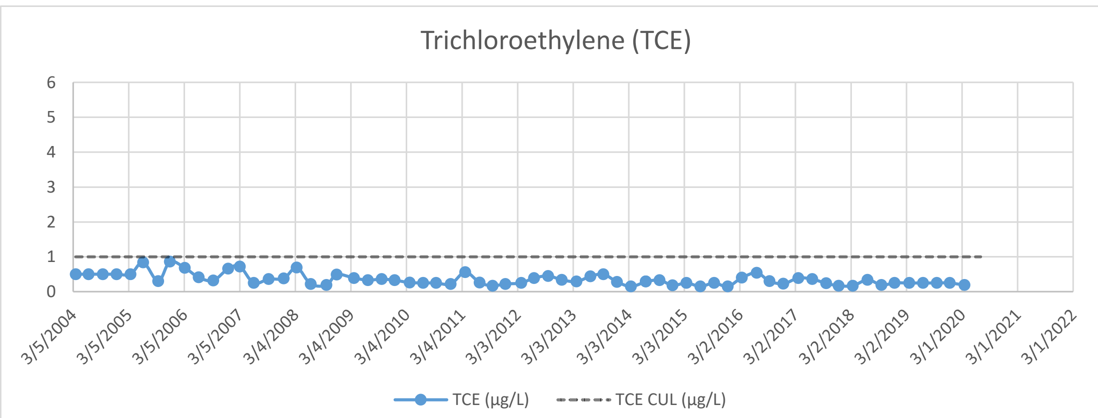

Groundwater Elevation (feet)
0 2 4 6 8 10 12 14 16 18 20
3/5/2004 3/5/2005 3/5/2006 3/5/2007 3/4/2008 3/4/2009 3/4/2010 3/4/2011 3/3/2012 3/3/2013 3/3/2014 3/3/2015 3/2/2016 3/2/2017 3/2/2018 3/2/2019 3/1/2020 3/1/2021

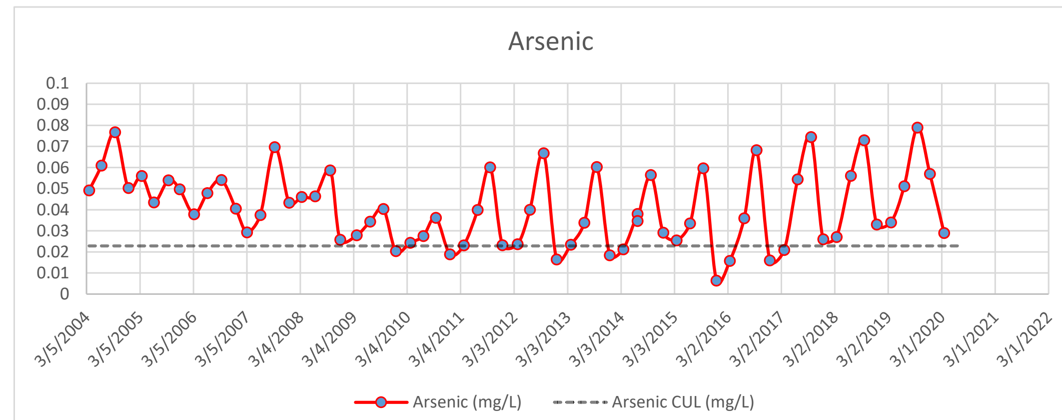

Vinyl Chloride (VC)
0 0.2 0.4 0.6 0.8 1 1.2
3/5/2004 3/5/2005 3/5/2006 3/5/2007 3/4/2008 3/4/2009 3/4/2010 3/4/2011 3/3/2012 3/3/2013 3/3/2014 3/3/2015 3/2/2016 3/2/2017 3/2/2018 3/2/2019 3/1/2020 3/1/2021 3/1/2022
VC (µg/L)
VC CUL (µg/L)

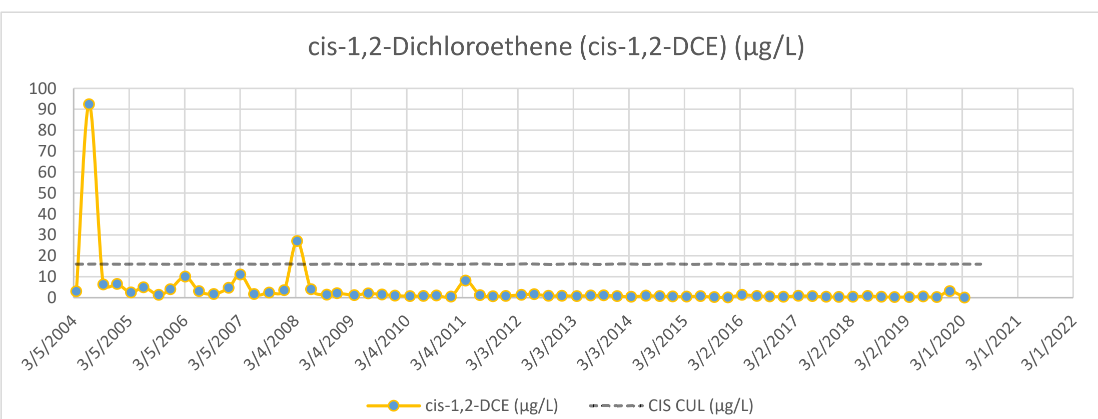
MC-14

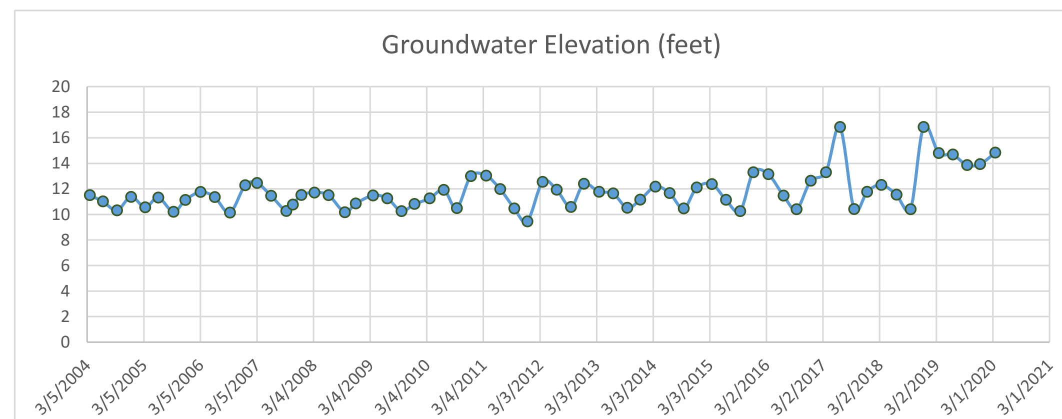

Tetrachloroethylene (PCE)
PCE (µg/L)
PCE CUL (µg/L)

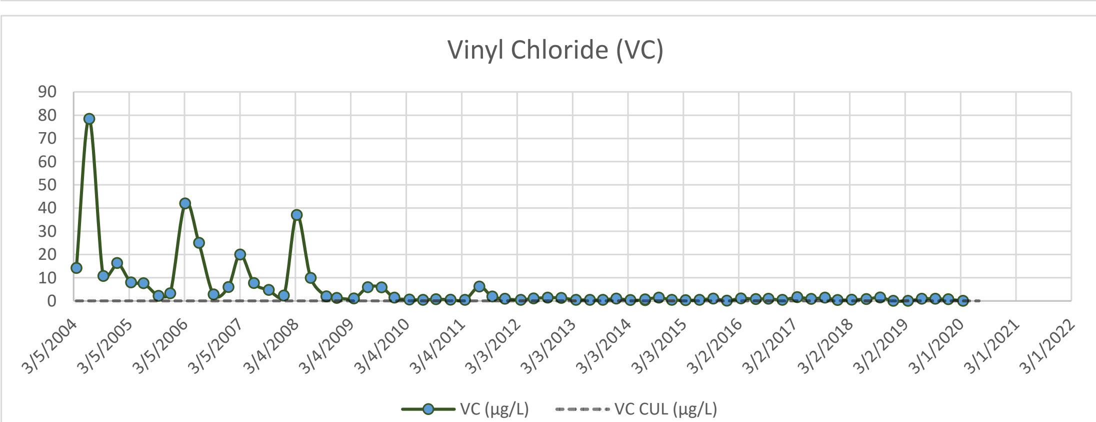

1,4-Dioxane
1,4-Dioxane (µg/L)
1,4-D CUL (µg/L)


Trichloroethylene (TCE)
TCE (µg/L)
TCE CUL (µg/L)

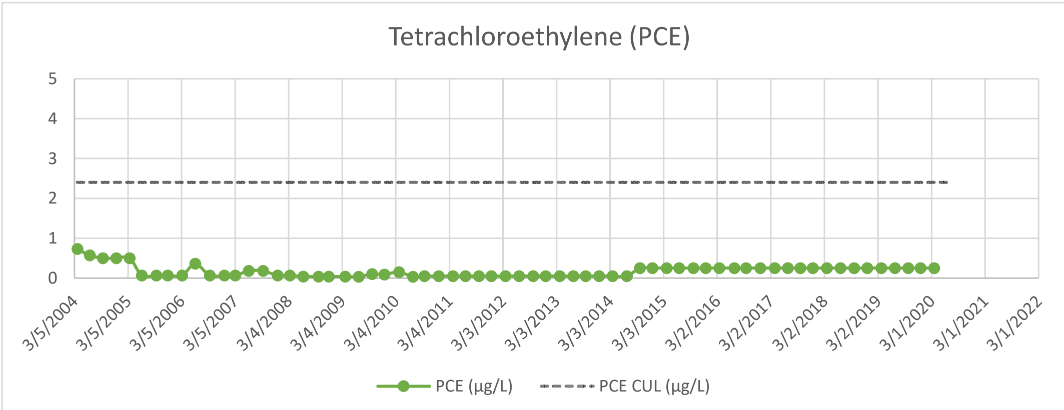

Arsenic
Arsenic (mg/L)
Arsenic CUL (mg/L)

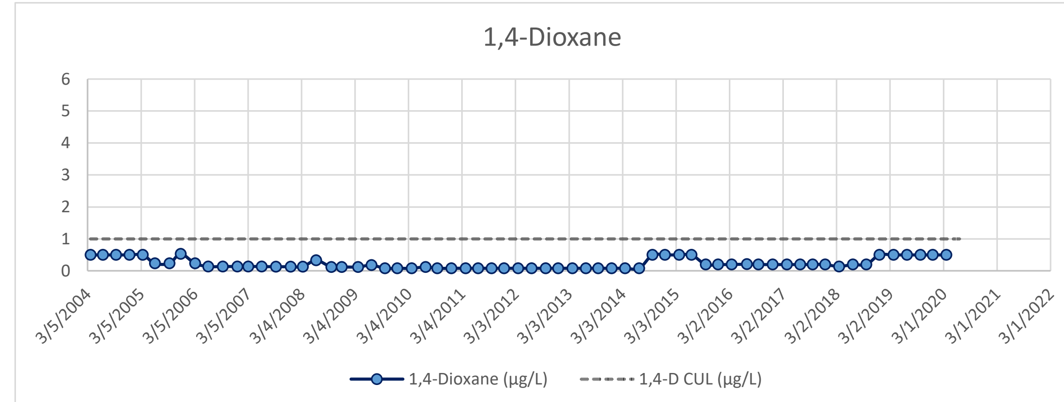

cis-1,2-Dichloroethene (cis-1,2-DCE) (µg/L)
cis-1,2-DCE (µg/L)
CIS CUL (µg/L)

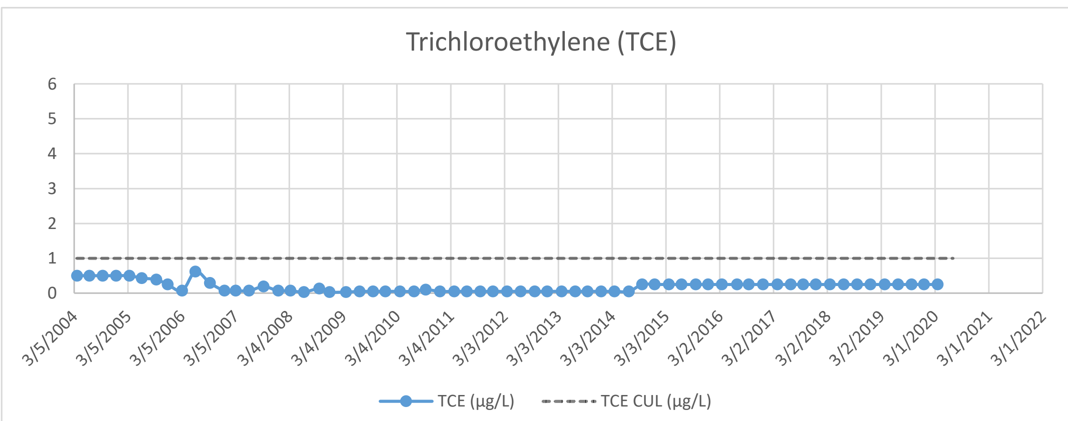

Groundwater Elevation (feet)

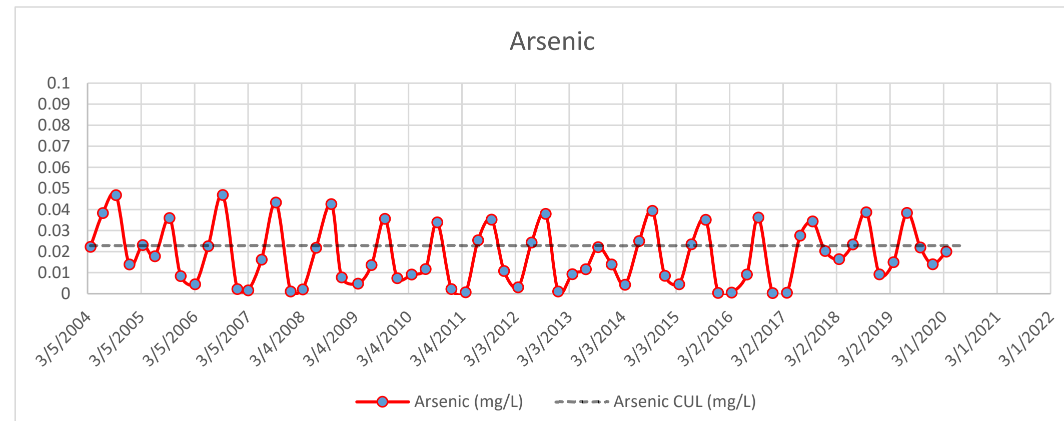

Vinyl Chloride (VC)
VC (µg/L)
VC CUL (µg/L)

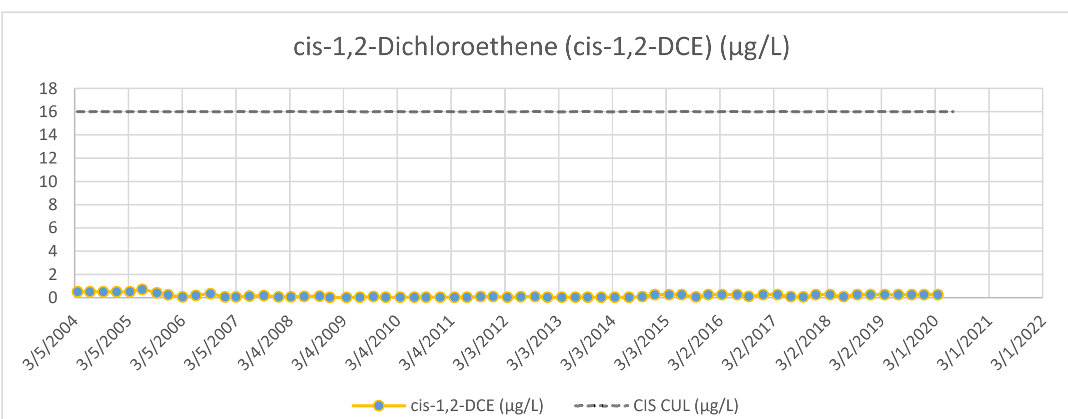
MC-15

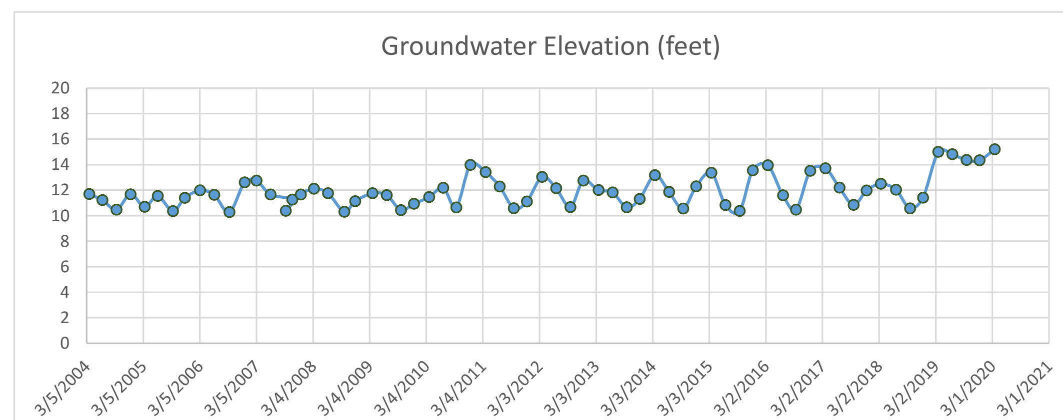

Tetrachloroethylene (PCE)
5
4
3
2
1
0
3/5/2004 3/5/2005 3/5/2006 3/5/2007 3/4/2008 3/4/2009 3/4/2010 3/4/2011 3/3/2012 3/3/2013 3/3/2014 3/3/2015 3/2/2016 3/2/2017 3/2/2018 3/2/2019 3/1/2020 3/1/2021 3/1/2022
PCE (µg/L)
PCE CUL (µg/L)

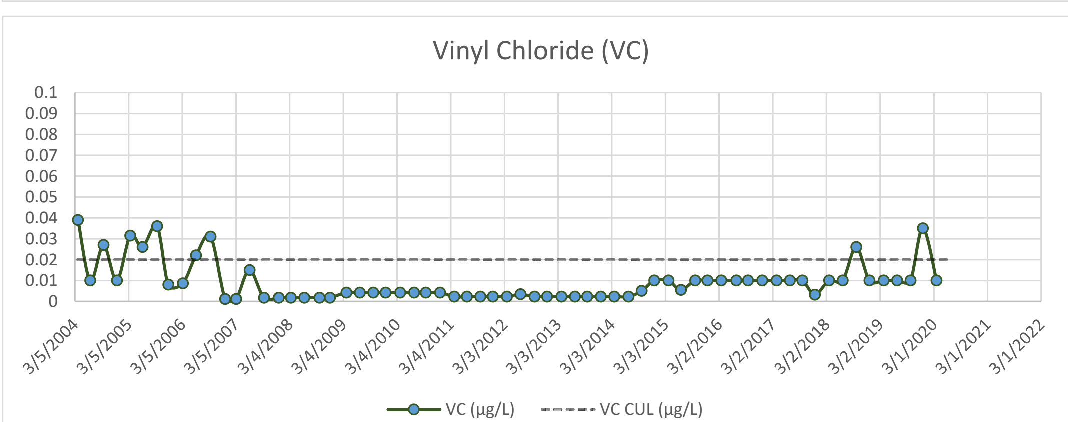

1,4-Dioxane
6
5
4
3
2
1
0
3/5/2004 3/5/2005 3/5/2006 3/5/2007 3/4/2008 3/4/2009 3/4/2010 3/4/2011 3/3/2012 3/3/2013 3/3/2014 3/3/2015 3/2/2016 3/2/2017 3/2/2018 3/2/2019 3/1/2020 3/1/2021 3/1/2022
1,4-Dioxane (µg/L)
1,4-D CUL (µg/L)


Trichloroethylene (TCE)
6
5
4
3
2
1
0
3/5/2004 3/5/2005 3/5/2006 3/5/2007 3/4/2008 3/4/2009 3/4/2010 3/4/2011 3/3/2012 3/3/2013 3/3/2014 3/3/2015 3/2/2016 3/2/2017 3/2/2018 3/2/2019 3/1/2020 3/1/2021 3/1/2022
TCE (µg/L)
TCE CUL (µg/L)

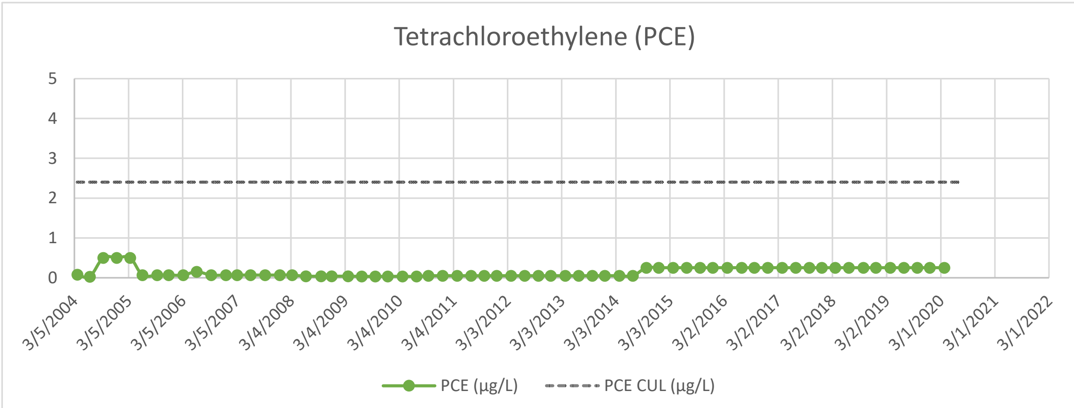

Arsenic
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
3/5/2004 3/5/2005 3/5/2006 3/5/2007 3/4/2008 3/4/2009 3/4/2010 3/4/2011 3/3/2012 3/3/2013 3/3/2014 3/3/2015 3/2/2016 3/2/2017 3/2/2018 3/2/2019 3/1/2020 3/1/2021 3/1/2022
Arsenic (mg/L)
Arsenic CUL (mg/L)


cis-1,2-Dichloroethene (cis-1,2-DCE) (µg/L)
18
16
14
12
10
8
6
4
2
0
3/5/2004 3/5/2005 3/5/2006 3/5/2007 3/4/2008 3/4/2009 3/4/2010 3/4/2011 3/3/2012 3/3/2013 3/3/2014 3/3/2015 3/2/2016 3/2/2017 3/2/2018 3/2/2019 3/1/2020 3/1/2021 3/1/2022
cis-1,2-DCE (µg/L)
CIS CUL (µg/L)

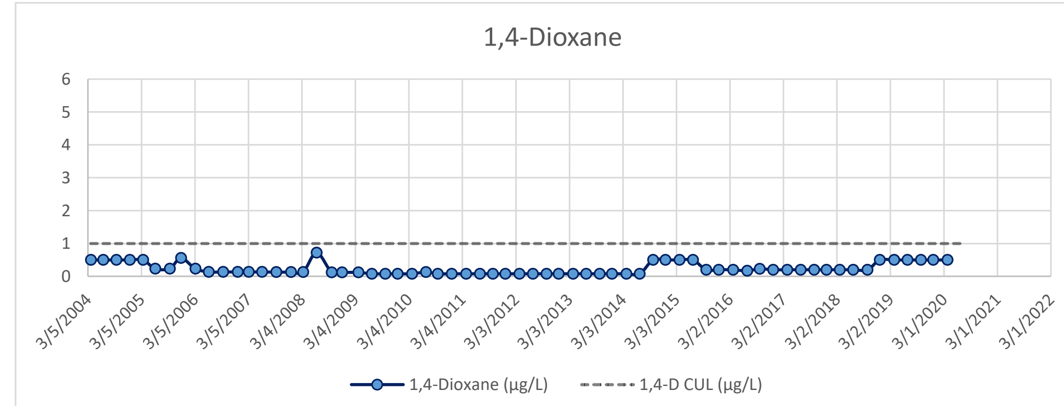

Groundwater Elevation (feet)
20
18
16
14
12
10
8
6
4
2
0
3/5/2004 3/5/2005 3/5/2006 3/5/2007 3/4/2008 3/4/2009 3/4/2010 3/4/2011 3/3/2012 3/3/2013 3/3/2014 3/3/2015 3/2/2016 3/2/2017 3/2/2018 3/2/2019 3/1/2020 3/1/2021


Vinyl Chloride (VC)
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
3/5/2004 3/5/2005 3/5/2006 3/5/2007 3/4/2008 3/4/2009 3/4/2010 3/4/2011 3/3/2012 3/3/2013 3/3/2014 3/3/2015 3/2/2016 3/2/2017 3/2/2018 3/2/2019 3/1/2020 3/1/2021 3/1/2022
VC (µg/L)
VC CUL (µg/L)

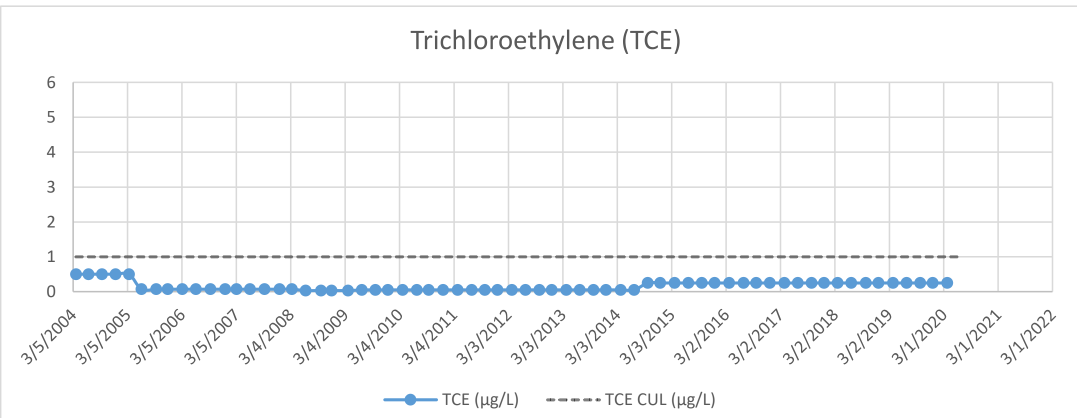
MC-16



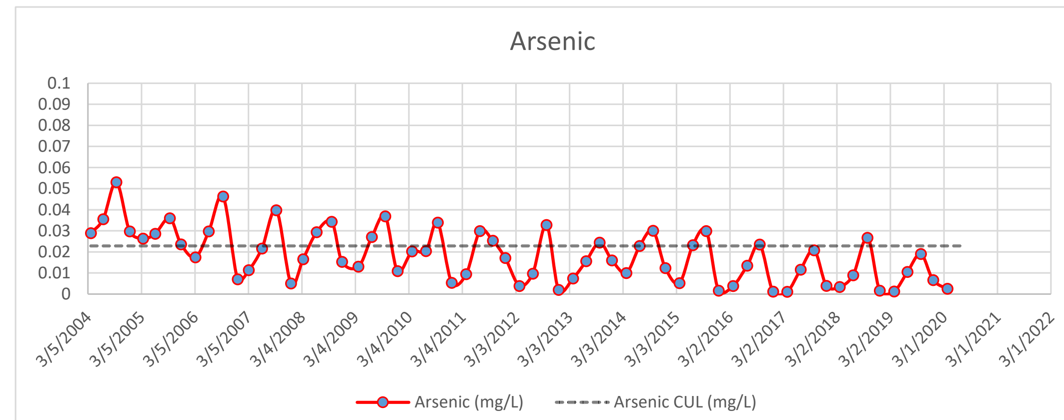
Tetrachloroethylene (PCE)
PCE (µg/L)
PCE CUL (µg/L)



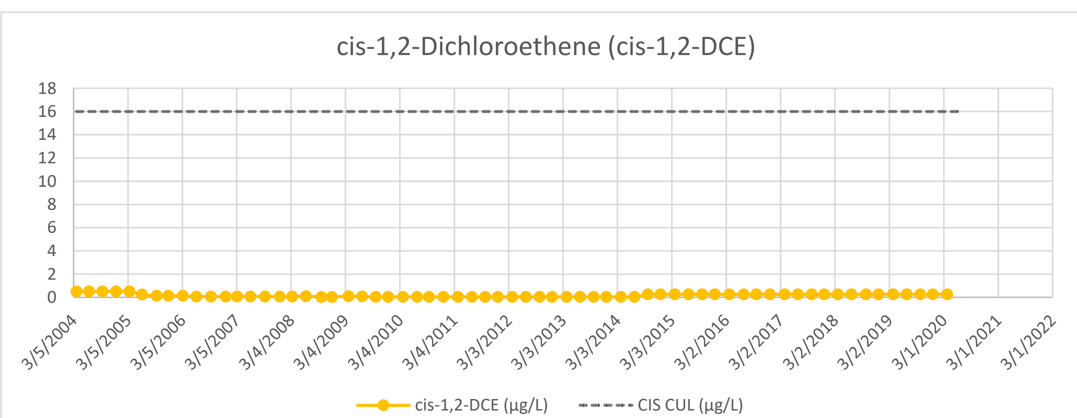
1,4-Dioxane
1,4-Dioxane (µg/L)
1,4-D CUL (µg/L)



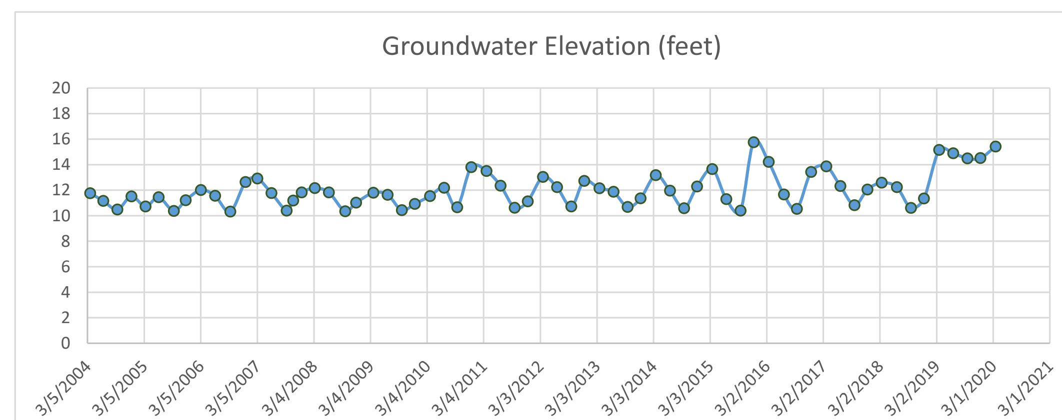
Trichloroethylene (TCE)
TCE (µg/L)
TCE CUL (µg/L)



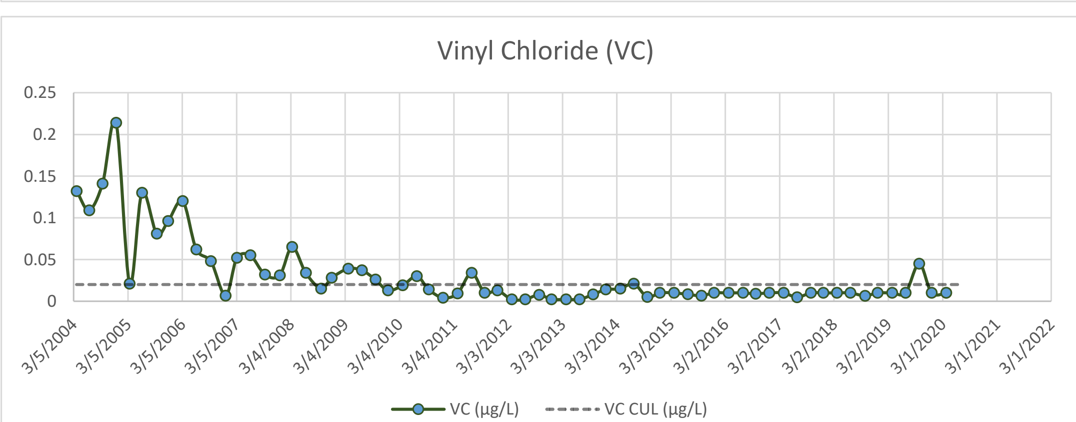
Arsenic
Arsenic (mg/L)
Arsenic CUL (mg/L)



cis-1,2-Dichloroethene (cis-1,2-DCE)
cis-1,2-DCE (µg/L)
CIS CUL (µg/L)

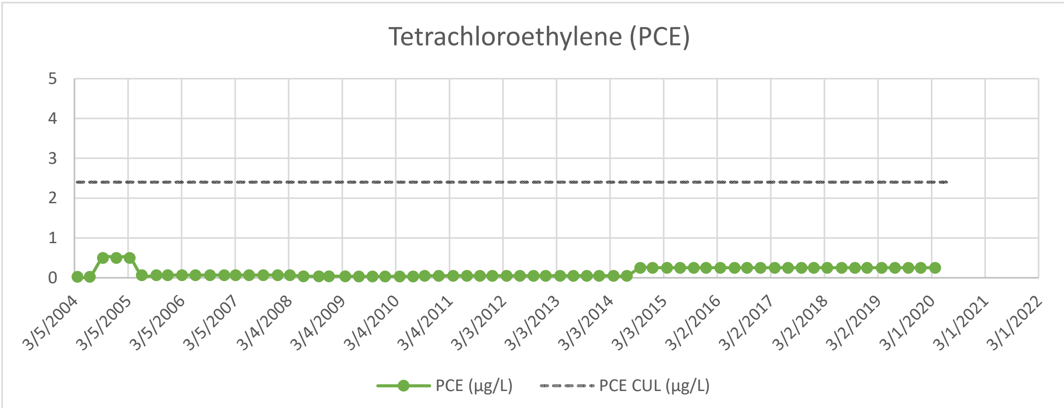


Groundwater Elevation (feet)

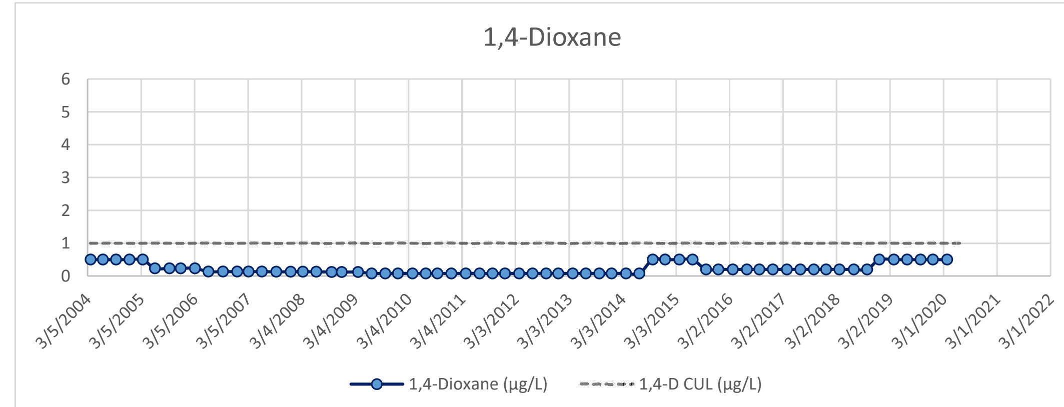


Vinyl Chloride (VC)
VC (µg/L)
VC CUL (µg/L)

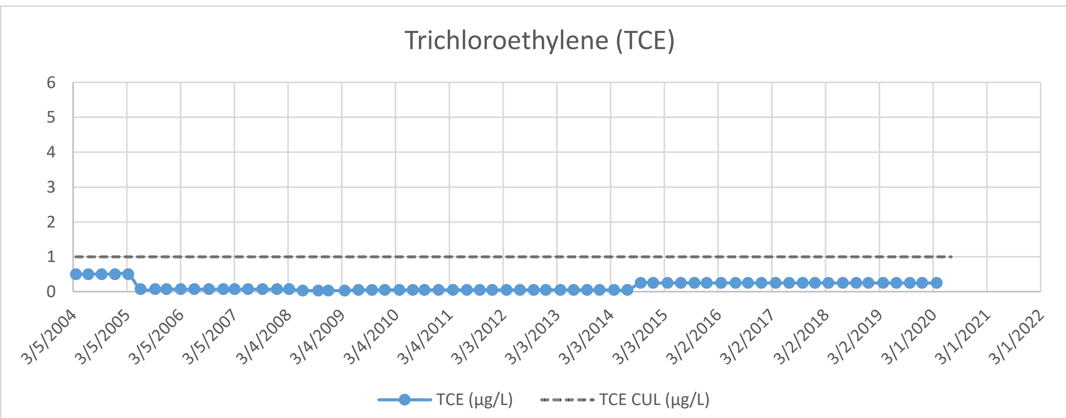
MC-17



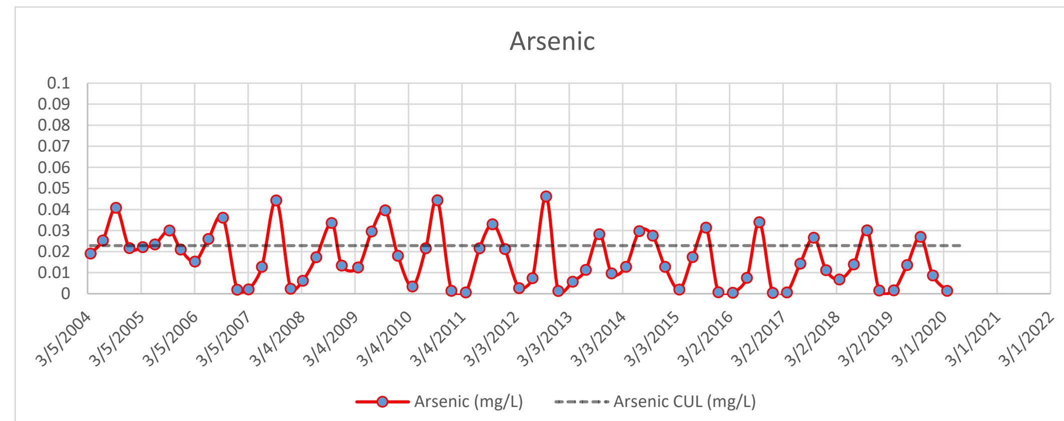
Tetrachloroethylene (PCE)
PCE (µg/L)
PCE CUL (µg/L)



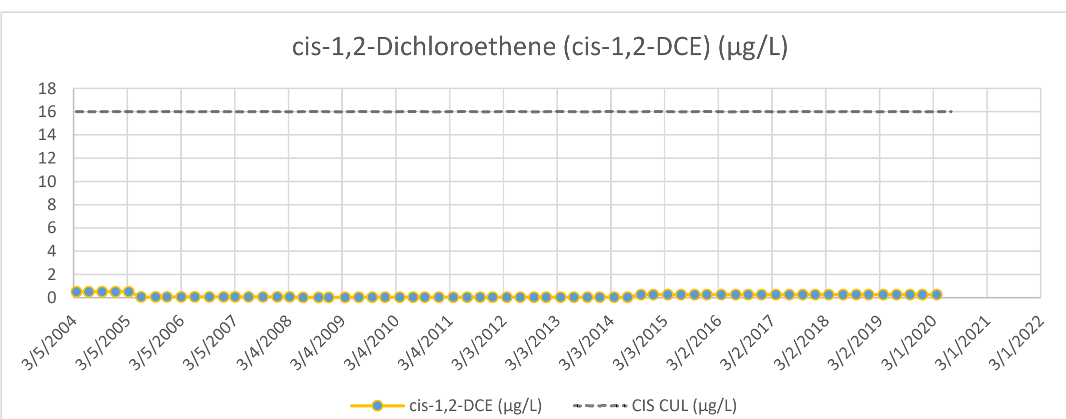
1,4-Dioxane
1,4-Dioxane (µg/L)
1,4-D CUL (µg/L)



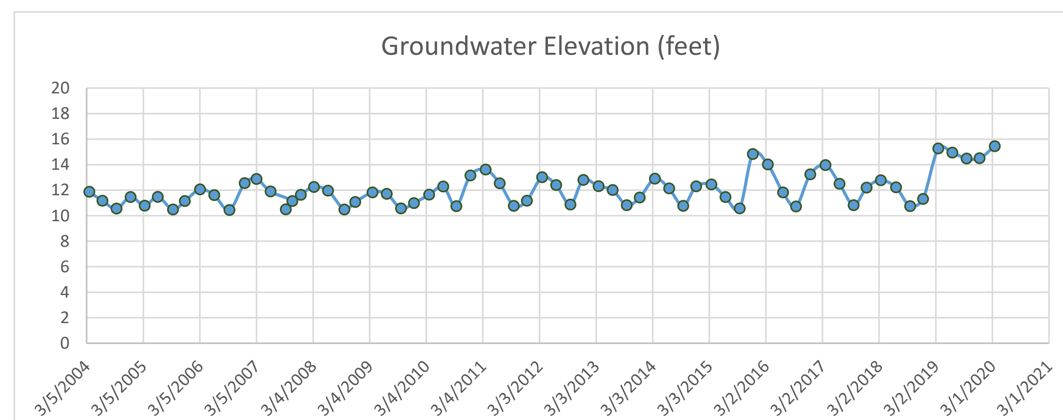
Trichloroethylene (TCE)
TCE (µg/L)
TCE CUL (µg/L)



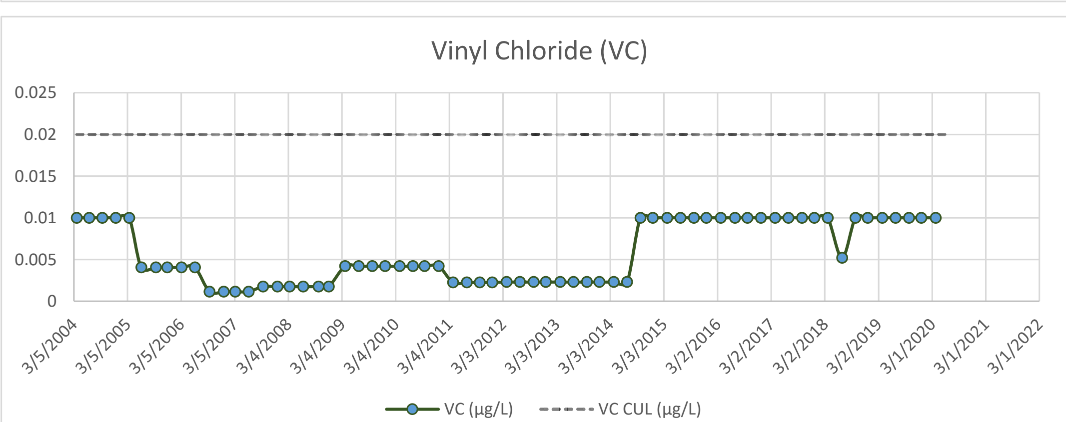
Arsenic
Arsenic (mg/L)
Arsenic CUL (mg/L)



cis-1,2-Dichloroethene (cis-1,2-DCE) (µg/L)
cis-1,2-DCE (µg/L)
CIS CUL (µg/L)

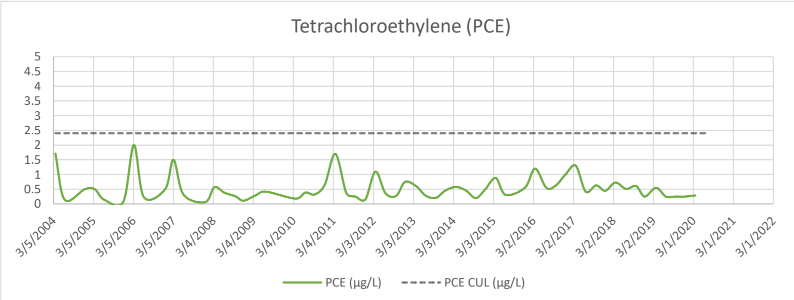


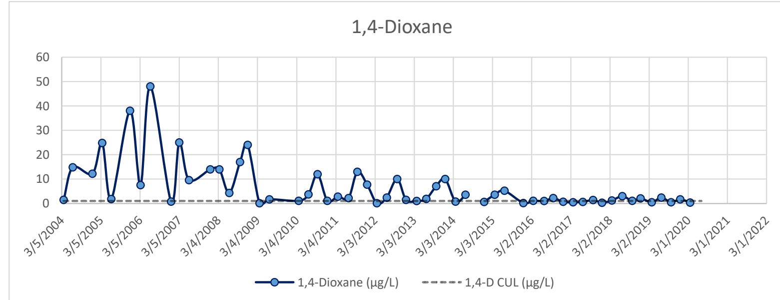
Groundwater Elevation (feet)

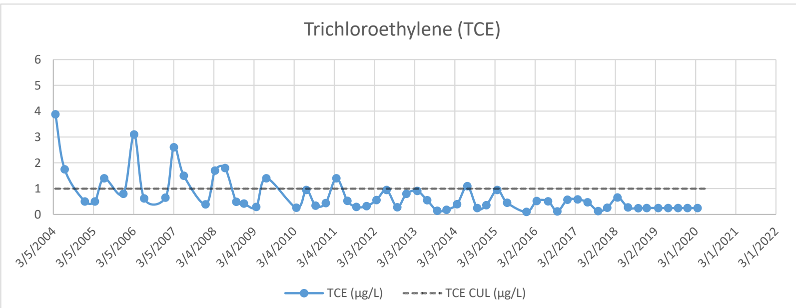


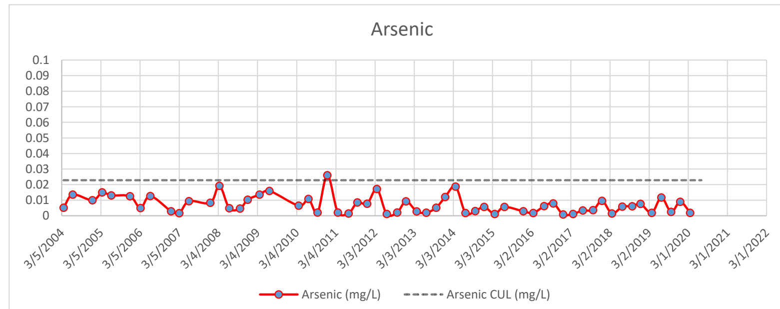
Vinyl Chloride (VC)
VC (µg/L)
VC CUL (µg/L)

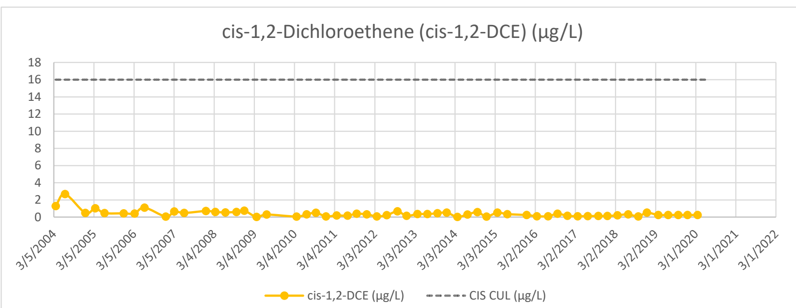
MC-20

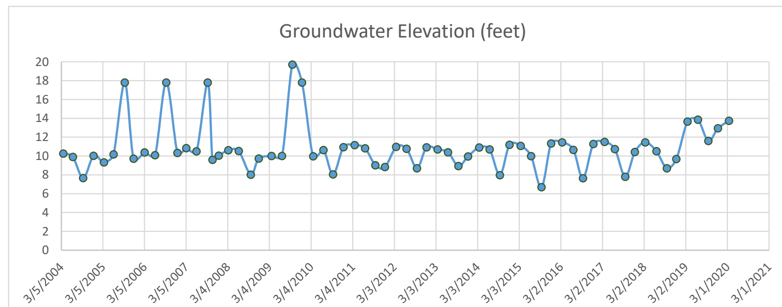

Tetrachloroethylene (PCE)
PCE (µg/L)
PCE CUL (µg/L)

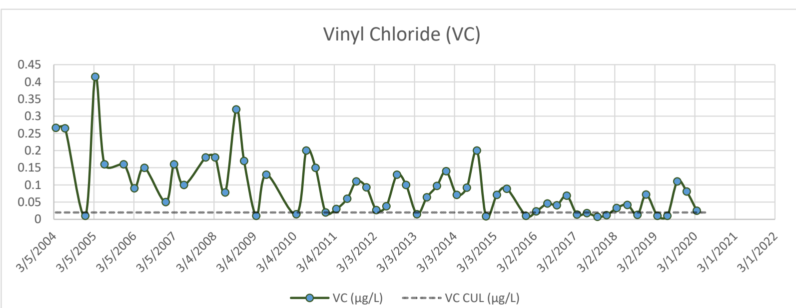

1,4-Dioxane
1,4-Dioxane (µg/L)
1,4-D CUL (µg/L)


Trichloroethylene (TCE)
TCE (µg/L)
TCE CUL (µg/L)

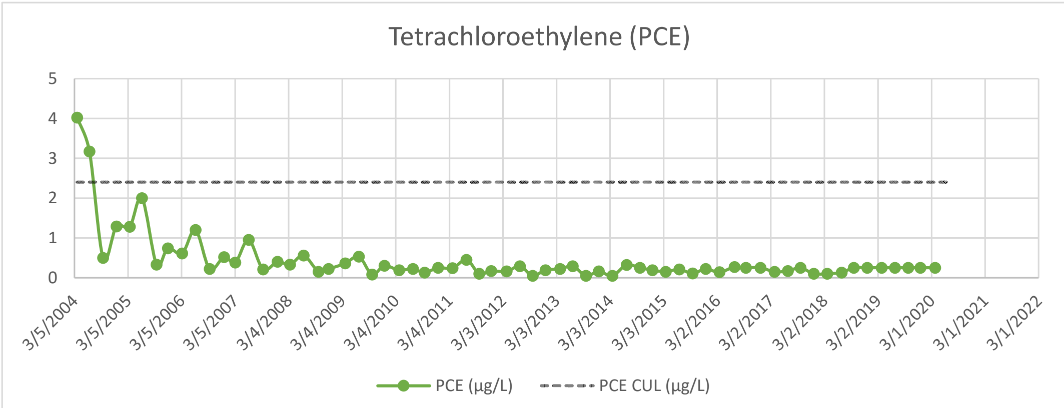

Arsenic
Arsenic (mg/L)
Arsenic CUL (mg/L)

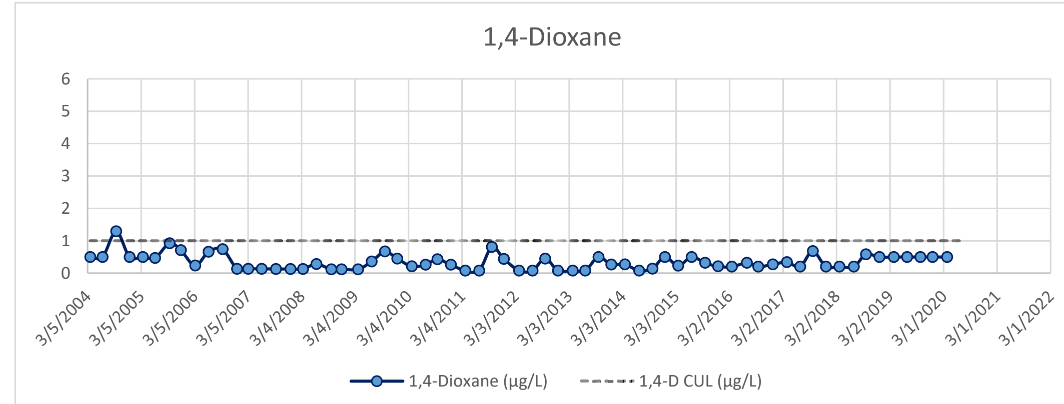

cis-1,2-Dichloroethene (cis-1,2-DCE) (µg/L)
cis-1,2-DCE (µg/L)
CIS CUL (µg/L)

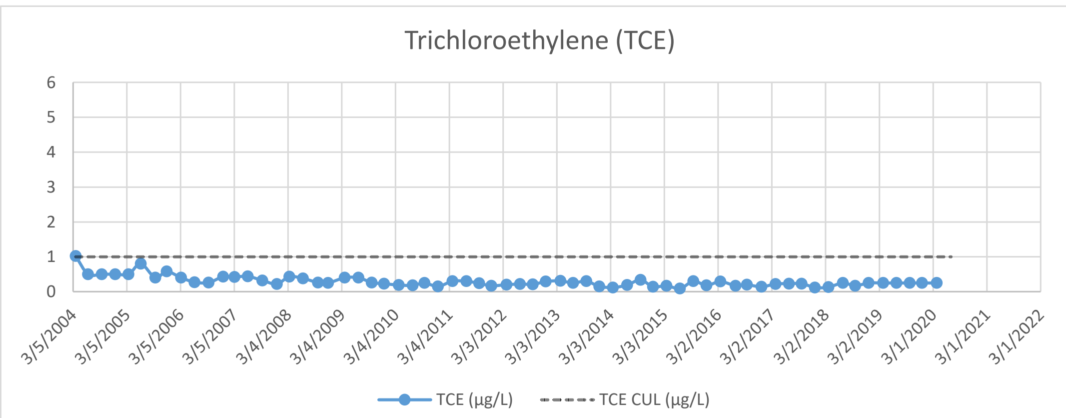

Groundwater Elevation (feet)

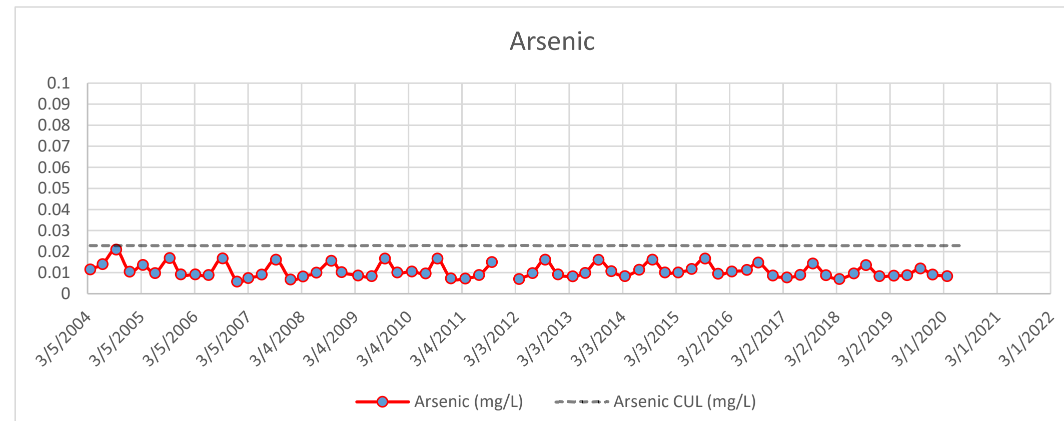

Vinyl Chloride (VC)
VC (µg/L)
VC CUL (µg/L)

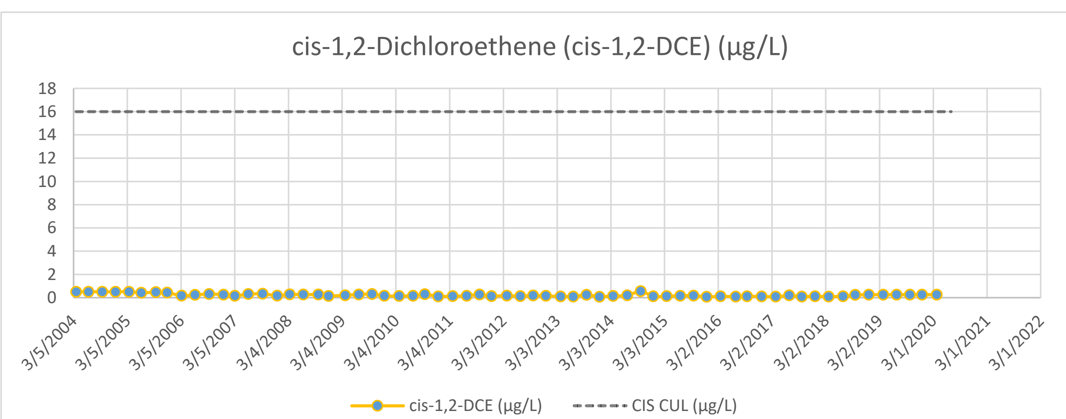
MC-21

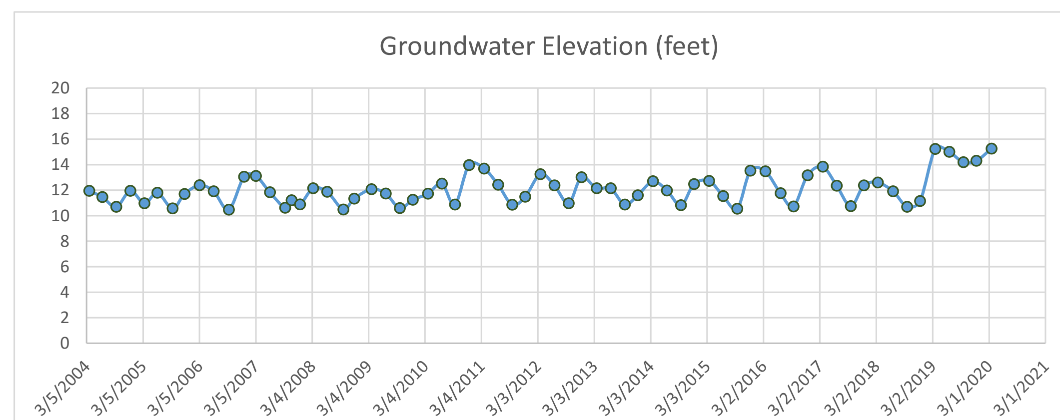

Tetrachloroethylene (PCE)
PCE (µg/L)
PCE CUL (µg/L)

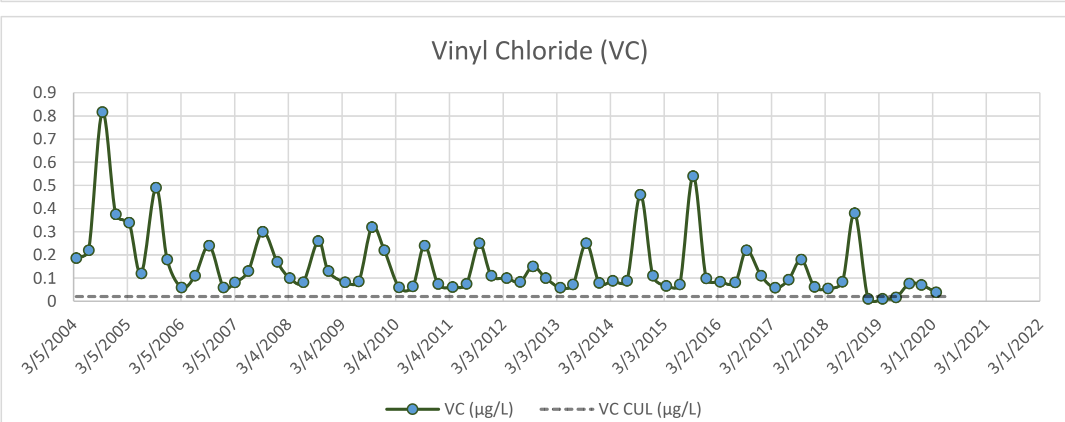

1,4-Dioxane
1,4-Dioxane (µg/L)
1,4-D CUL (µg/L)


Trichloroethylene (TCE)
TCE (µg/L)
TCE CUL (µg/L)

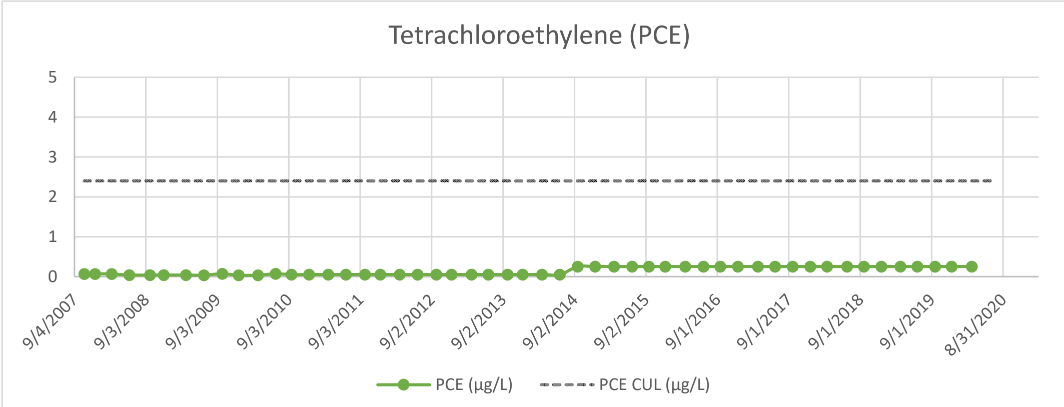

Arsenic
Arsenic (mg/L)
Arsenic CUL (mg/L)

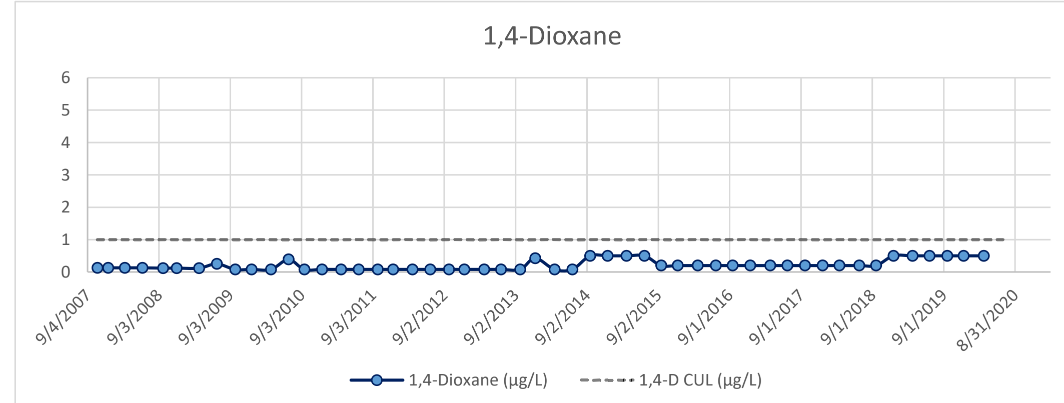

cis-1,2-Dichloroethene (cis-1,2-DCE) (µg/L)
cis-1,2-DCE (µg/L)
CIS CUL (µg/L)

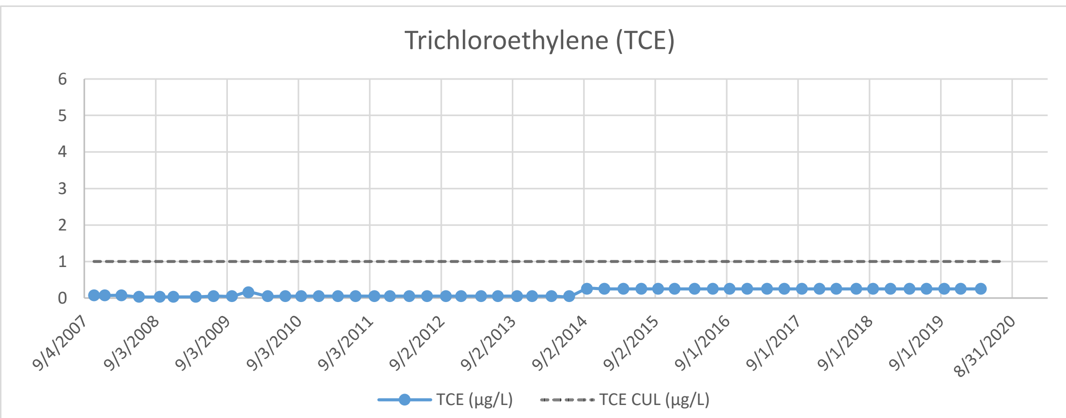

Groundwater Elevation (feet)

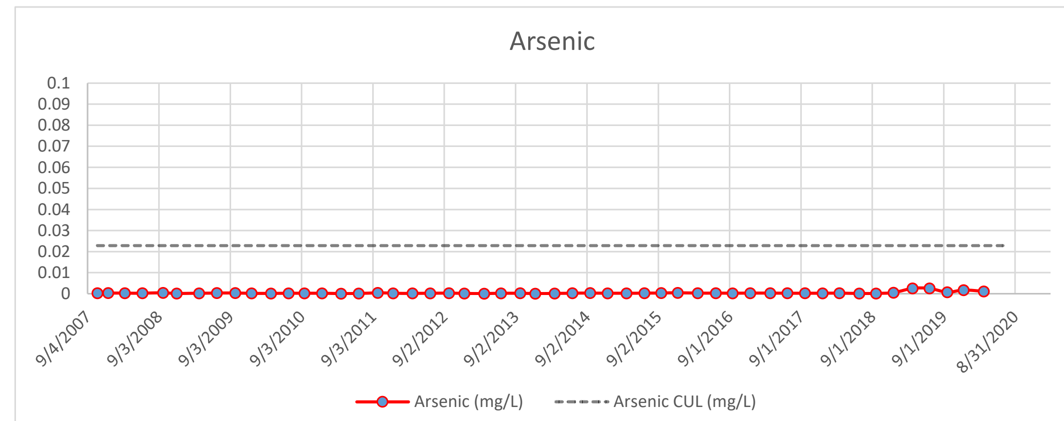

Vinyl Chloride (VC)
VC (µg/L)
VC CUL (µg/L)

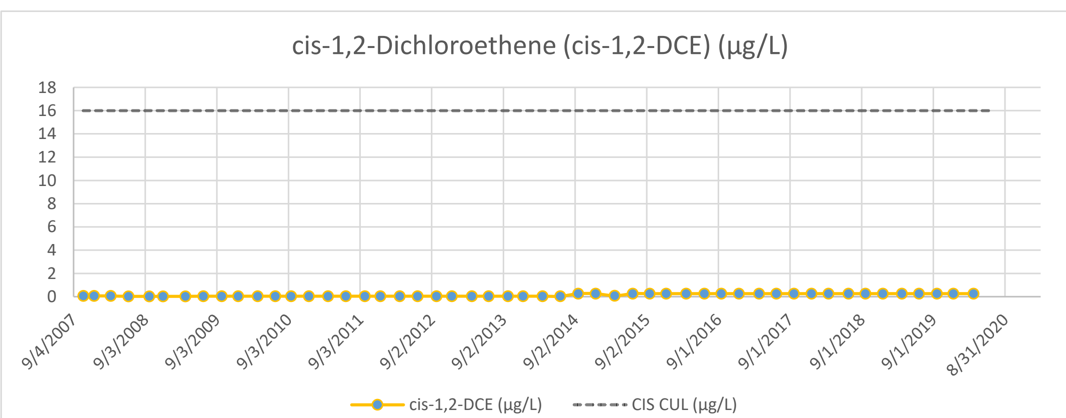
MC-24

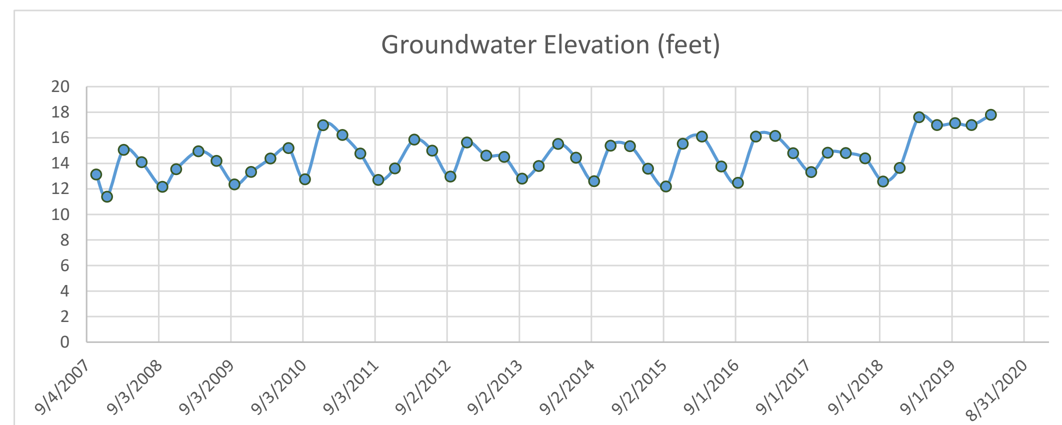

Tetrachloroethylene (PCE)
5
4
3
2
1
0
9/4/2007
9/3/2008
9/3/2009
9/3/2010
9/3/2011
9/2/2012
9/2/2013
9/2/2014
9/2/2015
9/1/2016
9/1/2017
9/1/2018
9/1/2019
8/31/2020
PCE (µg/L)
PCE CUL (µg/L)

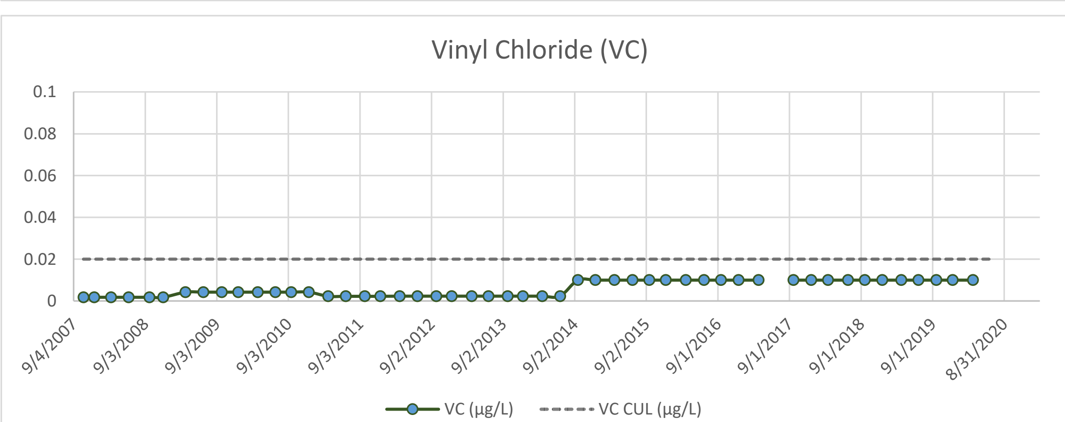

1,4-Dioxane
6
5
4
3
2
1
0
9/4/2007
9/3/2008
9/3/2009
9/3/2010
9/3/2011
9/2/2012
9/2/2013
9/2/2014
9/2/2015
9/1/2016
9/1/2017
9/1/2018
9/1/2019
8/31/2020
1,4-Dioxane (µg/L)
1,4-D CUL (µg/L)


Trichloroethylene (TCE)
6
5
4
3
2
1
0
9/4/2007
9/3/2008
9/3/2009
9/3/2010
9/3/2011
9/2/2012
9/2/2013
9/2/2014
9/2/2015
9/1/2016
9/1/2017
9/1/2018
9/1/2019
8/31/2020
TCE (µg/L)
TCE CUL (µg/L)

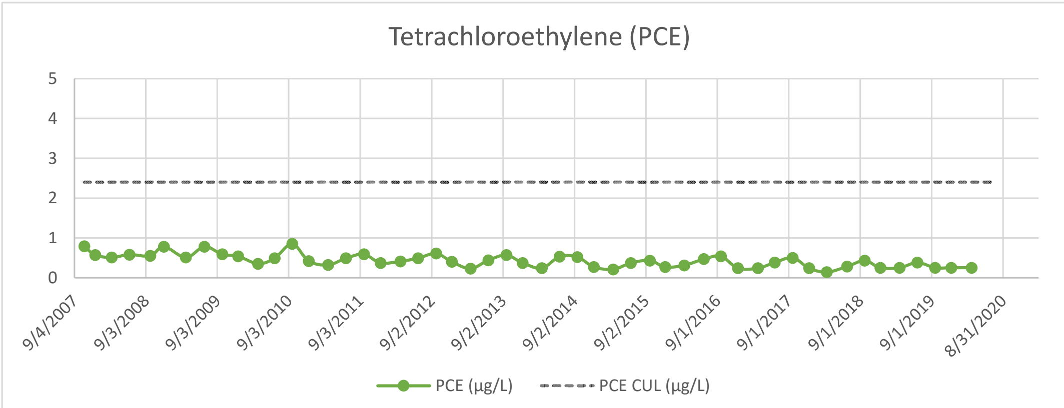

Arsenic
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
9/4/2007
9/3/2008
9/3/2009
9/3/2010
9/3/2011
9/2/2012
9/2/2013
9/2/2014
9/2/2015
9/1/2016
9/1/2017
9/1/2018
9/1/2019
8/31/2020
Arsenic (mg/L)
Arsenic CUL (mg/L)

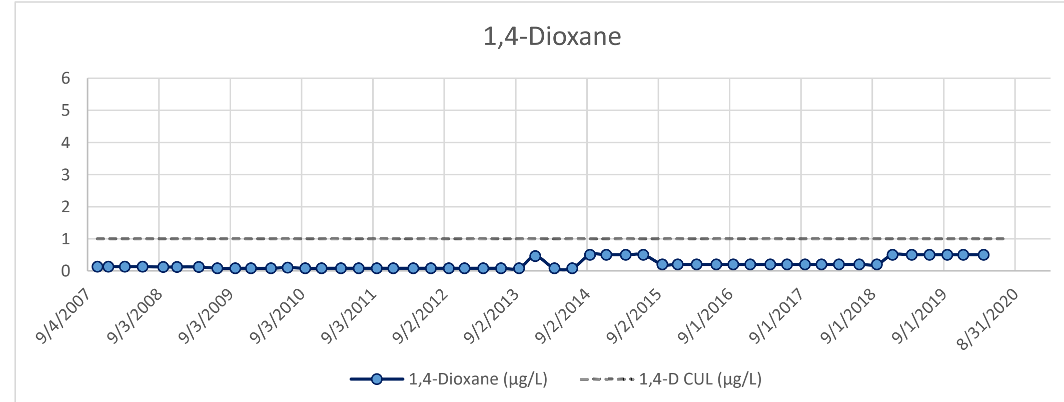

cis-1,2-Dichloroethene (cis-1,2-DCE) (µg/L)
18
16
14
12
10
8
6
4
2
0
9/4/2007
9/3/2008
9/3/2009
9/3/2010
9/3/2011
9/2/2012
9/2/2013
9/2/2014
9/2/2015
9/1/2016
9/1/2017
9/1/2018
9/1/2019
8/31/2020
cis-1,2-DCE (µg/L)
CIS CUL (µg/L)

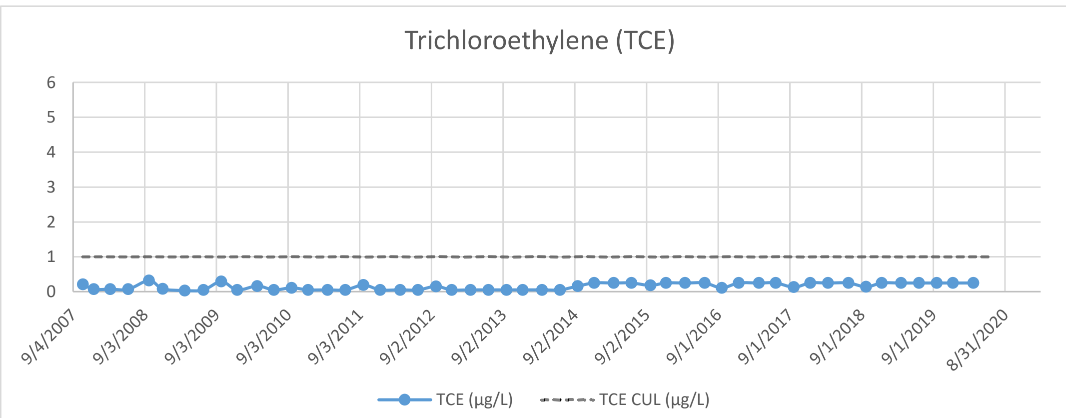

Groundwater Elevation (feet)
20
18
16
14
12
10
8
6
4
2
0
9/4/2007
9/3/2008
9/3/2009
9/3/2010
9/3/2011
9/2/2012
9/2/2013
9/2/2014
9/2/2015
9/1/2016
9/1/2017
9/1/2018
9/1/2019
8/31/2020

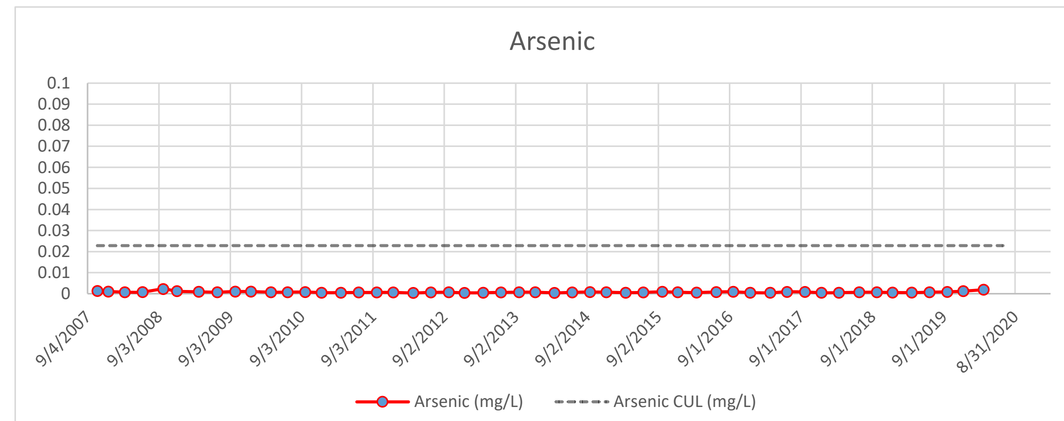

Vinyl Chloride (VC)
0.1
0.08
0.06
0.04
0.02
0
9/4/2007
9/3/2008
9/3/2009
9/3/2010
9/3/2011
9/2/2012
9/2/2013
9/2/2014
9/2/2015
9/1/2016
9/1/2017
9/1/2018
9/1/2019
8/31/2020
VC (µg/L)
VC CUL (µg/L)

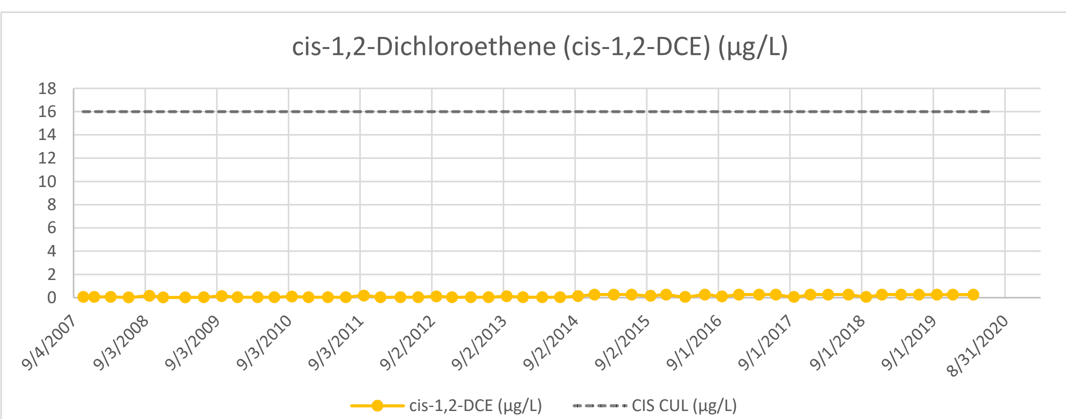
MC-25

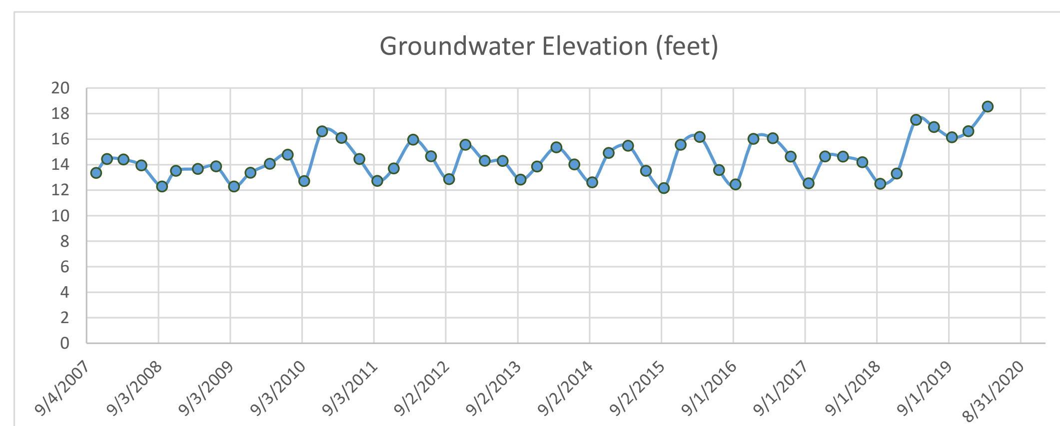

Tetrachloroethylene (PCE)
0
1
2
3
4
5
9/4/2007
9/3/2008
9/3/2009
9/3/2010
9/3/2011
9/2/2012
9/2/2013
9/2/2014
9/2/2015
9/1/2016
9/1/2017
9/1/2018
9/1/2019
8/31/2020
PCE (µg/L)
PCE CUL (µg/L)

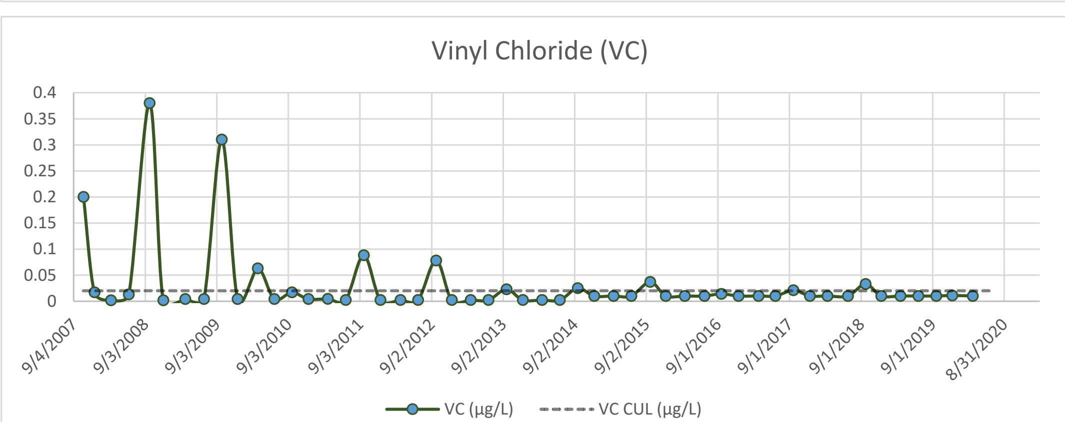

1,4-Dioxane
0
1
2
3
4
5
6
9/4/2007
9/3/2008
9/3/2009
9/3/2010
9/3/2011
9/2/2012
9/2/2013
9/2/2014
9/2/2015
9/1/2016
9/1/2017
9/1/2018
9/1/2019
8/31/2020
1,4-Dioxane (µg/L)
1,4-D CUL (µg/L)


Trichloroethylene (TCE)
0
1
2
3
4
5
6
9/4/2007
9/3/2008
9/3/2009
9/3/2010
9/3/2011
9/2/2012
9/2/2013
9/2/2014
9/2/2015
9/1/2016
9/1/2017
9/1/2018
9/1/2019
8/31/2020
TCE (µg/L)
TCE CUL (µg/L)

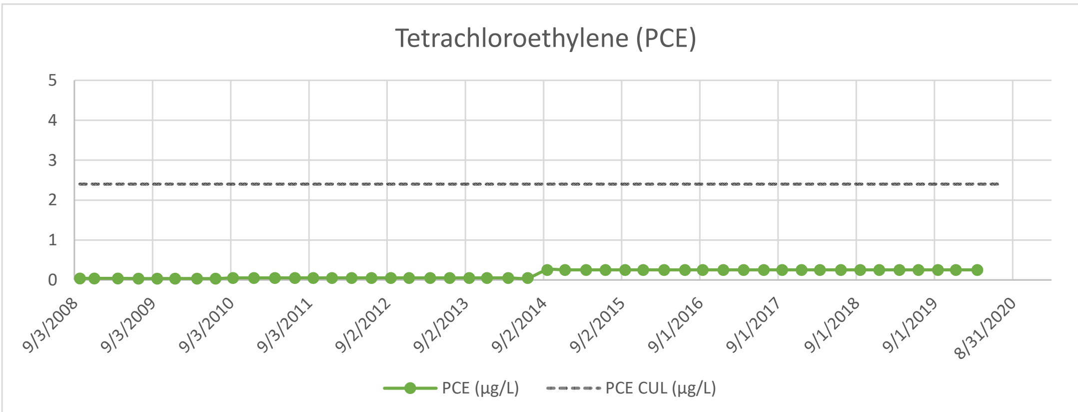

Arsenic
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.1
9/4/2007
9/3/2008
9/3/2009
9/3/2010
9/3/2011
9/2/2012
9/2/2013
9/2/2014
9/2/2015
9/1/2016
9/1/2017
9/1/2018
9/1/2019
8/31/2020
Arsenic (mg/L)
Arsenic CUL (mg/L)

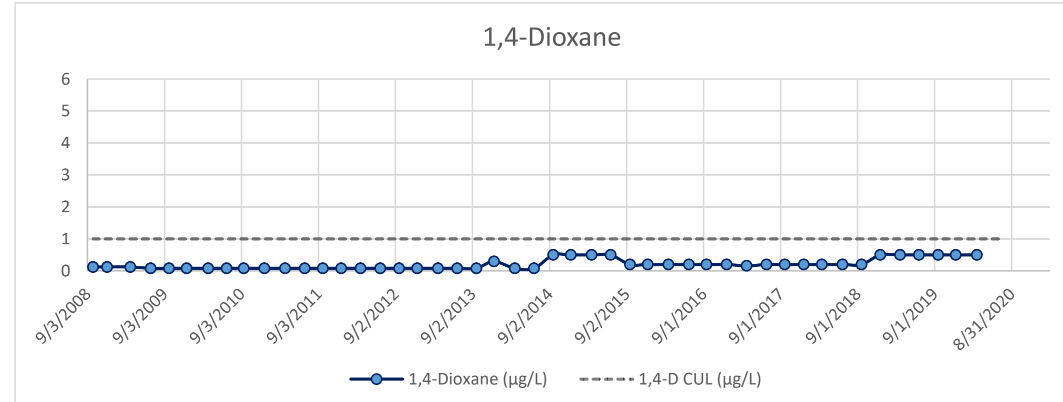

cis-1,2-Dichloroethene (cis-1,2-DCE) (µg/L)
0
2
4
6
8
10
12
14
16
18
9/4/2007
9/3/2008
9/3/2009
9/3/2010
9/3/2011
9/2/2012
9/2/2013
9/2/2014
9/2/2015
9/1/2016
9/1/2017
9/1/2018
9/1/2019
8/31/2020
cis-1,2-DCE (µg/L)
CIS CUL (µg/L)

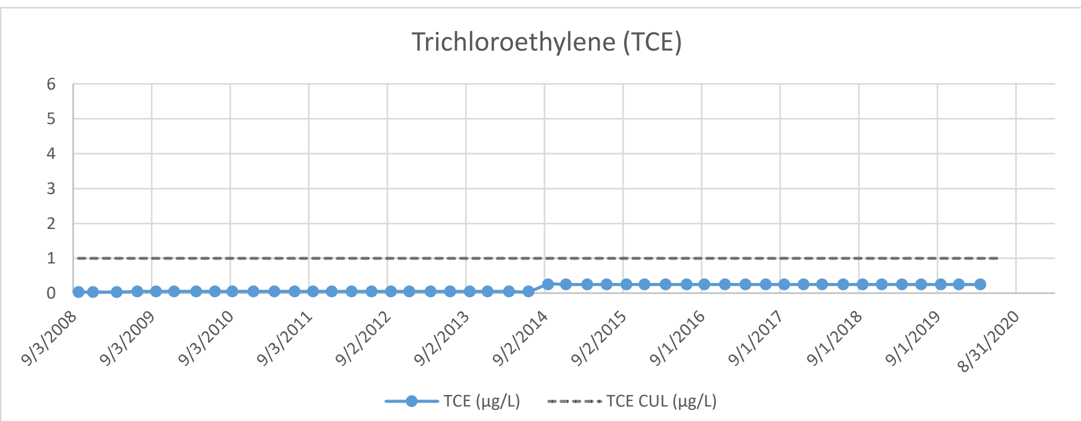

Groundwater Elevation (feet)
0
2
4
6
8
10
12
14
16
18
20
9/4/2007
9/3/2008
9/3/2009
9/3/2010
9/3/2011
9/2/2012
9/2/2013
9/2/2014
9/2/2015
9/1/2016
9/1/2017
9/1/2018
9/1/2019
8/31/2020

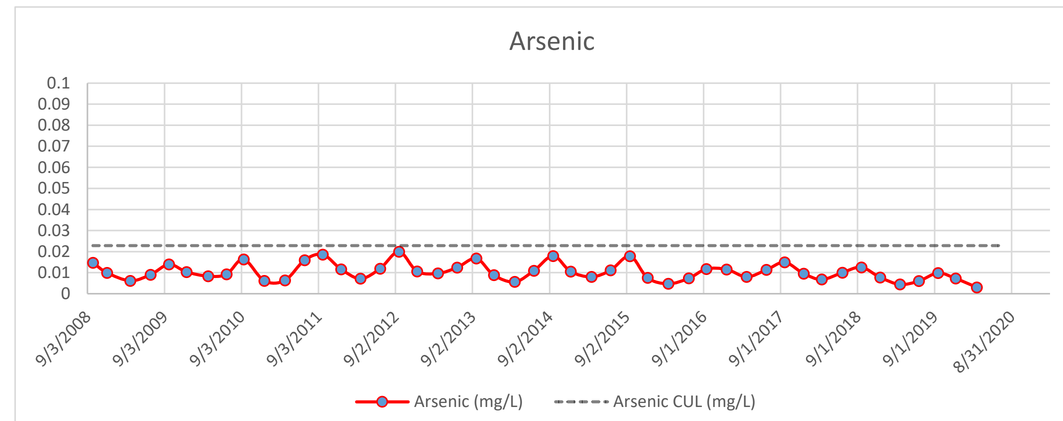

Vinyl Chloride (VC)
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
9/4/2007
9/3/2008
9/3/2009
9/3/2010
9/3/2011
9/2/2012
9/2/2013
9/2/2014
9/2/2015
9/1/2016
9/1/2017
9/1/2018
9/1/2019
8/31/2020
VC (µg/L)
VC CUL (µg/L)

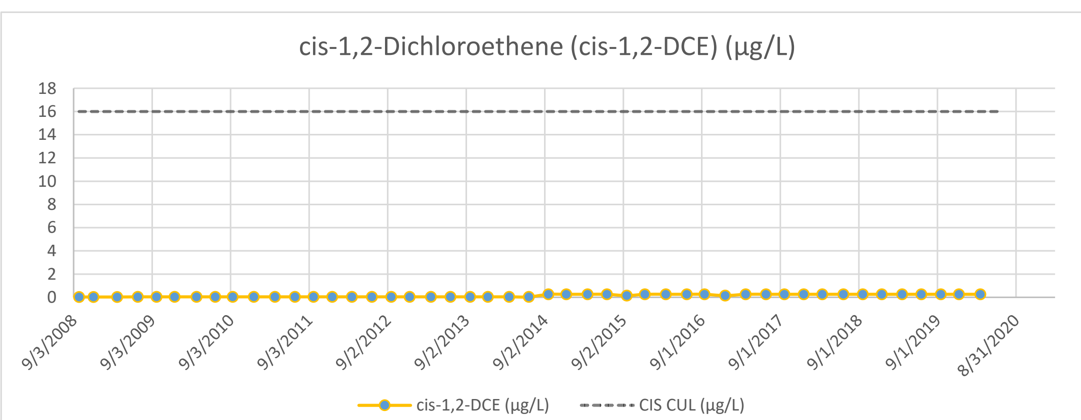
MC-30

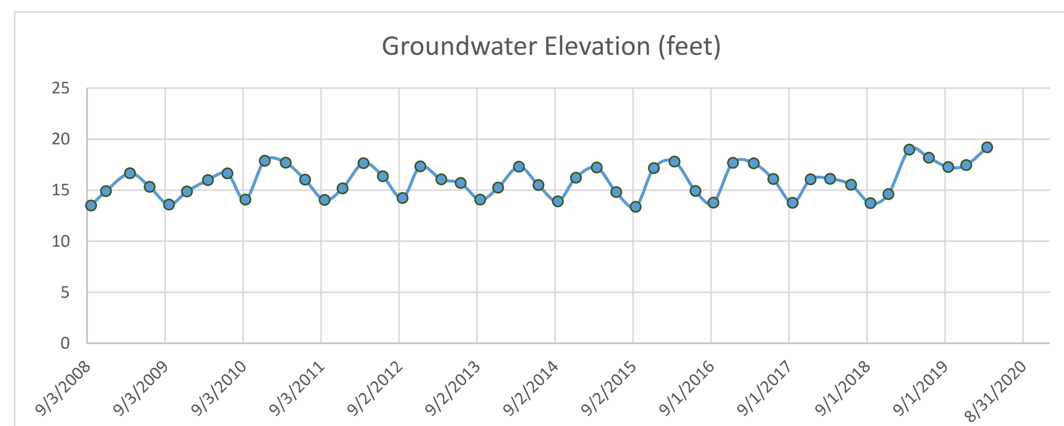

Tetrachloroethylene (PCE)
PCE (µg/L)
PCE CUL (µg/L)

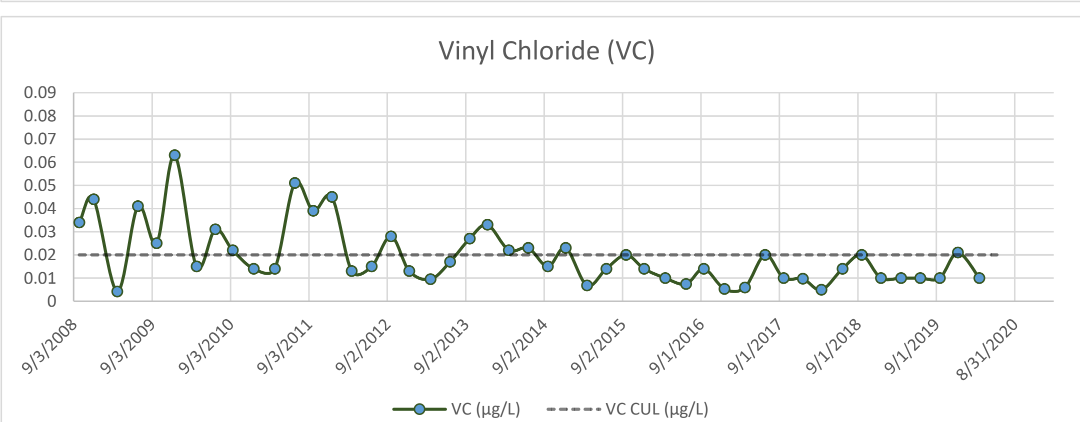

1,4-Dioxane
1,4-Dioxane (µg/L)
1,4-D CUL (µg/L)


Trichloroethylene (TCE)
TCE (µg/L)
TCE CUL (µg/L)


Arsenic
Arsenic (mg/L)
Arsenic CUL (mg/L)


cis-1,2-Dichloroethene (cis-1,2-DCE) (µg/L)
cis-1,2-DCE (µg/L)
CIS CUL (µg/L)


Groundwater Elevation (feet)


Vinyl Chloride (VC)
VC (µg/L)
VC CUL (µg/L)

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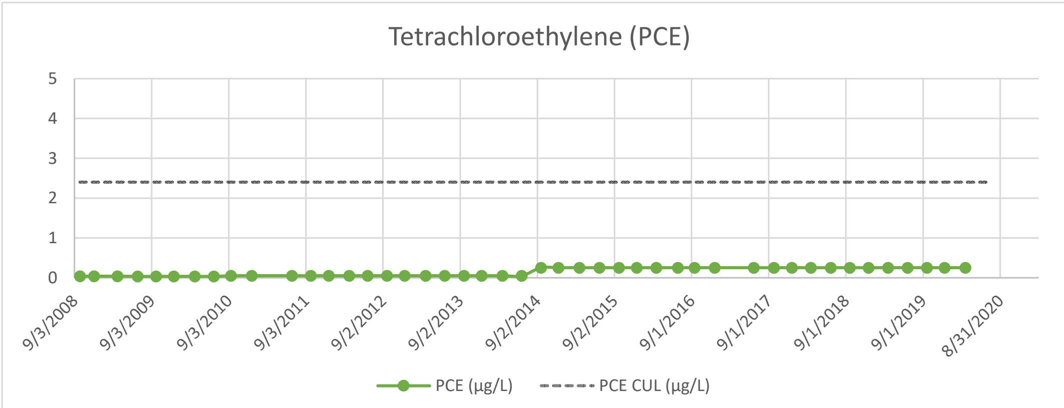
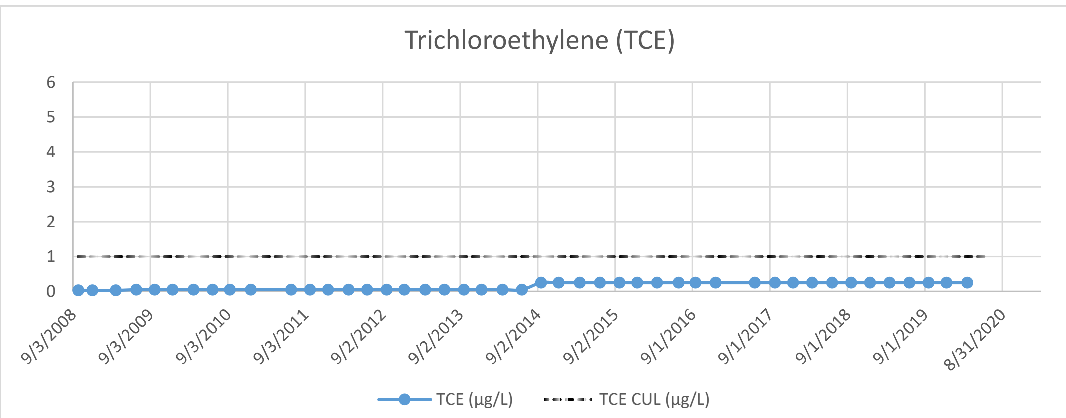
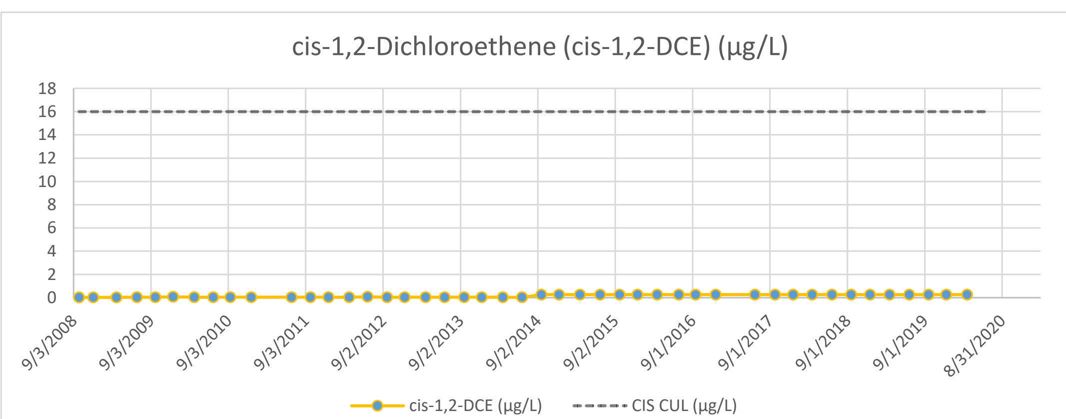
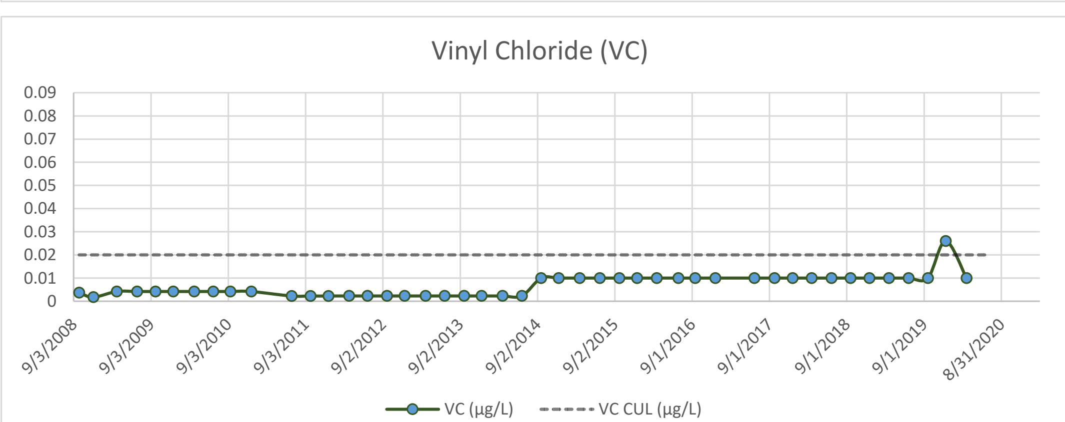
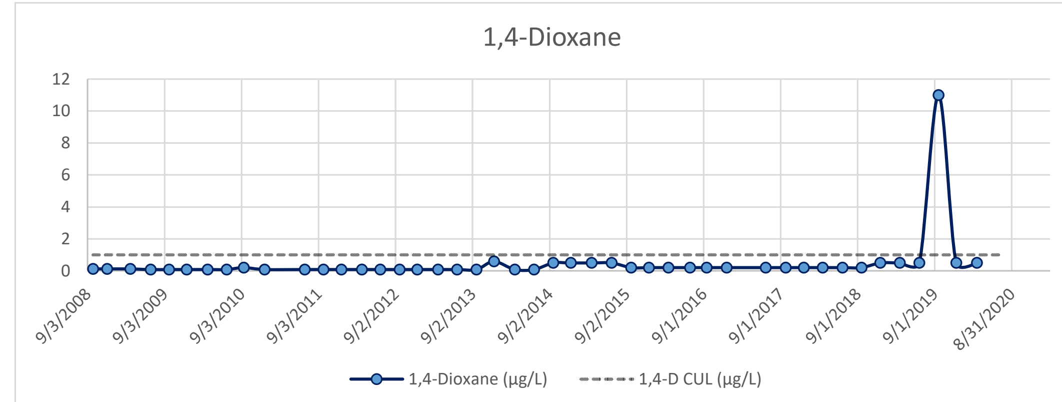
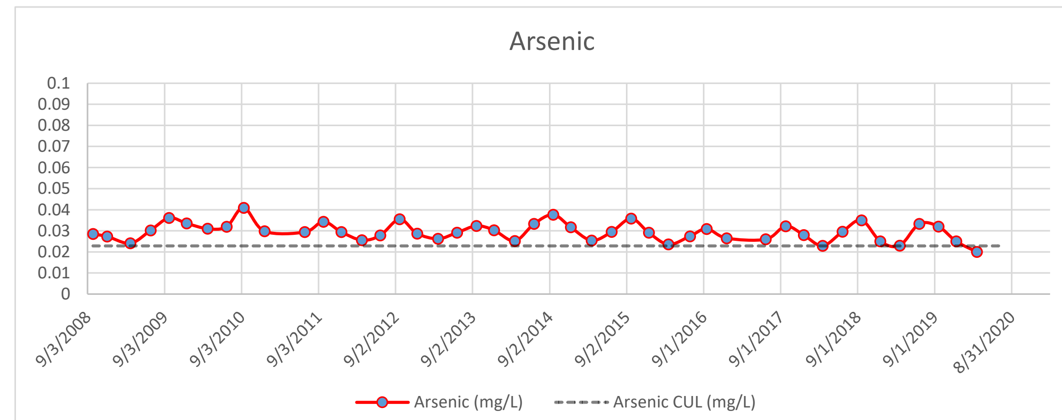

Tetrachloroethylene (PCE)
0
1
2
3
4
5
9/3/2008
9/3/2009
9/3/2010
9/3/2011
9/2/2012
9/2/2013
9/2/2014
9/2/2015
9/1/2016
9/1/2017
9/1/2018
9/1/2019
8/31/2020
PCE (µg/L)
PCE CUL (µg/L)

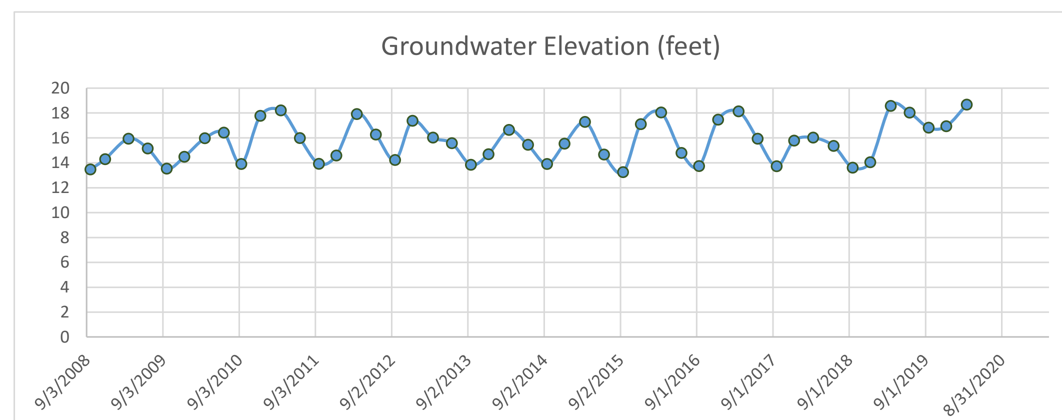

Trichloroethylene (TCE)
0
1
2
3
4
5
6
9/3/2008
9/3/2009
9/3/2010
9/3/2011
9/2/2012
9/2/2013
9/2/2014
9/2/2015
9/1/2016
9/1/2017
9/1/2018
9/1/2019
8/31/2020
TCE (µg/L)
TCE CUL (µg/L)


cis-1,2-Dichloroethene (cis-1,2-DCE) (µg/L)
0
2
4
6
8
10
12
14
16
18
9/3/2008
9/3/2009
9/3/2010
9/3/2011
9/2/2012
9/2/2013
9/2/2014
9/2/2015
9/1/2016
9/1/2017
9/1/2018
9/1/2019
8/31/2020
cis-1,2-DCE (µg/L)
CIS CUL (µg/L)


Vinyl Chloride (VC)
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
9/3/2008
9/3/2009
9/3/2010
9/3/2011
9/2/2012
9/2/2013
9/2/2014
9/2/2015
9/1/2016
9/1/2017
9/1/2018
9/1/2019
8/31/2020
VC (µg/L)
VC CUL (µg/L)


1,4-Dioxane
0
2
4
6
8
10
12
9/3/2008
9/3/2009
9/3/2010
9/3/2011
9/2/2012
9/2/2013
9/2/2014
9/2/2015
9/1/2016
9/1/2017
9/1/2018
9/1/2019
8/31/2020
1,4-Dioxane (µg/L)
1,4-D CUL (µg/L)


Arsenic
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.1
9/3/2008
9/3/2009
9/3/2010
9/3/2011
9/2/2012
9/2/2013
9/2/2014
9/2/2015
9/1/2016
9/1/2017
9/1/2018
9/1/2019
8/31/2020
Arsenic (mg/L)
Arsenic CUL (mg/L)


Groundwater Elevation (feet)
0
2
4
6
8
10
12
14
16
18
20
9/3/2008
9/3/2009
9/3/2010
9/3/2011
9/2/2012
9/2/2013
9/2/2014
9/2/2015
9/1/2016
9/1/2017
9/1/2018
9/1/2019
8/31/2020

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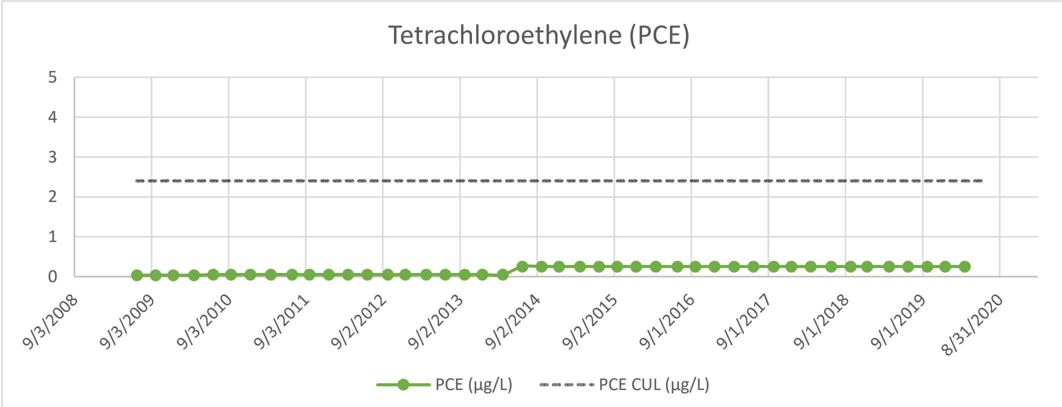
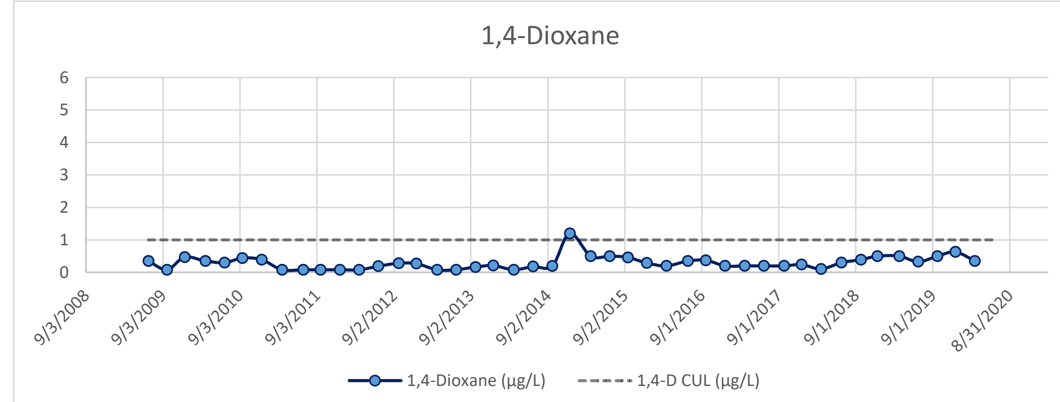
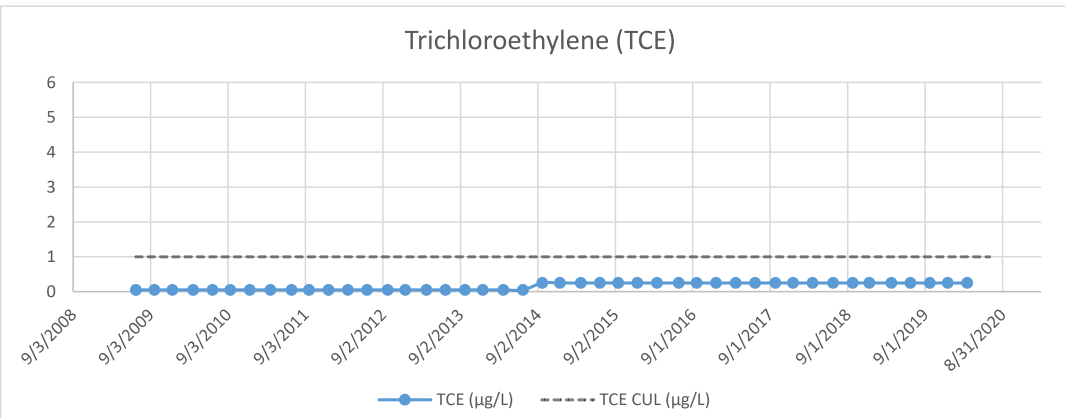


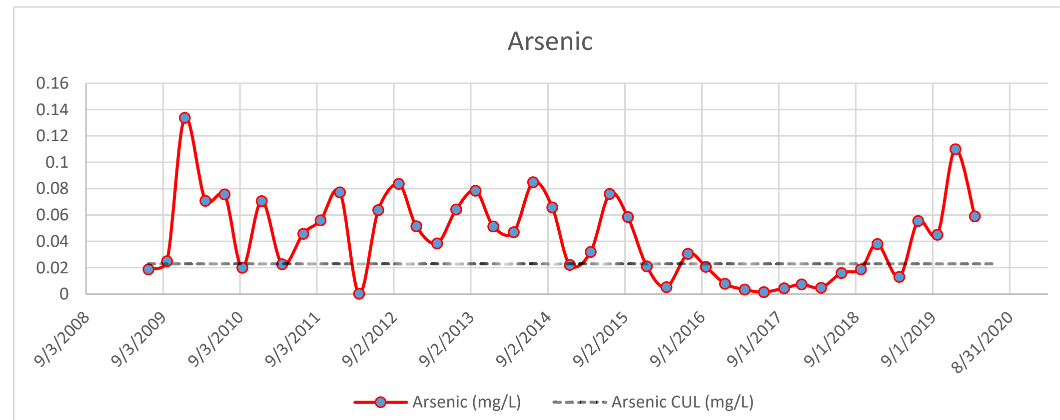
Tetrachloroethylene (PCE)
PCE (µg/L)
PCE CUL (µg/L)



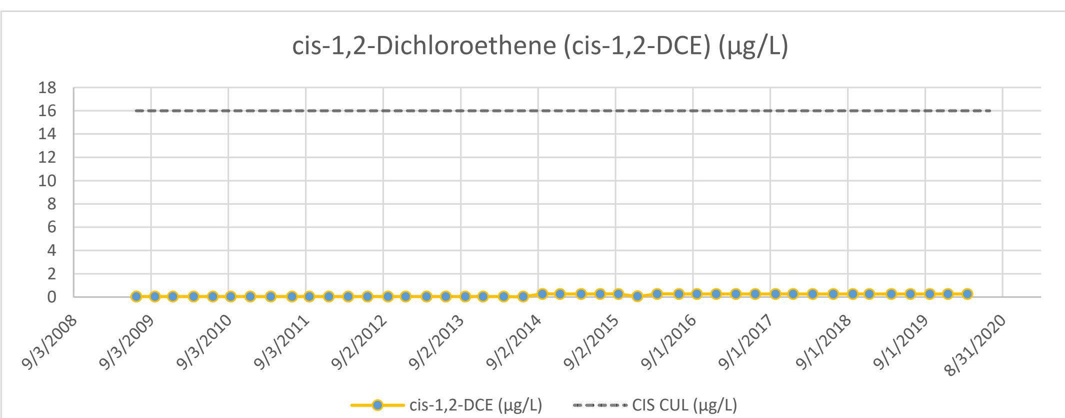
1,4-Dioxane
1,4-Dioxane (µg/L)
1,4-D CUL (µg/L)



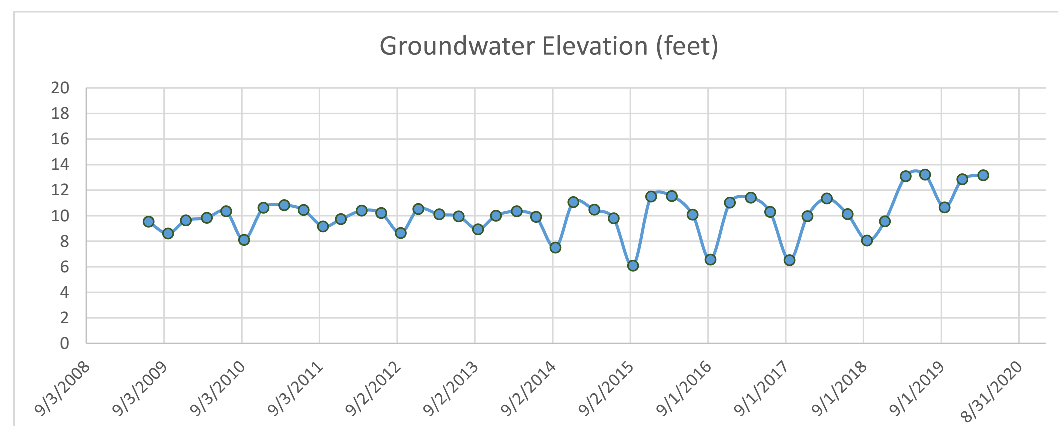
Trichloroethylene (TCE)
TCE (µg/L)
TCE CUL (µg/L)



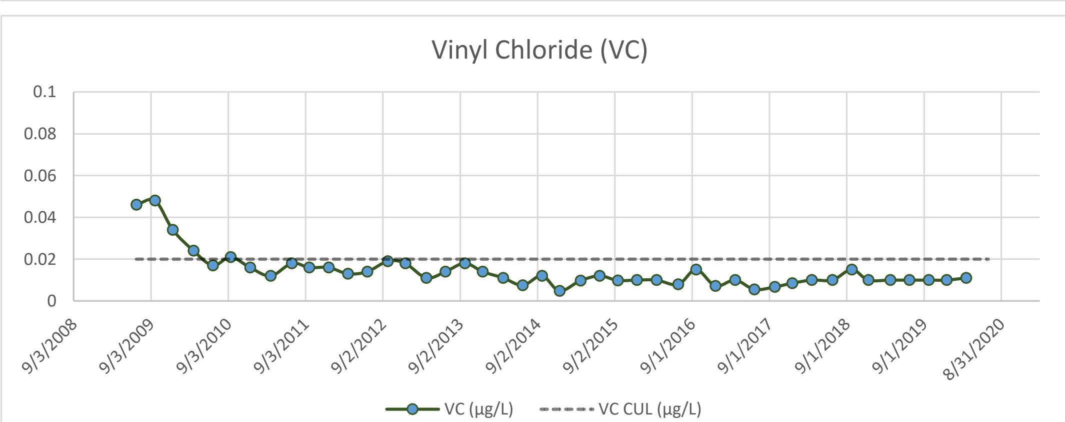
Arsenic
Arsenic (mg/L)
Arsenic CUL (mg/L)



cis-1,2-Dichloroethene (cis-1,2-DCE) (µg/L)
cis-1,2-DCE (µg/L)
CIS CUL (µg/L)



Groundwater Elevation (feet)



Vinyl Chloride (VC)
VC (µg/L)
VC CUL (µg/L)

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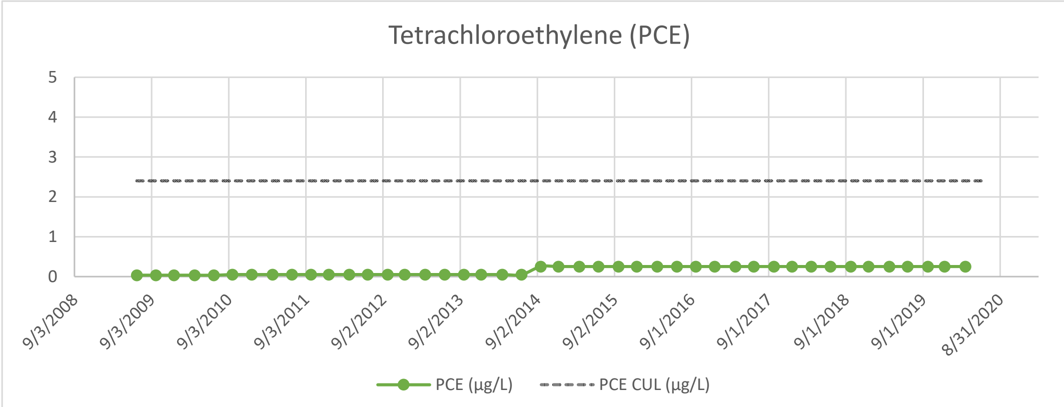
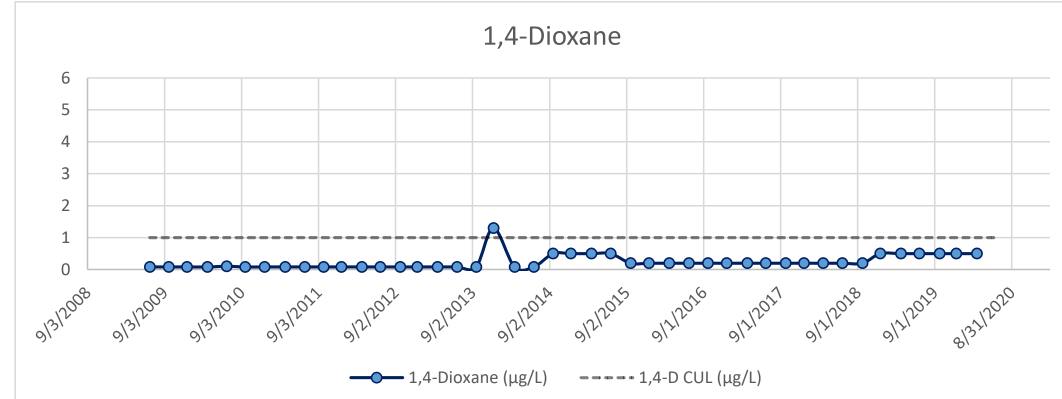
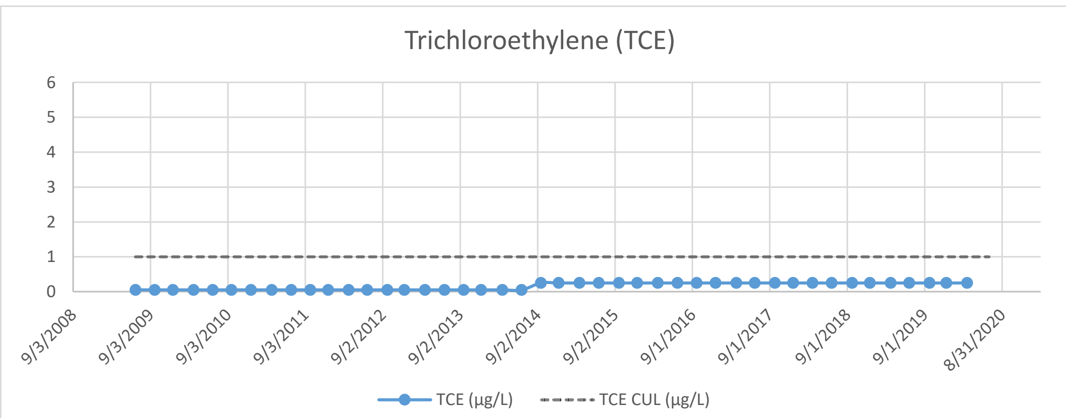
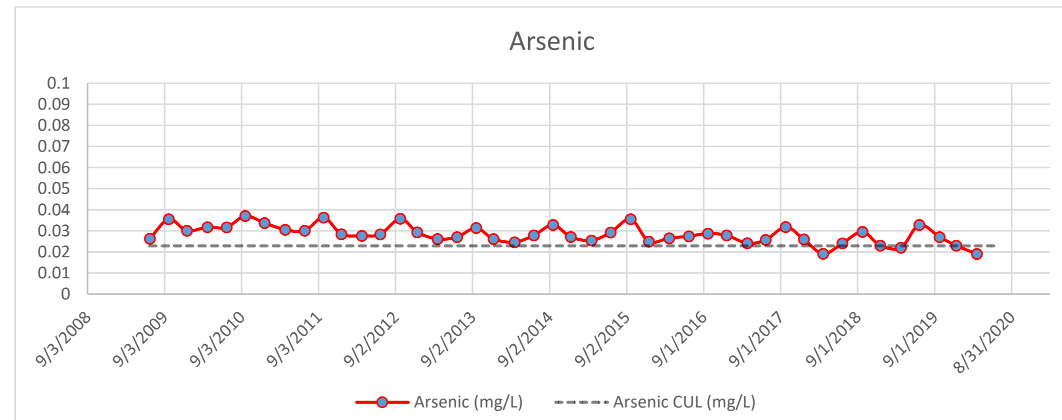
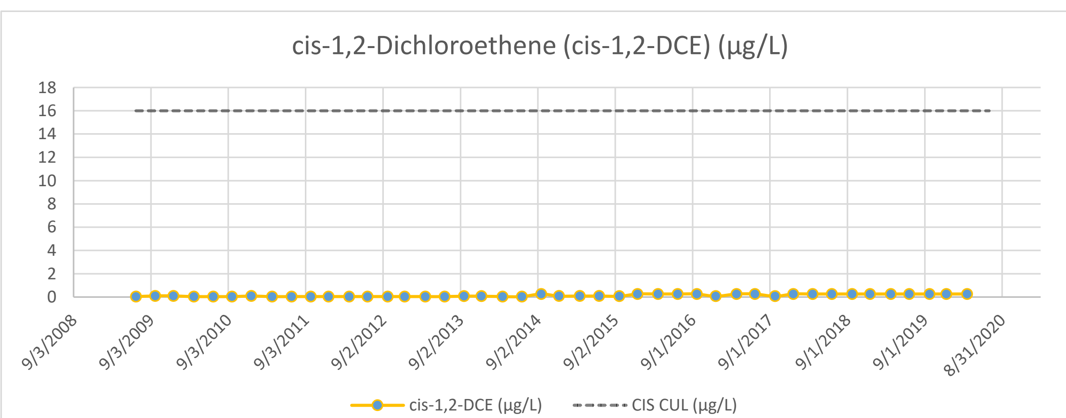
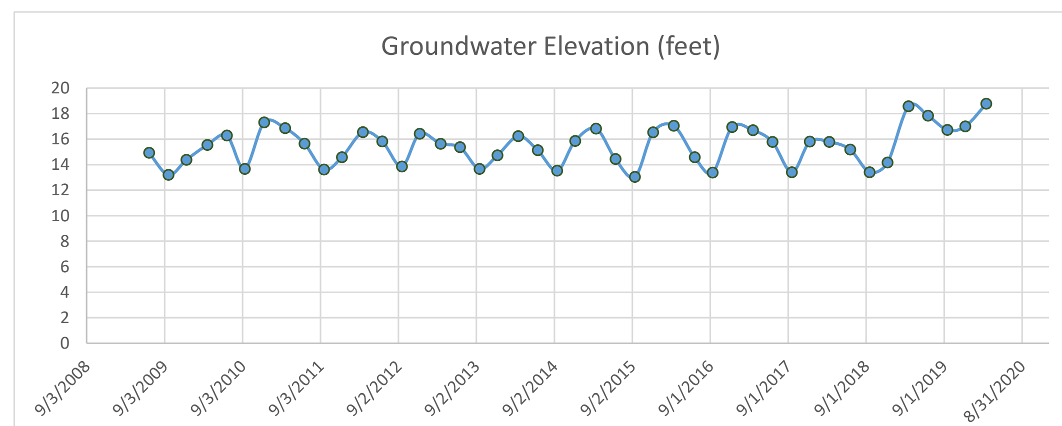

Tetrachloroethylene (PCE)
5
4
3
2
1
0
9/3/2008
9/3/2009
9/3/2010
9/3/2011
9/2/2012
9/2/2013
9/2/2014
9/2/2015
9/1/2016
9/1/2017
9/1/2018
9/1/2019
8/31/2020
PCE (µg/L)
PCE CUL (µg/L)

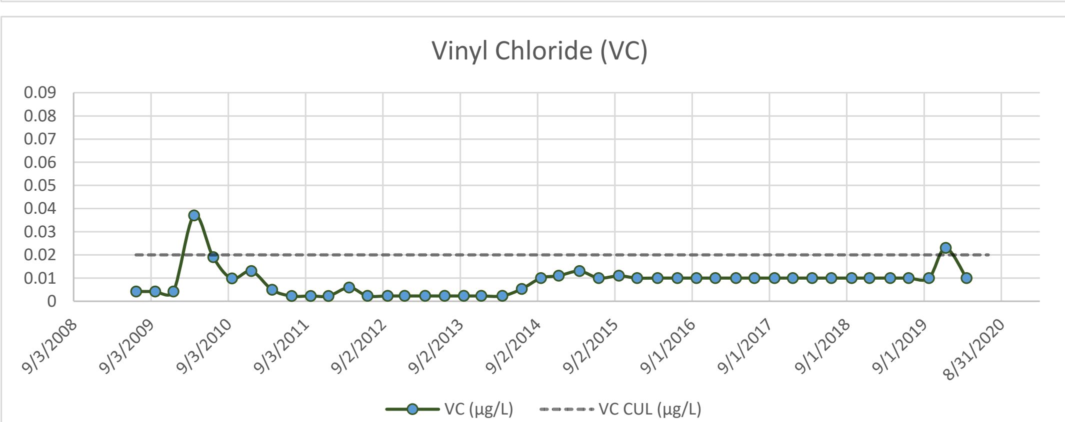

1,4-Dioxane
6
5
4
3
2
1
0
9/3/2008
9/3/2009
9/3/2010
9/3/2011
9/2/2012
9/2/2013
9/2/2014
9/2/2015
9/1/2016
9/1/2017
9/1/2018
9/1/2019
8/31/2020
1,4-Dioxane (µg/L)
1,4-D CUL (µg/L)


Trichloroethylene (TCE)
6
5
4
3
2
1
0
9/3/2008
9/3/2009
9/3/2010
9/3/2011
9/2/2012
9/2/2013
9/2/2014
9/2/2015
9/1/2016
9/1/2017
9/1/2018
9/1/2019
8/31/2020
TCE (µg/L)
TCE CUL (µg/L)


Arsenic
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
9/3/2008
9/3/2009
9/3/2010
9/3/2011
9/2/2012
9/2/2013
9/2/2014
9/2/2015
9/1/2016
9/1/2017
9/1/2018
9/1/2019
8/31/2020
Arsenic (mg/L)
Arsenic CUL (mg/L)


cis-1,2-Dichloroethene (cis-1,2-DCE) (µg/L)
18
16
14
12
10
8
6
4
2
0
9/3/2008
9/3/2009
9/3/2010
9/3/2011
9/2/2012
9/2/2013
9/2/2014
9/2/2015
9/1/2016
9/1/2017
9/1/2018
9/1/2019
8/31/2020
cis-1,2-DCE (µg/L)
CIS CUL (µg/L)


Groundwater Elevation (feet)
20
18
16
14
12
10
8
6
4
2
0
9/3/2008
9/3/2009
9/3/2010
9/3/2011
9/2/2012
9/2/2013
9/2/2014
9/2/2015
9/1/2016
9/1/2017
9/1/2018
9/1/2019
8/31/2020


Vinyl Chloride (VC)
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
9/3/2008
9/3/2009
9/3/2010
9/3/2011
9/2/2012
9/2/2013
9/2/2014
9/2/2015
9/1/2016
9/1/2017
9/1/2018
9/1/2019
8/31/2020
VC (µg/L)
VC CUL (µg/L)

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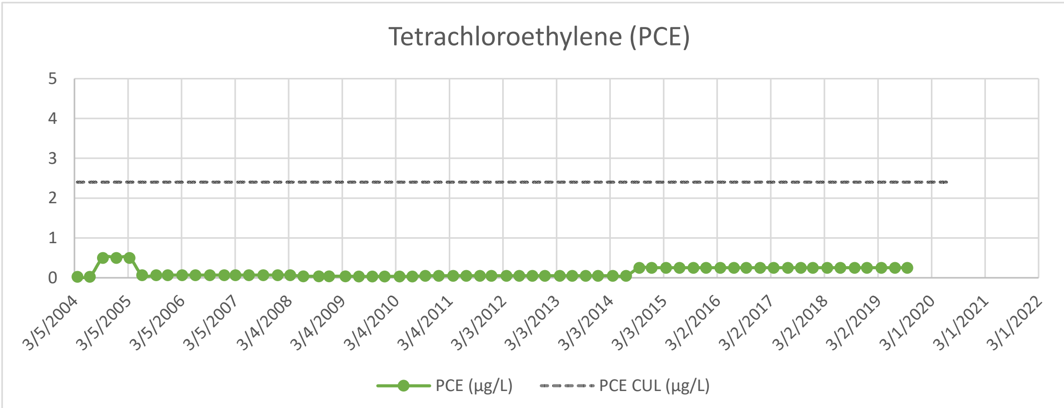
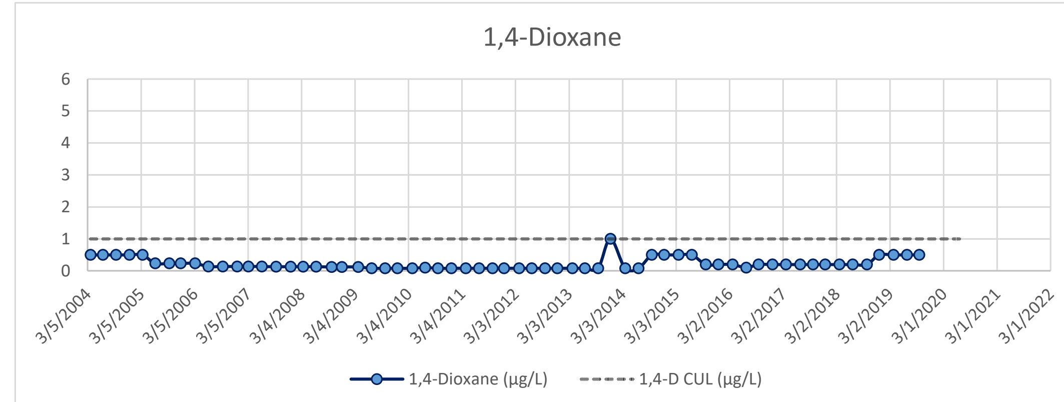
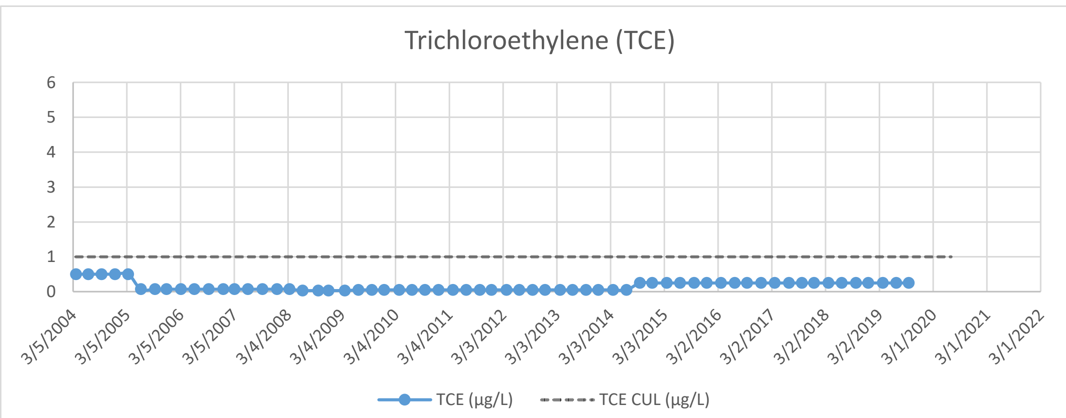
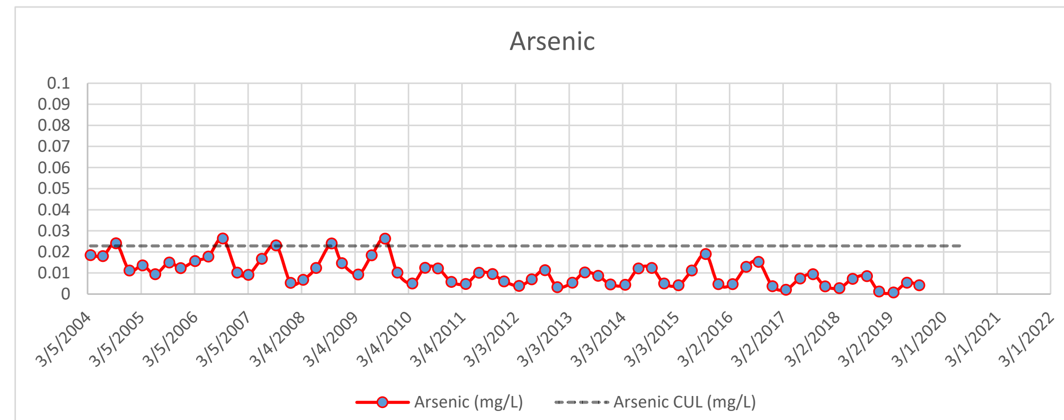
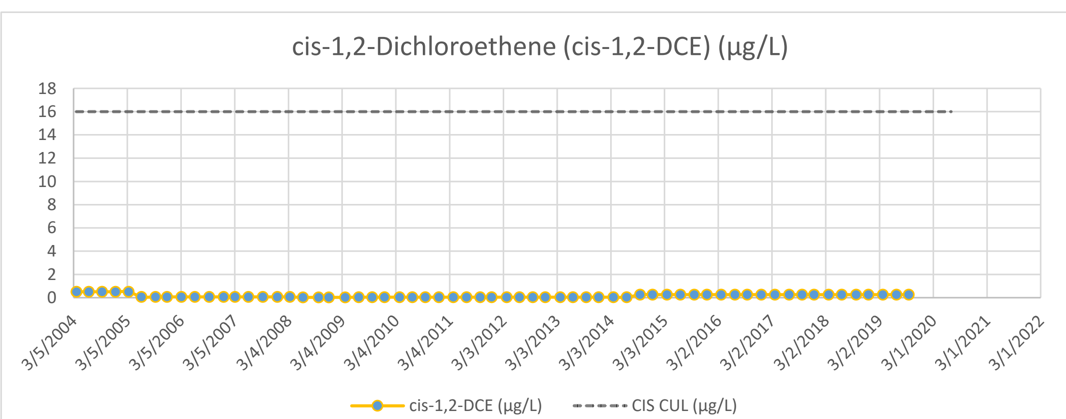
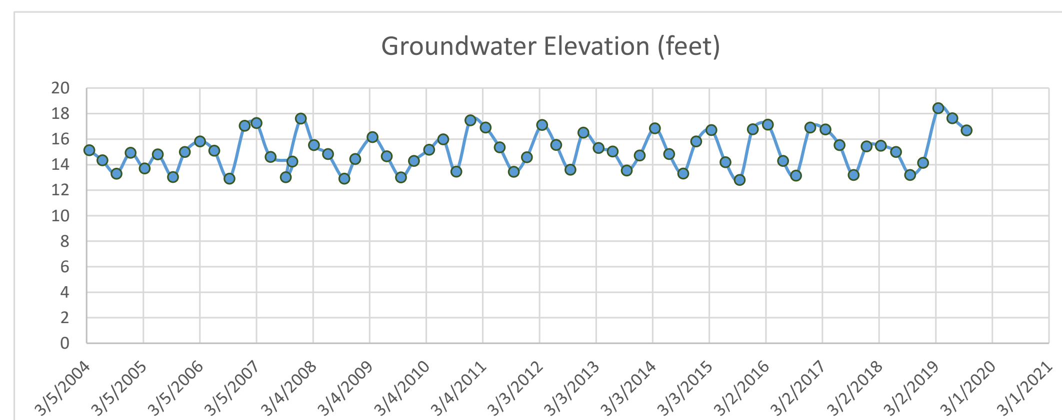

Tetrachloroethylene (PCE)
PCE (µg/L)
PCE CUL (µg/L)

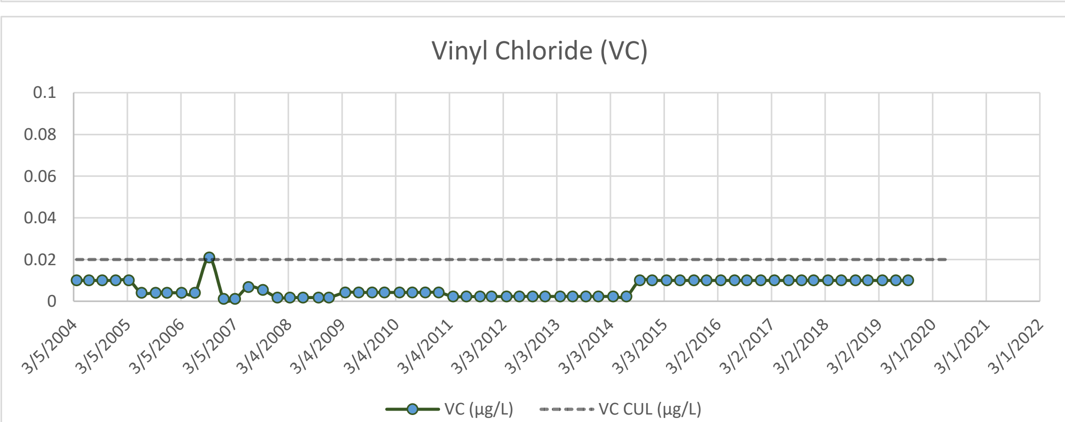

1,4-Dioxane
1,4-Dioxane (µg/L)
1,4-D CUL (µg/L)


Trichloroethylene (TCE)
TCE (µg/L)
TCE CUL (µg/L)


Arsenic
Arsenic (mg/L)
Arsenic CUL (mg/L)


cis-1,2-Dichloroethene (cis-1,2-DCE) (µg/L)
cis-1,2-DCE (µg/L)
CIS CUL (µg/L)


Groundwater Elevation (feet)


Vinyl Chloride (VC)
VC (µg/L)
VC CUL (µg/L)

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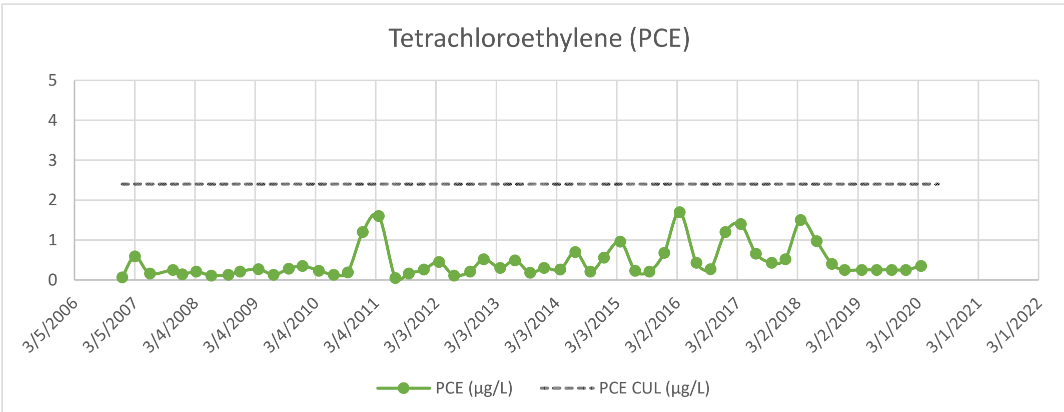
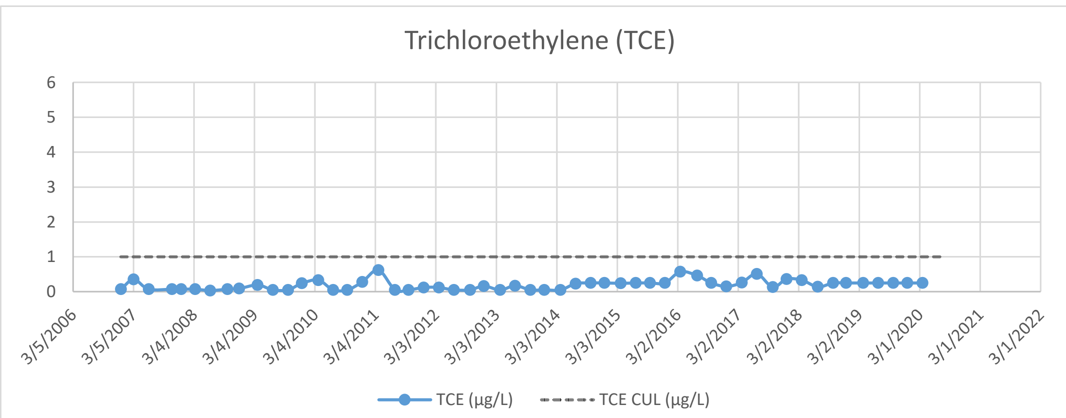
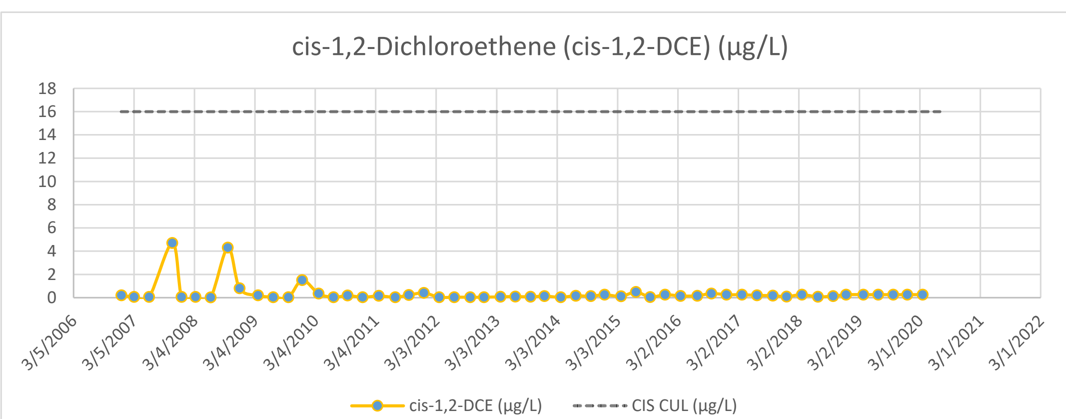
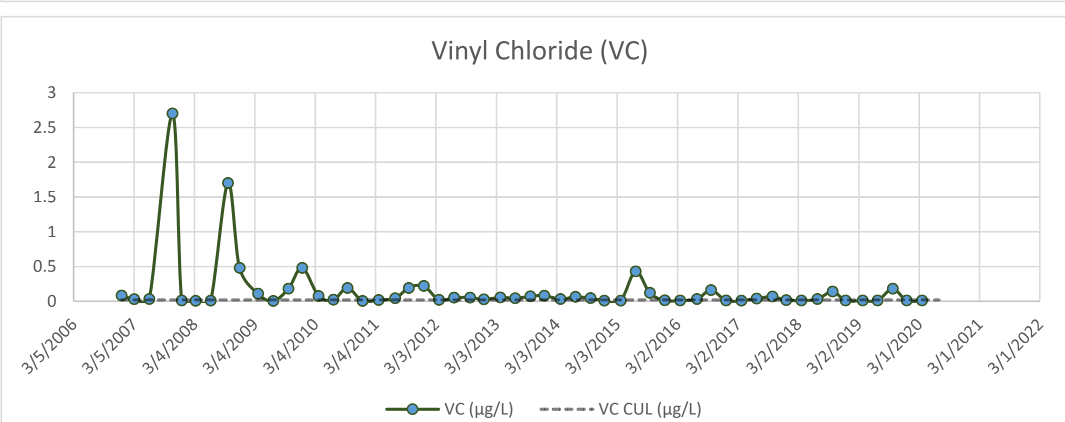
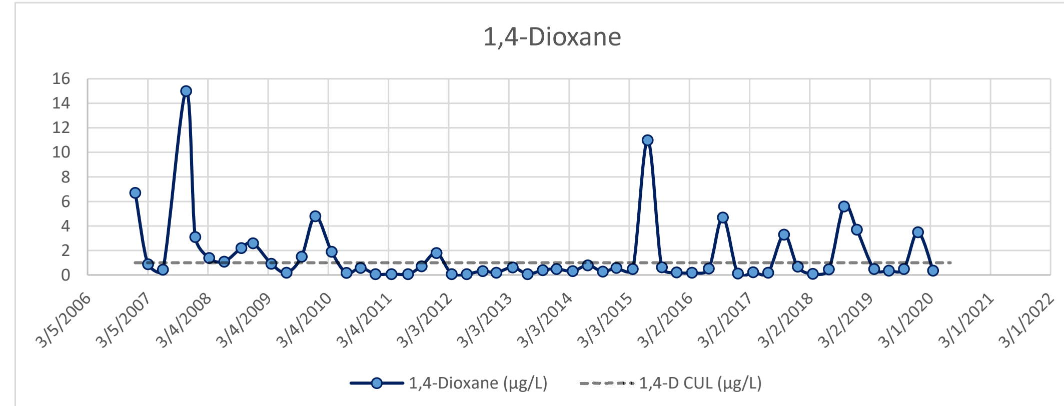
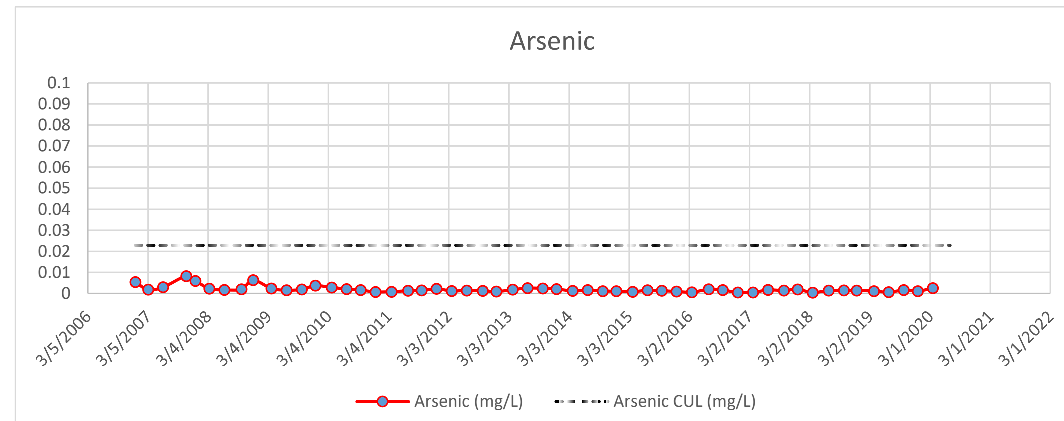

Tetrachloroethylene (PCE)
0
1
2
3
4
5
3/5/2006
3/5/2007
3/4/2008
3/4/2009
3/4/2010
3/4/2011
3/3/2012
3/3/2013
3/3/2014
3/3/2015
3/2/2016
3/2/2017
3/2/2018
3/2/2019
3/1/2020
3/1/2021
3/1/2022
PCE (µg/L)
PCE CUL (µg/L)

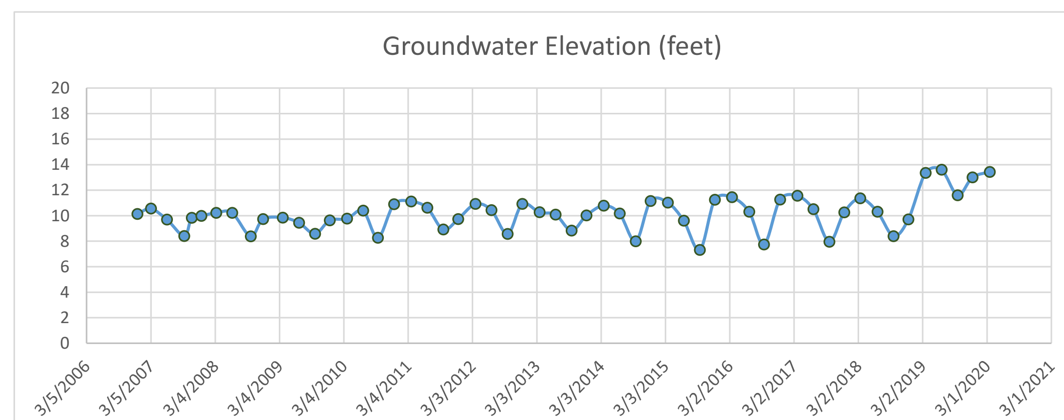

Trichloroethylene (TCE)
0
1
2
3
4
5
6
3/5/2006
3/5/2007
3/4/2008
3/4/2009
3/4/2010
3/4/2011
3/3/2012
3/3/2013
3/3/2014
3/3/2015
3/2/2016
3/2/2017
3/2/2018
3/2/2019
3/1/2020
3/1/2021
3/1/2022
TCE (µg/L)
TCE CUL (µg/L)


cis-1,2-Dichloroethene (cis-1,2-DCE) (µg/L)
0
2
4
6
8
10
12
14
16
18
3/5/2006
3/5/2007
3/4/2008
3/4/2009
3/4/2010
3/4/2011
3/3/2012
3/3/2013
3/3/2014
3/3/2015
3/2/2016
3/2/2017
3/2/2018
3/2/2019
3/1/2020
3/1/2021
3/1/2022
cis-1,2-DCE (µg/L)
CIS CUL (µg/L)

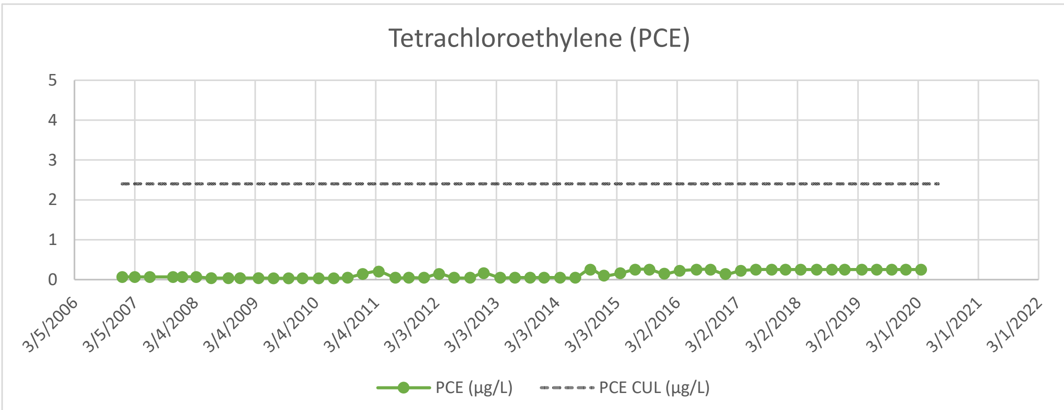

Vinyl Chloride (VC)
0
0.5
1
1.5
2
2.5
3
3/5/2006
3/5/2007
3/4/2008
3/4/2009
3/4/2010
3/4/2011
3/3/2012
3/3/2013
3/3/2014
3/3/2015
3/2/2016
3/2/2017
3/2/2018
3/2/2019
3/1/2020
3/1/2021
3/1/2022
VC (µg/L)
VC CUL (µg/L)


1,4-Dioxane
0
2
4
6
8
10
12
14
16
3/5/2006
3/5/2007
3/4/2008
3/4/2009
3/4/2010
3/4/2011
3/3/2012
3/3/2013
3/3/2014
3/3/2015
3/2/2016
3/2/2017
3/2/2018
3/2/2019
3/1/2020
3/1/2021
3/1/2022
1,4-Dioxane (µg/L)
1,4-D CUL (µg/L)

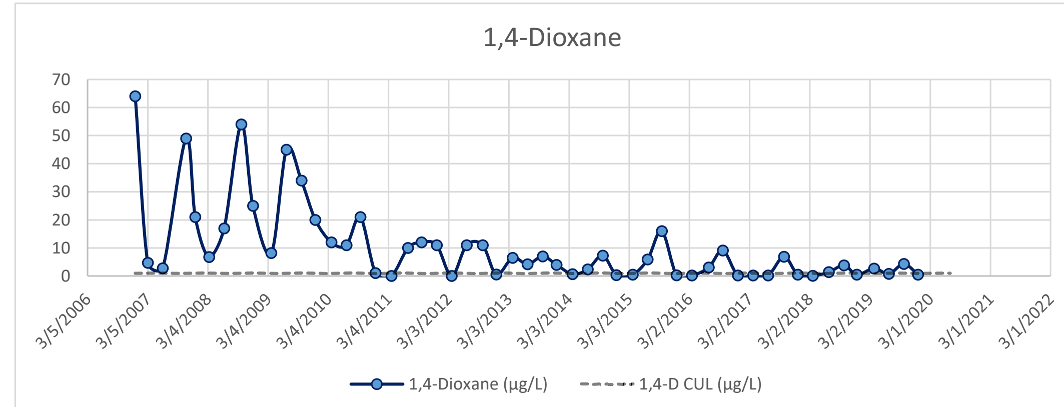

Arsenic
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.1
3/5/2006
3/5/2007
3/4/2008
3/4/2009
3/4/2010
3/4/2011
3/3/2012
3/3/2013
3/3/2014
3/3/2015
3/2/2016
3/2/2017
3/2/2018
3/2/2019
3/1/2020
3/1/2021
3/1/2022
Arsenic (mg/L)
Arsenic CUL (mg/L)


Groundwater Elevation (feet)
0
2
4
6
8
10
12
14
16
18
20
3/5/2006
3/5/2007
3/4/2008
3/4/2009
3/4/2010
3/4/2011
3/3/2012
3/3/2013
3/3/2014
3/3/2015
3/2/2016
3/2/2017
3/2/2018
3/2/2019
3/1/2020
3/1/2021

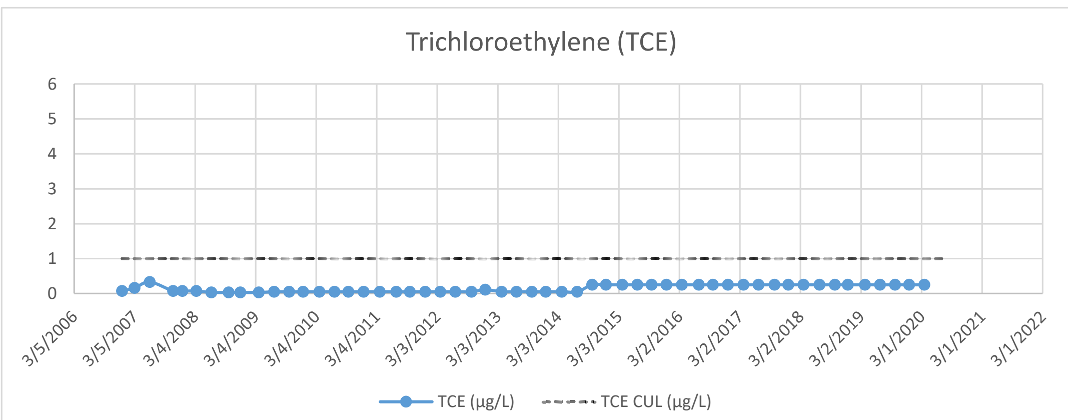
MC-123



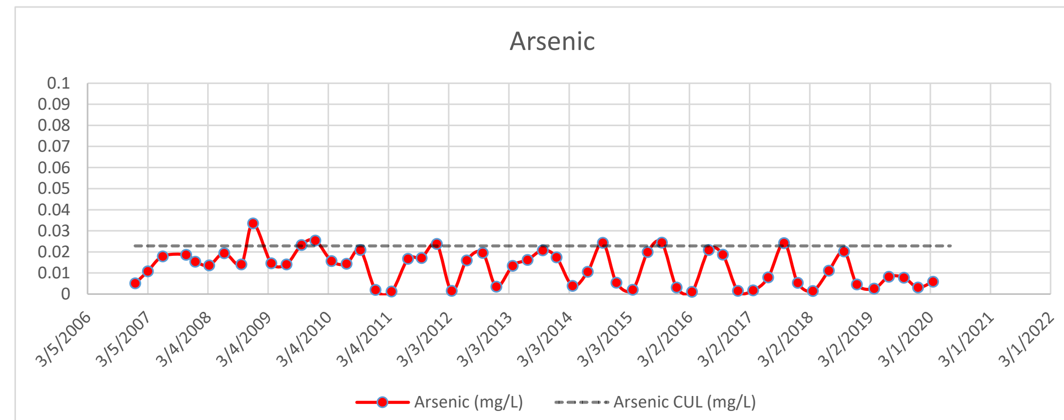
Tetrachloroethylene (PCE)
PCE (µg/L)
PCE CUL (µg/L)



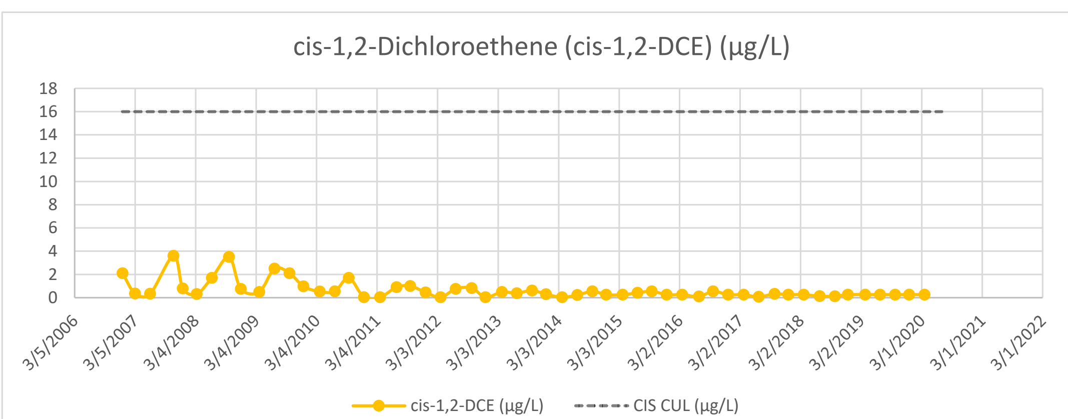
1,4-Dioxane
1,4-Dioxane (µg/L)
1,4-D CUL (µg/L)



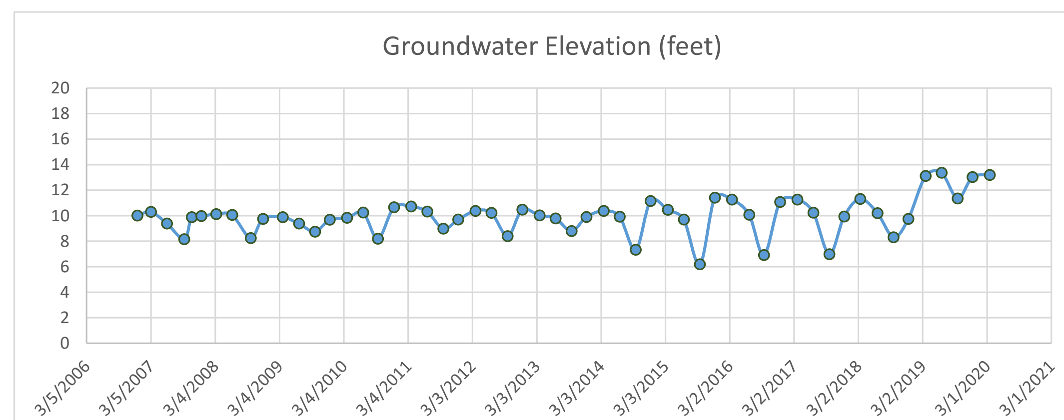
Trichloroethylene (TCE)
TCE (µg/L)
TCE CUL (µg/L)



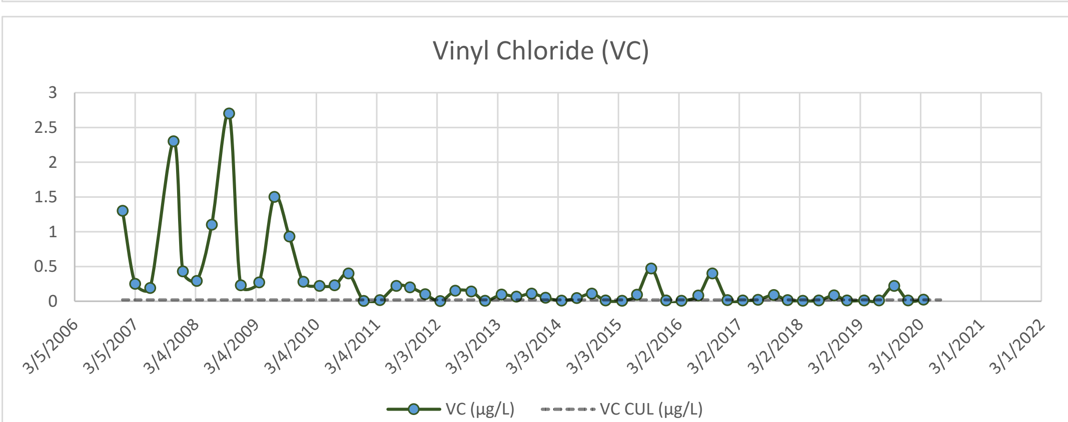
Arsenic
Arsenic (mg/L)
Arsenic CUL (mg/L)



cis-1,2-Dichloroethene (cis-1,2-DCE) (µg/L)
cis-1,2-DCE (µg/L)
CIS CUL (µg/L)

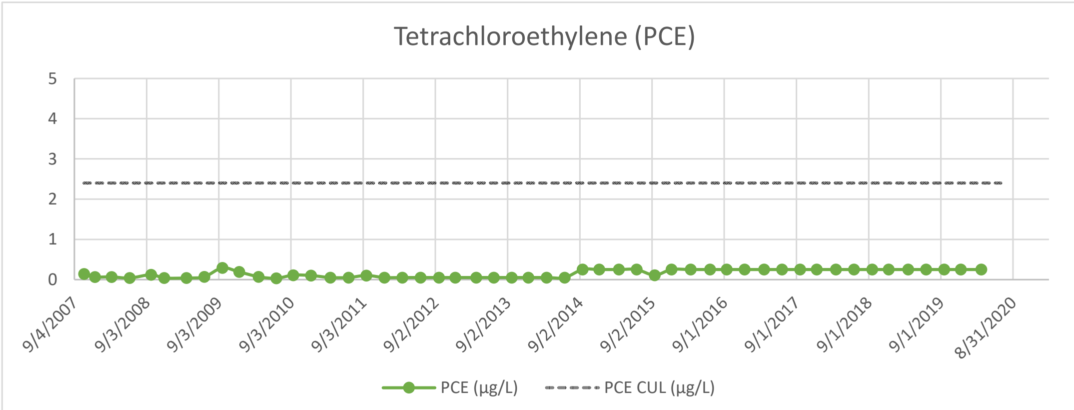


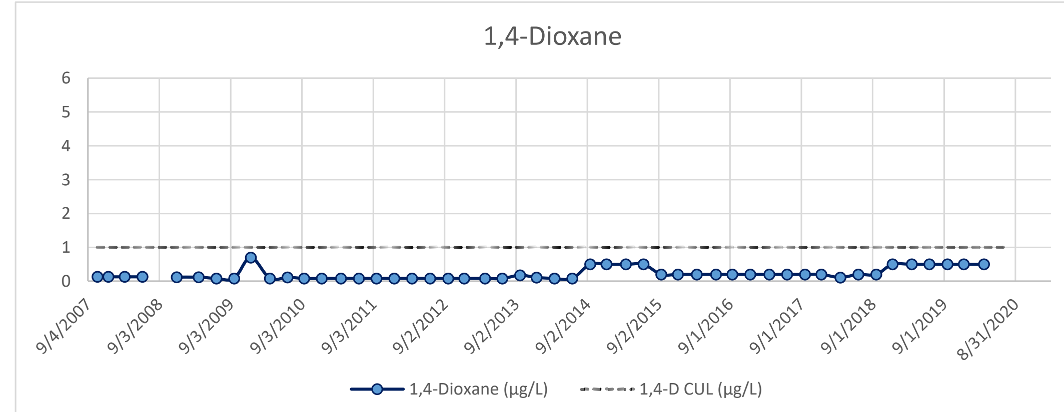
Groundwater Elevation (feet)

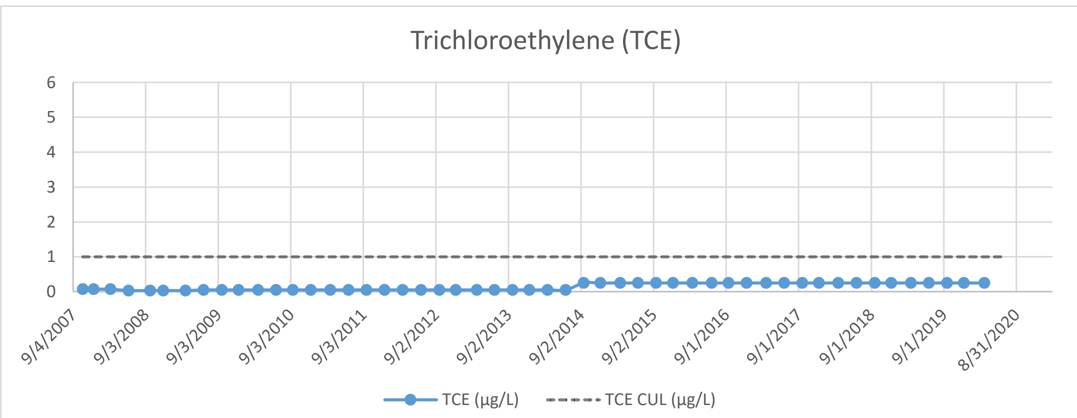


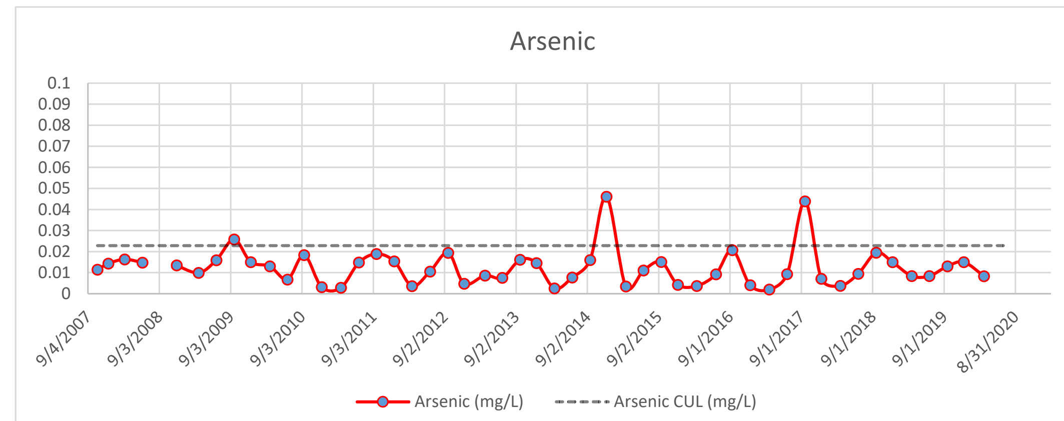
Vinyl Chloride (VC)
VC (µg/L)
VC CUL (µg/L)

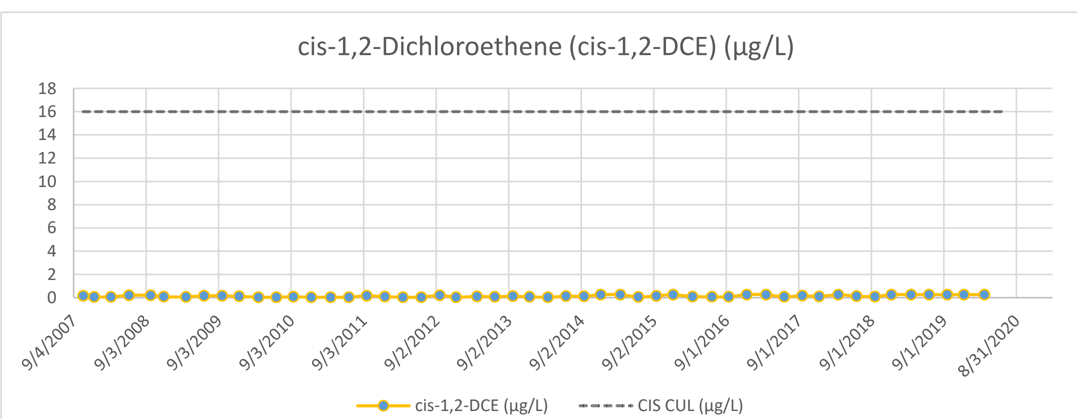
PZU-4

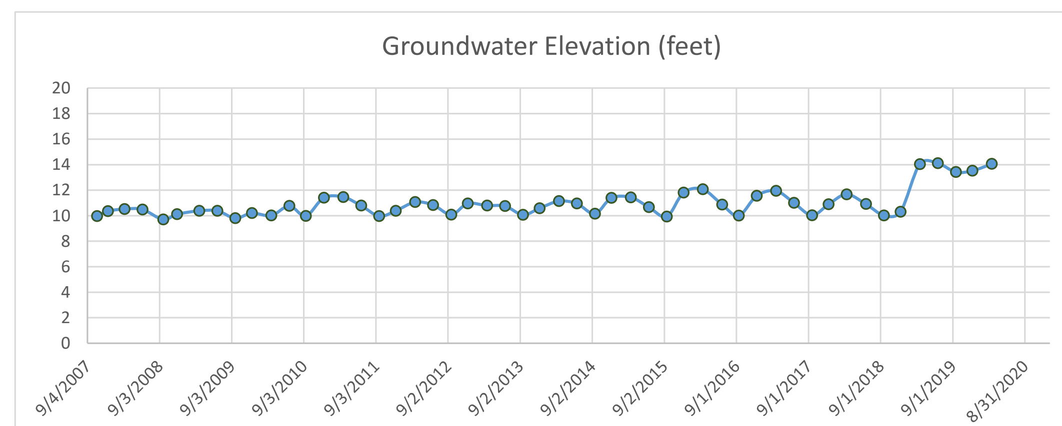

Tetrachloroethylene (PCE)
PCE (µg/L)
PCE CUL (µg/L)

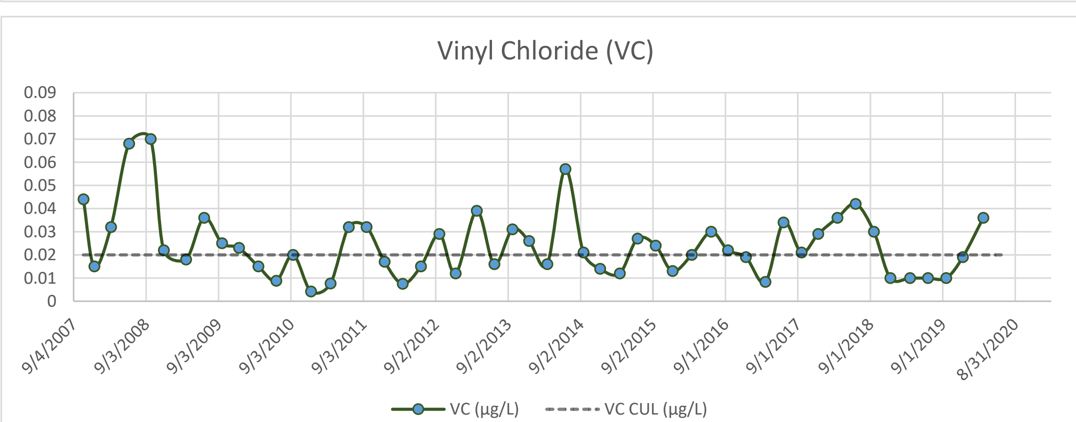

1,4-Dioxane
1,4-Dioxane (µg/L)
1,4-D CUL (µg/L)


Trichloroethylene (TCE)
TCE (µg/L)
TCE CUL (µg/L)

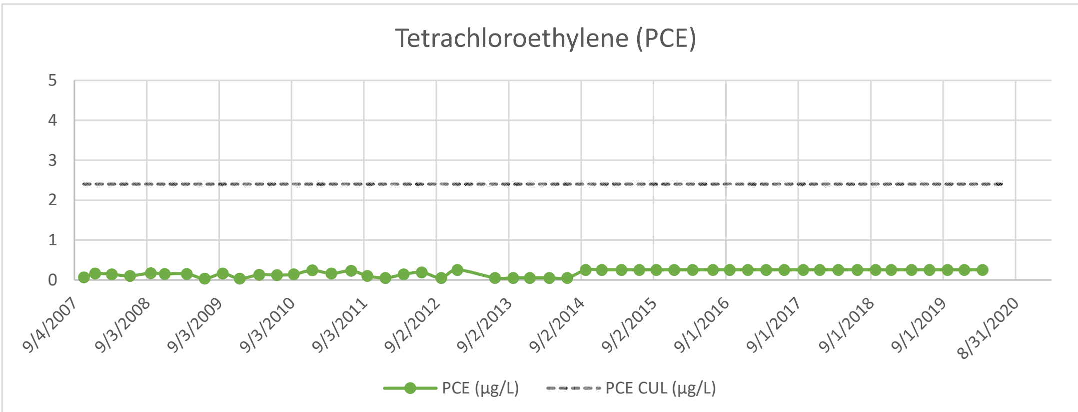

Arsenic
Arsenic (mg/L)
Arsenic CUL (mg/L)

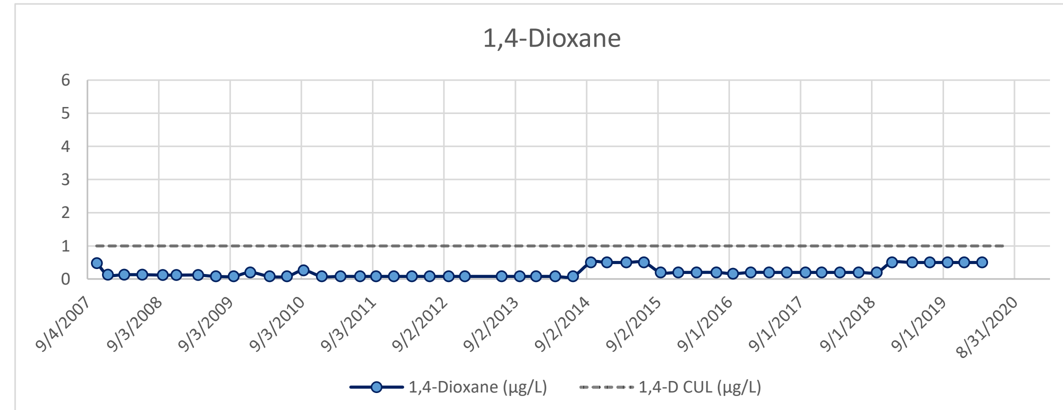

cis-1,2-Dichloroethene (cis-1,2-DCE) (µg/L)
cis-1,2-DCE (µg/L)
CIS CUL (µg/L)

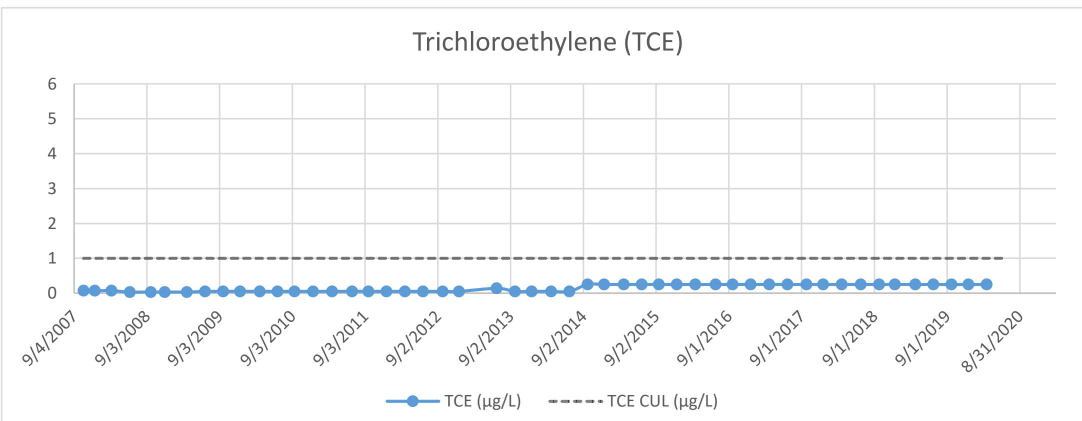

Groundwater Elevation (feet)

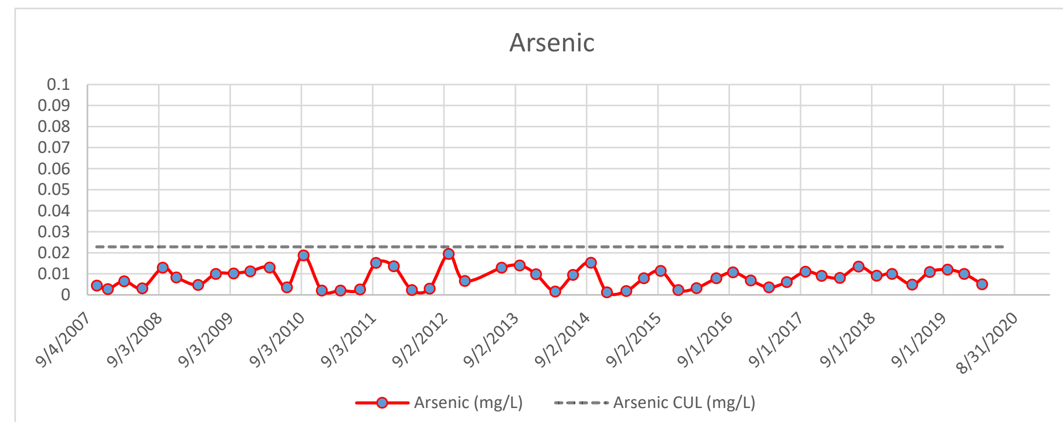

Vinyl Chloride (VC)
VC (µg/L)
VC CUL (µg/L)

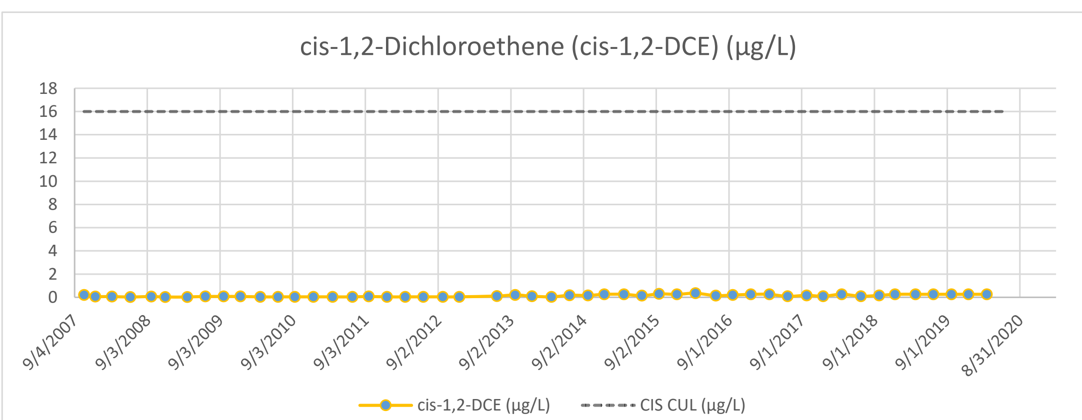
PZU-5/PZU-5R

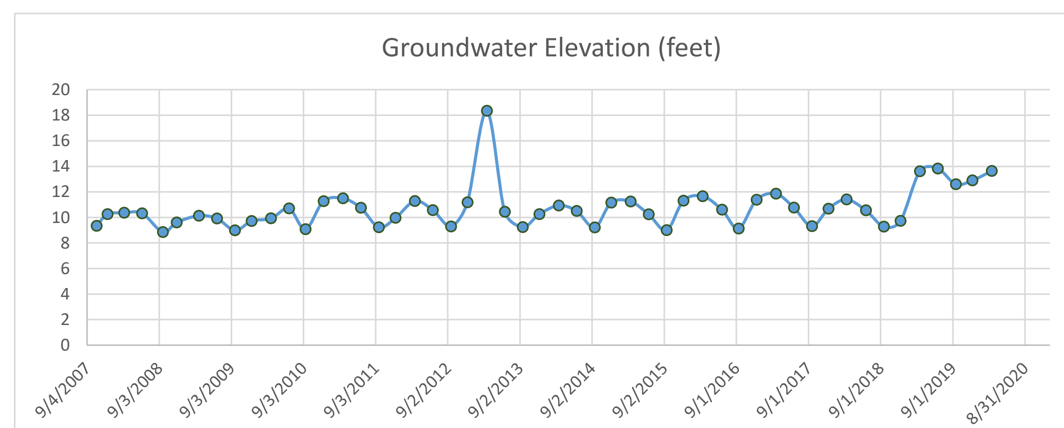

Tetrachloroethylene (PCE)
PCE (µg/L)
PCE CUL (µg/L)

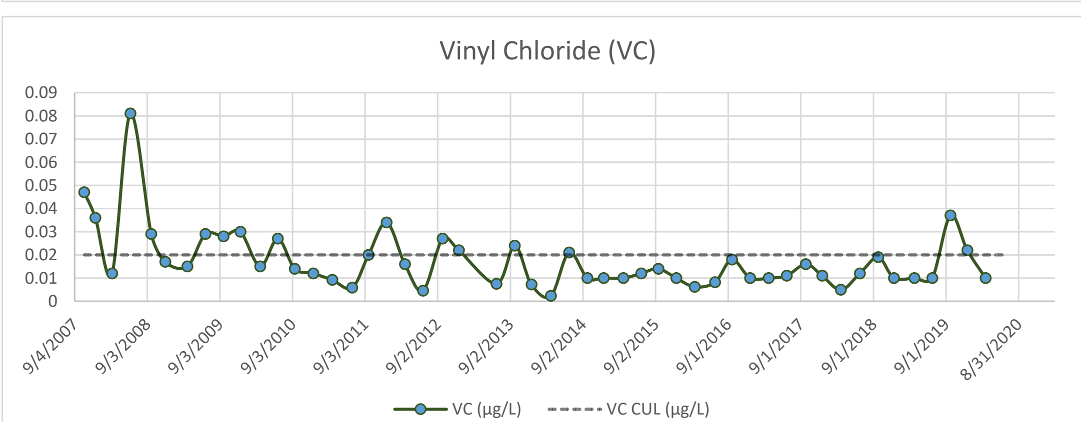

1,4-Dioxane
1,4-Dioxane (µg/L)
1,4-D CUL (µg/L)


Trichloroethylene (TCE)
TCE (µg/L)
TCE CUL (µg/L)

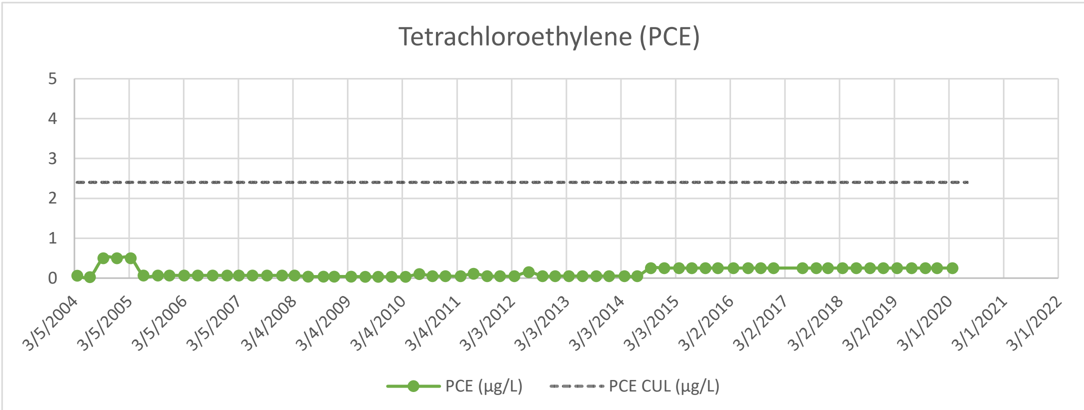

Arsenic
Arsenic (mg/L)
Arsenic CUL (mg/L)


cis-1,2-Dichloroethene (cis-1,2-DCE) (µg/L)
cis-1,2-DCE (µg/L)
CIS CUL (µg/L)

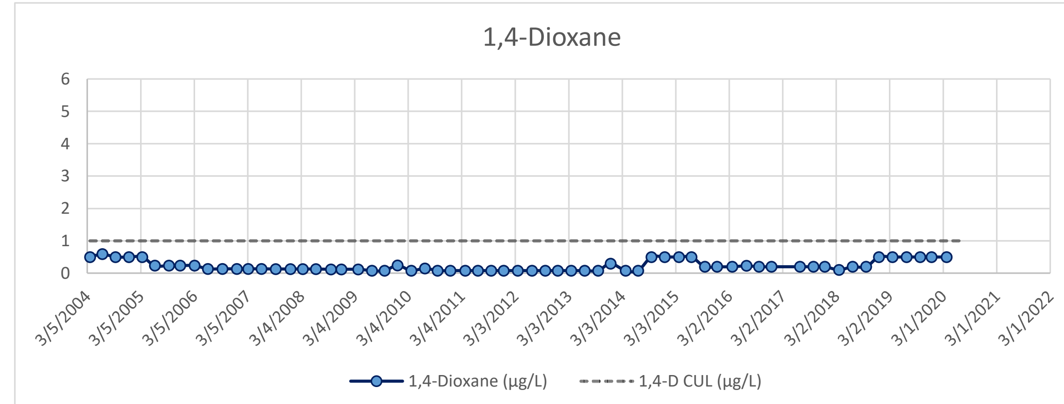

Groundwater Elevation (feet)


Vinyl Chloride (VC)
VC (µg/L)
VC CUL (µg/L)

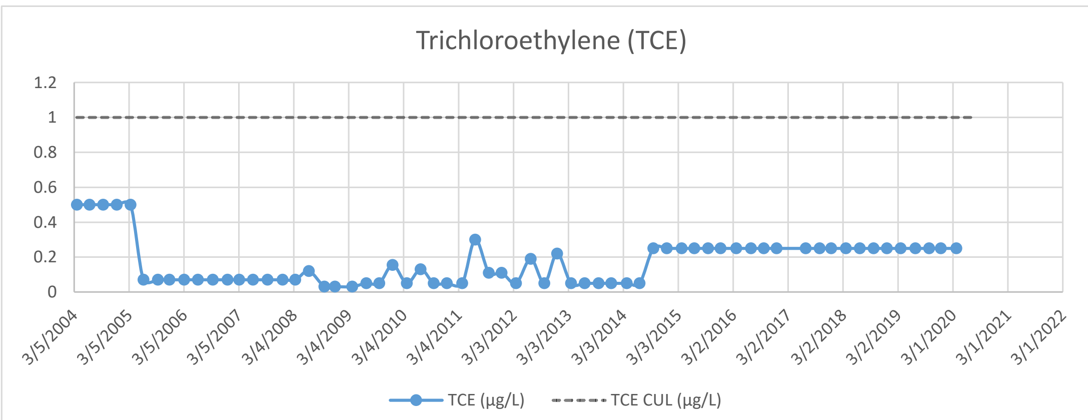
MC-2D



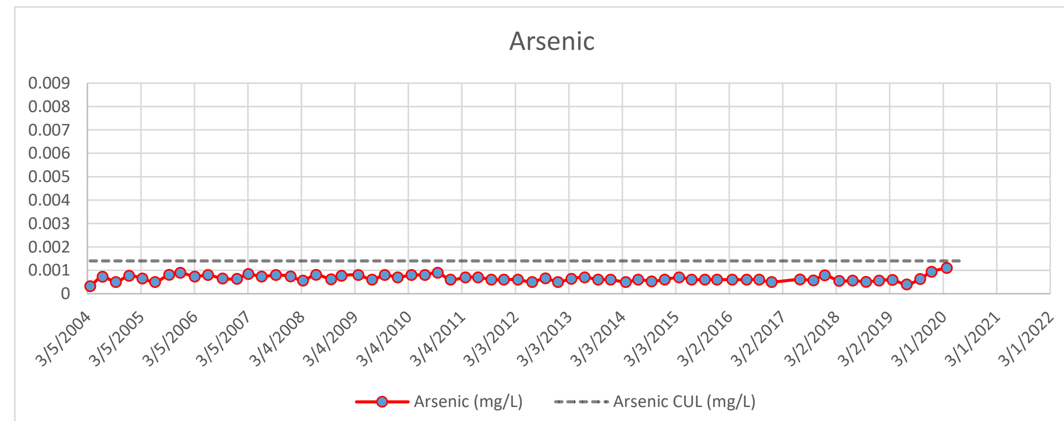
Tetrachloroethylene (PCE)
PCE (µg/L)
PCE CUL (µg/L)



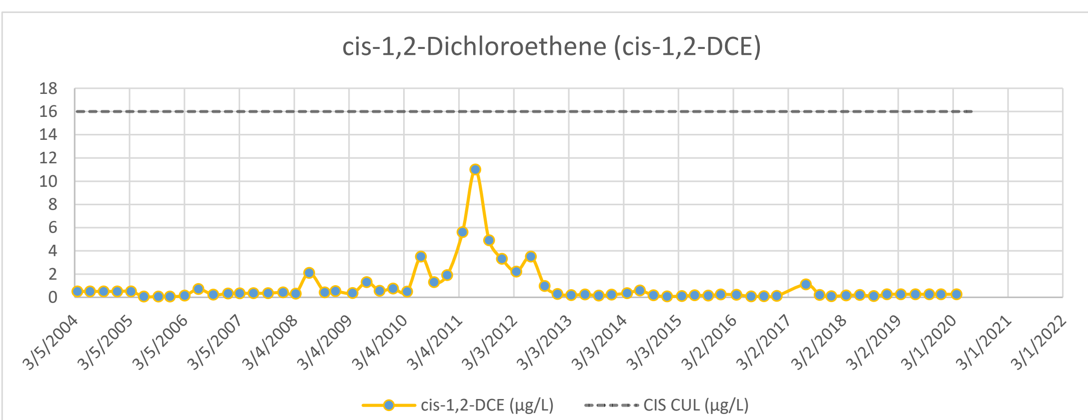
1,4-Dioxane
1,4-Dioxane (µg/L)
1,4-D CUL (µg/L)



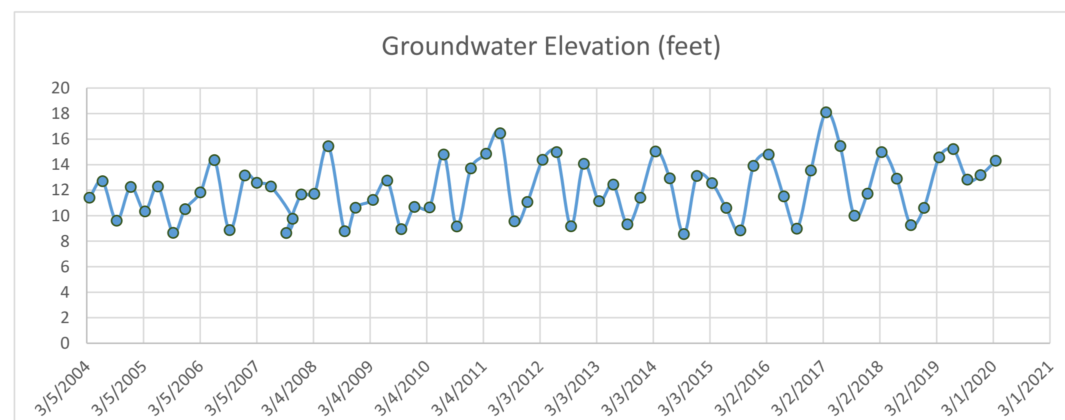
Trichloroethylene (TCE)
TCE (µg/L)
TCE CUL (µg/L)



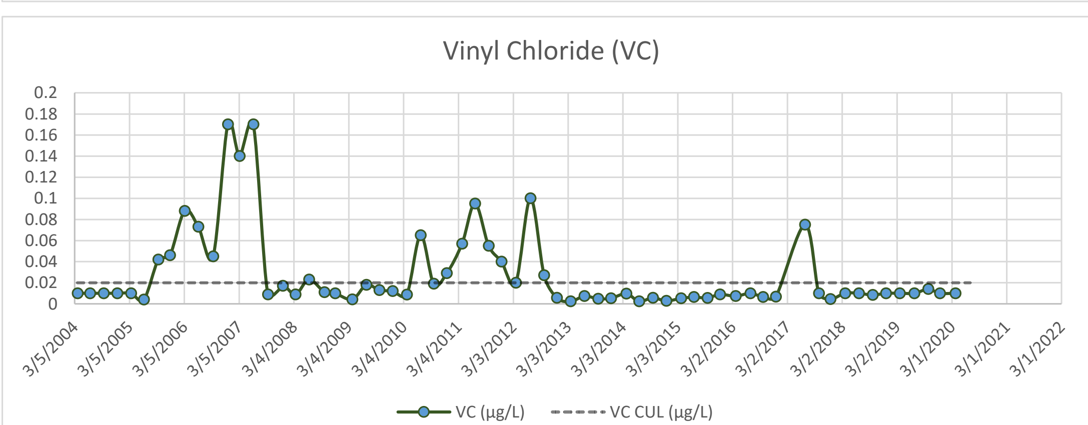
Arsenic
Arsenic (mg/L)
Arsenic CUL (mg/L)



cis-1,2-Dichloroethene (cis-1,2-DCE)
cis-1,2-DCE (µg/L)
CIS CUL (µg/L)

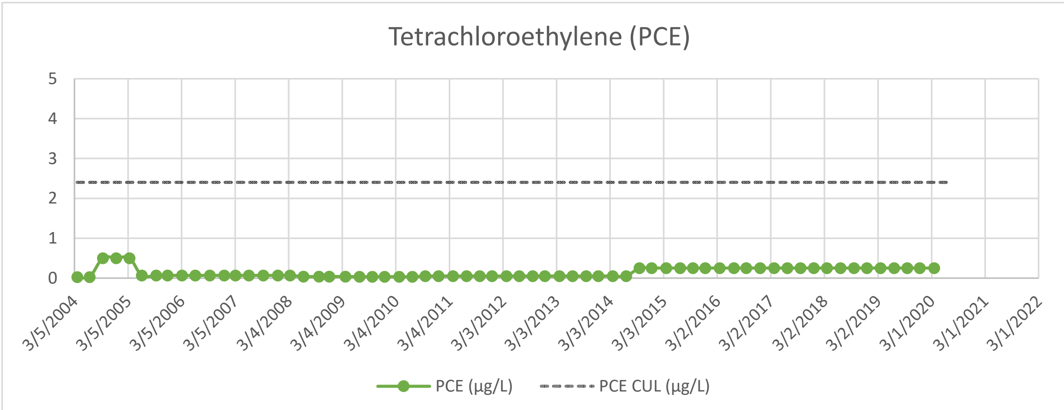


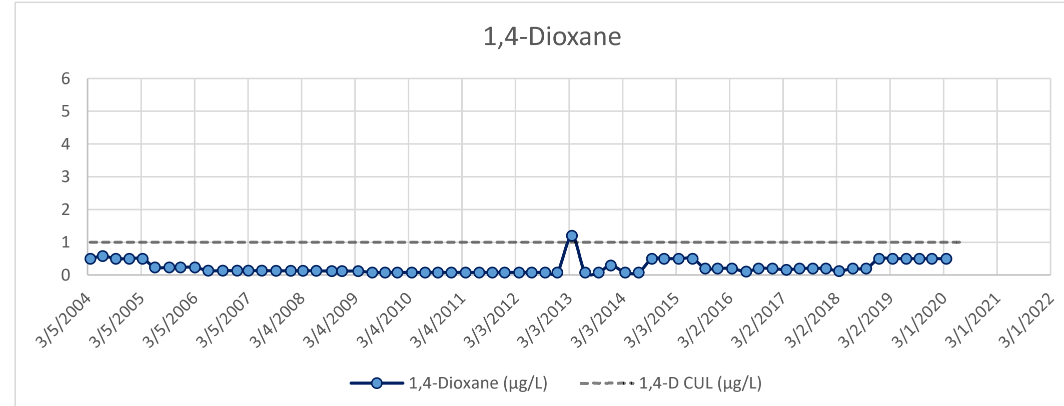
Groundwater Elevation (feet)

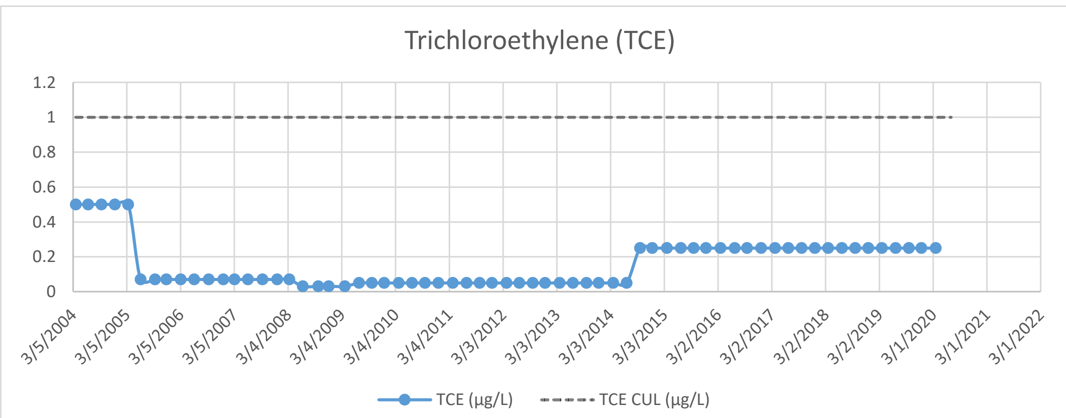


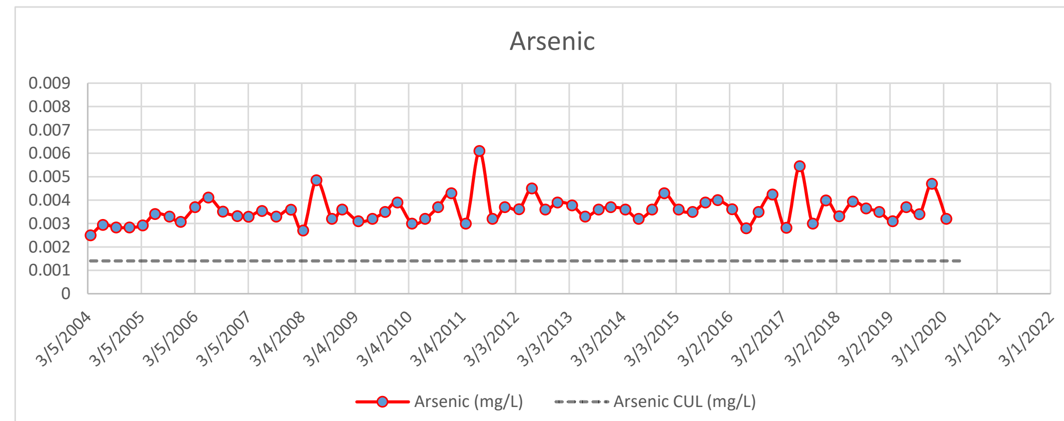
Vinyl Chloride (VC)
VC (µg/L)
VC CUL (µg/L)

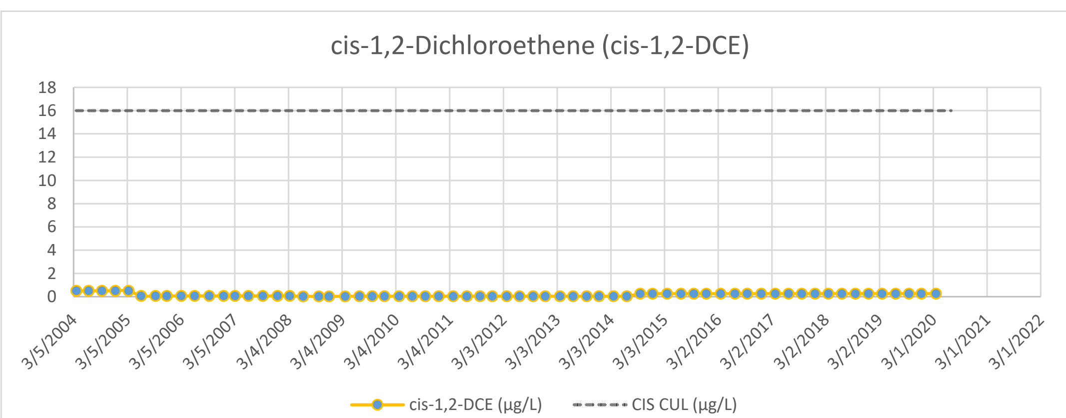
MC-10D

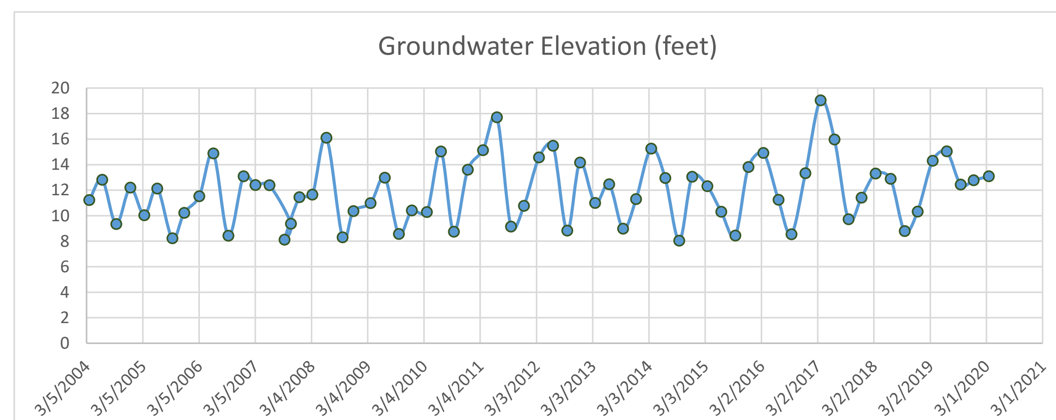

Tetrachloroethylene (PCE)
0 1 2 3 4 5
3/5/2004 3/5/2005 3/5/2006 3/5/2007 3/4/2008 3/4/2009 3/4/2010 3/4/2011 3/3/2012 3/3/2013 3/3/2014 3/3/2015 3/2/2016 3/2/2017 3/2/2018 3/2/2019 3/1/2020 3/1/2021 3/1/2022
PCE (µg/L)
PCE CUL (µg/L)

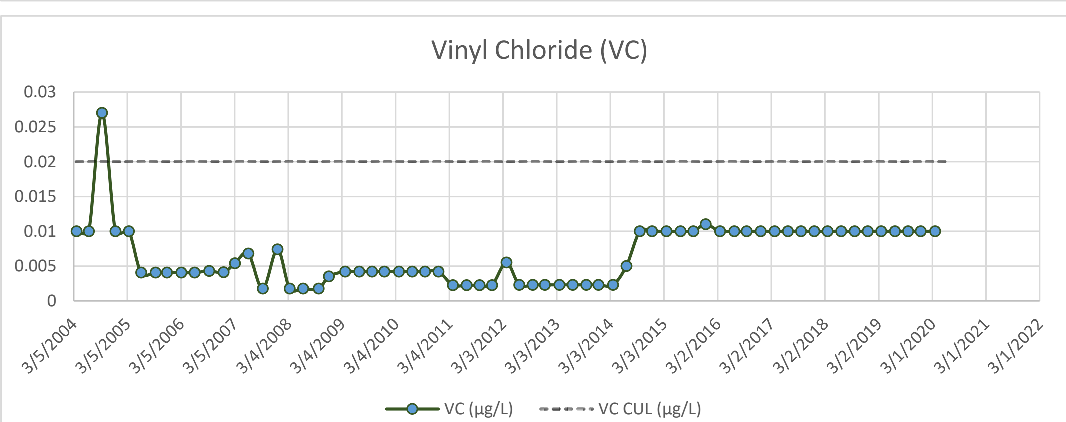

1,4-Dioxane
0 1 2 3 4 5 6
3/5/2004 3/5/2005 3/5/2006 3/5/2007 3/4/2008 3/4/2009 3/4/2010 3/4/2011 3/3/2012 3/3/2013 3/3/2014 3/3/2015 3/2/2016 3/2/2017 3/2/2018 3/2/2019 3/1/2020 3/1/2021 3/1/2022
1,4-Dioxane (µg/L)
1,4-D CUL (µg/L)


Trichloroethylene (TCE)
0 0.2 0.4 0.6 0.8 1 1.2
3/5/2004 3/5/2005 3/5/2006 3/5/2007 3/4/2008 3/4/2009 3/4/2010 3/4/2011 3/3/2012 3/3/2013 3/3/2014 3/3/2015 3/2/2016 3/2/2017 3/2/2018 3/2/2019 3/1/2020 3/1/2021 3/1/2022
TCE (µg/L)
TCE CUL (µg/L)

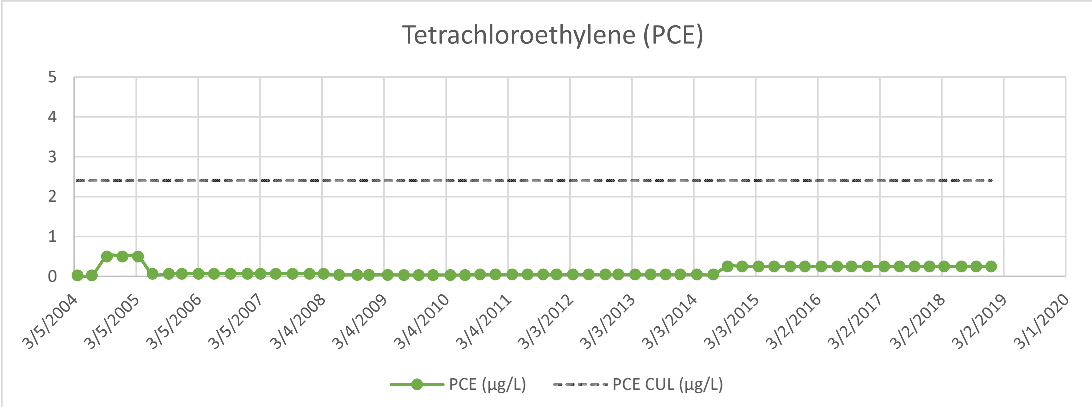

Arsenic
0 0.001 0.002 0.003 0.004 0.005 0.006 0.007 0.008 0.009
3/5/2004 3/5/2005 3/5/2006 3/5/2007 3/4/2008 3/4/2009 3/4/2010 3/4/2011 3/3/2012 3/3/2013 3/3/2014 3/3/2015 3/2/2016 3/2/2017 3/2/2018 3/2/2019 3/1/2020 3/1/2021 3/1/2022
Arsenic (mg/L)
Arsenic CUL (mg/L)

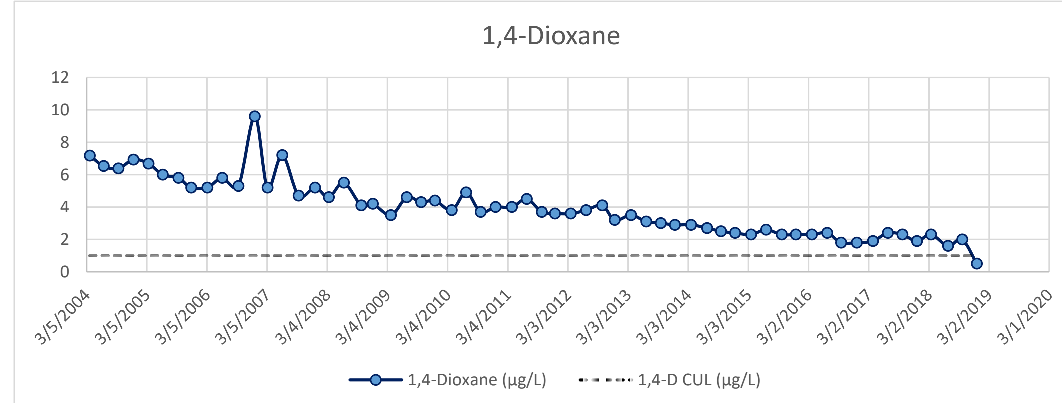

cis-1,2-Dichloroethene (cis-1,2-DCE)
0 2 4 6 8 10 12 14 16 18
3/5/2004 3/5/2005 3/5/2006 3/5/2007 3/4/2008 3/4/2009 3/4/2010 3/4/2011 3/3/2012 3/3/2013 3/3/2014 3/3/2015 3/2/2016 3/2/2017 3/2/2018 3/2/2019 3/1/2020 3/1/2021 3/1/2022
cis-1,2-DCE (µg/L)
CIS CUL (µg/L)

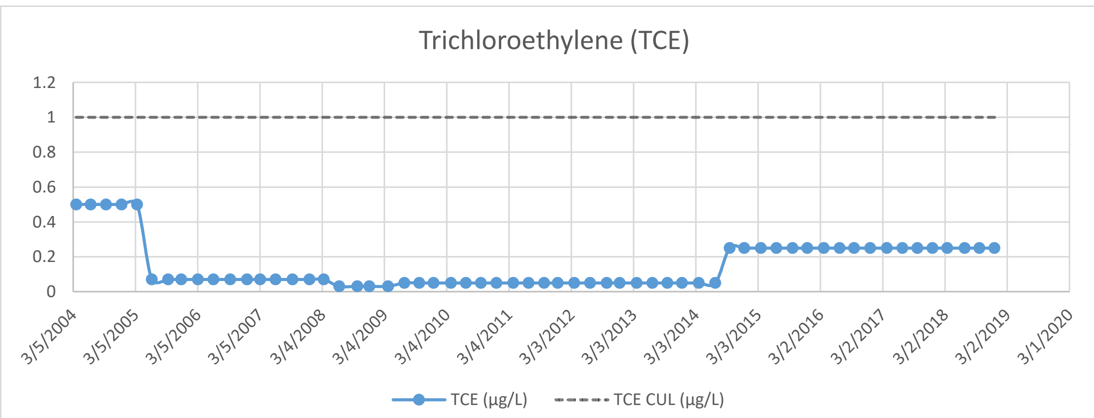

Groundwater Elevation (feet)
0 2 4 6 8 10 12 14 16 18 20
3/5/2004 3/5/2005 3/5/2006 3/5/2007 3/4/2008 3/4/2009 3/4/2010 3/4/2011 3/3/2012 3/3/2013 3/3/2014 3/3/2015 3/2/2016 3/2/2017 3/2/2018 3/2/2019 3/1/2020 3/1/2021

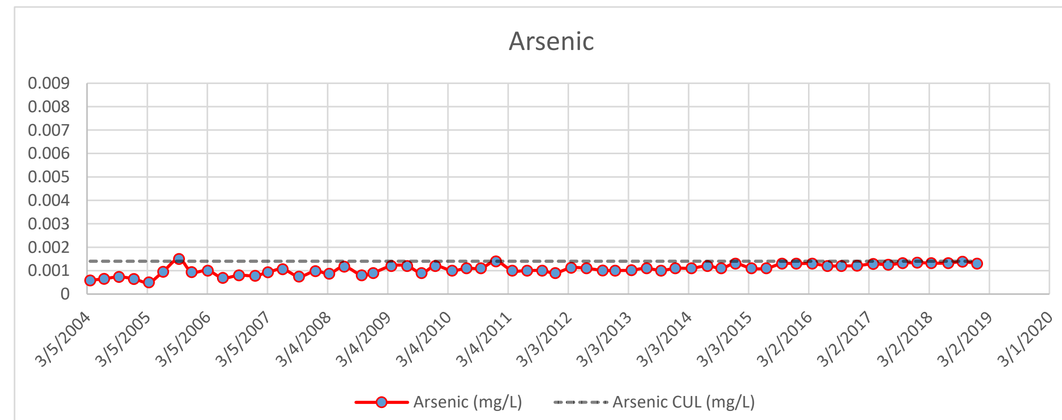

Vinyl Chloride (VC)
0 0.005 0.01 0.015 0.02 0.025 0.03
3/5/2004 3/5/2005 3/5/2006 3/5/2007 3/4/2008 3/4/2009 3/4/2010 3/4/2011 3/3/2012 3/3/2013 3/3/2014 3/3/2015 3/2/2016 3/2/2017 3/2/2018 3/2/2019 3/1/2020 3/1/2021 3/1/2022
VC (µg/L)
VC CUL (µg/L)

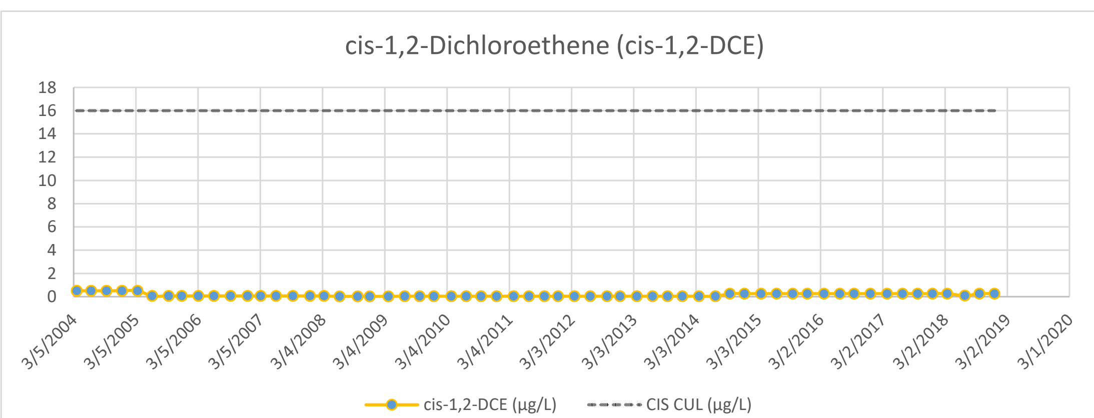
MC-12D

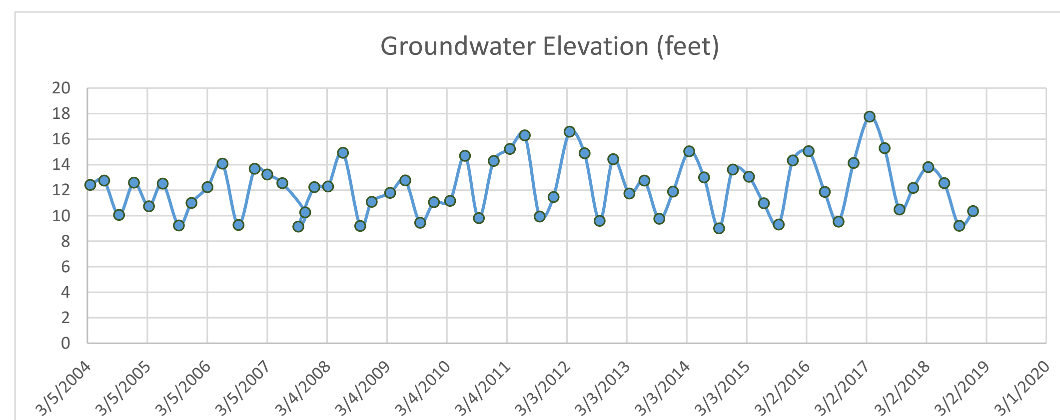

Tetrachloroethylene (PCE)
PCE (µg/L)
PCE CUL (µg/L)

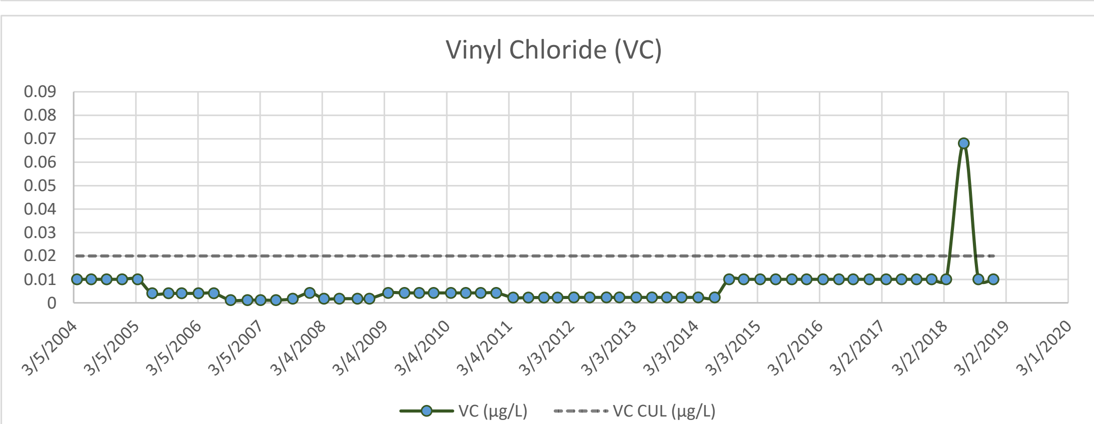

1,4-Dioxane
1,4-Dioxane (µg/L)
1,4-D CUL (µg/L)


Trichloroethylene (TCE)
TCE (µg/L)
TCE CUL (µg/L)

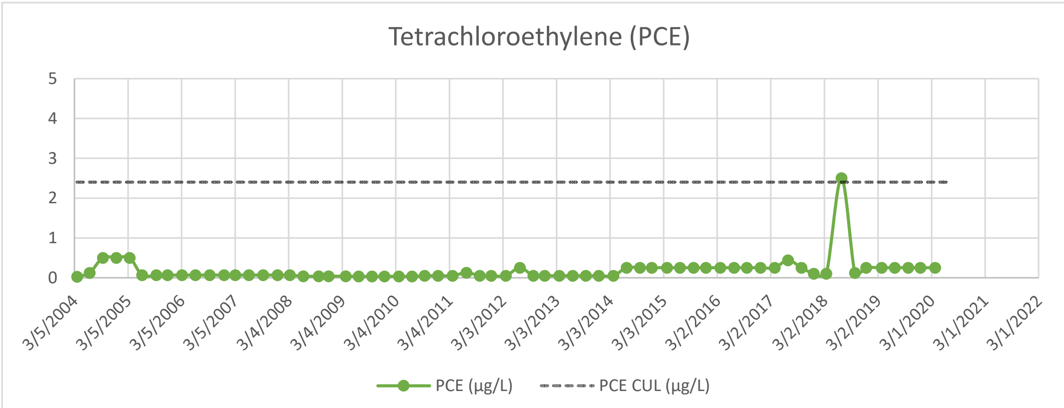

Arsenic
Arsenic (mg/L)
Arsenic CUL (mg/L)

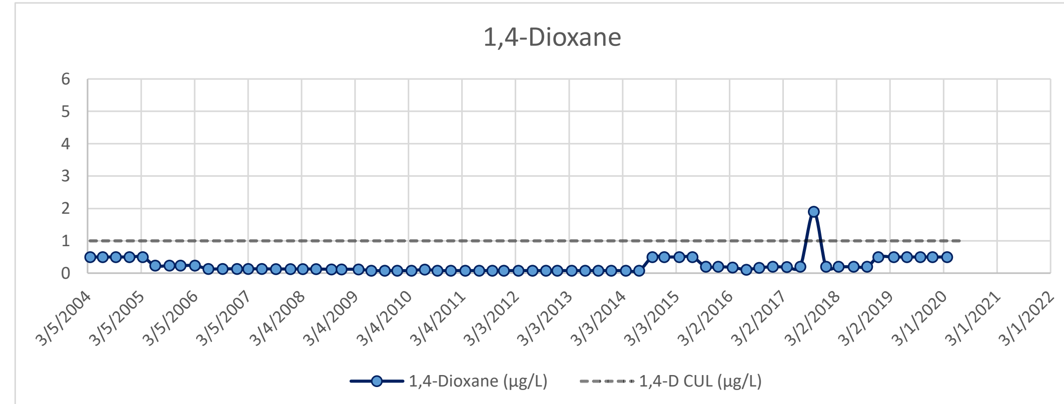

cis-1,2-Dichloroethene (cis-1,2-DCE)
cis-1,2-DCE (µg/L)
CIS CUL (µg/L)

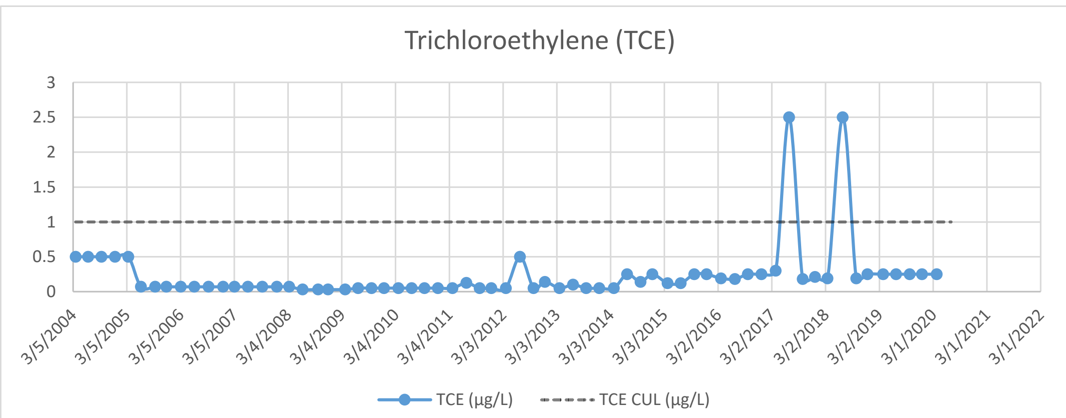

Groundwater Elevation (feet)

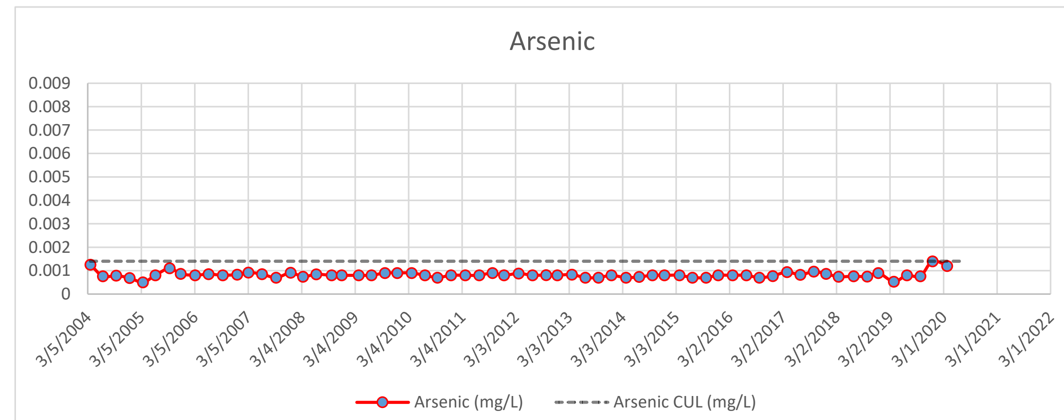

Vinyl Chloride (VC)
VC (µg/L)
VC CUL (µg/L)

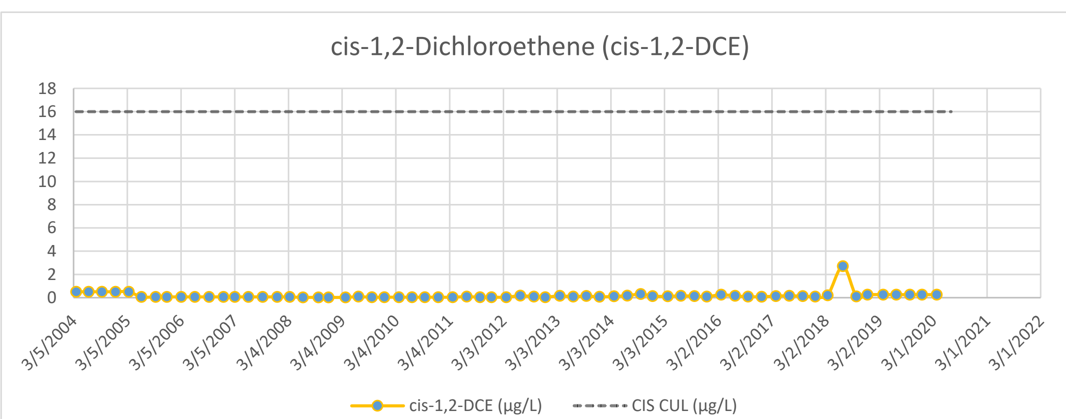
MC-13D

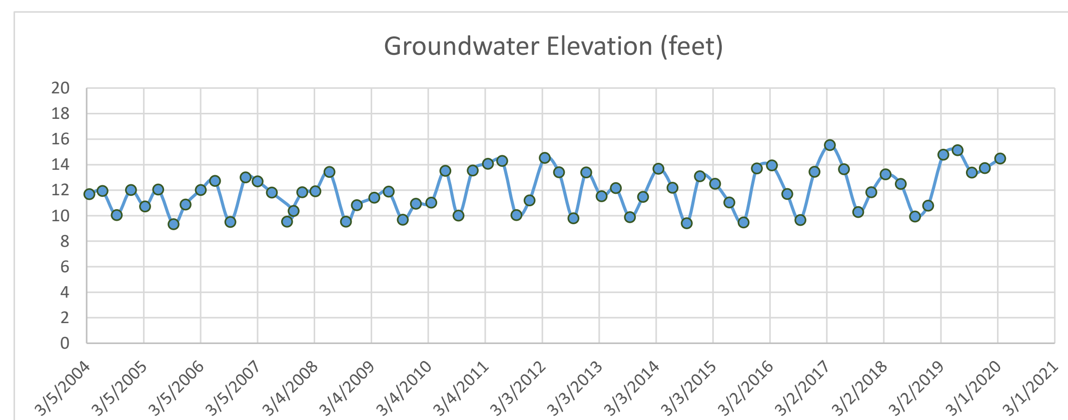

Tetrachloroethylene (PCE)
PCE (µg/L)
PCE CUL (µg/L)

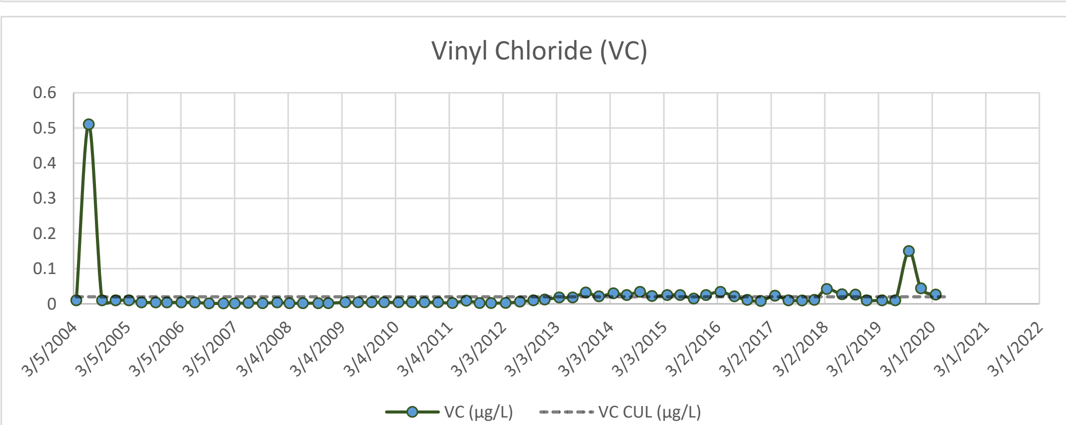

1,4-Dioxane
1,4-Dioxane (µg/L)
1,4-D CUL (µg/L)


Trichloroethylene (TCE)
TCE (µg/L)
TCE CUL (µg/L)

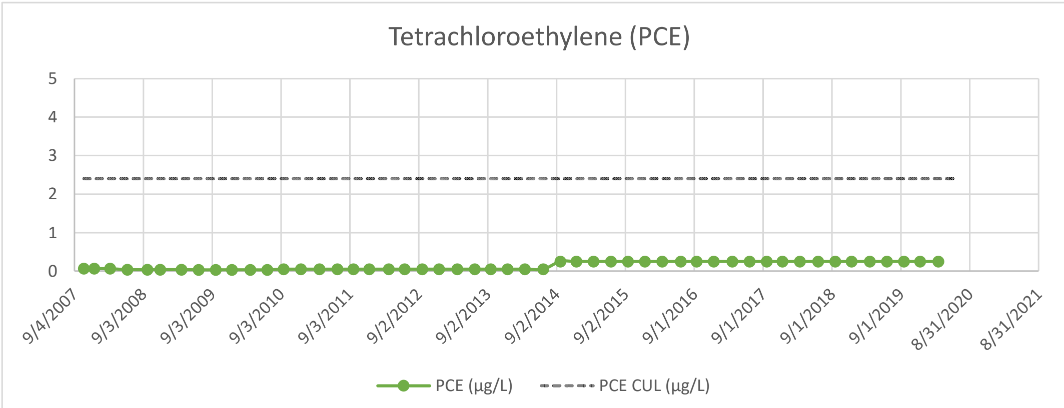

Arsenic
Arsenic (mg/L)
Arsenic CUL (mg/L)

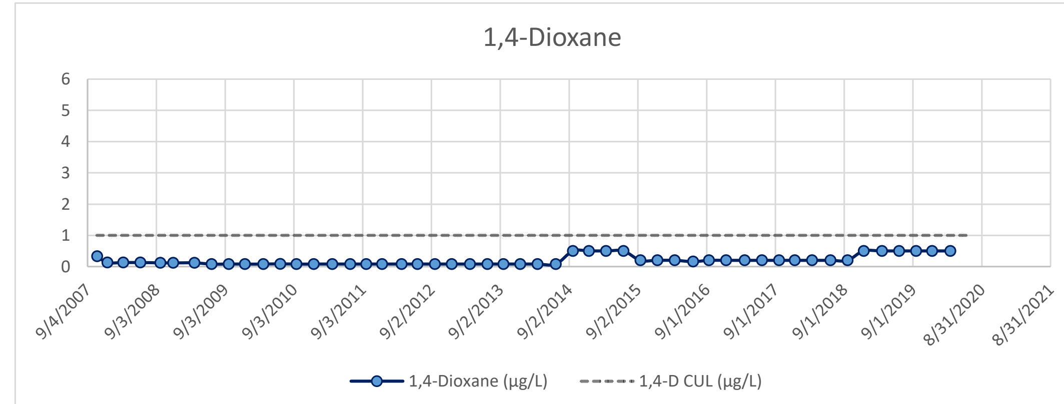

cis-1,2-Dichloroethene (cis-1,2-DCE)
cis-1,2-DCE (µg/L)
CIS CUL (µg/L)

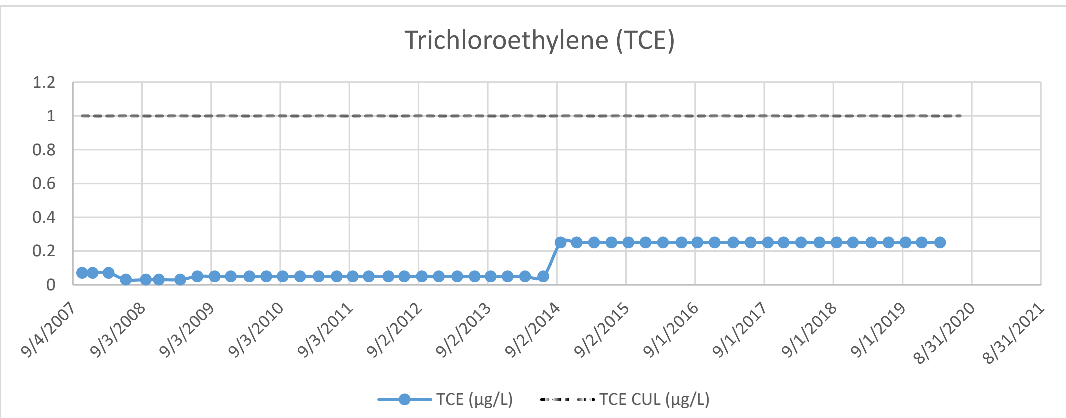

Groundwater Elevation (feet)

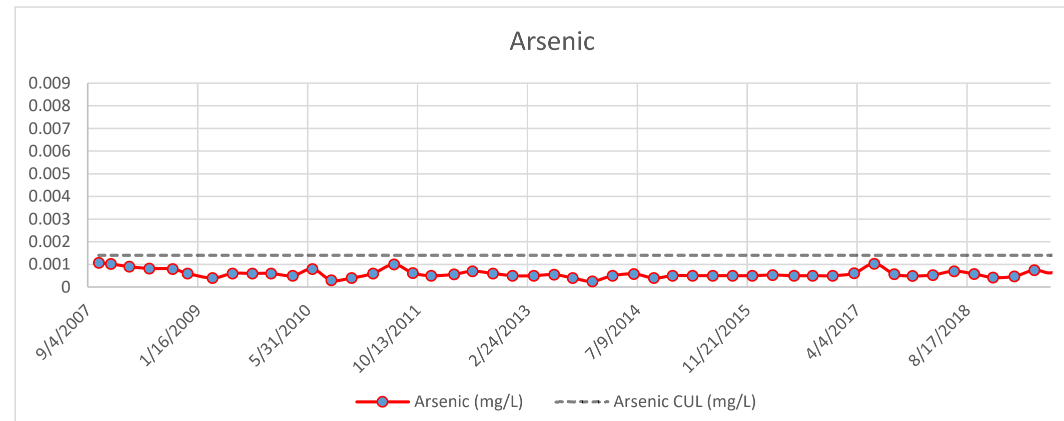

Vinyl Chloride (VC)
VC (µg/L)
VC CUL (µg/L)

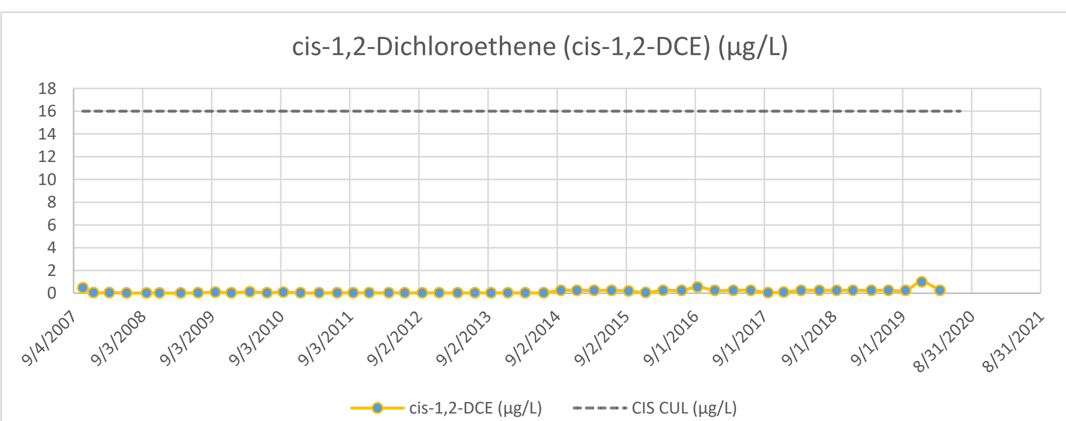
MC-14D

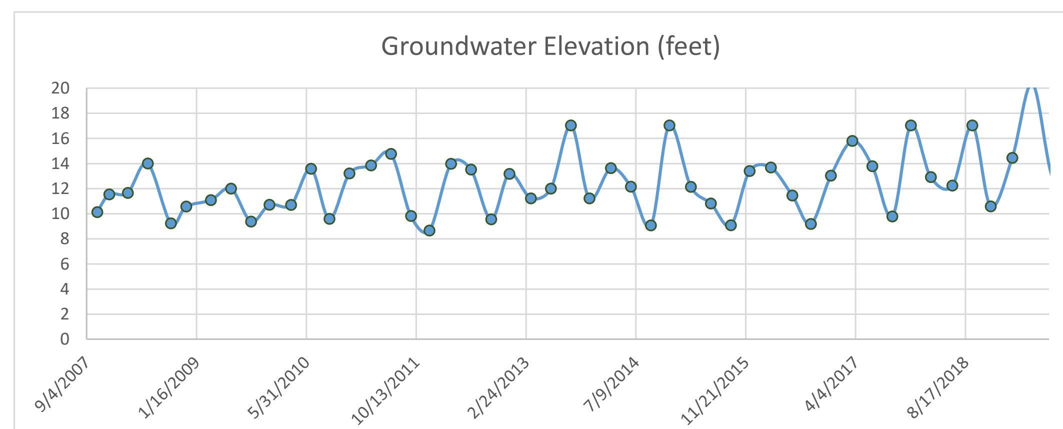

Tetrachloroethylene (PCE)
0
1
2
3
4
5
9/4/2007
9/3/2008
9/3/2009
9/3/2010
9/3/2011
9/2/2012
9/2/2013
9/2/2014
9/2/2015
9/1/2016
9/1/2017
9/1/2018
9/1/2019
8/31/2020
8/31/2021
PCE (µg/L)
PCE CUL (µg/L)

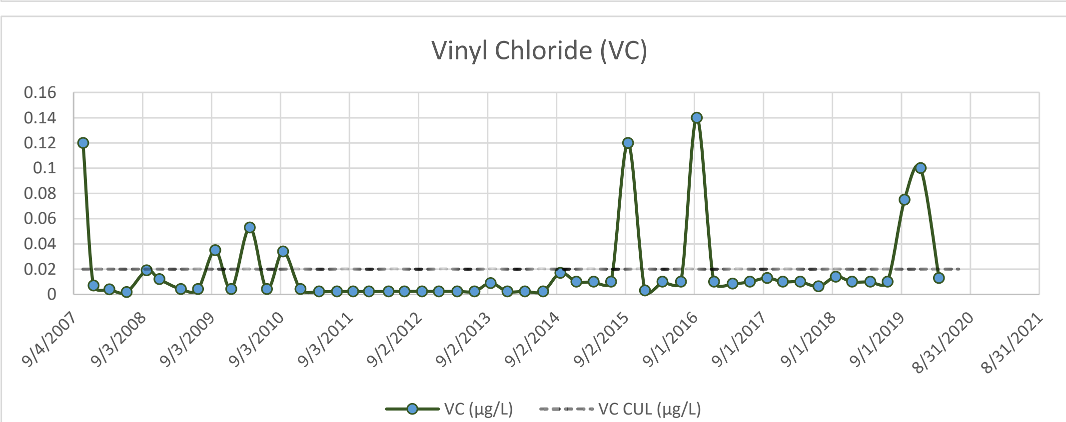

1,4-Dioxane
0
1
2
3
4
5
6
9/4/2007
9/3/2008
9/3/2009
9/3/2010
9/3/2011
9/2/2012
9/2/2013
9/2/2014
9/2/2015
9/1/2016
9/1/2017
9/1/2018
9/1/2019
8/31/2020
8/31/2021
1,4-Dioxane (µg/L)
1,4-D CUL (µg/L)


Trichloroethylene (TCE)
0
0.2
0.4
0.6
0.8
1
1.2
9/4/2007
9/3/2008
9/3/2009
9/3/2010
9/3/2011
9/2/2012
9/2/2013
9/2/2014
9/2/2015
9/1/2016
9/1/2017
9/1/2018
9/1/2019
8/31/2020
8/31/2021
TCE (µg/L)
TCE CUL (µg/L)

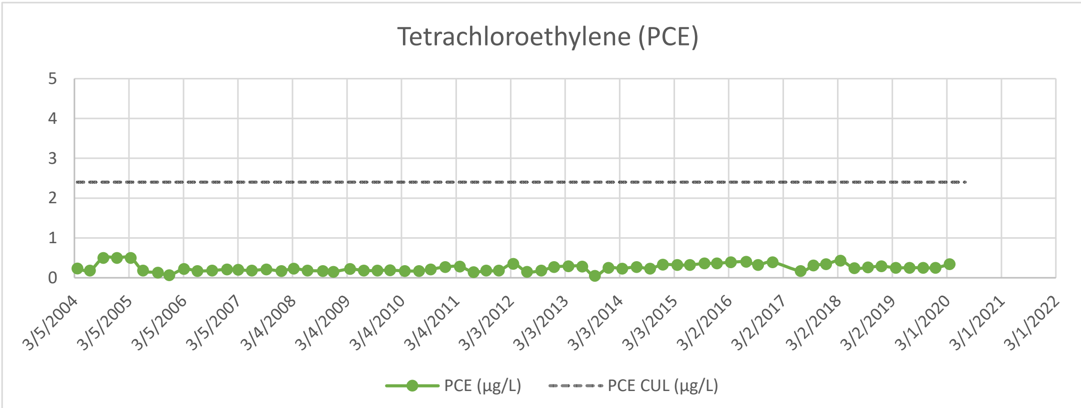

Arsenic
0
0.001
0.002
0.003
0.004
0.005
0.006
0.007
0.008
0.009
9/4/2007
1/16/2009
5/31/2010
10/13/2011
2/24/2013
7/9/2014
11/21/2015
4/4/2017
8/17/2018
Arsenic (mg/L)
Arsenic CUL (mg/L)

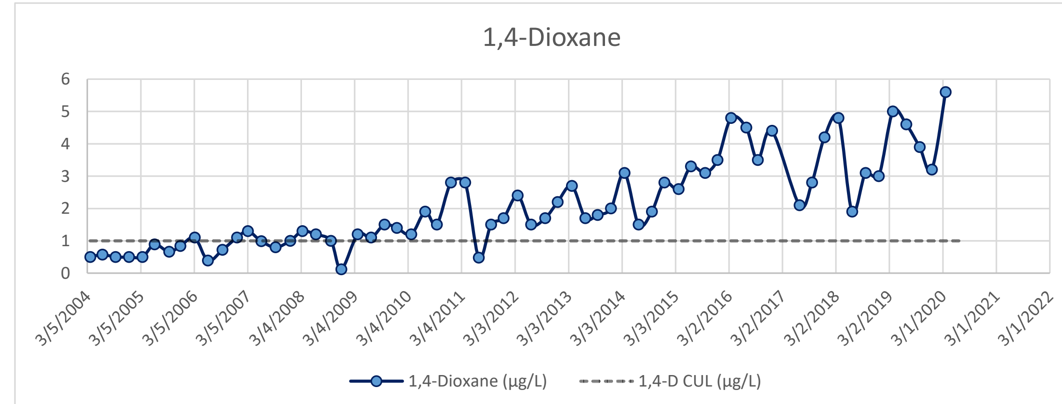

cis-1,2-Dichloroethene (cis-1,2-DCE) (µg/L)
0
2
4
6
8
10
12
14
16
18
9/4/2007
9/3/2008
9/3/2009
9/3/2010
9/3/2011
9/2/2012
9/2/2013
9/2/2014
9/2/2015
9/1/2016
9/1/2017
9/1/2018
9/1/2019
8/31/2020
8/31/2021
cis-1,2-DCE (µg/L)
CIS CUL (µg/L)

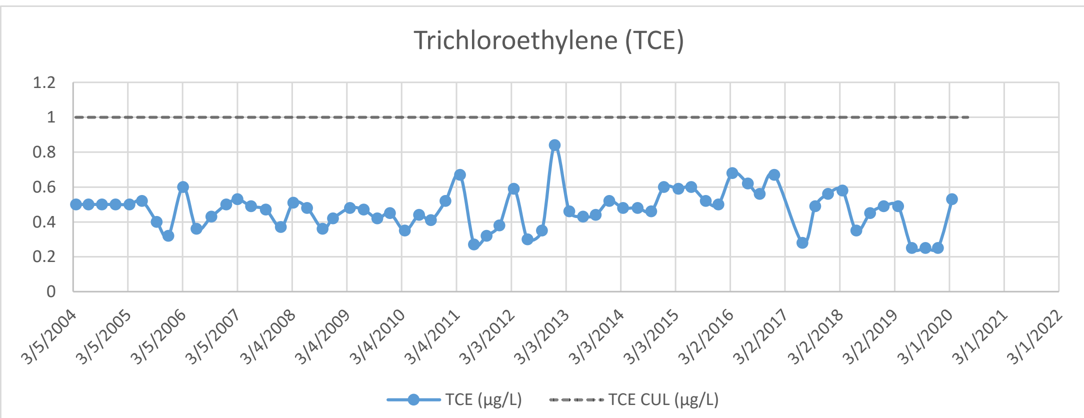

Groundwater Elevation (feet)
0
2
4
6
8
10
12
14
16
18
20
9/4/2007
1/16/2009
5/31/2010
10/13/2011
2/24/2013
7/9/2014
11/21/2015
4/4/2017
8/17/2018

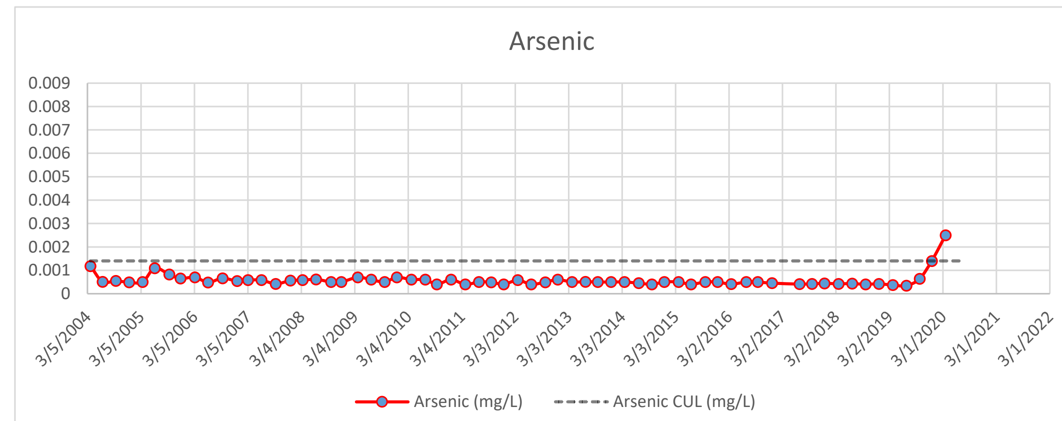

Vinyl Chloride (VC)
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
9/4/2007
9/3/2008
9/3/2009
9/3/2010
9/3/2011
9/2/2012
9/2/2013
9/2/2014
9/2/2015
9/1/2016
9/1/2017
9/1/2018
9/1/2019
8/31/2020
8/31/2021
VC (µg/L)
VC CUL (µg/L)

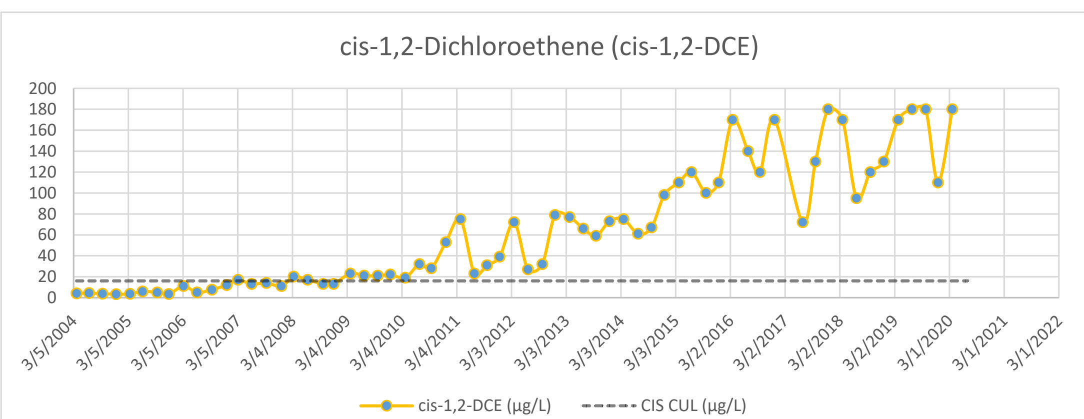
MC-15D

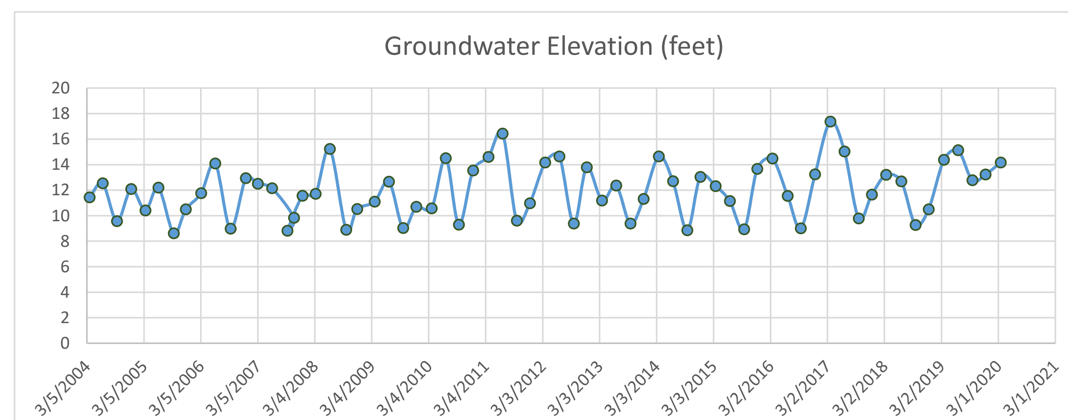

Tetrachloroethylene (PCE)
5
4
3
2
1
0
3/5/2004 3/5/2005 3/5/2006 3/5/2007 3/4/2008 3/4/2009 3/4/2010 3/4/2011 3/3/2012 3/3/2013 3/3/2014 3/3/2015 3/2/2016 3/2/2017 3/2/2018 3/2/2019 3/1/2020 3/1/2021 3/1/2022
PCE (µg/L)
PCE CUL (µg/L)

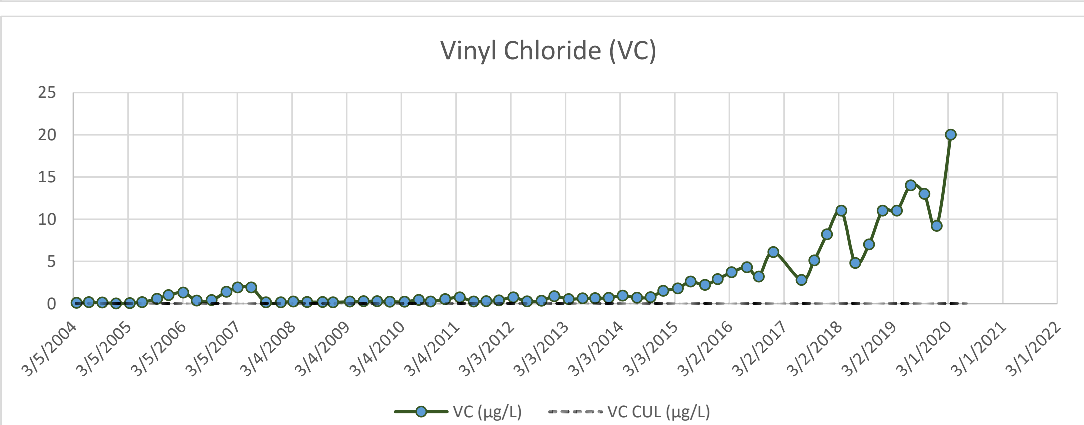

1,4-Dioxane
6
5
4
3
2
1
0
3/5/2004 3/5/2005 3/5/2006 3/5/2007 3/4/2008 3/4/2009 3/4/2010 3/4/2011 3/3/2012 3/3/2013 3/3/2014 3/3/2015 3/2/2016 3/2/2017 3/2/2018 3/2/2019 3/1/2020 3/1/2021 3/1/2022
1,4-Dioxane (µg/L)
1,4-D CUL (µg/L)


Trichloroethylene (TCE)
1.2
1
0.8
0.6
0.4
0.2
0
3/5/2004 3/5/2005 3/5/2006 3/5/2007 3/4/2008 3/4/2009 3/4/2010 3/4/2011 3/3/2012 3/3/2013 3/3/2014 3/3/2015 3/2/2016 3/2/2017 3/2/2018 3/2/2019 3/1/2020 3/1/2021 3/1/2022
TCE (µg/L)
TCE CUL (µg/L)

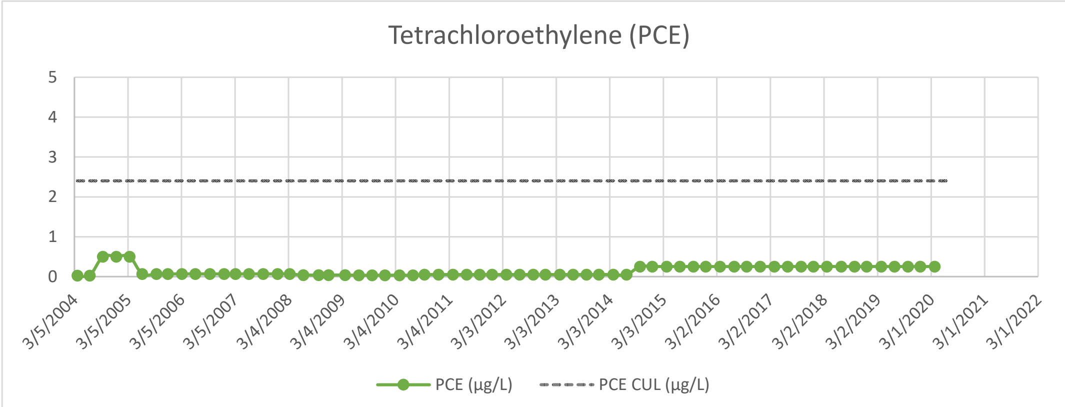

Arsenic
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
3/5/2004 3/5/2005 3/5/2006 3/5/2007 3/4/2008 3/4/2009 3/4/2010 3/4/2011 3/3/2012 3/3/2013 3/3/2014 3/3/2015 3/2/2016 3/2/2017 3/2/2018 3/2/2019 3/1/2020 3/1/2021 3/1/2022
Arsenic (mg/L)
Arsenic CUL (mg/L)

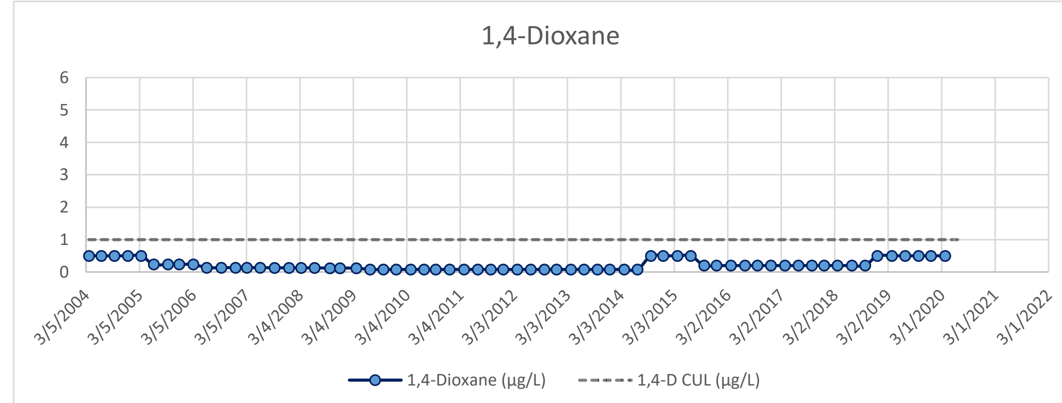

cis-1,2-Dichloroethene (cis-1,2-DCE)
200
180
160
140
120
100
80
60
40
20
0
3/5/2004 3/5/2005 3/5/2006 3/5/2007 3/4/2008 3/4/2009 3/4/2010 3/4/2011 3/3/2012 3/3/2013 3/3/2014 3/3/2015 3/2/2016 3/2/2017 3/2/2018 3/2/2019 3/1/2020 3/1/2021 3/1/2022
cis-1,2-DCE (µg/L)
CIS CUL (µg/L)

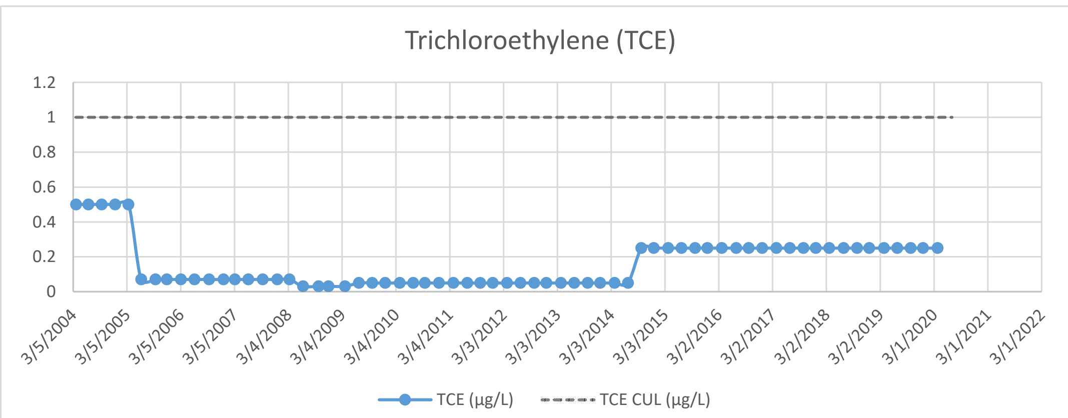

Groundwater Elevation (feet)
20
18
16
14
12
10
8
6
4
2
0
3/5/2004 3/5/2005 3/5/2006 3/5/2007 3/4/2008 3/4/2009 3/4/2010 3/4/2011 3/3/2012 3/3/2013 3/3/2014 3/3/2015 3/2/2016 3/2/2017 3/2/2018 3/2/2019 3/1/2020 3/1/2021

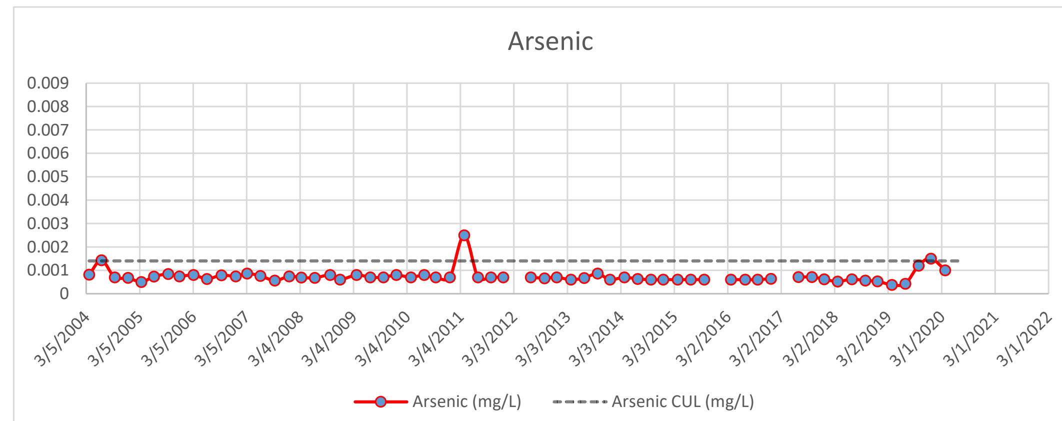

Vinyl Chloride (VC)
25
20
15
10
5
0
3/5/2004 3/5/2005 3/5/2006 3/5/2007 3/4/2008 3/4/2009 3/4/2010 3/4/2011 3/3/2012 3/3/2013 3/3/2014 3/3/2015 3/2/2016 3/2/2017 3/2/2018 3/2/2019 3/1/2020 3/1/2021 3/1/2022
VC (µg/L)
VC CUL (µg/L)

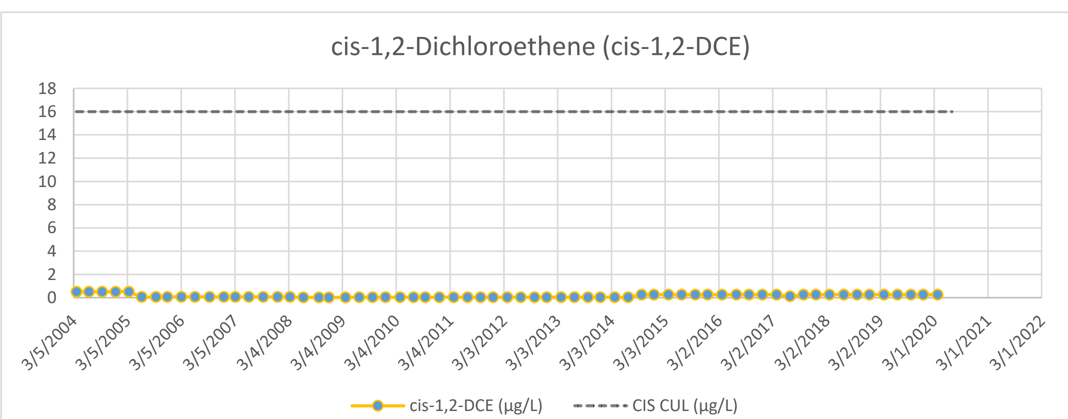
MC-17D

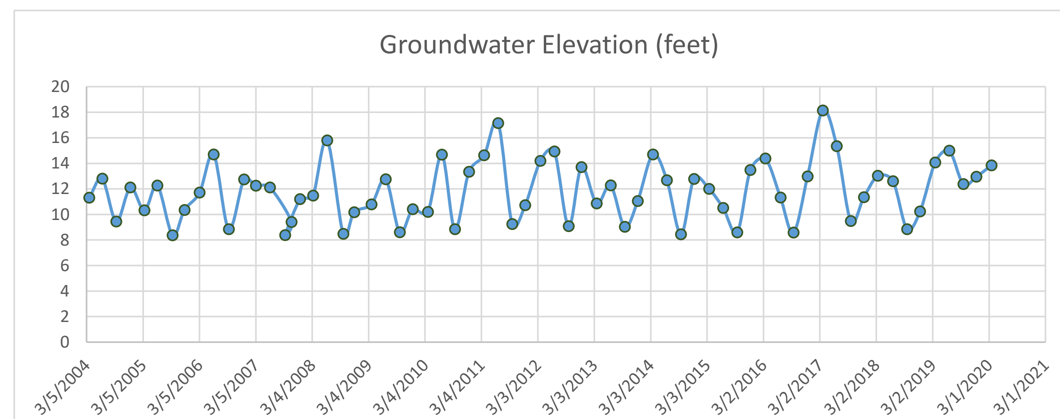

Tetrachloroethylene (PCE)
PCE (µg/L)
PCE CUL (µg/L)

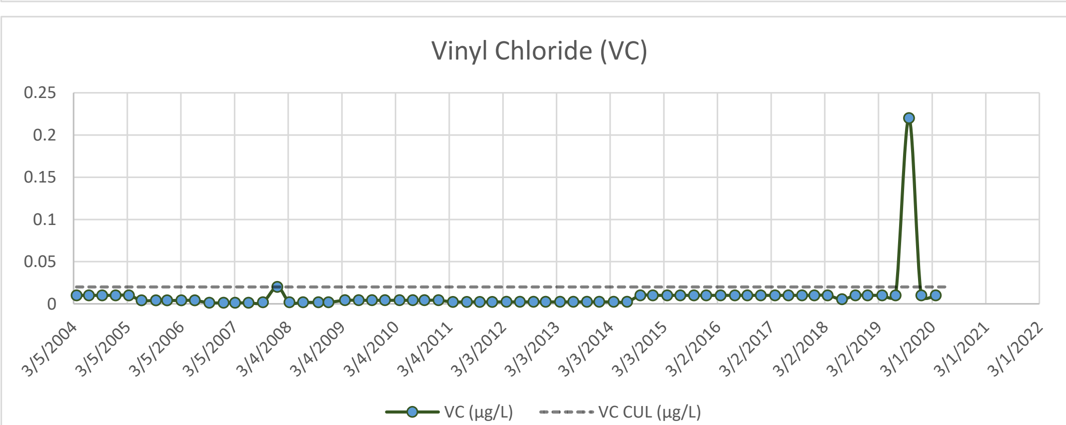

1,4-Dioxane
1,4-Dioxane (µg/L)
1,4-D CUL (µg/L)


Trichloroethylene (TCE)
TCE (µg/L)
TCE CUL (µg/L)

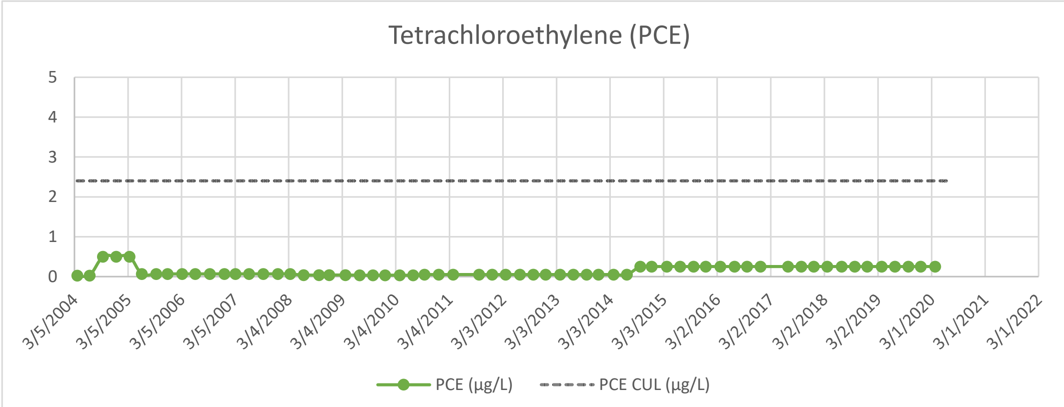

Arsenic
Arsenic (mg/L)
Arsenic CUL (mg/L)

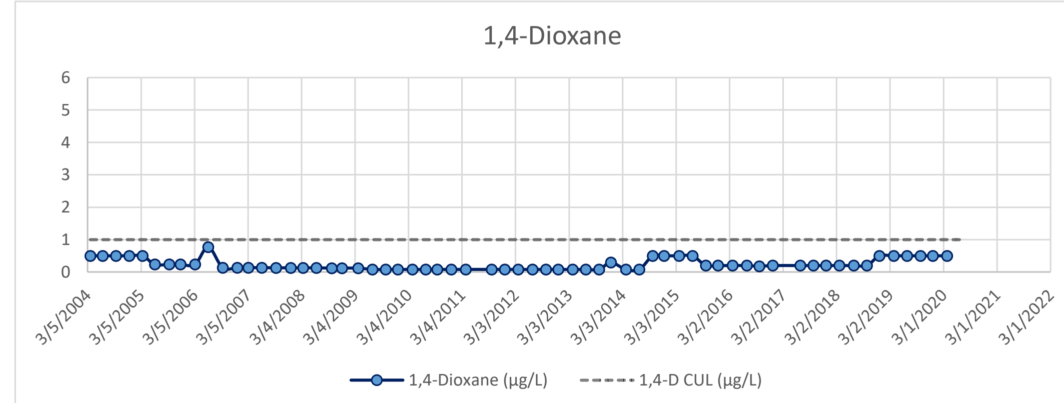

cis-1,2-Dichloroethene (cis-1,2-DCE)
cis-1,2-DCE (µg/L)
CIS CUL (µg/L)

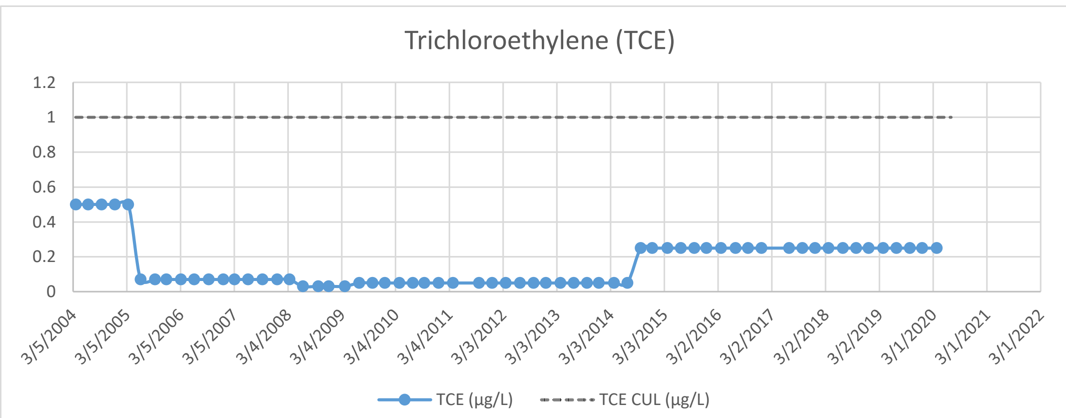

Groundwater Elevation (feet)

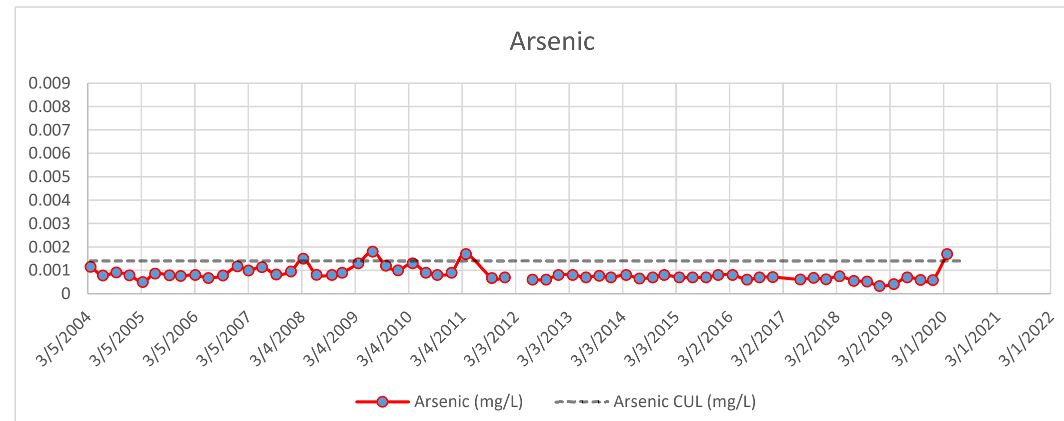

Vinyl Chloride (VC)
VC (µg/L)
VC CUL (µg/L)

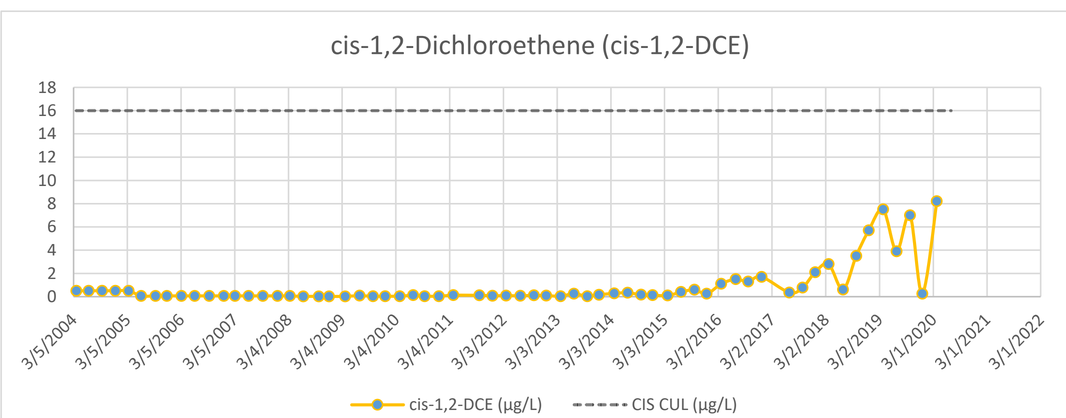
MC-19D

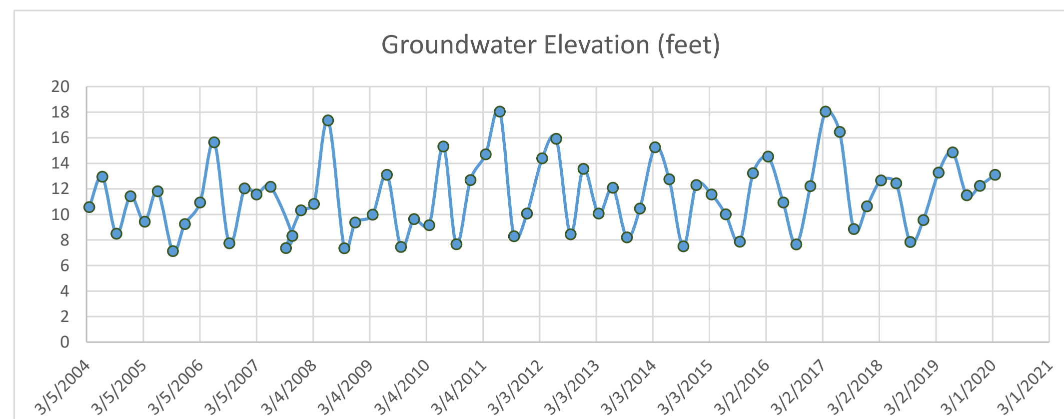

Tetrachloroethylene (PCE)
5
4
3
2
1
0
3/5/2004 3/5/2005 3/5/2006 3/5/2007 3/4/2008 3/4/2009 3/4/2010 3/4/2011 3/3/2012 3/3/2013 3/3/2014 3/3/2015 3/2/2016 3/2/2017 3/2/2018 3/2/2019 3/1/2020 3/1/2021 3/1/2022
PCE (µg/L)
PCE CUL (µg/L)

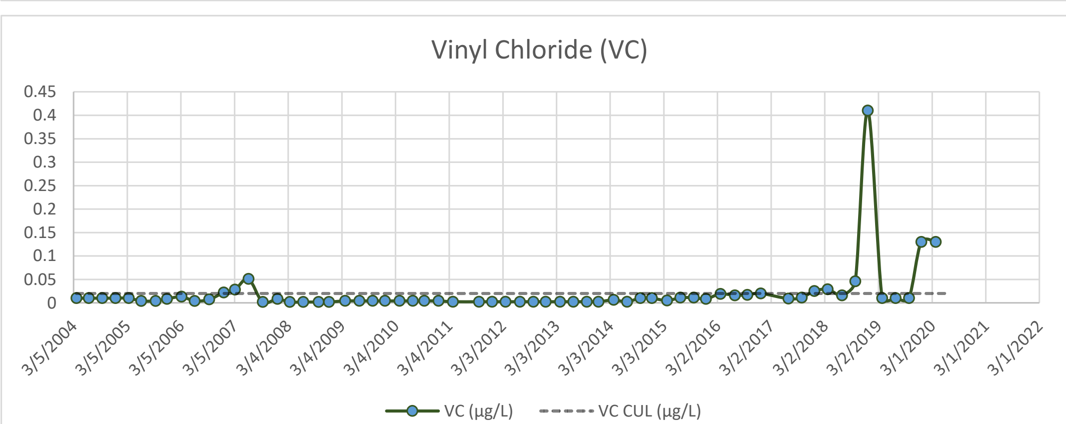

1,4-Dioxane
6
5
4
3
2
1
0
3/5/2004 3/5/2005 3/5/2006 3/5/2007 3/4/2008 3/4/2009 3/4/2010 3/4/2011 3/3/2012 3/3/2013 3/3/2014 3/3/2015 3/2/2016 3/2/2017 3/2/2018 3/2/2019 3/1/2020 3/1/2021 3/1/2022
1,4-Dioxane (µg/L)
1,4-D CUL (µg/L)


Trichloroethylene (TCE)
1.2
1
0.8
0.6
0.4
0.2
0
3/5/2004 3/5/2005 3/5/2006 3/5/2007 3/4/2008 3/4/2009 3/4/2010 3/4/2011 3/3/2012 3/3/2013 3/3/2014 3/3/2015 3/2/2016 3/2/2017 3/2/2018 3/2/2019 3/1/2020 3/1/2021 3/1/2022
TCE (µg/L)
TCE CUL (µg/L)

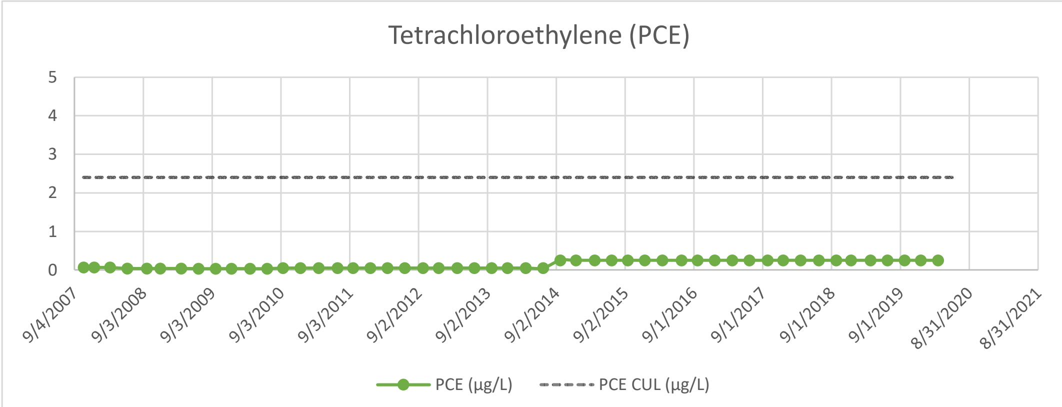

Arsenic
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
3/5/2004 3/5/2005 3/5/2006 3/5/2007 3/4/2008 3/4/2009 3/4/2010 3/4/2011 3/3/2012 3/3/2013 3/3/2014 3/3/2015 3/2/2016 3/2/2017 3/2/2018 3/2/2019 3/1/2020 3/1/2021 3/1/2022
Arsenic (mg/L)
Arsenic CUL (mg/L)


cis-1,2-Dichloroethene (cis-1,2-DCE)
18
16
14
12
10
8
6
4
2
0
3/5/2004 3/5/2005 3/5/2006 3/5/2007 3/4/2008 3/4/2009 3/4/2010 3/4/2011 3/3/2012 3/3/2013 3/3/2014 3/3/2015 3/2/2016 3/2/2017 3/2/2018 3/2/2019 3/1/2020 3/1/2021 3/1/2022
cis-1,2-DCE (µg/L)
CIS CUL (µg/L)

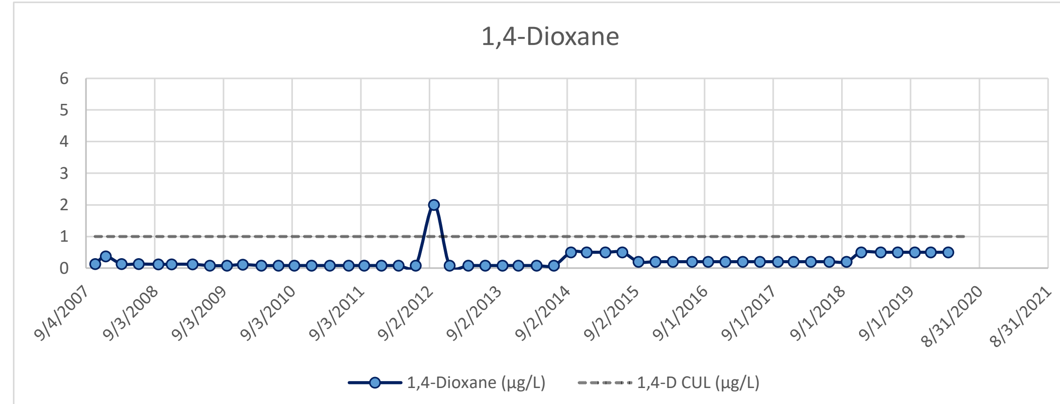

Groundwater Elevation (feet)
20
18
16
14
12
10
8
6
4
2
0
3/5/2004 3/5/2005 3/5/2006 3/5/2007 3/4/2008 3/4/2009 3/4/2010 3/4/2011 3/3/2012 3/3/2013 3/3/2014 3/3/2015 3/2/2016 3/2/2017 3/2/2018 3/2/2019 3/1/2020 3/1/2021


Vinyl Chloride (VC)
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
3/5/2004 3/5/2005 3/5/2006 3/5/2007 3/4/2008 3/4/2009 3/4/2010 3/4/2011 3/3/2012 3/3/2013 3/3/2014 3/3/2015 3/2/2016 3/2/2017 3/2/2018 3/2/2019 3/1/2020 3/1/2021 3/1/2022
VC (µg/L)
VC CUL (µg/L)

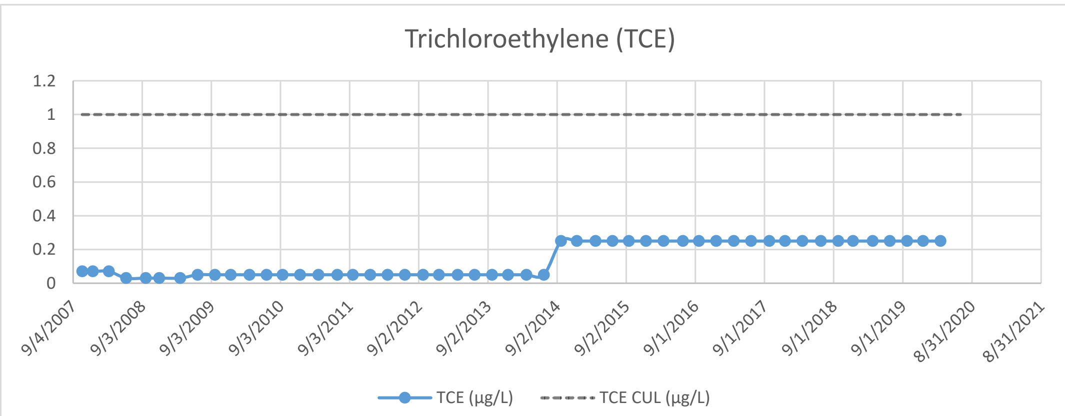
MC-20D



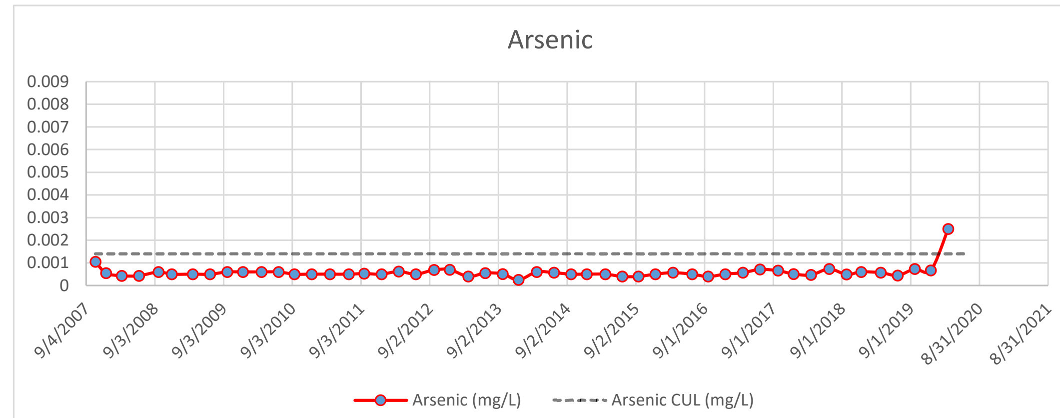
Tetrachloroethylene (PCE)
5
4
3
2
1
0
9/4/2007 9/3/2008 9/3/2009 9/3/2010 9/3/2011 9/2/2012 9/2/2013 9/2/2014 9/2/2015 9/1/2016 9/1/2017 9/1/2018 9/1/2019 8/31/2020 8/31/2021
PCE (µg/L)
PCE CUL (µg/L)



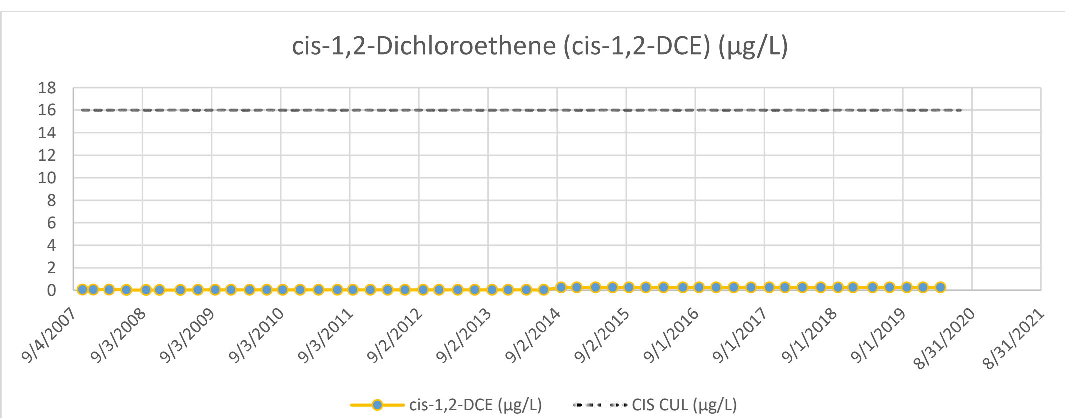
1,4-Dioxane
6
5
4
3
2
1
0
9/4/2007 9/3/2008 9/3/2009 9/3/2010 9/3/2011 9/2/2012 9/2/2013 9/2/2014 9/2/2015 9/1/2016 9/1/2017 9/1/2018 9/1/2019 8/31/2020 8/31/2021
1,4-Dioxane (µg/L)
1,4-D CUL (µg/L)



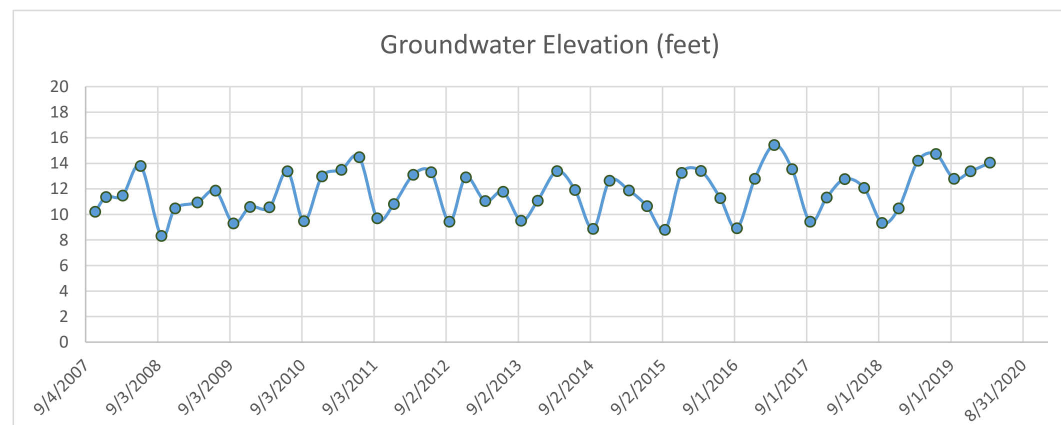
Trichloroethylene (TCE)
1.2
1
0.8
0.6
0.4
0.2
0
9/4/2007 9/3/2008 9/3/2009 9/3/2010 9/3/2011 9/2/2012 9/2/2013 9/2/2014 9/2/2015 9/1/2016 9/1/2017 9/1/2018 9/1/2019 8/31/2020 8/31/2021
TCE (µg/L)
TCE CUL (µg/L)



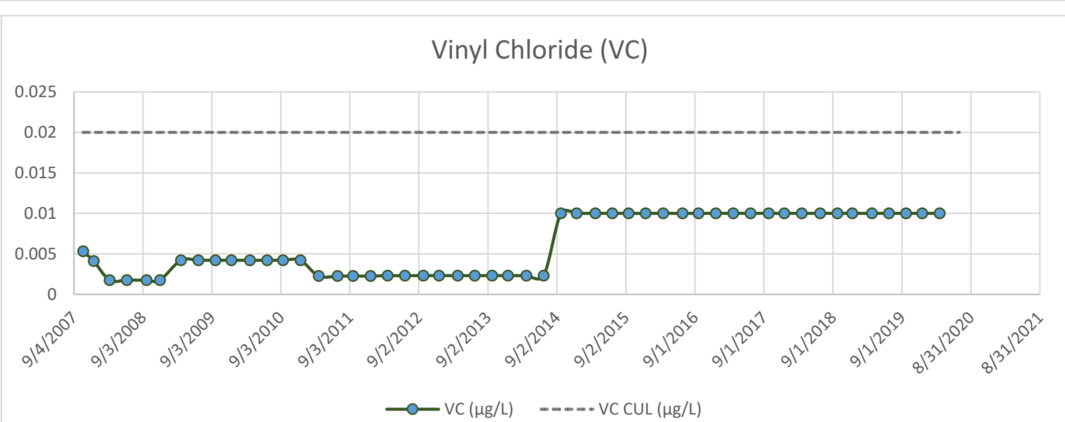
Arsenic
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
9/4/2007 9/3/2008 9/3/2009 9/3/2010 9/3/2011 9/2/2012 9/2/2013 9/2/2014 9/2/2015 9/1/2016 9/1/2017 9/1/2018 9/1/2019 8/31/2020 8/31/2021
Arsenic (mg/L)
Arsenic CUL (mg/L)



cis-1,2-Dichloroethene (cis-1,2-DCE) (µg/L)
18
16
14
12
10
8
6
4
2
0
9/4/2007 9/3/2008 9/3/2009 9/3/2010 9/3/2011 9/2/2012 9/2/2013 9/2/2014 9/2/2015 9/1/2016 9/1/2017 9/1/2018 9/1/2019 8/31/2020 8/31/2021
cis-1,2-DCE (µg/L)
CIS CUL (µg/L)

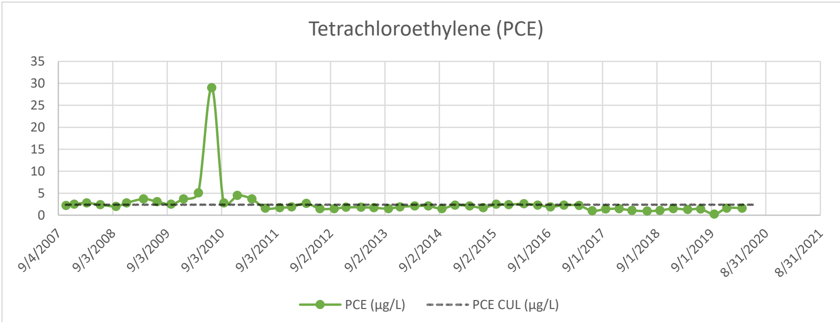


Groundwater Elevation (feet)
20
18
16
14
12
10
8
6
4
2
0
9/4/2007 9/3/2008 9/3/2009 9/3/2010 9/3/2011 9/2/2012 9/2/2013 9/2/2014 9/2/2015 9/1/2016 9/1/2017 9/1/2018 9/1/2019 8/31/2020

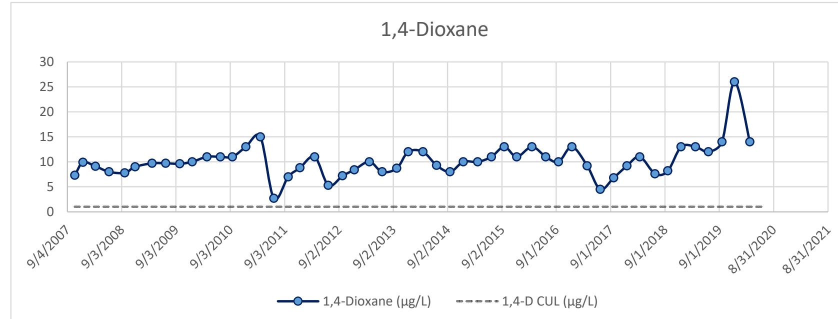


Vinyl Chloride (VC)
0.025
0.02
0.015
0.01
0.005
0
9/4/2007 9/3/2008 9/3/2009 9/3/2010 9/3/2011 9/2/2012 9/2/2013 9/2/2014 9/2/2015 9/1/2016 9/1/2017 9/1/2018 9/1/2019 8/31/2020 8/31/2021
VC (µg/L)
VC CUL (µg/L)

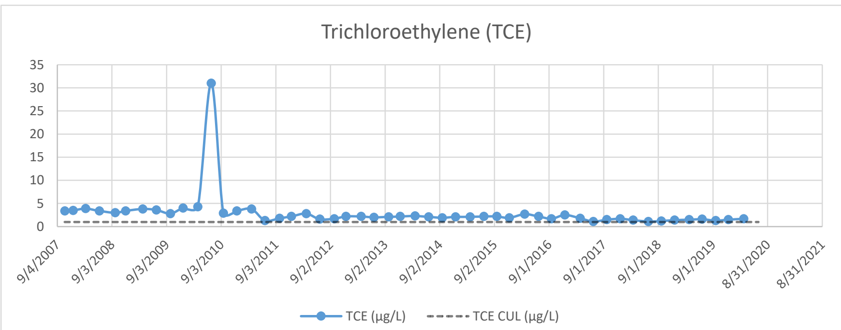
MC-24D



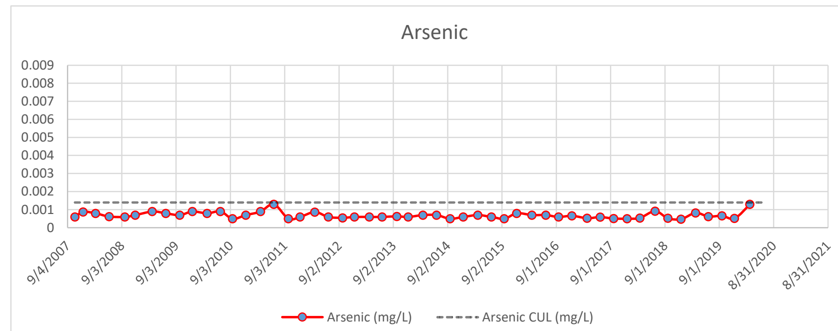
Tetrachloroethylene (PCE)
35
30
25
20
15
10
5
0
9/4/2007
9/3/2008
9/3/2009
9/3/2010
9/3/2011
9/2/2012
9/2/2013
9/2/2014
9/2/2015
9/1/2016
9/1/2017
9/1/2018
9/1/2019
8/31/2020
8/31/2021
PCE (µg/L)
PCE CUL (µg/L)



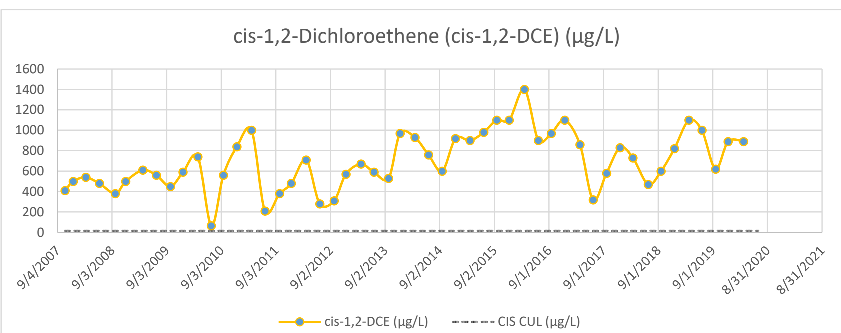
1,4-Dioxane
30
25
20
15
10
5
0
9/4/2007
9/3/2008
9/3/2009
9/3/2010
9/3/2011
9/2/2012
9/2/2013
9/2/2014
9/2/2015
9/1/2016
9/1/2017
9/1/2018
9/1/2019
8/31/2020
8/31/2021
1,4-Dioxane (µg/L)
1,4-D CUL (µg/L)



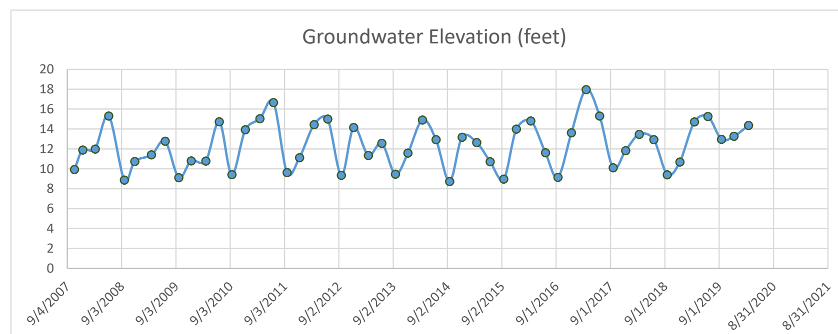
Trichloroethylene (TCE)
35
30
25
20
15
10
5
0
9/4/2007
9/3/2008
9/3/2009
9/3/2010
9/3/2011
9/2/2012
9/2/2013
9/2/2014
9/2/2015
9/1/2016
9/1/2017
9/1/2018
9/1/2019
8/31/2020
8/31/2021
TCE (µg/L)
TCE CUL (µg/L)



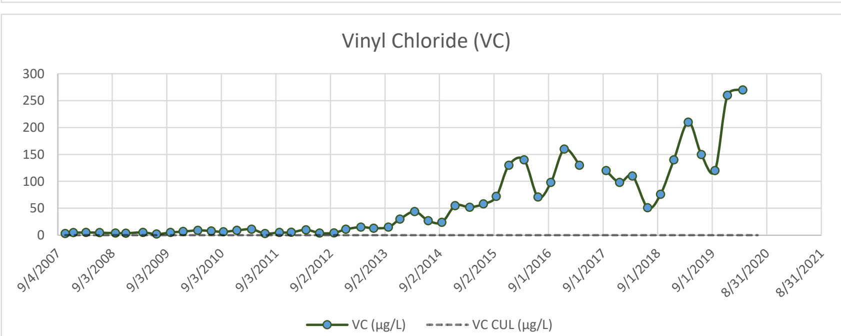
Arsenic
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
9/4/2007
9/3/2008
9/3/2009
9/3/2010
9/3/2011
9/2/2012
9/2/2013
9/2/2014
9/2/2015
9/1/2016
9/1/2017
9/1/2018
9/1/2019
8/31/2020
8/31/2021
Arsenic (mg/L)
Arsenic CUL (mg/L)



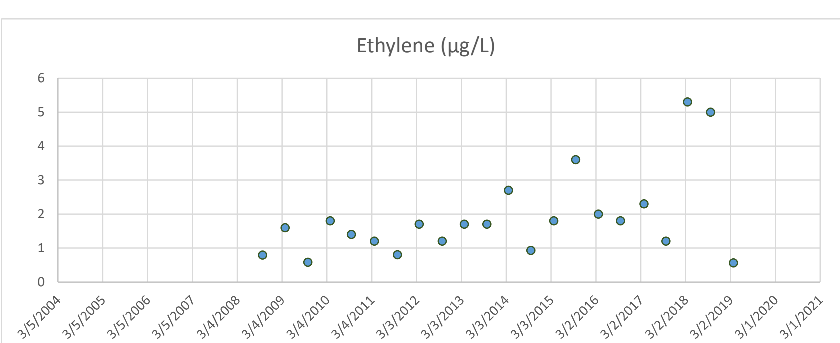
cis-1,2-Dichloroethene (cis-1,2-DCE) (µg/L)
1600
1400
1200
1000
800
600
400
200
0
9/4/2007
9/3/2008
9/3/2009
9/3/2010
9/3/2011
9/2/2012
9/2/2013
9/2/2014
9/2/2015
9/1/2016
9/1/2017
9/1/2018
9/1/2019
8/31/2020
8/31/2021
cis-1,2-DCE (µg/L)
CIS CUL (µg/L)



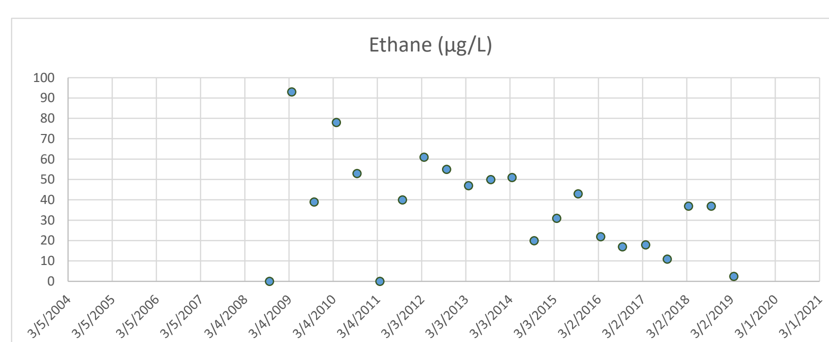
Groundwater Elevation (feet)
20
18
16
14
12
10
8
6
4
2
0
9/4/2007
9/3/2008
9/3/2009
9/3/2010
9/3/2011
9/2/2012
9/2/2013
9/2/2014
9/2/2015
9/1/2016
9/1/2017
9/1/2018
9/1/2019
8/31/2020
8/31/2021



Vinyl Chloride (VC)
300
250
200
150
100
50
0
9/4/2007
9/3/2008
9/3/2009
9/3/2010
9/3/2011
9/2/2012
9/2/2013
9/2/2014
9/2/2015
9/1/2016
9/1/2017
9/1/2018
9/1/2019
8/31/2020
8/31/2021
VC (µg/L)
VC CUL (µg/L)

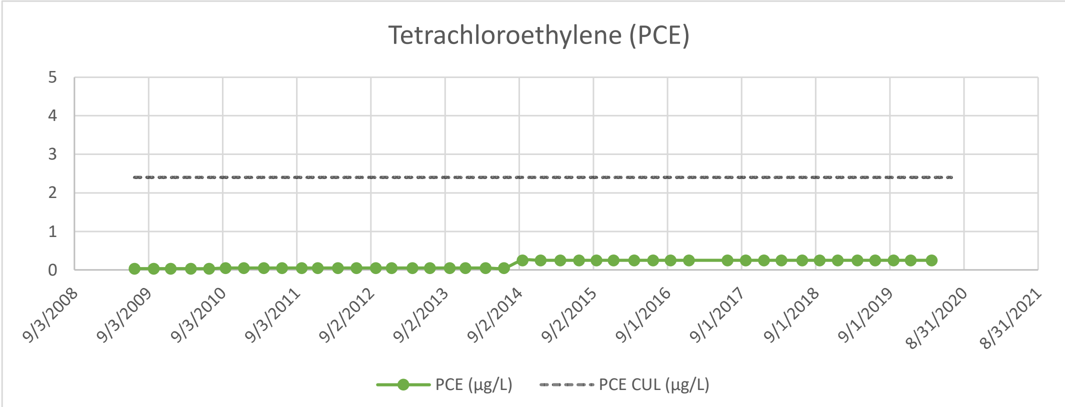


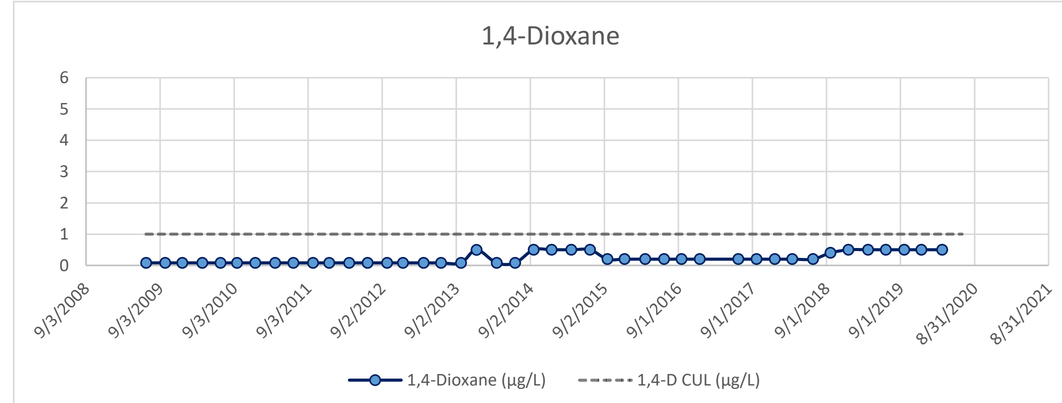
Ethylene (µg/L)
6
5
4
3
2
1
0
3/5/2004
3/5/2005
3/5/2006
3/5/2007
3/4/2008
3/4/2009
3/4/2010
3/4/2011
3/3/2012
3/3/2013
3/3/2014
3/3/2015
3/2/2016
3/2/2017
3/2/2018
3/2/2019
3/1/2020
3/1/2021

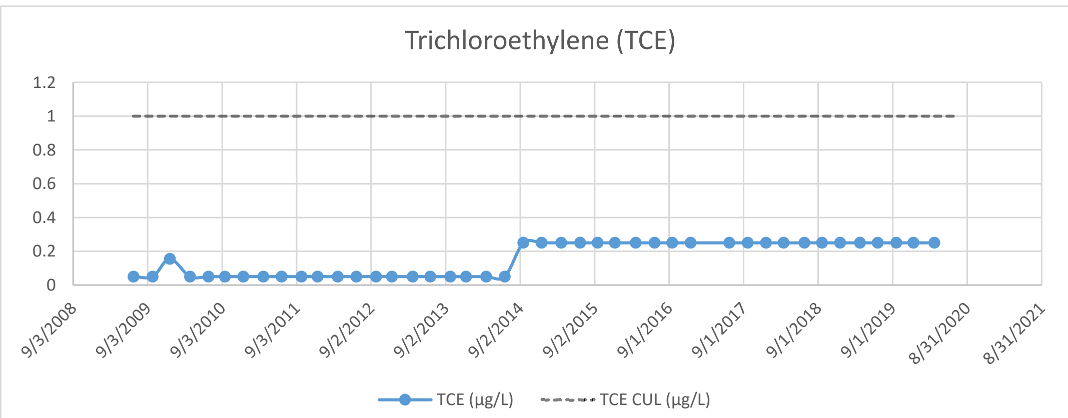


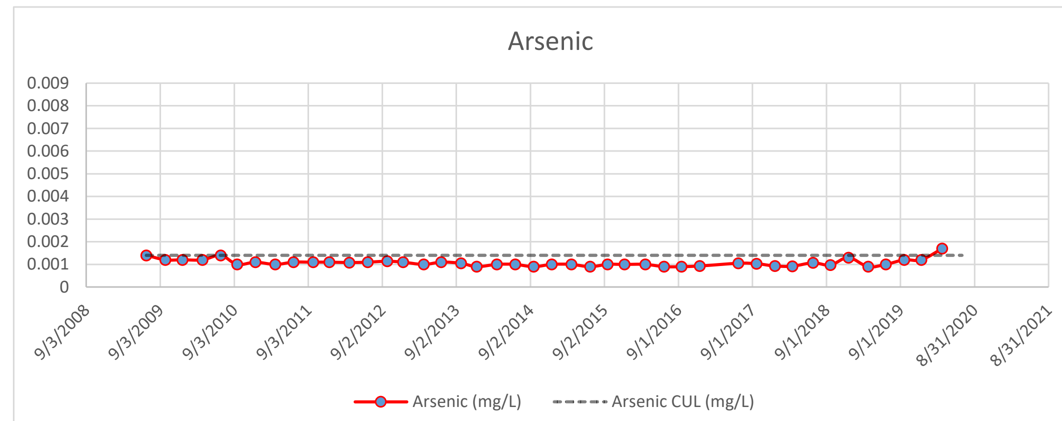
Ethane (µg/L)
100
90
80
70
60
50
40
30
20
10
0
3/5/2004
3/5/2005
3/5/2006
3/5/2007
3/4/2008
3/4/2009
3/4/2010
3/4/2011
3/3/2012
3/3/2013
3/3/2014
3/3/2015
3/2/2016
3/2/2017
3/2/2018
3/2/2019
3/1/2020
3/1/2021

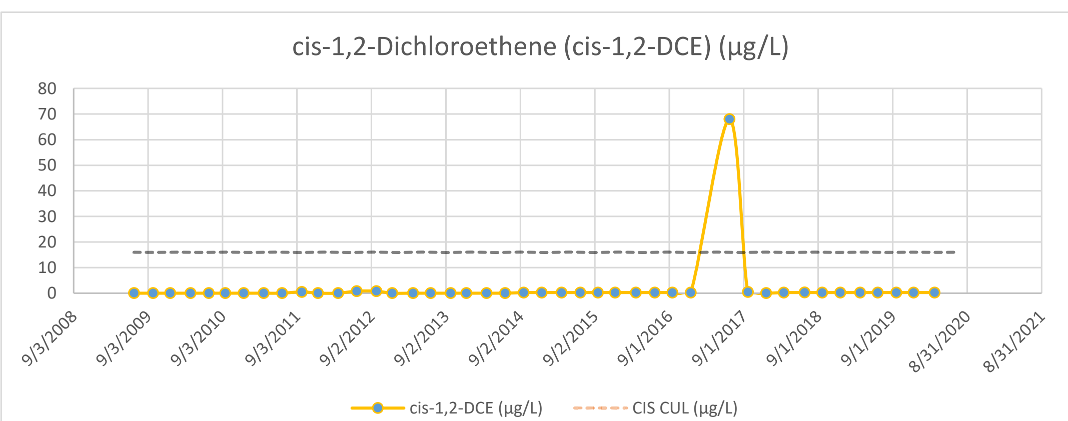
MC-24D2

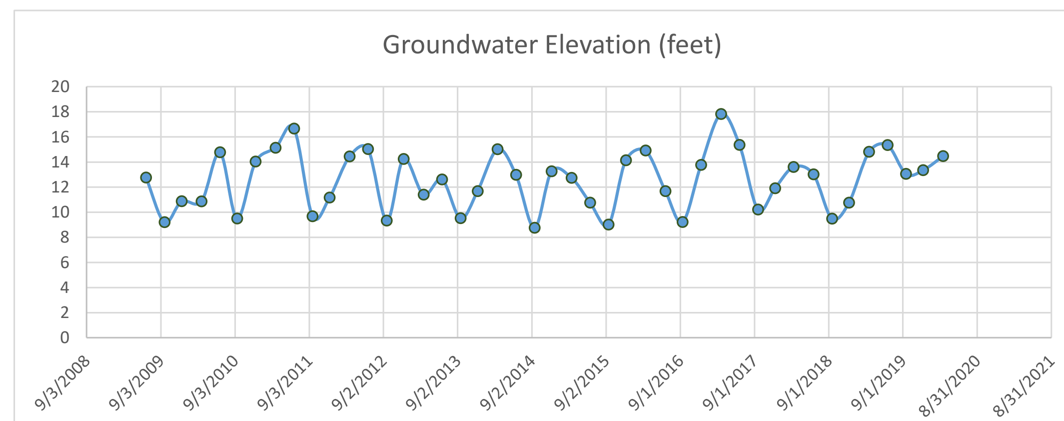

Tetrachloroethylene (PCE)
0
1
2
3
4
5
9/3/2008
9/3/2009
9/3/2010
9/3/2011
9/2/2012
9/2/2013
9/2/2014
9/2/2015
9/1/2016
9/1/2017
9/1/2018
9/1/2019
8/31/2020
8/31/2021
PCE (µg/L)
PCE CUL (µg/L)

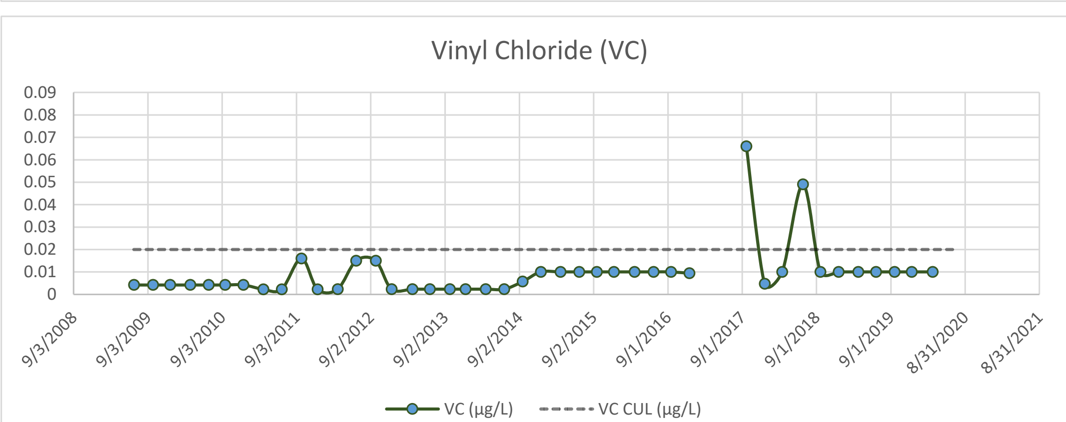

1,4-Dioxane
0
1
2
3
4
5
6
9/3/2008
9/3/2009
9/3/2010
9/3/2011
9/2/2012
9/2/2013
9/2/2014
9/2/2015
9/1/2016
9/1/2017
9/1/2018
9/1/2019
8/31/2020
8/31/2021
1,4-Dioxane (µg/L)
1,4-D CUL (µg/L)


Trichloroethylene (TCE)
0
0.2
0.4
0.6
0.8
1
1.2
9/3/2008
9/3/2009
9/3/2010
9/3/2011
9/2/2012
9/2/2013
9/2/2014
9/2/2015
9/1/2016
9/1/2017
9/1/2018
9/1/2019
8/31/2020
8/31/2021
TCE (µg/L)
TCE CUL (µg/L)

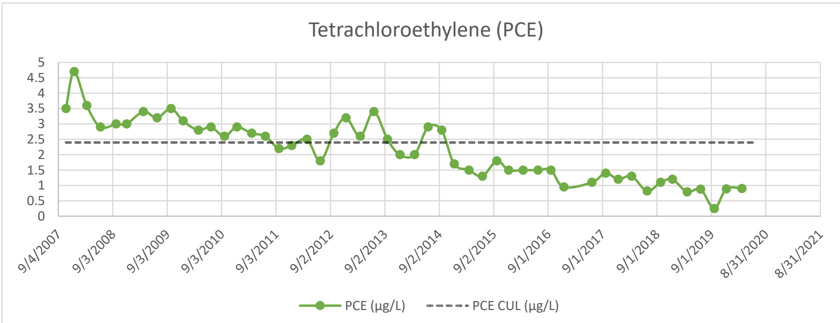

Arsenic
0
0.001
0.002
0.003
0.004
0.005
0.006
0.007
0.008
0.009
9/3/2008
9/3/2009
9/3/2010
9/3/2011
9/2/2012
9/2/2013
9/2/2014
9/2/2015
9/1/2016
9/1/2017
9/1/2018
9/1/2019
8/31/2020
8/31/2021
Arsenic (mg/L)
Arsenic CUL (mg/L)

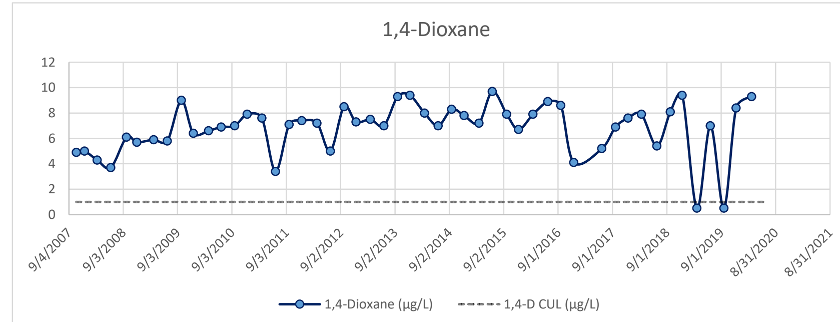

cis-1,2-Dichloroethene (cis-1,2-DCE) (µg/L)
0
10
20
30
40
50
60
70
80
9/3/2008
9/3/2009
9/3/2010
9/3/2011
9/2/2012
9/2/2013
9/2/2014
9/2/2015
9/1/2016
9/1/2017
9/1/2018
9/1/2019
8/31/2020
8/31/2021
cis-1,2-DCE (µg/L)
CIS CUL (µg/L)

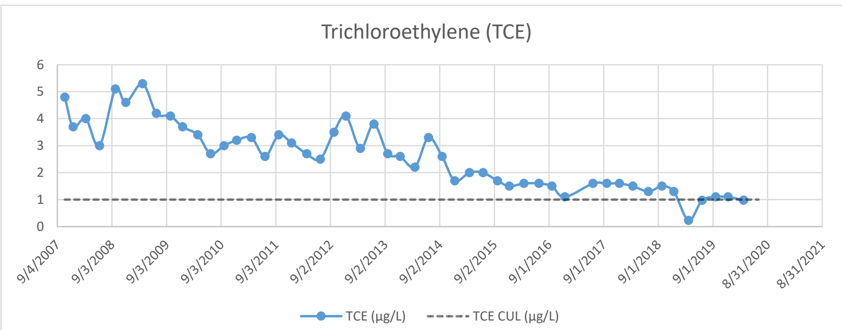

Groundwater Elevation (feet)
0
2
4
6
8
10
12
14
16
18
20
9/3/2008
9/3/2009
9/3/2010
9/3/2011
9/2/2012
9/2/2013
9/2/2014
9/2/2015
9/1/2016
9/1/2017
9/1/2018
9/1/2019
8/31/2020
8/31/2021

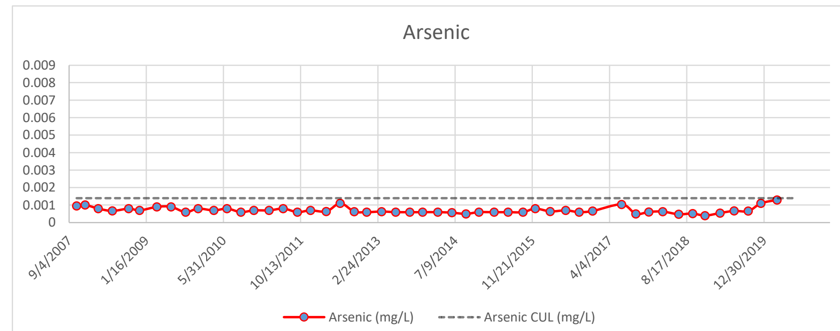

Vinyl Chloride (VC)
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
9/3/2008
9/3/2009
9/3/2010
9/3/2011
9/2/2012
9/2/2013
9/2/2014
9/2/2015
9/1/2016
9/1/2017
9/1/2018
9/1/2019
8/31/2020
8/31/2021
VC (µg/L)
VC CUL (µg/L)

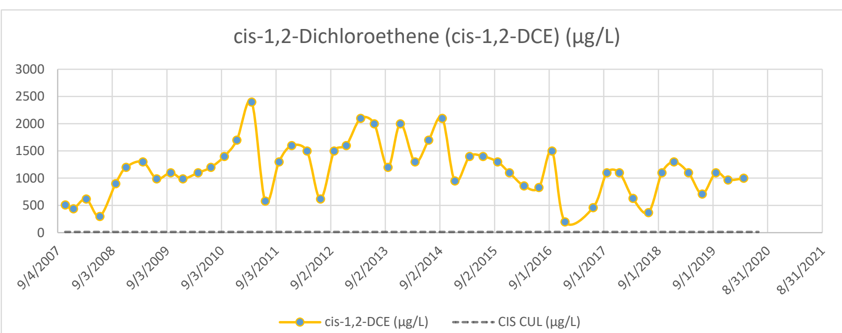
MC-25D

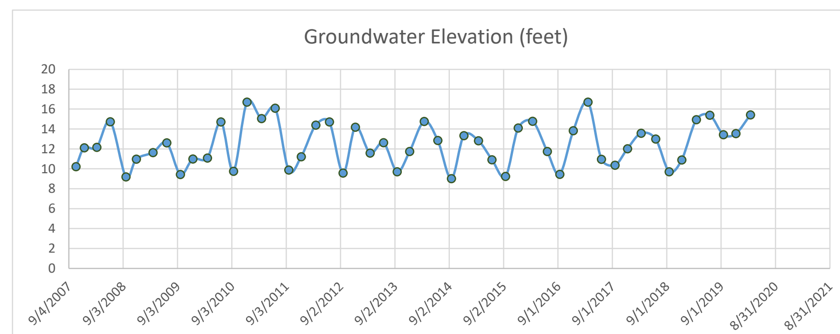

Tetrachloroethylene (PCE)
PCE (µg/L)
PCE CUL (µg/L)

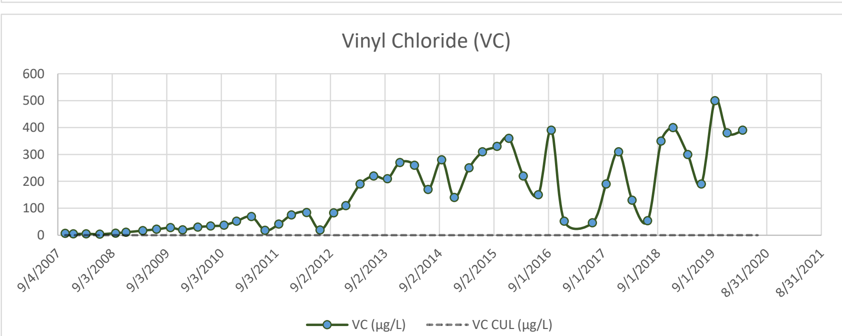

1,4-Dioxane
1,4-Dioxane (µg/L)
1,4-D CUL (µg/L)

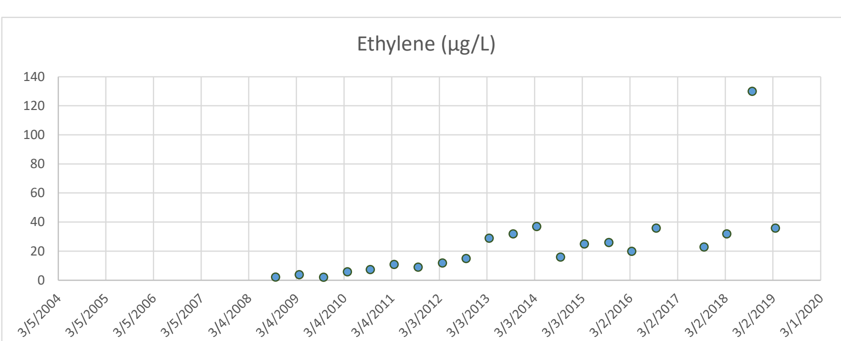

Trichloroethylene (TCE)
TCE (µg/L)
TCE CUL (µg/L)

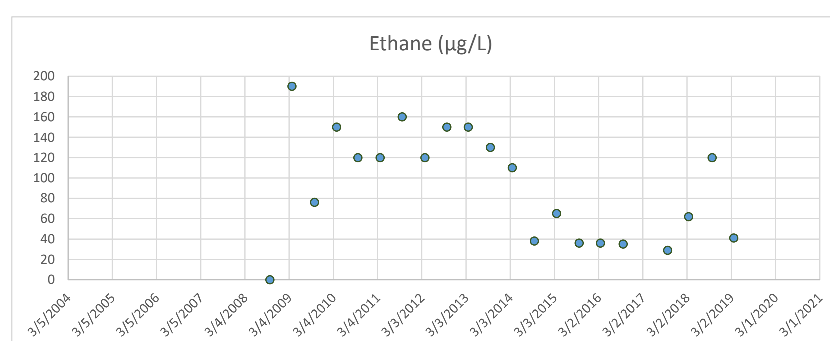

Arsenic
Arsenic (mg/L)
Arsenic CUL (mg/L)


cis-1,2-Dichloroethene (cis-1,2-DCE) (µg/L)
cis-1,2-DCE (µg/L)
CIS CUL (µg/L)

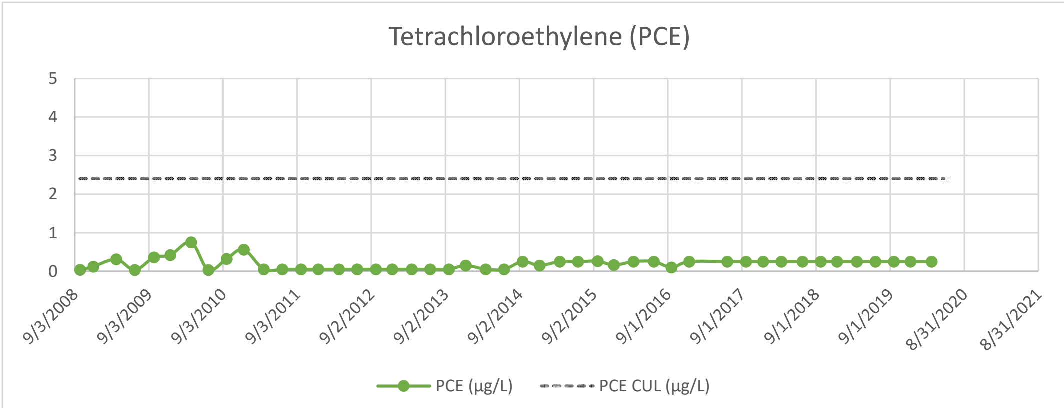

Groundwater Elevation (feet)

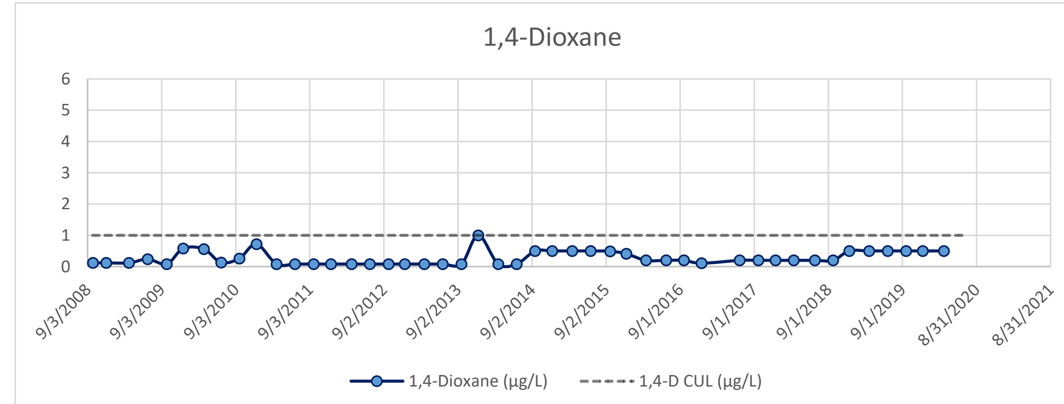

Vinyl Chloride (VC)
VC (µg/L)
VC CUL (µg/L)

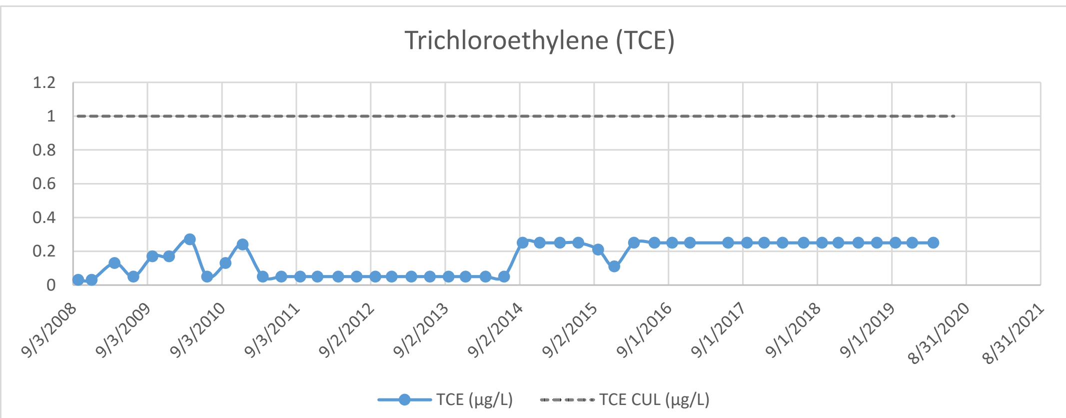

Ethylene (µg/L)

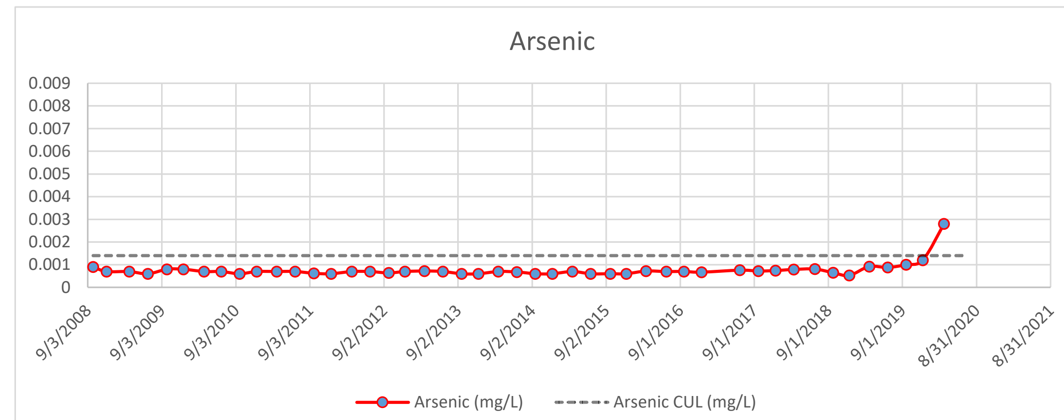

Ethane (µg/L)

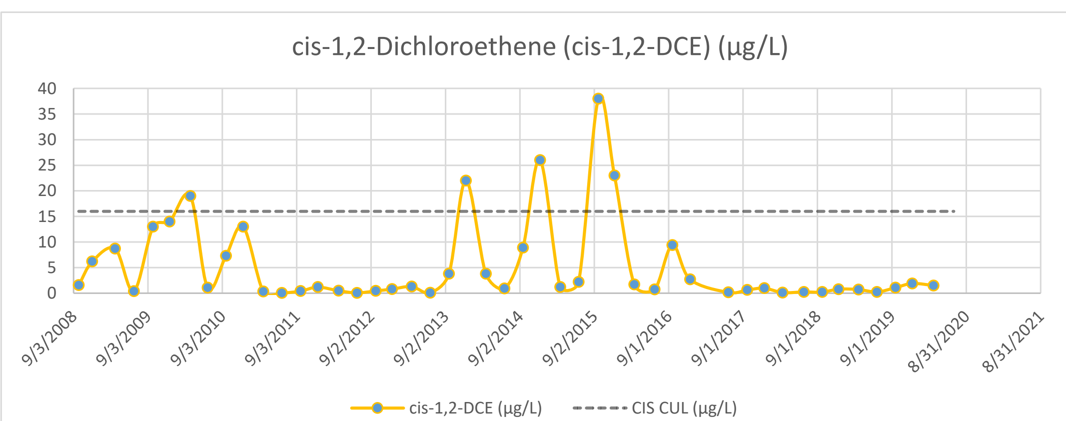
MC-25D2

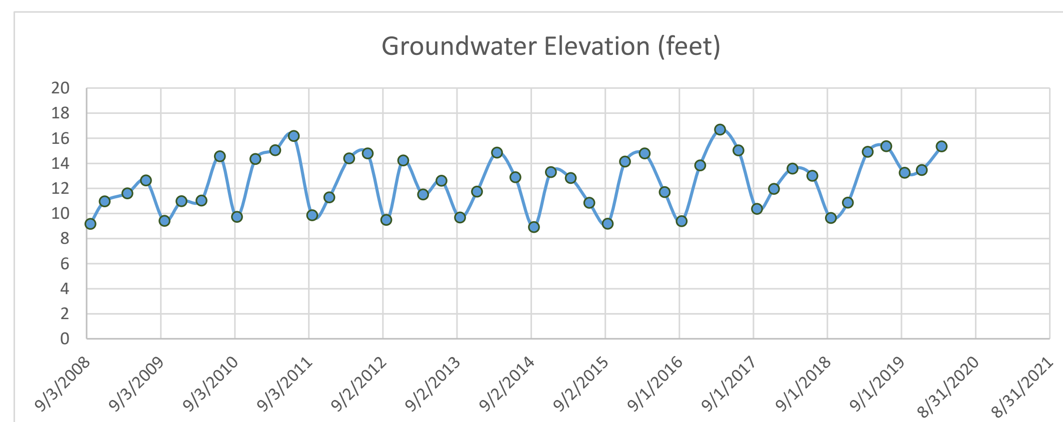

Tetrachloroethylene (PCE)
0
1
2
3
4
5
9/3/2008
9/3/2009
9/3/2010
9/3/2011
9/2/2012
9/2/2013
9/2/2014
9/2/2015
9/1/2016
9/1/2017
9/1/2018
9/1/2019
8/31/2020
8/31/2021
PCE (µg/L)
PCE CUL (µg/L)

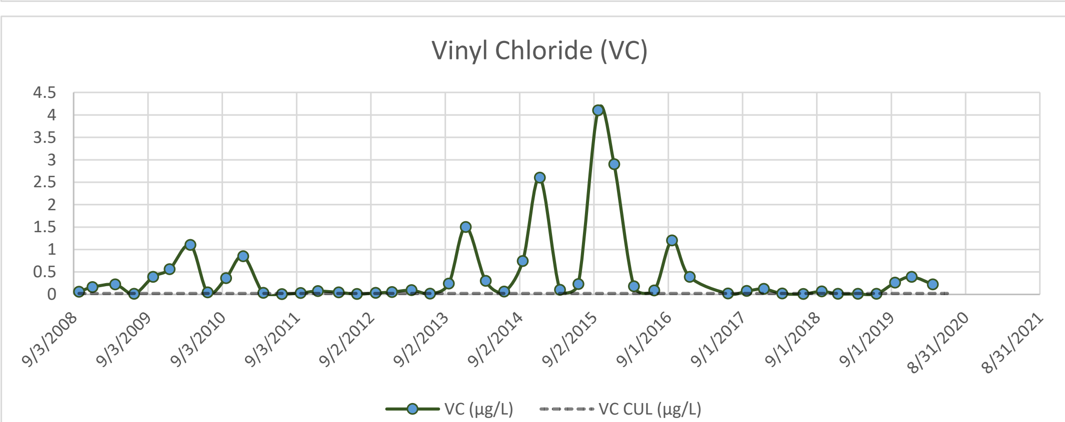

1,4-Dioxane
0
1
2
3
4
5
6
9/3/2008
9/3/2009
9/3/2010
9/3/2011
9/2/2012
9/2/2013
9/2/2014
9/2/2015
9/1/2016
9/1/2017
9/1/2018
9/1/2019
8/31/2020
8/31/2021
1,4-Dioxane (µg/L)
1,4-D CUL (µg/L)


Trichloroethylene (TCE)
0
0.2
0.4
0.6
0.8
1
1.2
9/3/2008
9/3/2009
9/3/2010
9/3/2011
9/2/2012
9/2/2013
9/2/2014
9/2/2015
9/1/2016
9/1/2017
9/1/2018
9/1/2019
8/31/2020
8/31/2021
TCE (µg/L)
TCE CUL (µg/L)

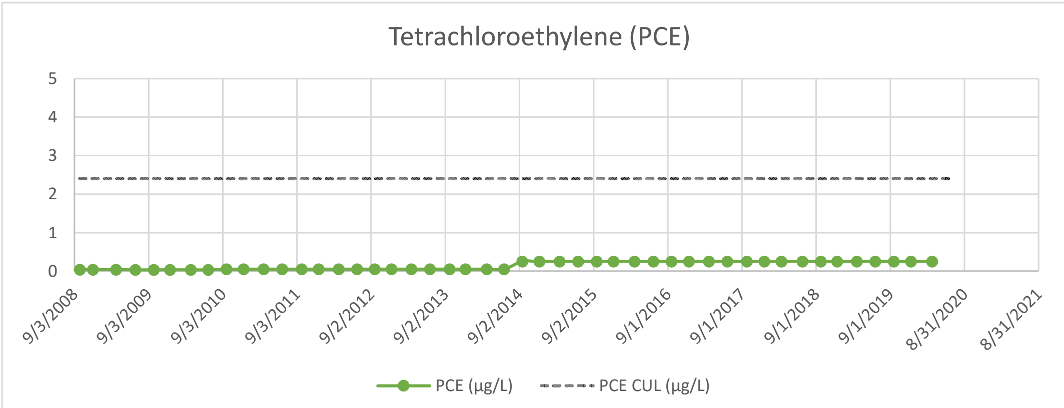

Arsenic
0
0.001
0.002
0.003
0.004
0.005
0.006
0.007
0.008
0.009
9/3/2008
9/3/2009
9/3/2010
9/3/2011
9/2/2012
9/2/2013
9/2/2014
9/2/2015
9/1/2016
9/1/2017
9/1/2018
9/1/2019
8/31/2020
8/31/2021
Arsenic (mg/L)
Arsenic CUL (mg/L)

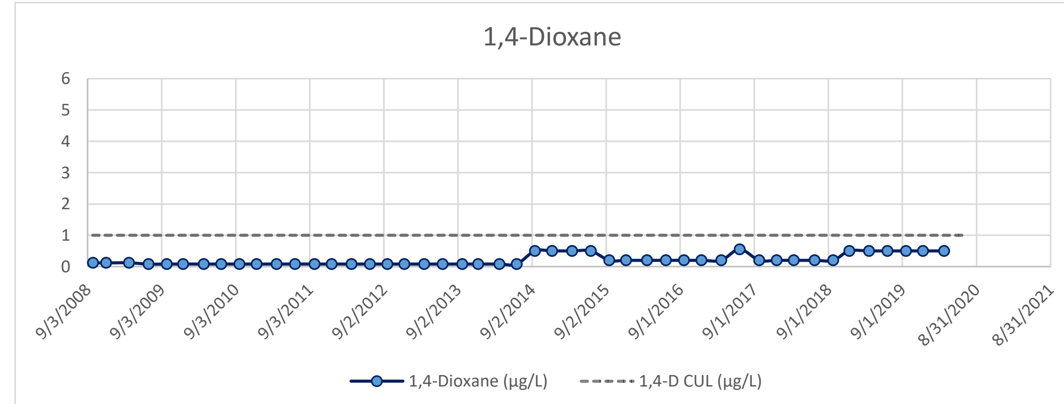

cis-1,2-Dichloroethene (cis-1,2-DCE) (µg/L)
0
5
10
15
20
25
30
35
40
9/3/2008
9/3/2009
9/3/2010
9/3/2011
9/2/2012
9/2/2013
9/2/2014
9/2/2015
9/1/2016
9/1/2017
9/1/2018
9/1/2019
8/31/2020
8/31/2021
cis-1,2-DCE (µg/L)
CIS CUL (µg/L)

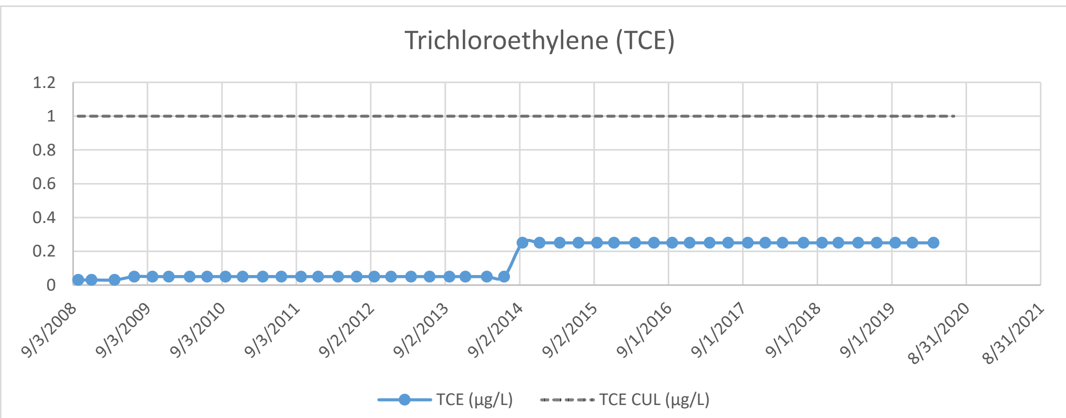

Groundwater Elevation (feet)
0
2
4
6
8
10
12
14
16
18
20
9/3/2008
9/3/2009
9/3/2010
9/3/2011
9/2/2012
9/2/2013
9/2/2014
9/2/2015
9/1/2016
9/1/2017
9/1/2018
9/1/2019
8/31/2020
8/31/2021

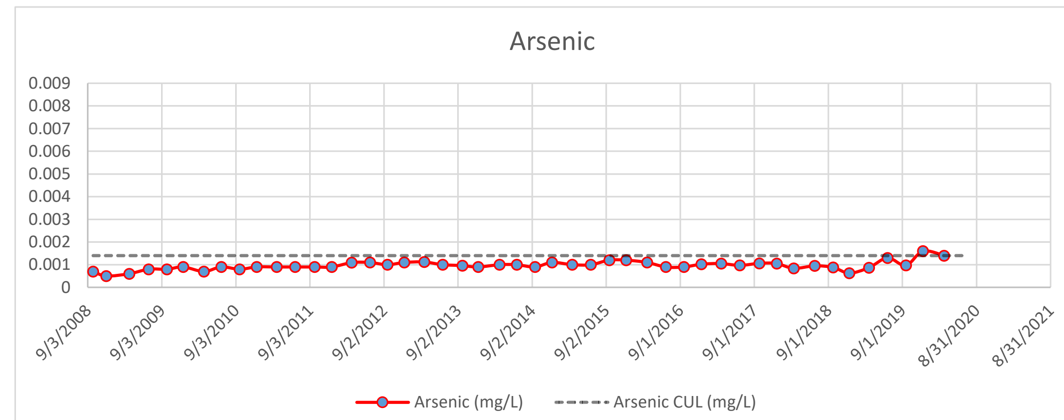

Vinyl Chloride (VC)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
9/3/2008
9/3/2009
9/3/2010
9/3/2011
9/2/2012
9/2/2013
9/2/2014
9/2/2015
9/1/2016
9/1/2017
9/1/2018
9/1/2019
8/31/2020
8/31/2021
VC (µg/L)
VC CUL (µg/L)

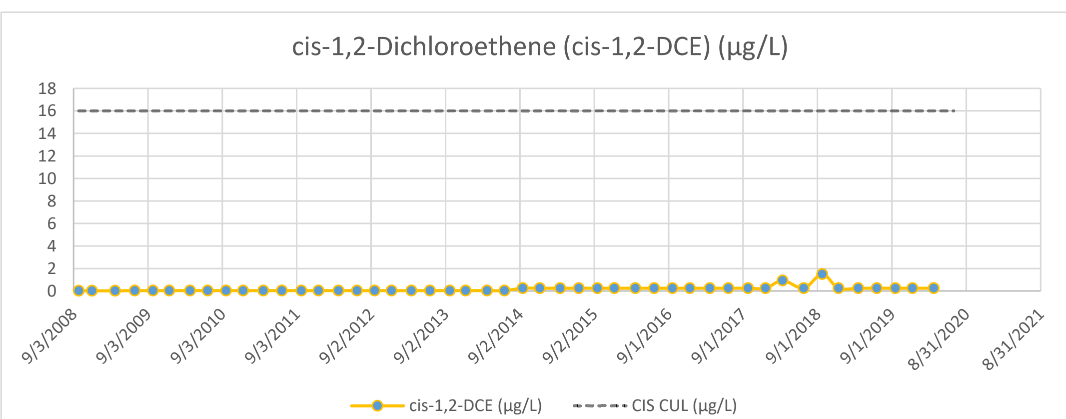
MC-26D2

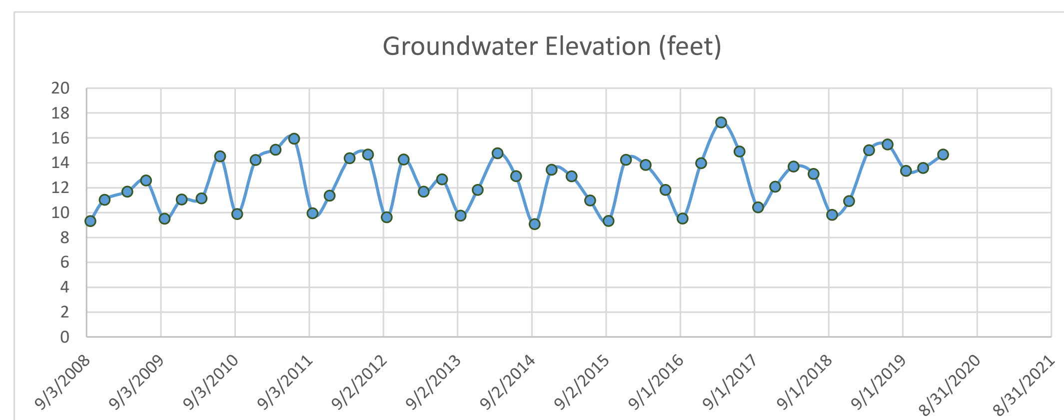

Tetrachloroethylene (PCE)
PCE (µg/L)
PCE CUL (µg/L)

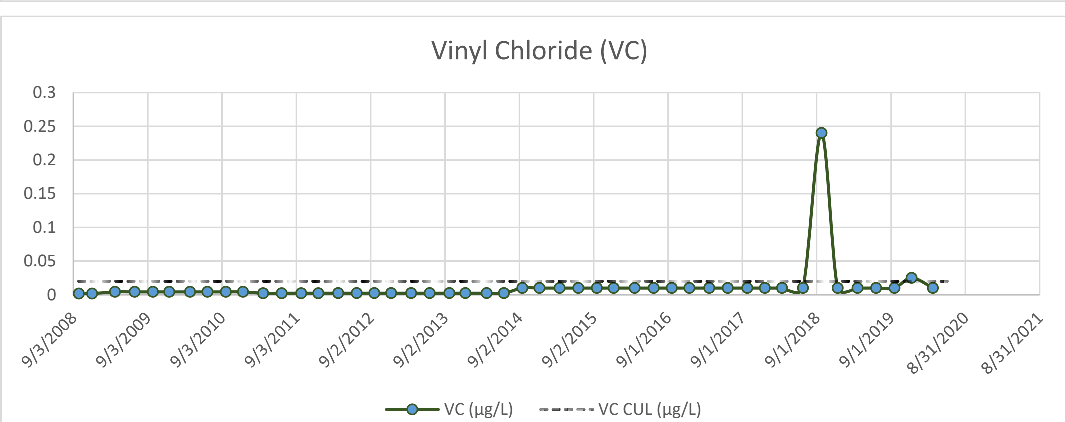

1,4-Dioxane
1,4-Dioxane (µg/L)
1,4-D CUL (µg/L)


Trichloroethylene (TCE)
TCE (µg/L)
TCE CUL (µg/L)

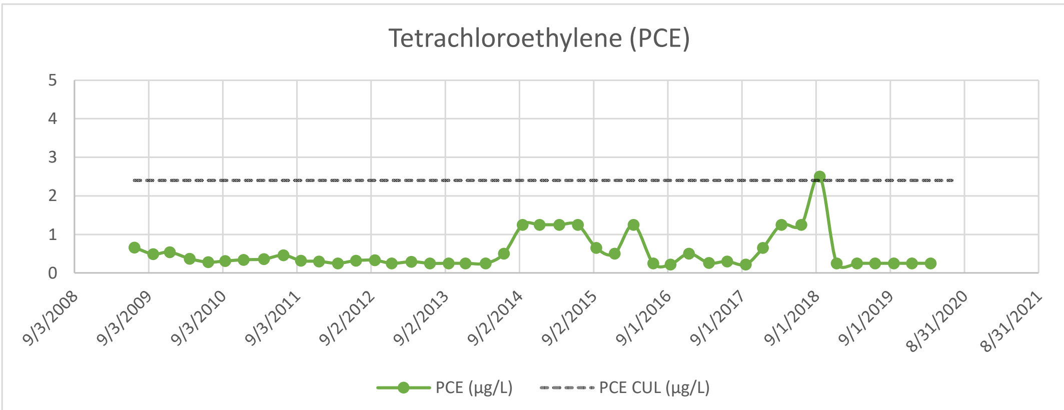

Arsenic
Arsenic (mg/L)
Arsenic CUL (mg/L)

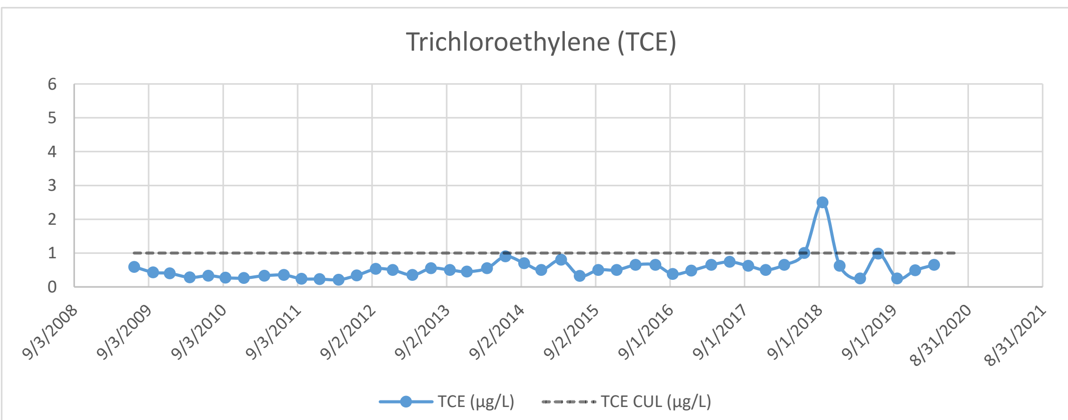

cis-1,2-Dichloroethene (cis-1,2-DCE) (µg/L)
cis-1,2-DCE (µg/L)
CIS CUL (µg/L)

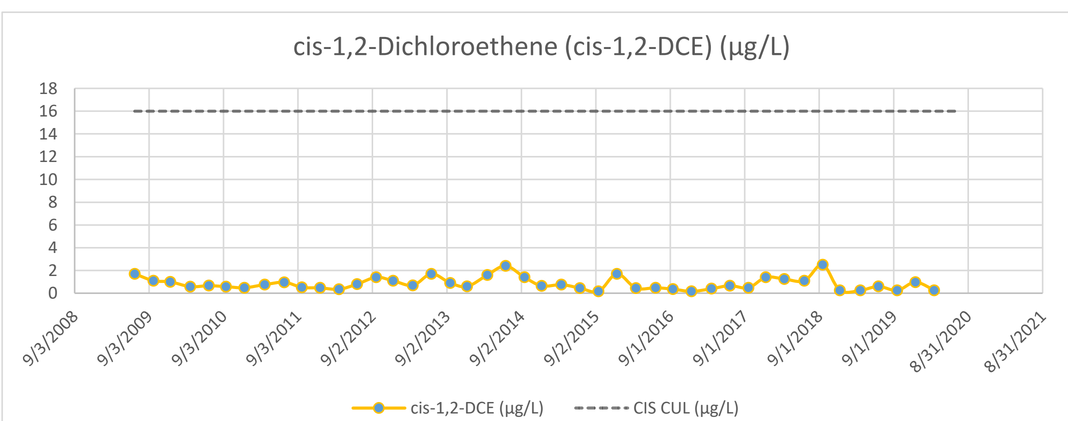

Groundwater Elevation (feet)

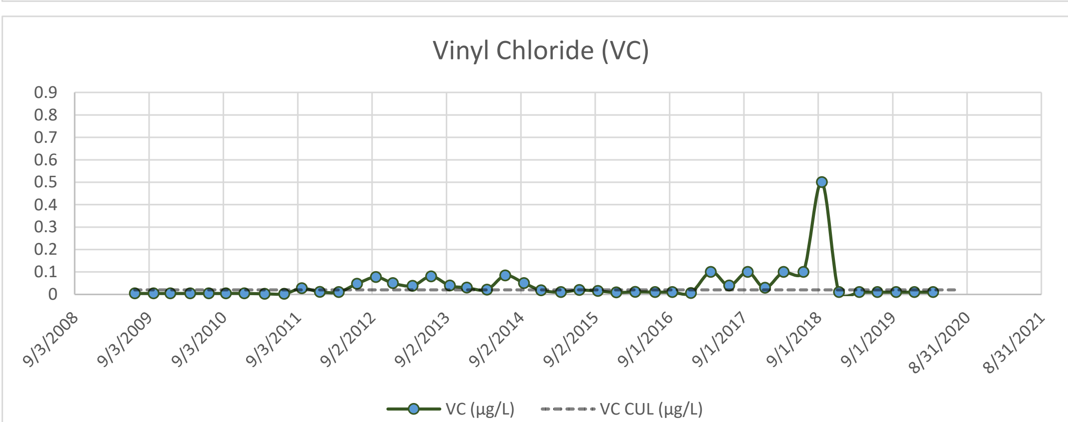

Vinyl Chloride (VC)
VC (µg/L)
VC CUL (µg/L)

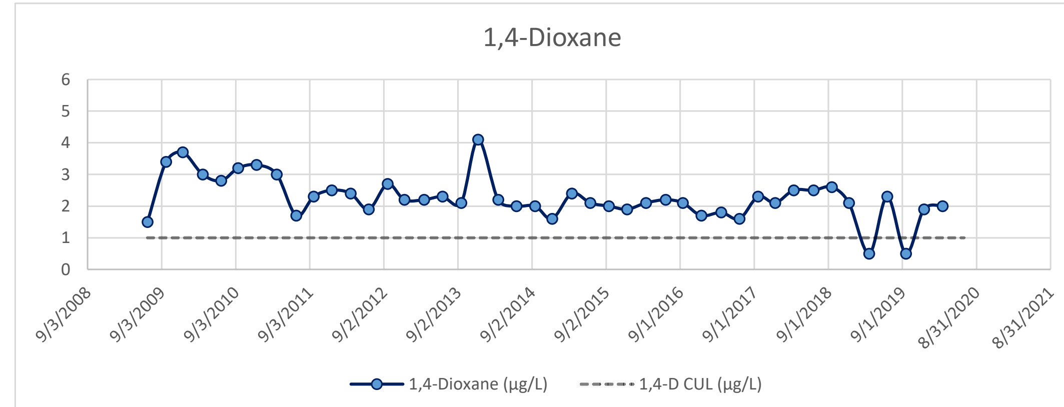
MC-27D

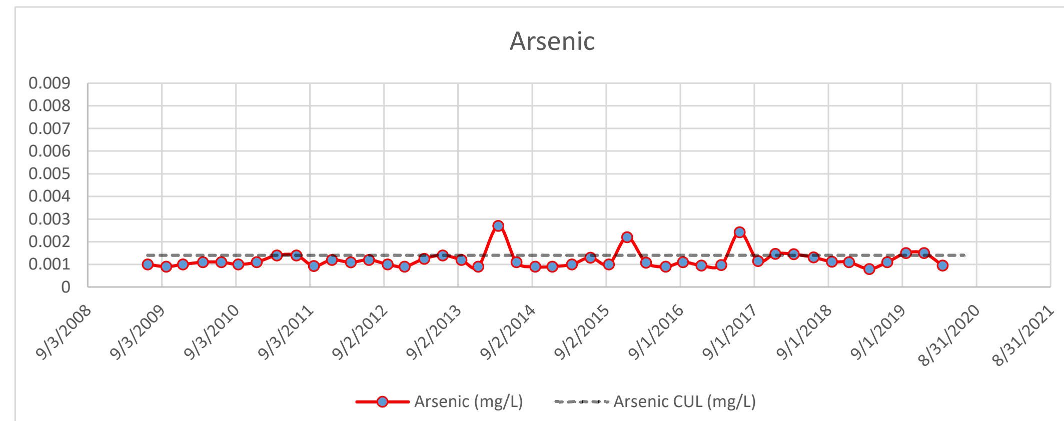

Tetrachloroethylene (PCE)
0
1
2
3
4
5
9/3/2008
9/3/2009
9/3/2010
9/3/2011
9/2/2012
9/2/2013
9/2/2014
9/2/2015
9/1/2016
9/1/2017
9/1/2018
9/1/2019
8/31/2020
8/31/2021
PCE (µg/L)
PCE CUL (µg/L)

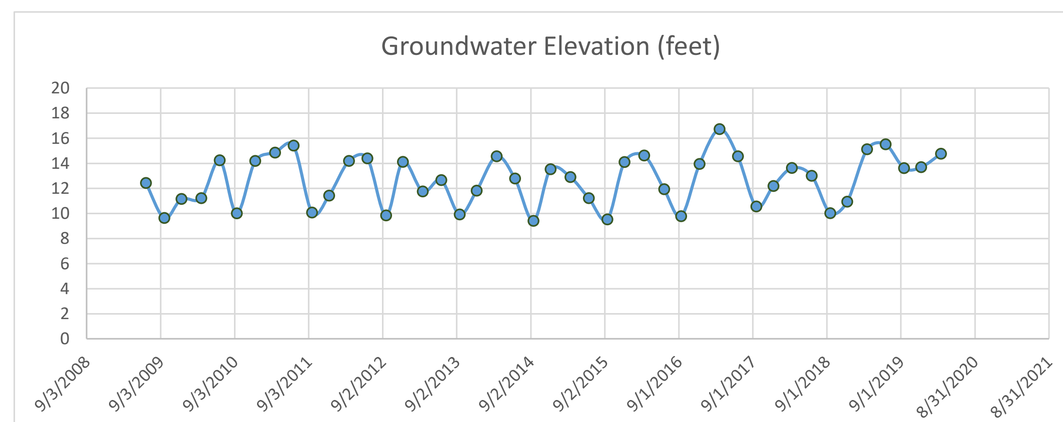

Trichloroethylene (TCE)
0
1
2
3
4
5
6
9/3/2008
9/3/2009
9/3/2010
9/3/2011
9/2/2012
9/2/2013
9/2/2014
9/2/2015
9/1/2016
9/1/2017
9/1/2018
9/1/2019
8/31/2020
8/31/2021
TCE (µg/L)
TCE CUL (µg/L)


cis-1,2-Dichloroethene (cis-1,2-DCE) (µg/L)
0
2
4
6
8
10
12
14
16
18
9/3/2008
9/3/2009
9/3/2010
9/3/2011
9/2/2012
9/2/2013
9/2/2014
9/2/2015
9/1/2016
9/1/2017
9/1/2018
9/1/2019
8/31/2020
8/31/2021
cis-1,2-DCE (µg/L)
CIS CUL (µg/L)

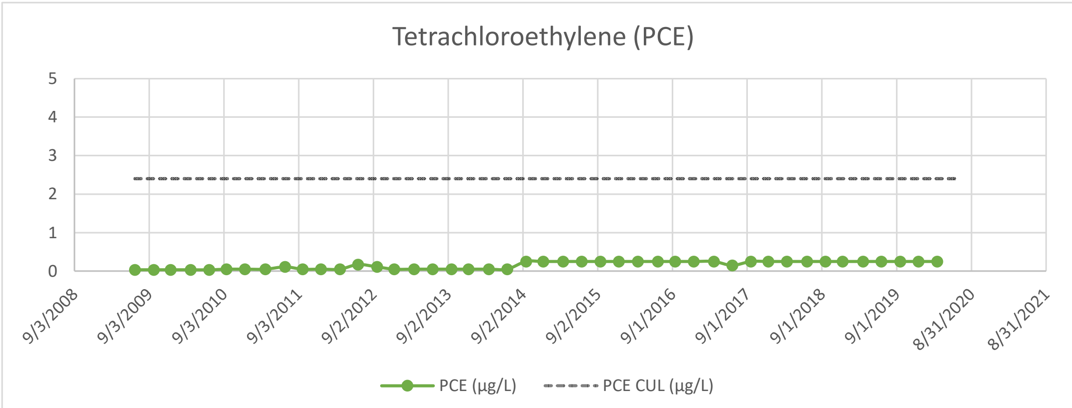

Vinyl Chloride (VC)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
9/3/2008
9/3/2009
9/3/2010
9/3/2011
9/2/2012
9/2/2013
9/2/2014
9/2/2015
9/1/2016
9/1/2017
9/1/2018
9/1/2019
8/31/2020
8/31/2021
VC (µg/L)
VC CUL (µg/L)

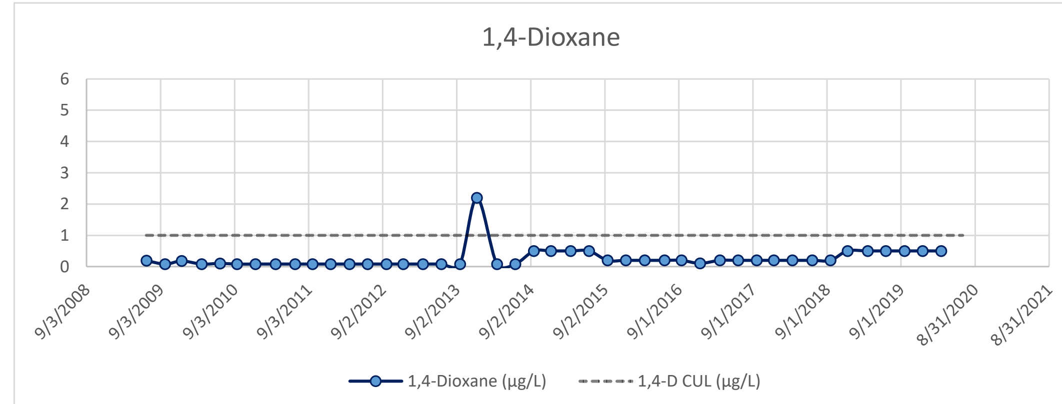

1,4-Dioxane
0
1
2
3
4
5
6
9/3/2008
9/3/2009
9/3/2010
9/3/2011
9/2/2012
9/2/2013
9/2/2014
9/2/2015
9/1/2016
9/1/2017
9/1/2018
9/1/2019
8/31/2020
8/31/2021
1,4-Dioxane (µg/L)
1,4-D CUL (µg/L)

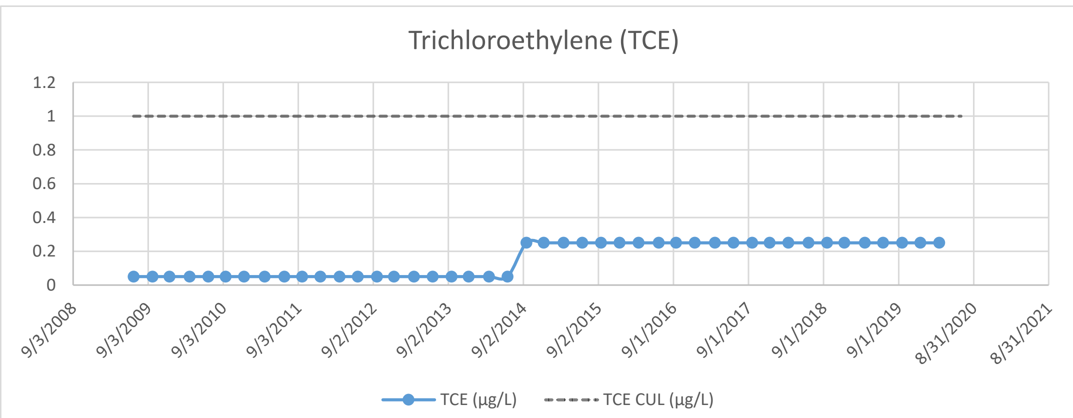

Arsenic
0
0.001
0.002
0.003
0.004
0.005
0.006
0.007
0.008
0.009
9/3/2008
9/3/2009
9/3/2010
9/3/2011
9/2/2012
9/2/2013
9/2/2014
9/2/2015
9/1/2016
9/1/2017
9/1/2018
9/1/2019
8/31/2020
8/31/2021
Arsenic (mg/L)
Arsenic CUL (mg/L)

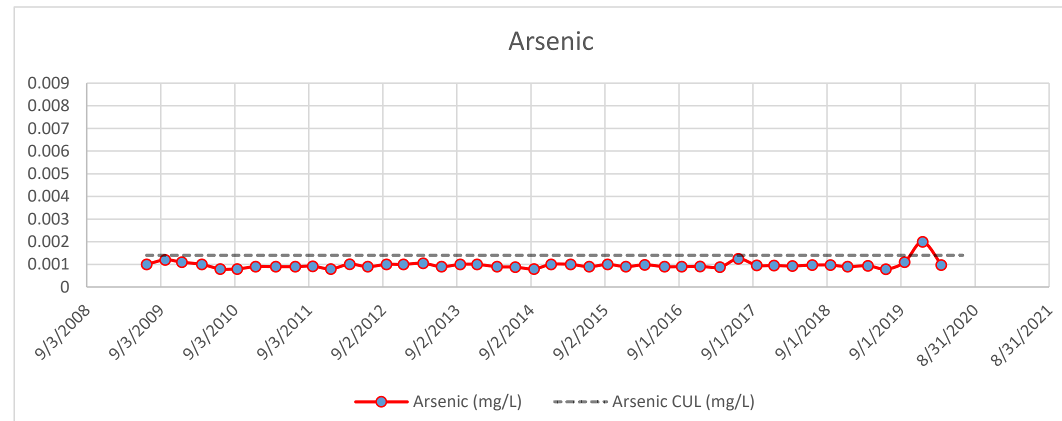

Groundwater Elevation (feet)
0
2
4
6
8
10
12
14
16
18
20
9/3/2008
9/3/2009
9/3/2010
9/3/2011
9/2/2012
9/2/2013
9/2/2014
9/2/2015
9/1/2016
9/1/2017
9/1/2018
9/1/2019
8/31/2020
8/31/2021

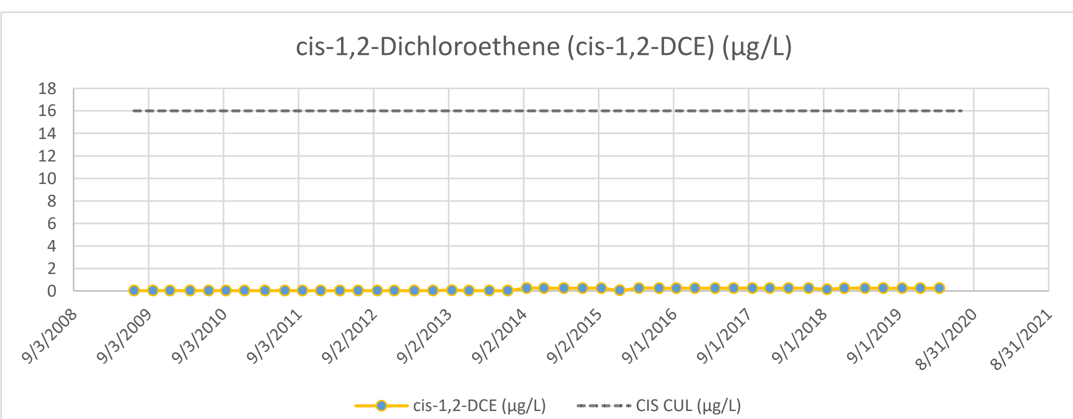
MC-28D

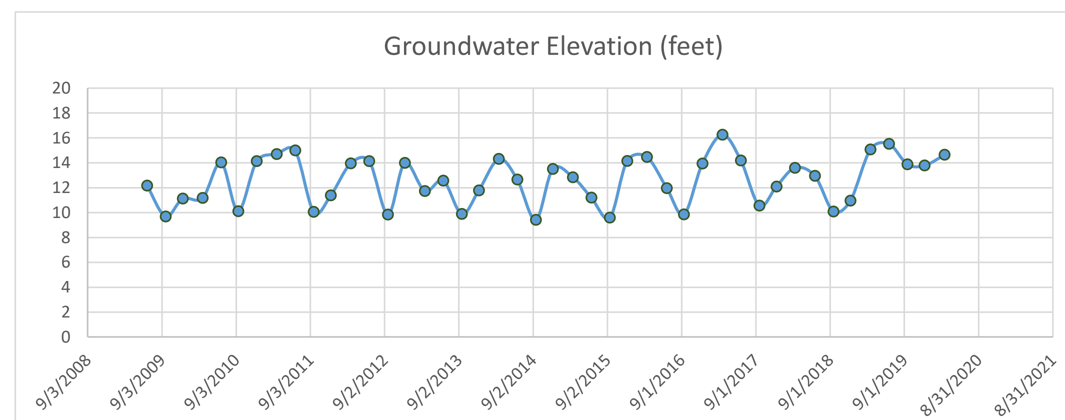

Tetrachloroethylene (PCE)
0
1
2
3
4
5
9/3/2008
9/3/2009
9/3/2010
9/3/2011
9/2/2012
9/2/2013
9/2/2014
9/2/2015
9/1/2016
9/1/2017
9/1/2018
9/1/2019
8/31/2020
8/31/2021
PCE (µg/L)
PCE CUL (µg/L)

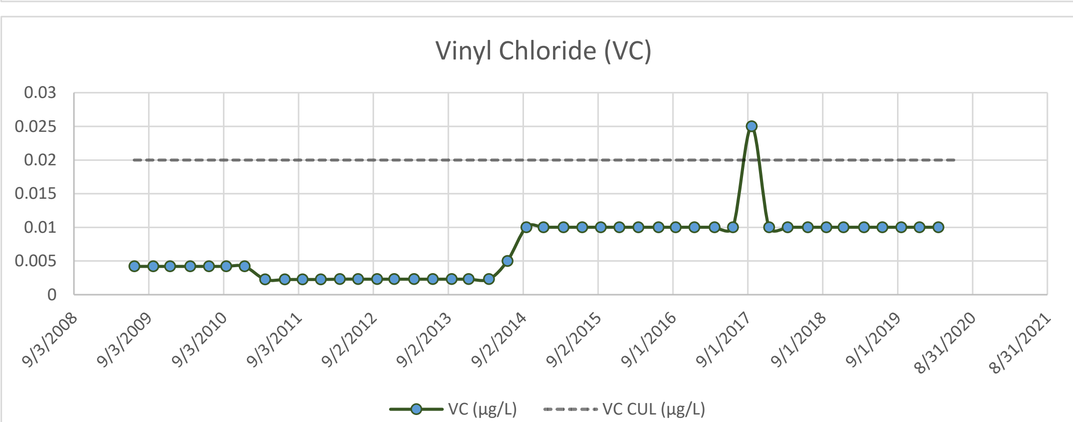

1,4-Dioxane
0
1
2
3
4
5
6
9/3/2008
9/3/2009
9/3/2010
9/3/2011
9/2/2012
9/2/2013
9/2/2014
9/2/2015
9/1/2016
9/1/2017
9/1/2018
9/1/2019
8/31/2020
8/31/2021
1,4-Dioxane (µg/L)
1,4-D CUL (µg/L)


Trichloroethylene (TCE)
0
0.2
0.4
0.6
0.8
1
1.2
9/3/2008
9/3/2009
9/3/2010
9/3/2011
9/2/2012
9/2/2013
9/2/2014
9/2/2015
9/1/2016
9/1/2017
9/1/2018
9/1/2019
8/31/2020
8/31/2021
TCE (µg/L)
TCE CUL (µg/L)

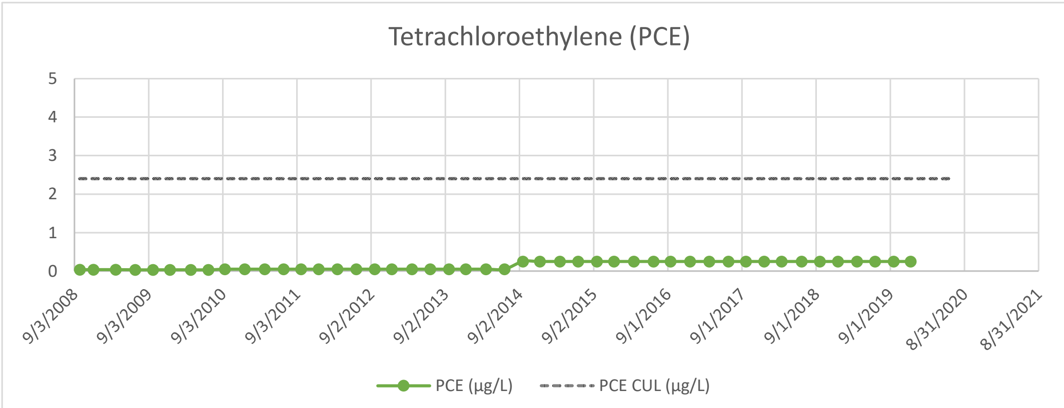

Arsenic
0
0.001
0.002
0.003
0.004
0.005
0.006
0.007
0.008
0.009
9/3/2008
9/3/2009
9/3/2010
9/3/2011
9/2/2012
9/2/2013
9/2/2014
9/2/2015
9/1/2016
9/1/2017
9/1/2018
9/1/2019
8/31/2020
8/31/2021
Arsenic (mg/L)
Arsenic CUL (mg/L)

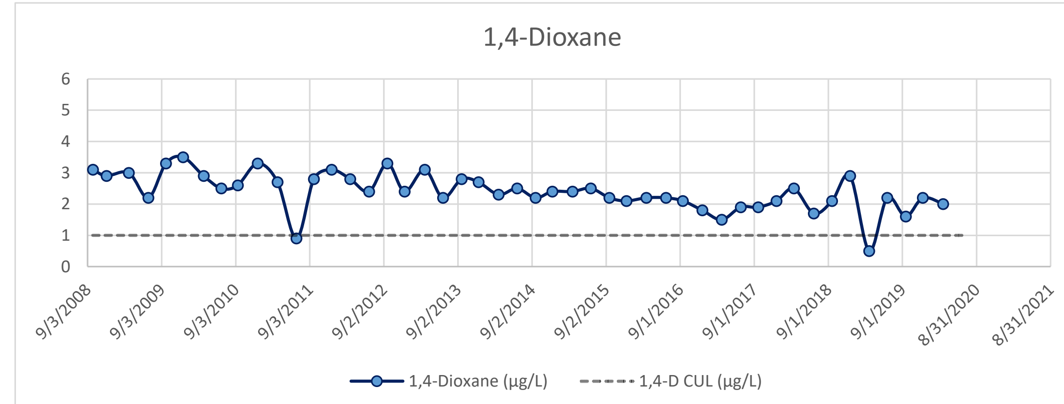

cis-1,2-Dichloroethene (cis-1,2-DCE) (µg/L)
0
2
4
6
8
10
12
14
16
18
9/3/2008
9/3/2009
9/3/2010
9/3/2011
9/2/2012
9/2/2013
9/2/2014
9/2/2015
9/1/2016
9/1/2017
9/1/2018
9/1/2019
8/31/2020
8/31/2021
cis-1,2-DCE (µg/L)
CIS CUL (µg/L)

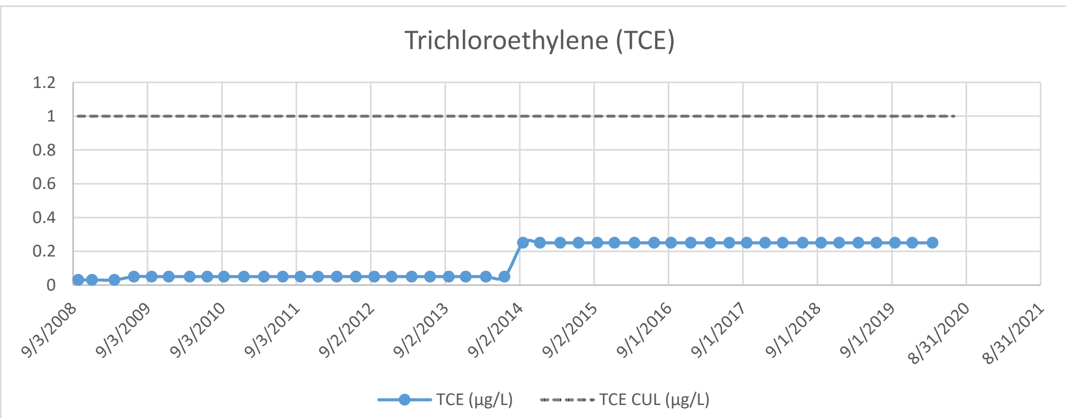

Groundwater Elevation (feet)
0
2
4
6
8
10
12
14
16
18
20
9/3/2008
9/3/2009
9/3/2010
9/3/2011
9/2/2012
9/2/2013
9/2/2014
9/2/2015
9/1/2016
9/1/2017
9/1/2018
9/1/2019
8/31/2020
8/31/2021

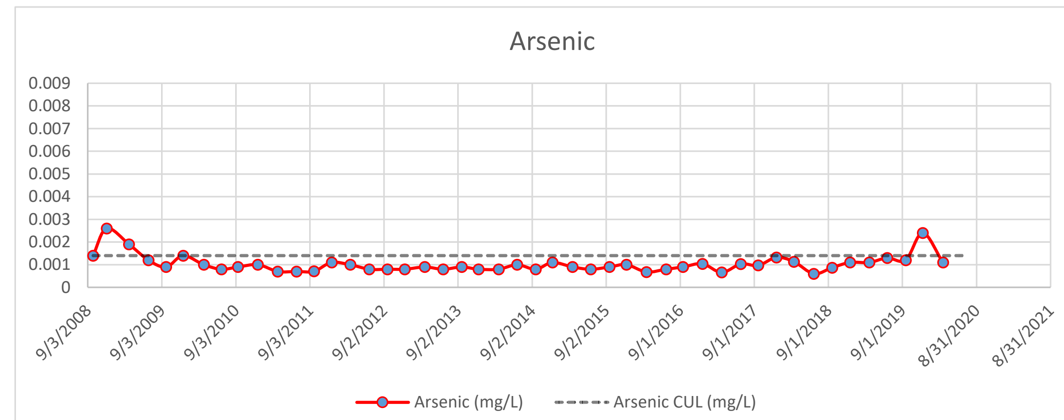

Vinyl Chloride (VC)
0
0.005
0.01
0.015
0.02
0.025
0.03
9/3/2008
9/3/2009
9/3/2010
9/3/2011
9/2/2012
9/2/2013
9/2/2014
9/2/2015
9/1/2016
9/1/2017
9/1/2018
9/1/2019
8/31/2020
8/31/2021
VC (µg/L)
VC CUL (µg/L)

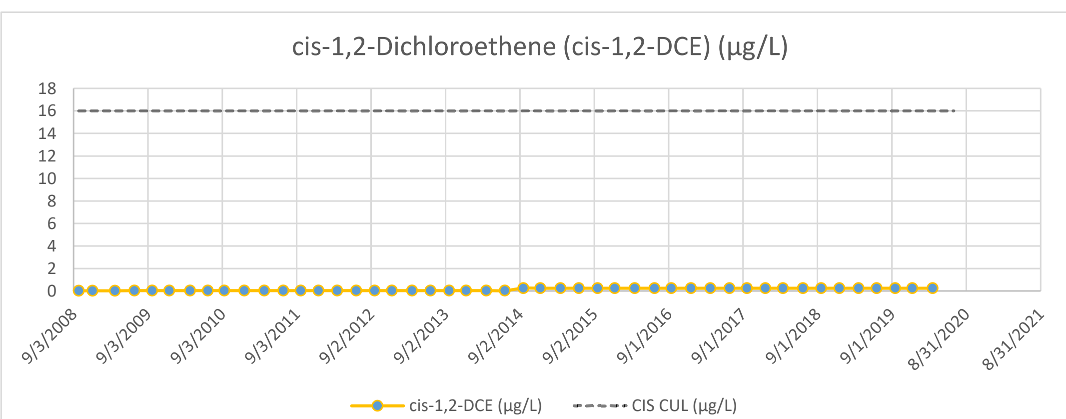
MC-30D

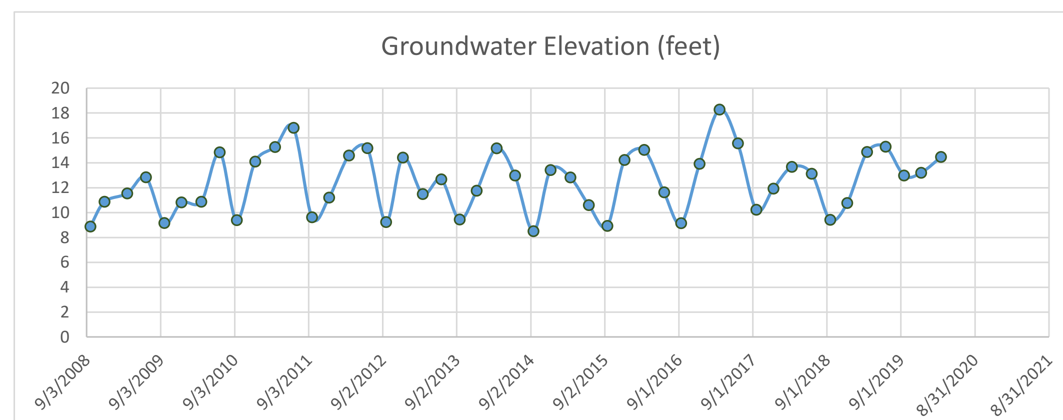

Tetrachloroethylene (PCE)
0 1 2 3 4 5
9/3/2008 9/3/2009 9/3/2010 9/3/2011 9/2/2012 9/2/2013 9/2/2014 9/2/2015 9/1/2016 9/1/2017 9/1/2018 9/1/2019 8/31/2020 8/31/2021
PCE (µg/L)
PCE CUL (µg/L)

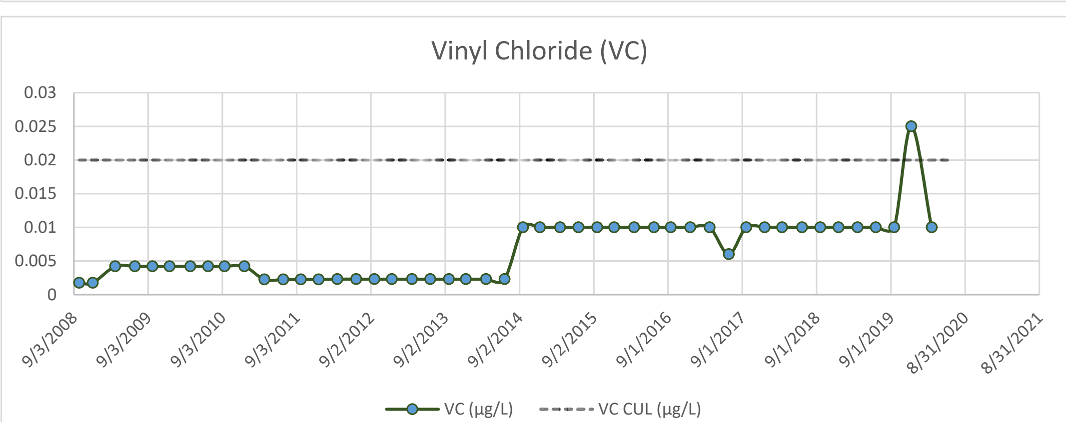

1,4-Dioxane
0 1 2 3 4 5 6
9/3/2008 9/3/2009 9/3/2010 9/3/2011 9/2/2012 9/2/2013 9/2/2014 9/2/2015 9/1/2016 9/1/2017 9/1/2018 9/1/2019 8/31/2020 8/31/2021
1,4-Dioxane (µg/L)
1,4-D CUL (µg/L)


Trichloroethylene (TCE)
0 0.2 0.4 0.6 0.8 1 1.2
9/3/2008 9/3/2009 9/3/2010 9/3/2011 9/2/2012 9/2/2013 9/2/2014 9/2/2015 9/1/2016 9/1/2017 9/1/2018 9/1/2019 8/31/2020 8/31/2021
TCE (µg/L)
TCE CUL (µg/L)

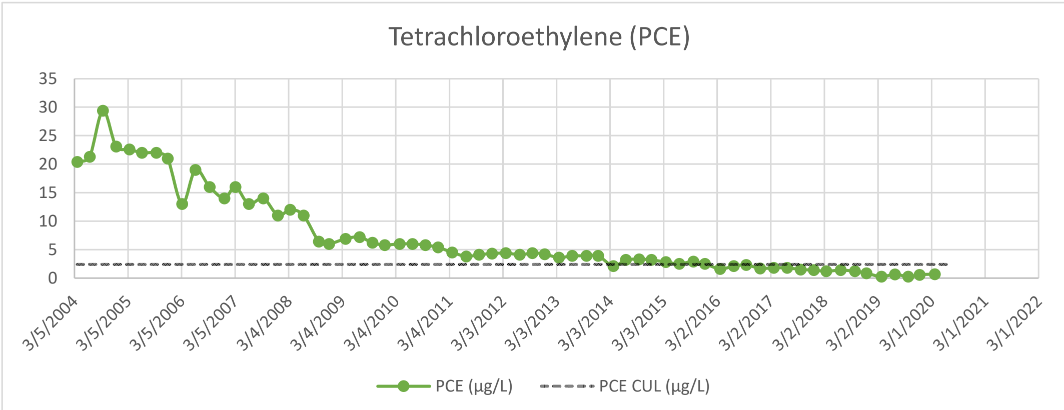

Arsenic
0 0.001 0.002 0.003 0.004 0.005 0.006 0.007 0.008 0.009
9/3/2008 9/3/2009 9/3/2010 9/3/2011 9/2/2012 9/2/2013 9/2/2014 9/2/2015 9/1/2016 9/1/2017 9/1/2018 9/1/2019 8/31/2020 8/31/2021
Arsenic (mg/L)
Arsenic CUL (mg/L)

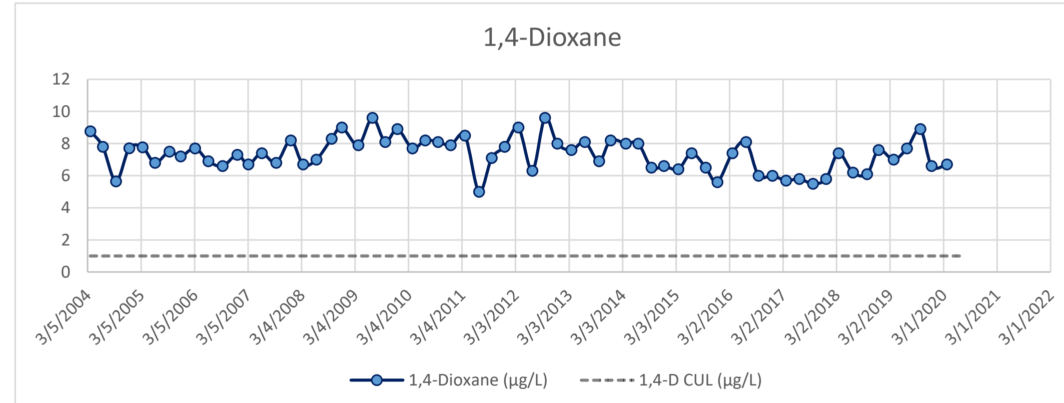

cis-1,2-Dichloroethene (cis-1,2-DCE) (µg/L)
0 2 4 6 8 10 12 14 16 18
9/3/2008 9/3/2009 9/3/2010 9/3/2011 9/2/2012 9/2/2013 9/2/2014 9/2/2015 9/1/2016 9/1/2017 9/1/2018 9/1/2019 8/31/2020 8/31/2021
cis-1,2-DCE (µg/L)
CIS CUL (µg/L)

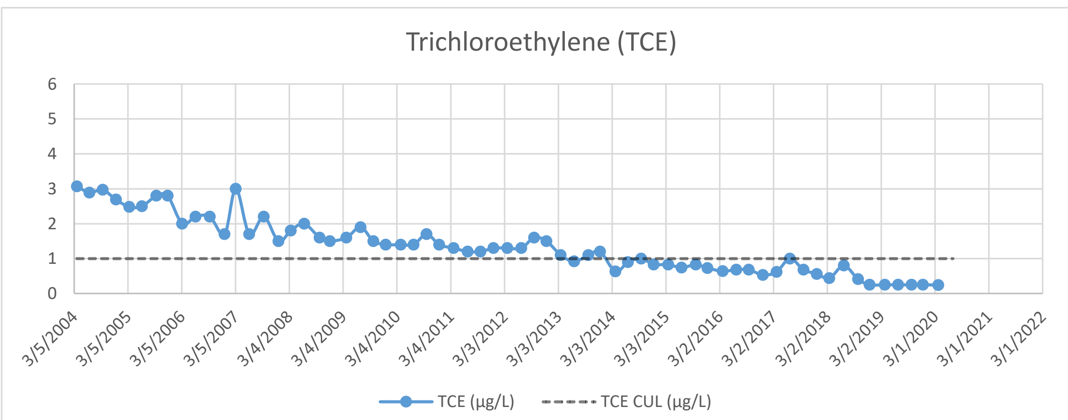

Groundwater Elevation (feet)
0 2 4 6 8 10 12 14 16 18 20
9/3/2008 9/3/2009 9/3/2010 9/3/2011 9/2/2012 9/2/2013 9/2/2014 9/2/2015 9/1/2016 9/1/2017 9/1/2018 9/1/2019 8/31/2020 8/31/2021

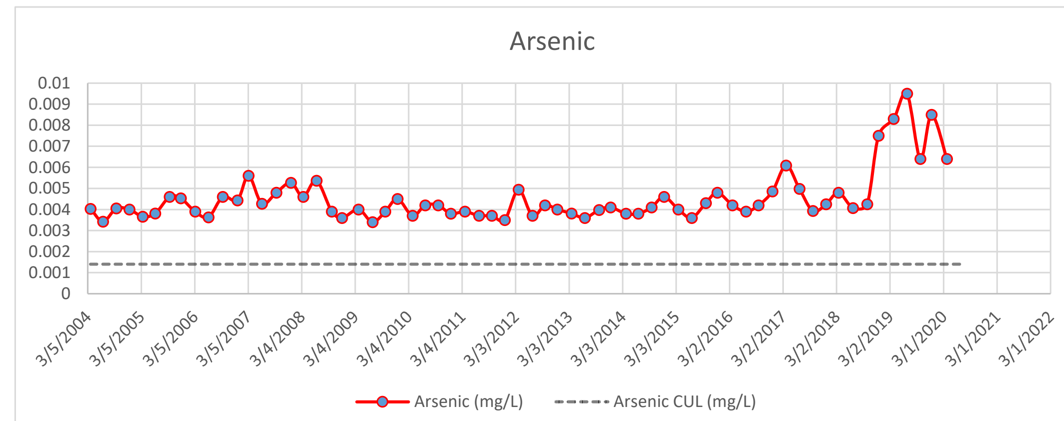

Vinyl Chloride (VC)
0 0.005 0.01 0.015 0.02 0.025 0.03
9/3/2008 9/3/2009 9/3/2010 9/3/2011 9/2/2012 9/2/2013 9/2/2014 9/2/2015 9/1/2016 9/1/2017 9/1/2018 9/1/2019 8/31/2020 8/31/2021
VC (µg/L)
VC CUL (µg/L)

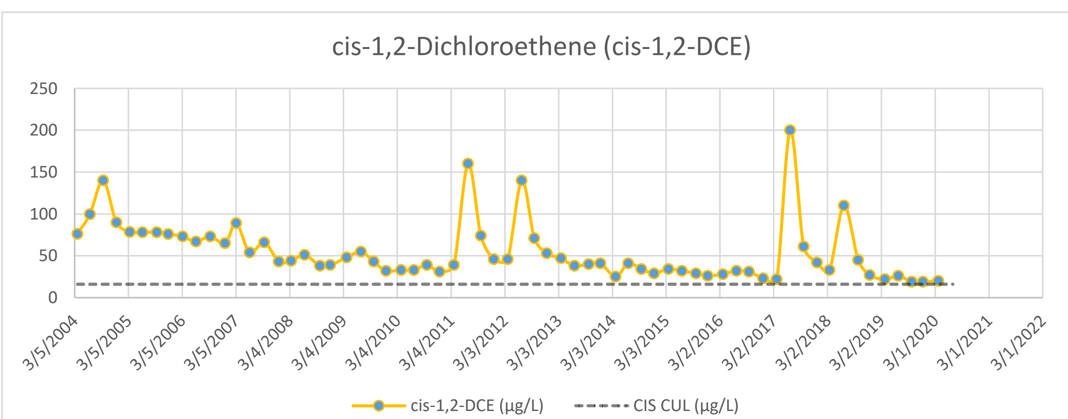
MC-118D

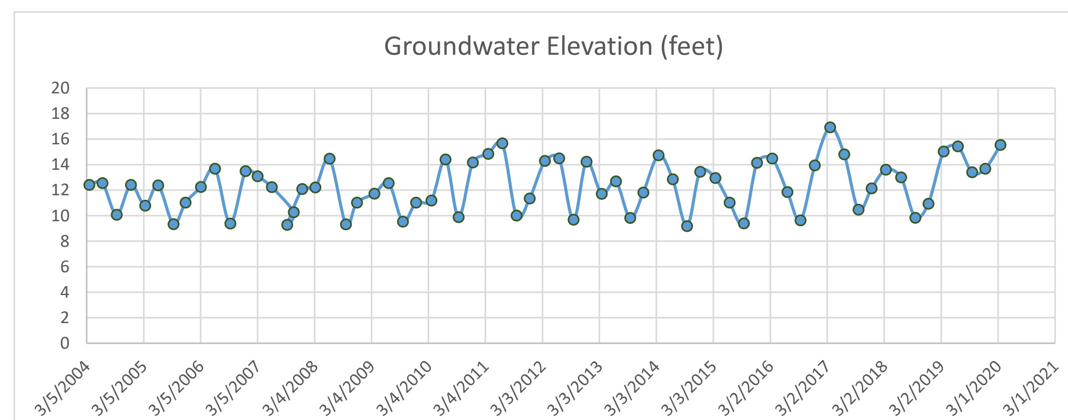

Tetrachloroethylene (PCE)
35
30
25
20
15
10
5
0
3/5/2004
3/5/2005
3/5/2006
3/5/2007
3/4/2008
3/4/2009
3/4/2010
3/4/2011
3/3/2012
3/3/2013
3/3/2014
3/3/2015
3/2/2016
3/2/2017
3/2/2018
3/2/2019
3/1/2020
3/1/2021
3/1/2022
PCE (µg/L)
PCE CUL (µg/L)

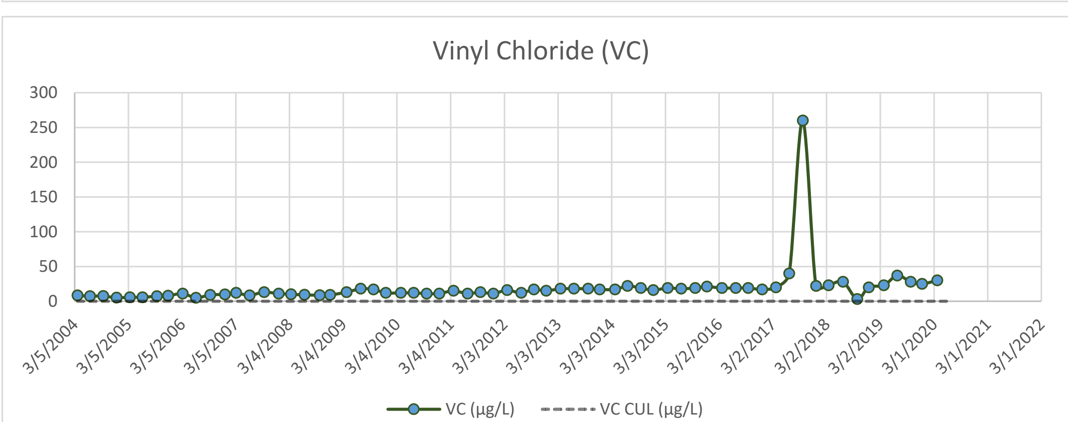

1,4-Dioxane
12
10
8
6
4
2
0
3/5/2004
3/5/2005
3/5/2006
3/5/2007
3/4/2008
3/4/2009
3/4/2010
3/4/2011
3/3/2012
3/3/2013
3/3/2014
3/3/2015
3/2/2016
3/2/2017
3/2/2018
3/2/2019
3/1/2020
3/1/2021
3/1/2022
1,4-Dioxane (µg/L)
1,4-D CUL (µg/L)


Trichloroethylene (TCE)
6
5
4
3
2
1
0
3/5/2004
3/5/2005
3/5/2006
3/5/2007
3/4/2008
3/4/2009
3/4/2010
3/4/2011
3/3/2012
3/3/2013
3/3/2014
3/3/2015
3/2/2016
3/2/2017
3/2/2018
3/2/2019
3/1/2020
3/1/2021
3/1/2022
TCE (µg/L)
TCE CUL (µg/L)

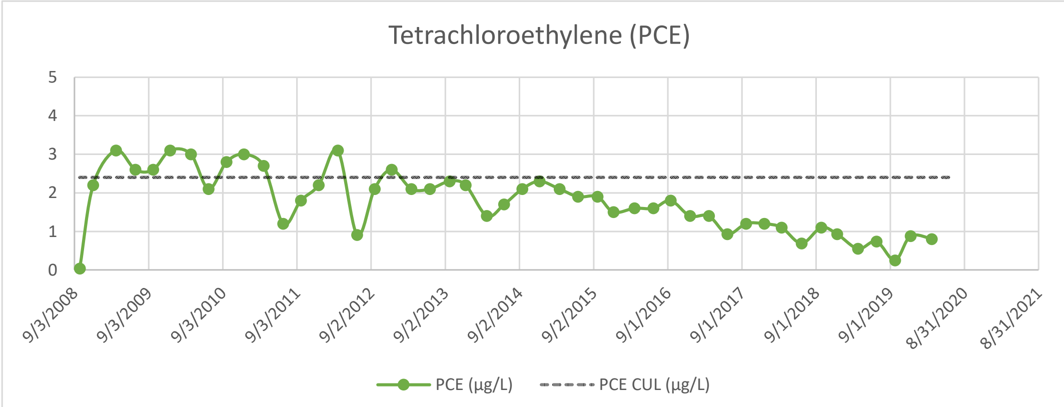

Arsenic
0.01
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
3/5/2004
3/5/2005
3/5/2006
3/5/2007
3/4/2008
3/4/2009
3/4/2010
3/4/2011
3/3/2012
3/3/2013
3/3/2014
3/3/2015
3/2/2016
3/2/2017
3/2/2018
3/2/2019
3/1/2020
3/1/2021
3/1/2022
Arsenic (mg/L)
Arsenic CUL (mg/L)

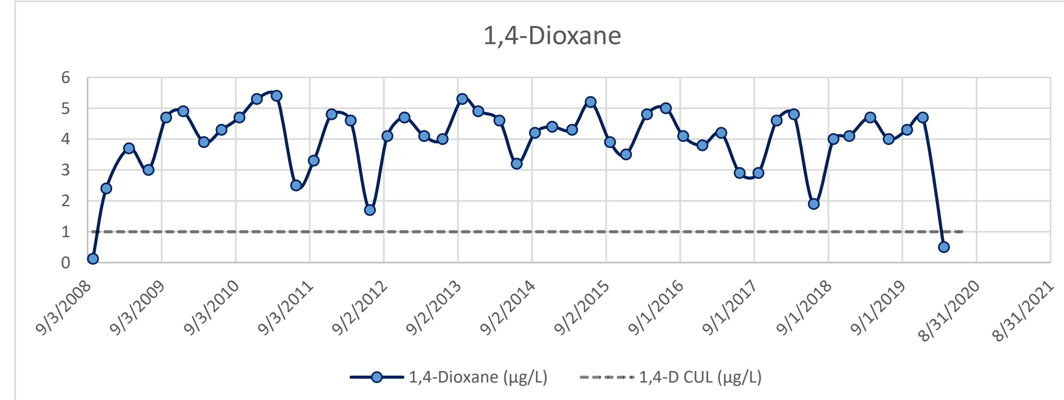

cis-1,2-Dichloroethene (cis-1,2-DCE)
250
200
150
100
50
0
3/5/2004
3/5/2005
3/5/2006
3/5/2007
3/4/2008
3/4/2009
3/4/2010
3/4/2011
3/3/2012
3/3/2013
3/3/2014
3/3/2015
3/2/2016
3/2/2017
3/2/2018
3/2/2019
3/1/2020
3/1/2021
3/1/2022
cis-1,2-DCE (µg/L)
CIS CUL (µg/L)

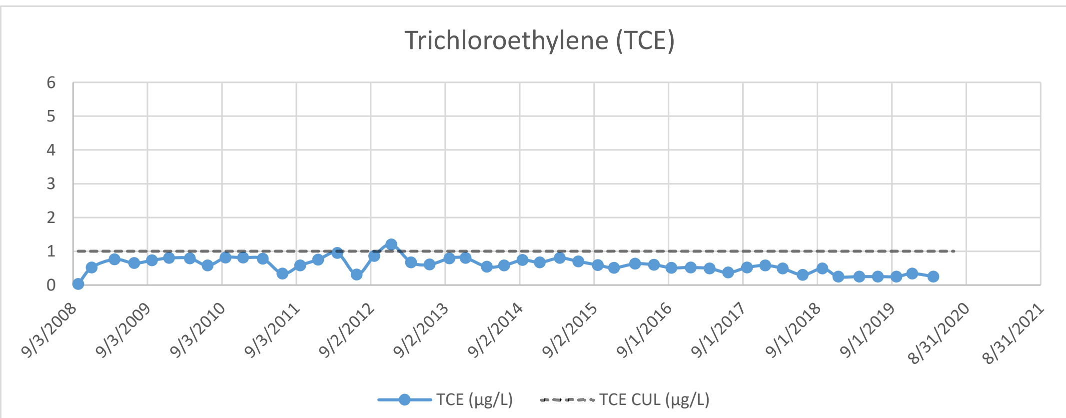

Groundwater Elevation (feet)
20
18
16
14
12
10
8
6
4
2
0
3/5/2004
3/5/2005
3/5/2006
3/5/2007
3/4/2008
3/4/2009
3/4/2010
3/4/2011
3/3/2012
3/3/2013
3/3/2014
3/3/2015
3/2/2016
3/2/2017
3/2/2018
3/2/2019
3/1/2020
3/1/2021

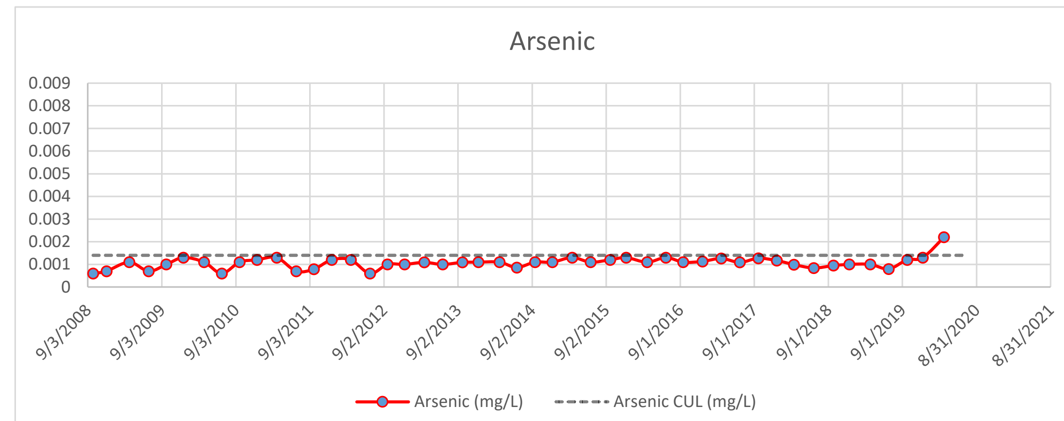

Vinyl Chloride (VC)
300
250
200
150
100
50
0
3/5/2004
3/5/2005
3/5/2006
3/5/2007
3/4/2008
3/4/2009
3/4/2010
3/4/2011
3/3/2012
3/3/2013
3/3/2014
3/3/2015
3/2/2016
3/2/2017
3/2/2018
3/2/2019
3/1/2020
3/1/2021
3/1/2022
VC (µg/L)
VC CUL (µg/L)

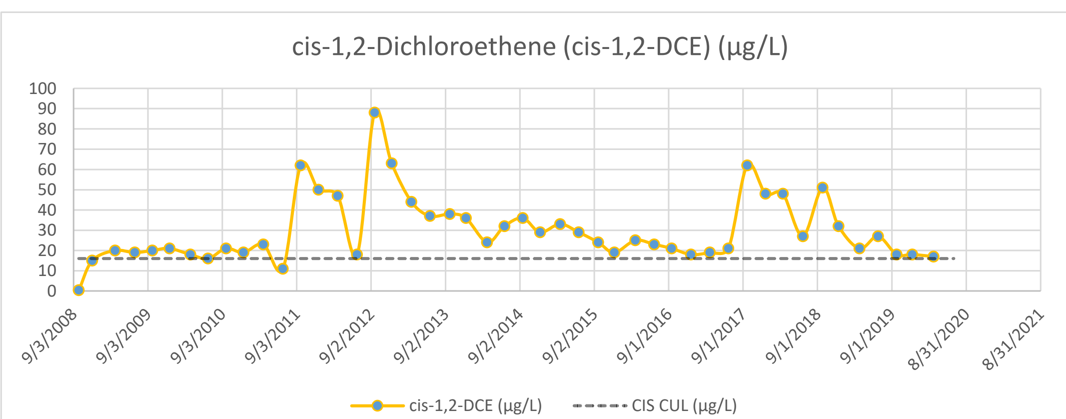
MC-118D2

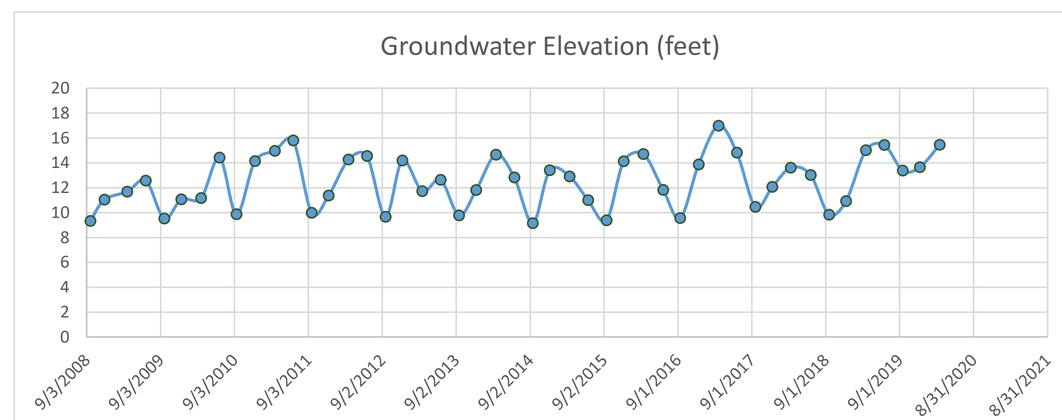

Tetrachloroethylene (PCE)
PCE (µg/L)
PCE CUL (µg/L)

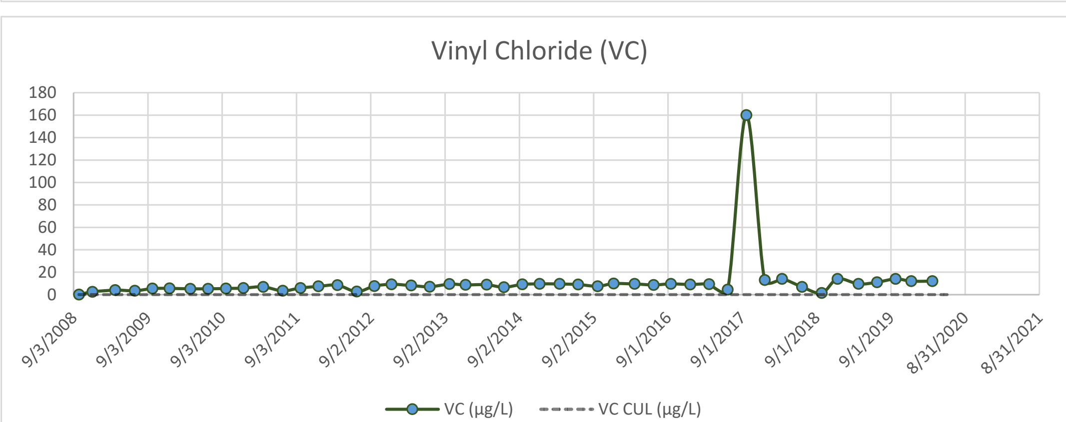

1,4-Dioxane
1,4-Dioxane (µg/L)
1,4-D CUL (µg/L)


Trichloroethylene (TCE)
TCE (µg/L)
TCE CUL (µg/L)


Arsenic
Arsenic (mg/L)
Arsenic CUL (mg/L)


cis-1,2-Dichloroethene (cis-1,2-DCE) (µg/L)
cis-1,2-DCE (µg/L)
CIS CUL (µg/L)


Groundwater Elevation (feet)


Vinyl Chloride (VC)
VC (µg/L)
VC CUL (µg/L)

Nature and Extent Figures

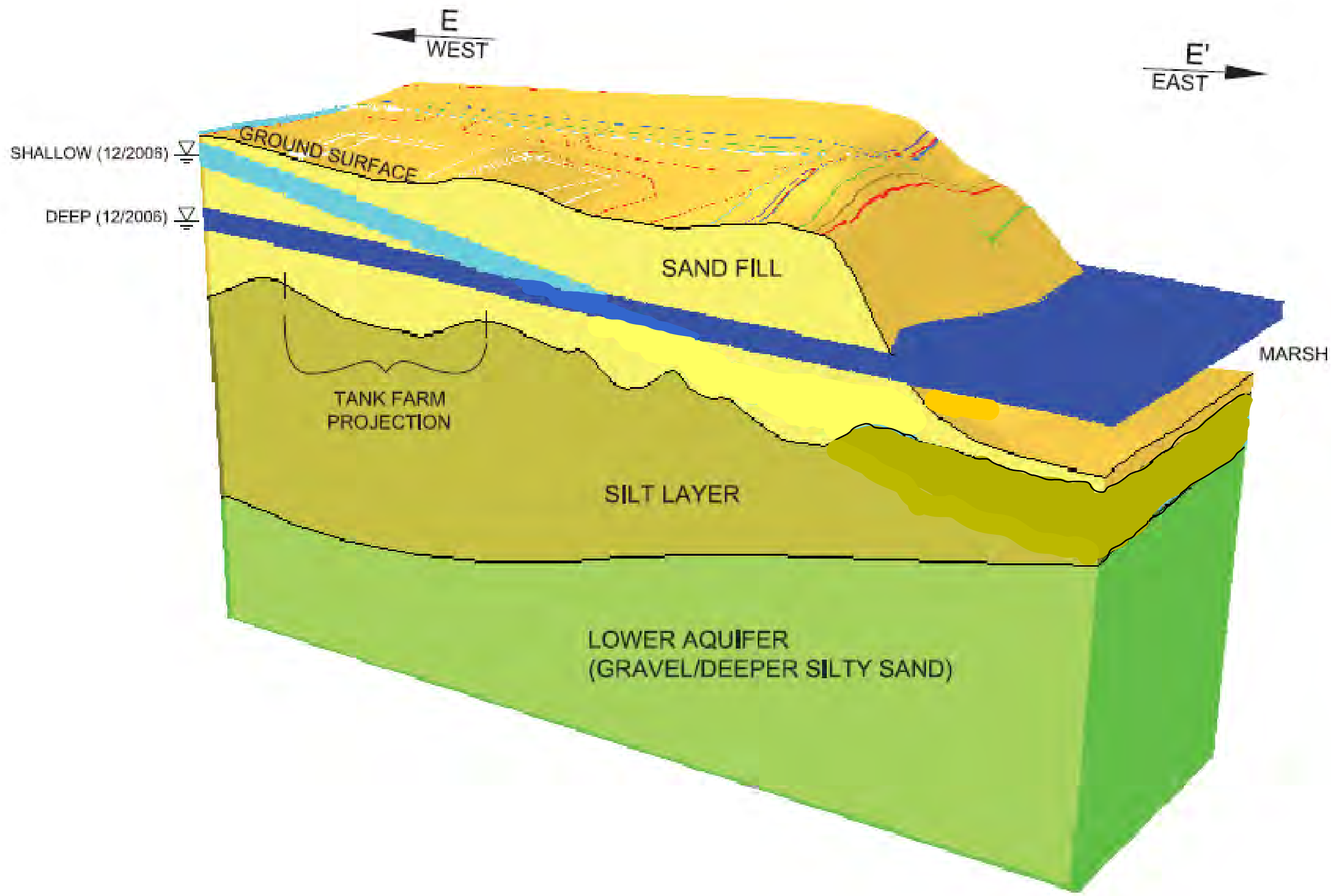
Presented during February 19, 2020 Meeting & Updated following Ecology Comments

Nature And Extent Summary Slides

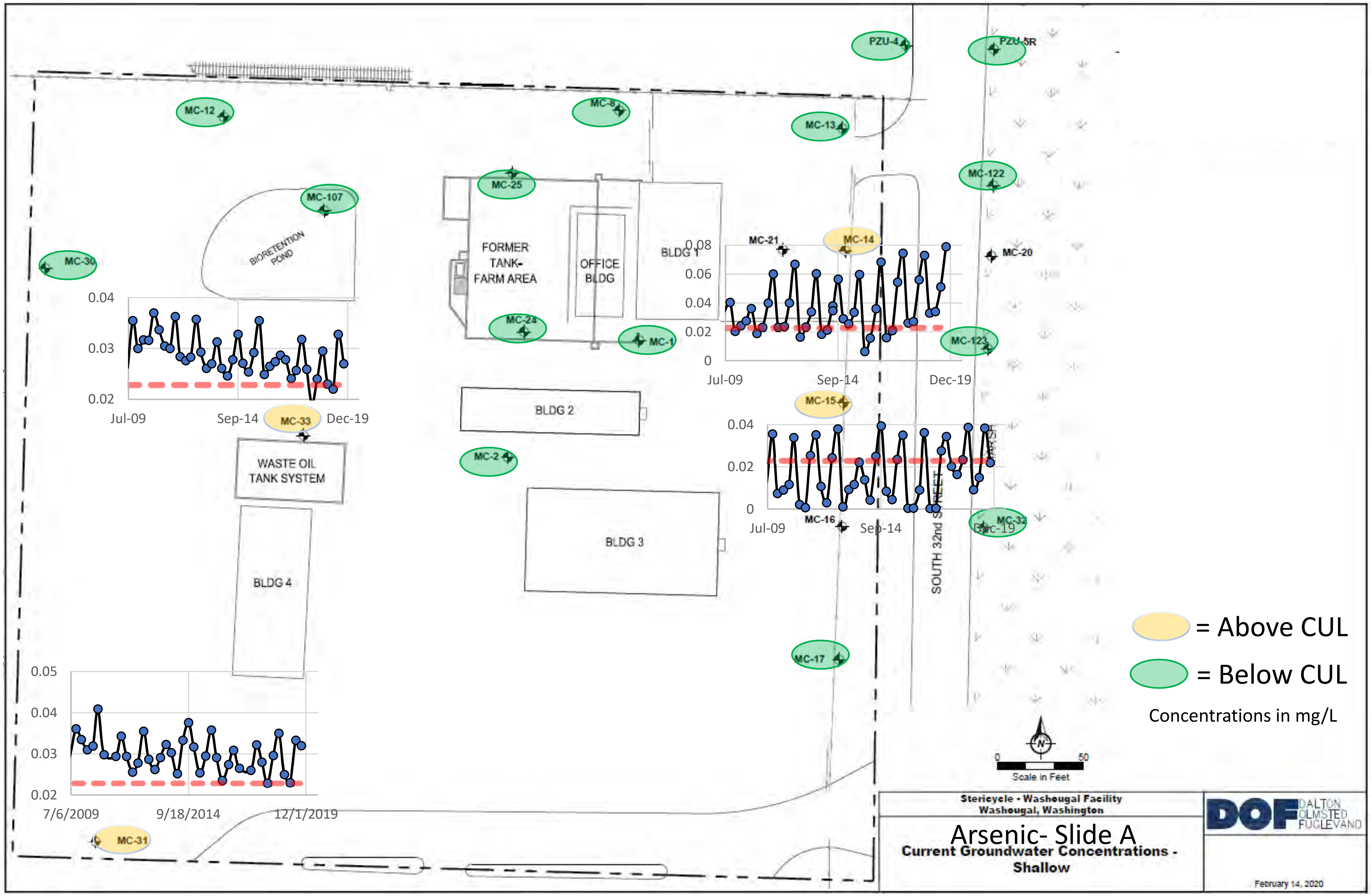
Stericycle Washougal

Slides are generally paired as follows:

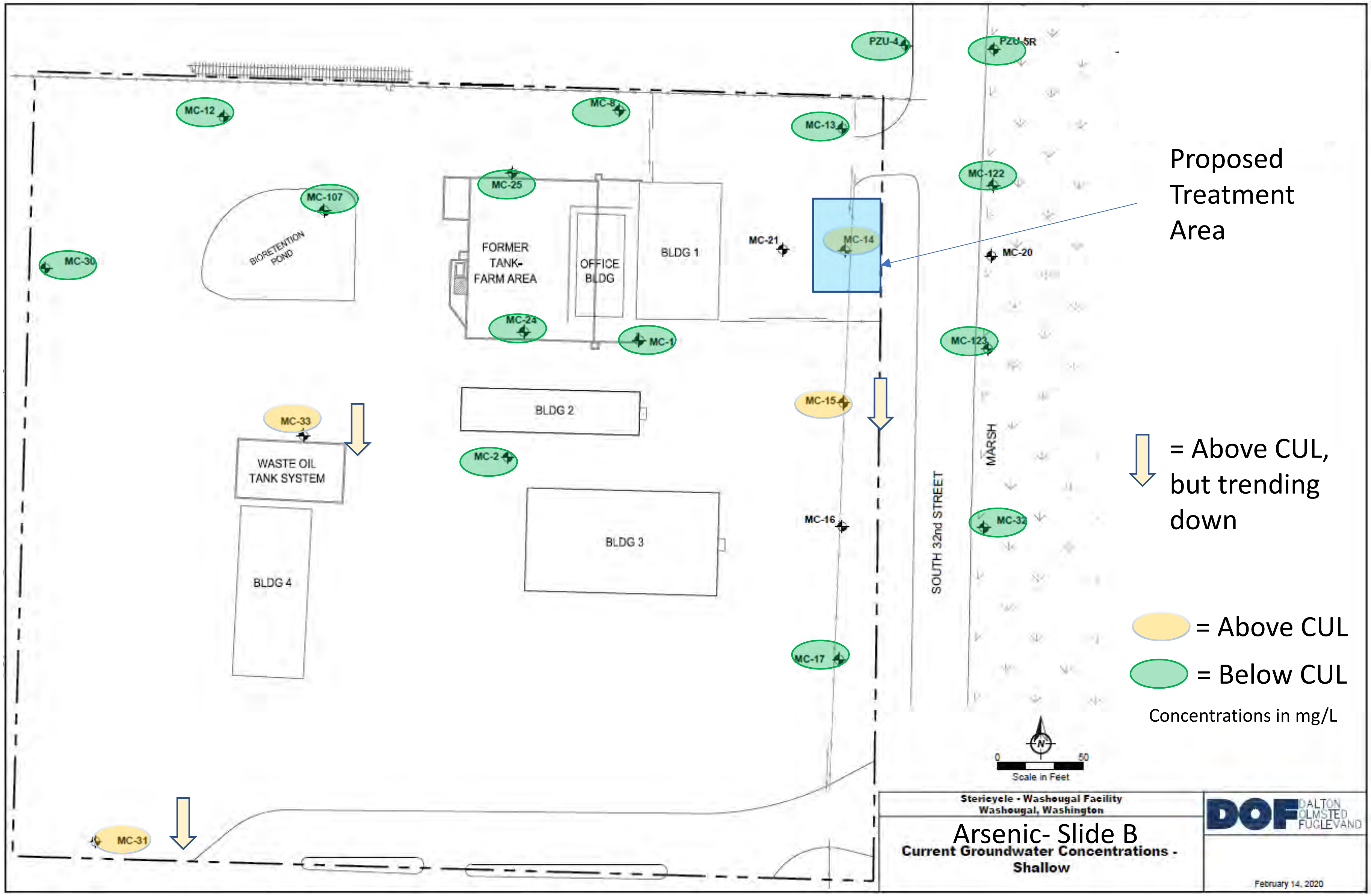
- Slide A - Trend charts are plotted onto a plan view of the facility.
- Slide B - Shows approximate location of proposed treatment areas relative to CUL exceedances at monitoring locations.
- Additional slides are provided to look at important trends in more detail.



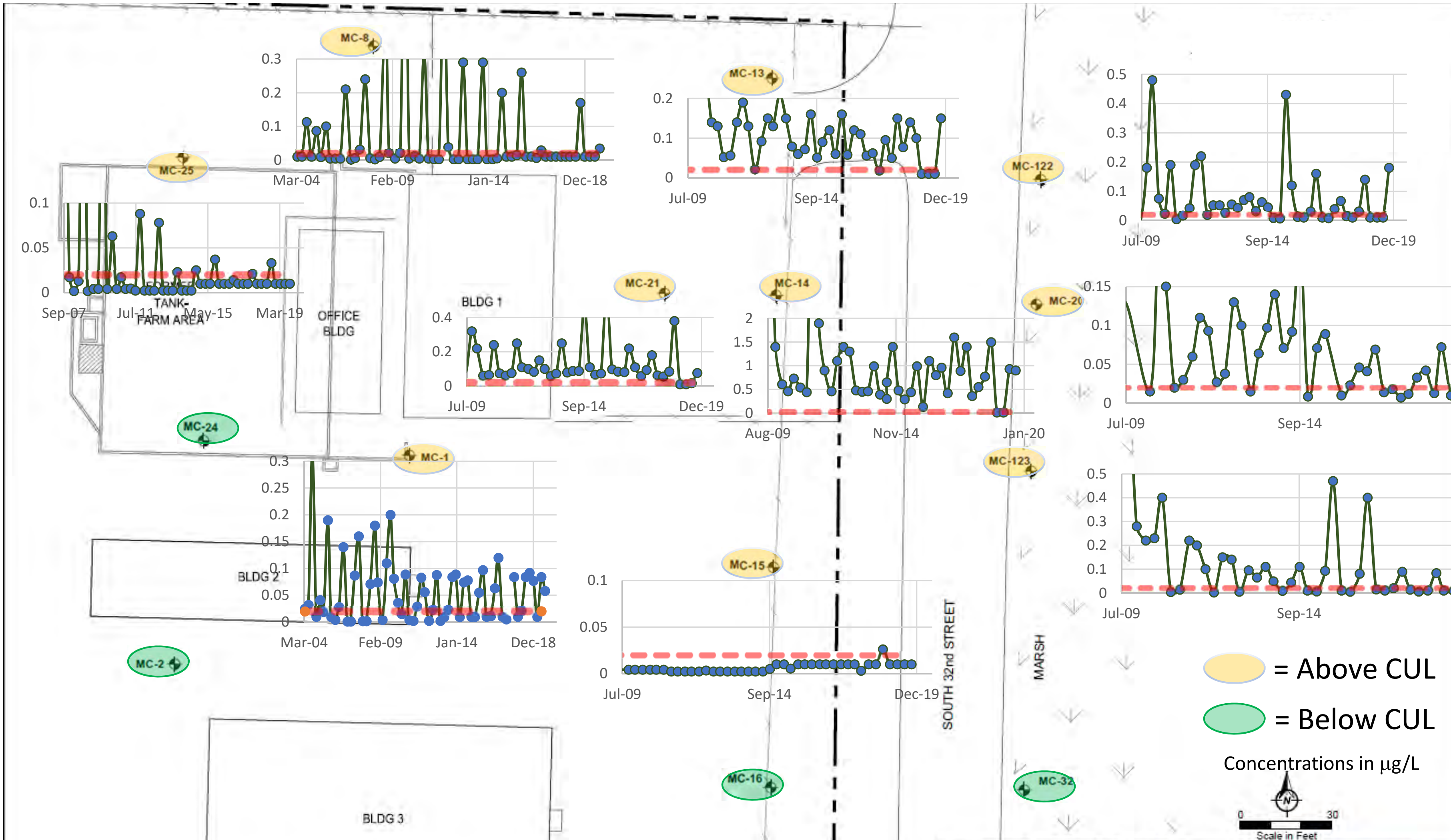
E
WEST
E'
EAST
SHALLOW (12/2006)
DEEP (12/2006)
GROUND SURFACE
SAND FILL
MARSH
TANK FARM
PROJECTION
SILT LAYER
LOWER AQUIFER
(GRAVEL/DEEPER SILTY SAND)



PZU-4
PZU-5R
MC-12
MC-8
MC-13
MC-122
MC-107
BIORETENTION POND
MC-25
FORMER TANK-FARM AREA
OFFICE BLDG
BLDG 1
MC-21
MC-14
MC-20
MC-30
MC-24
MC-1
MC-123
MC-33
MC-15
BLDG 2
WASTE OIL TANK SYSTEM
MC-2
MC-16
MC-32
BLDG 3
BLDG 4
SOUTH 32nd STREET
MC-17
MC-31
0.04
0.03
0.02
Jul-09
Sep-14
Dec-19
0.08
0.06
0.04
0.02
0
Jul-09
Sep-14
Dec-19
0.04
0.02
0
Jul-09
Sep-14
Dec-19
0.05
0.04
0.03
0.02
7/6/2009
9/18/2014
12/1/2019
= Above CUL
= Below CUL
Concentrations in mg/L
Scale in Feet
0
50
N
Stericycle - Washougal Facility
Washougal, Washington
Arsenic- Slide A
Current Groundwater Concentrations - Shallow
DOF DALTON OLMSTED FUGLEVAND
February 14, 2020



Proposed Treatment Area
= Above CUL, but trending down
= Above CUL
= Below CUL
Concentrations in mg/L
PZU-4
PZU-5R
MC-12
MC-8
MC-13
MC-122
MC-107
MC-25
MC-30
BIORETENTION POND
FORMER TANK-FARM AREA
OFFICE BLDG
BLDG 1
MC-21
MC-14
MC-20
MC-24
MC-1
MC-123
MC-33
MC-15
BLDG 2
WASTE OIL TANK SYSTEM
MC-2
MARSH
SOUTH 32nd STREET
MC-16
MC-32
BLDG 3
BLDG 4
MC-17
MC-31
Scale in Feet
0
50
N
Stericycle - Washougal Facility
Washougal, Washington
Arsenic- Slide B
Current Groundwater Concentrations - Shallow
DOF
DALTON OLMSTED FUGLEVAND
February 14, 2020



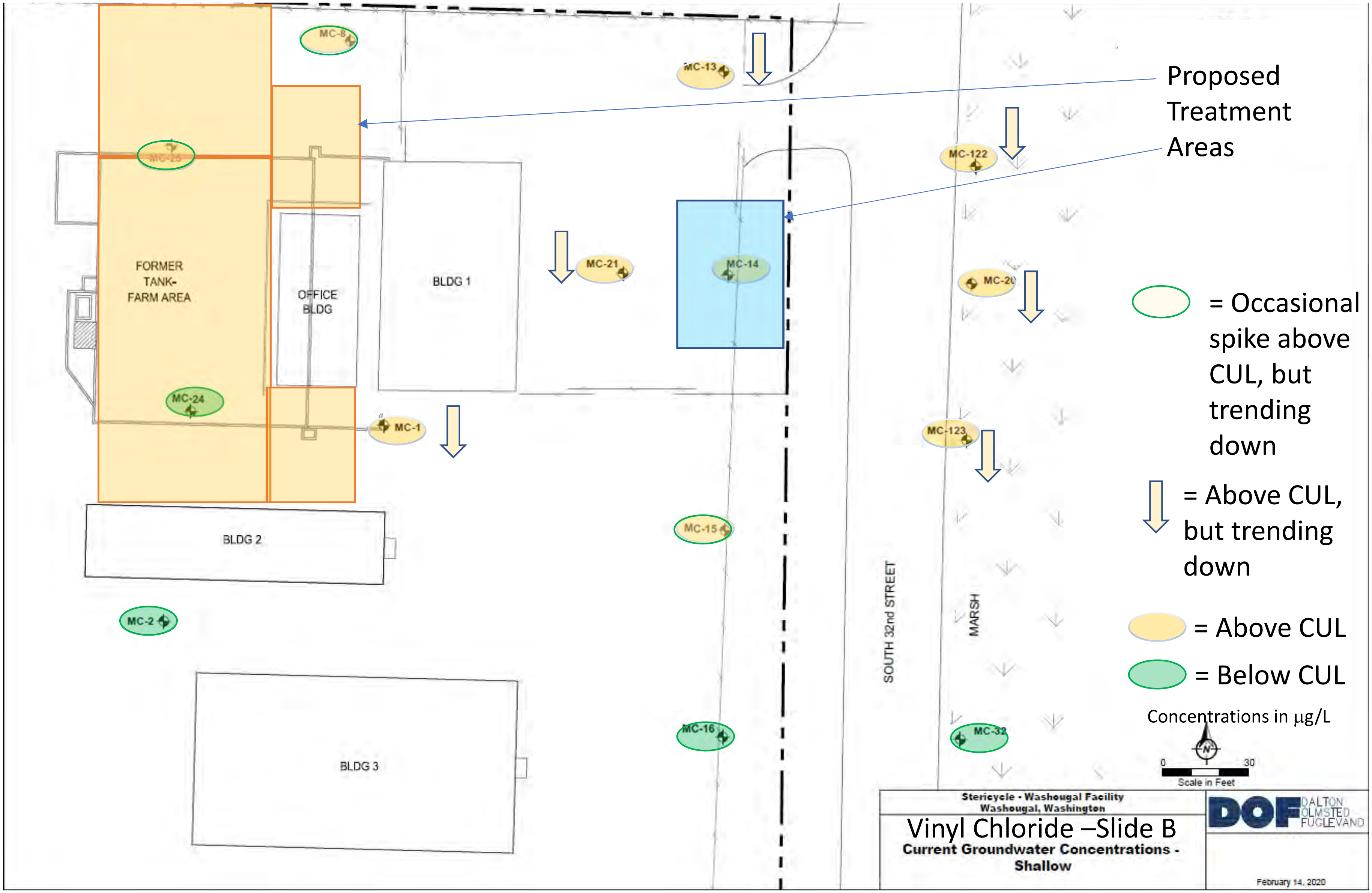
Stericycle - Washougal Facility
Washougal, Washington

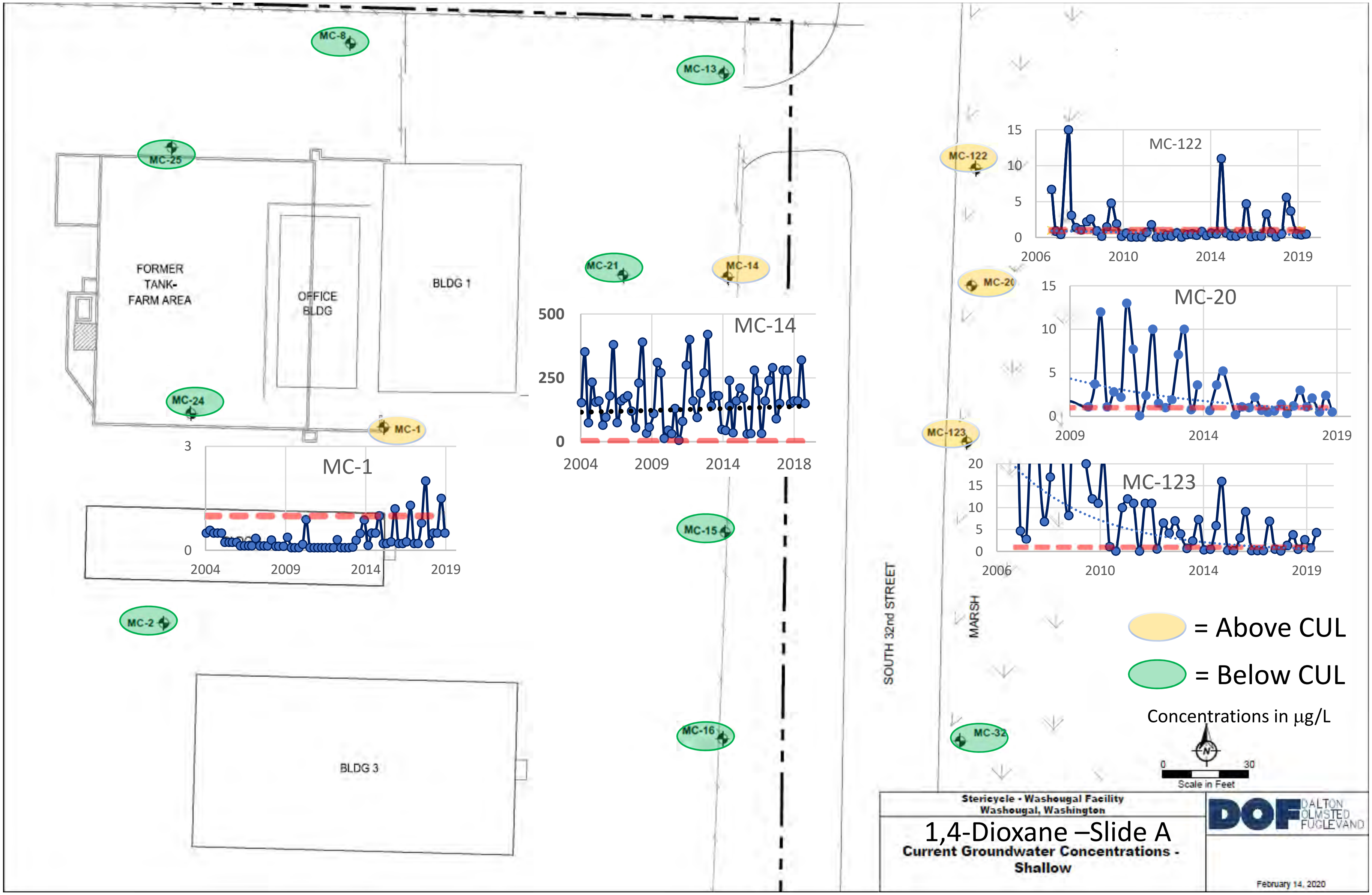
Vinyl Chloride –Slide A

Current Groundwater Concentrations - Shallow

DALTON OLMSTED FUGLEVAND

February 14, 2020


Proposed
Treatment
Areas
FORMER
TANK-
FARM AREA
OFFICE
BLDG
BLDG 1
BLDG 2
BLDG 3
MC-8
MC-13
MC-25
MC-21
MC-14
MC-122
MC-20
MC-24
MC-1
MC-123
MC-15
MC-2
MC-16
MC-32
SOUTH 32nd STREET
MARSH
= Occasional spike above CUL, but trending down
= Above CUL, but trending down
= Above CUL
= Below CUL
Concentrations in µg/L
0
30
Scale in Feet
Stericycle - Washougal Facility
Washougal, Washington
Vinyl Chloride –Slide B
Current Groundwater Concentrations -
Shallow
DOF
DALTON
OLMSTED
FUGLEVAND
February 14, 2020



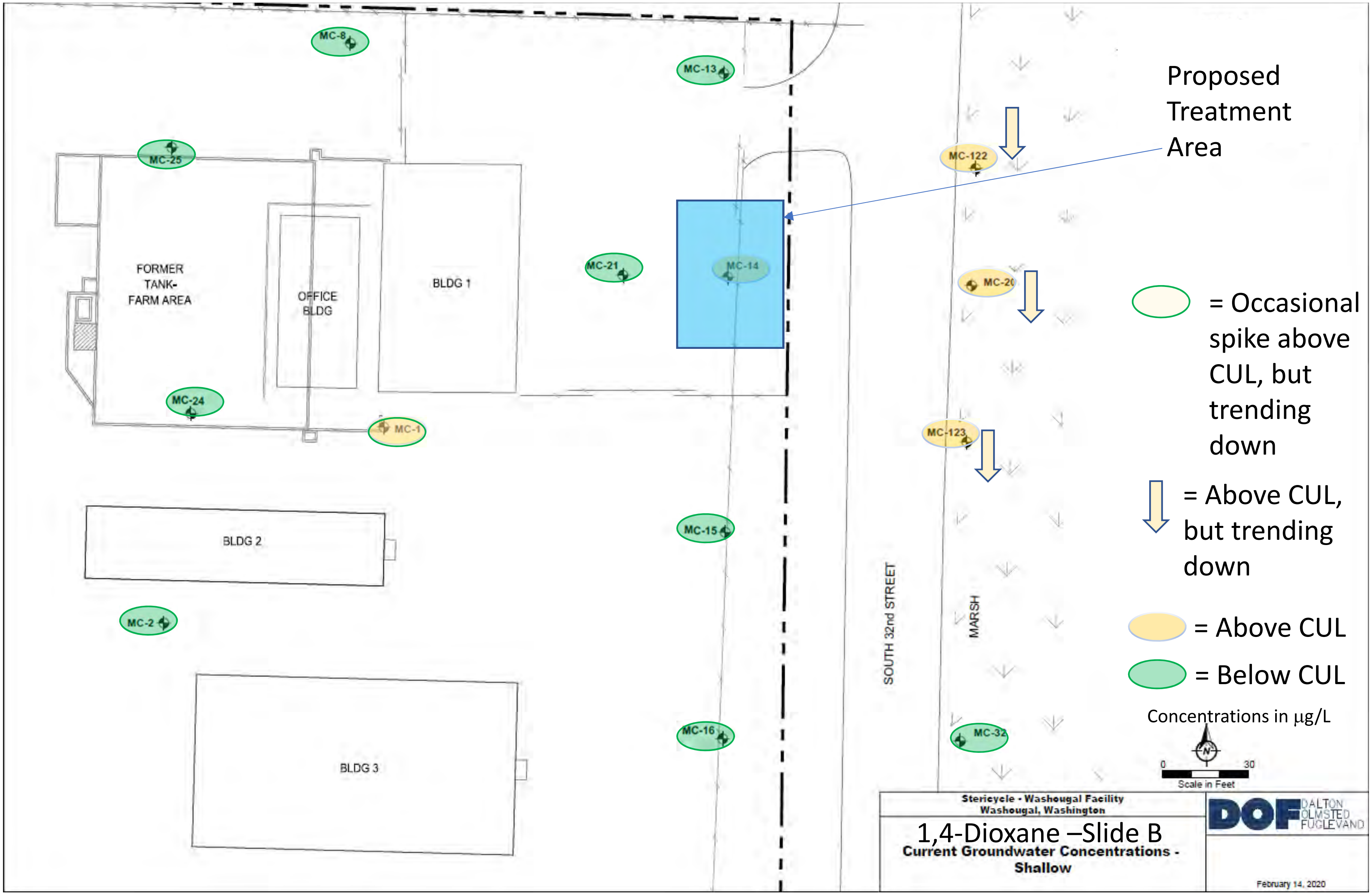
Stericycle - Washougal Facility
Washougal, Washington

1,4-Dioxane –Slide A

Current Groundwater Concentrations - Shallow

DALTON OLMSTED FUGLEVAND

February 14, 2020



Stericycle - Washougal Facility
Washougal, Washington

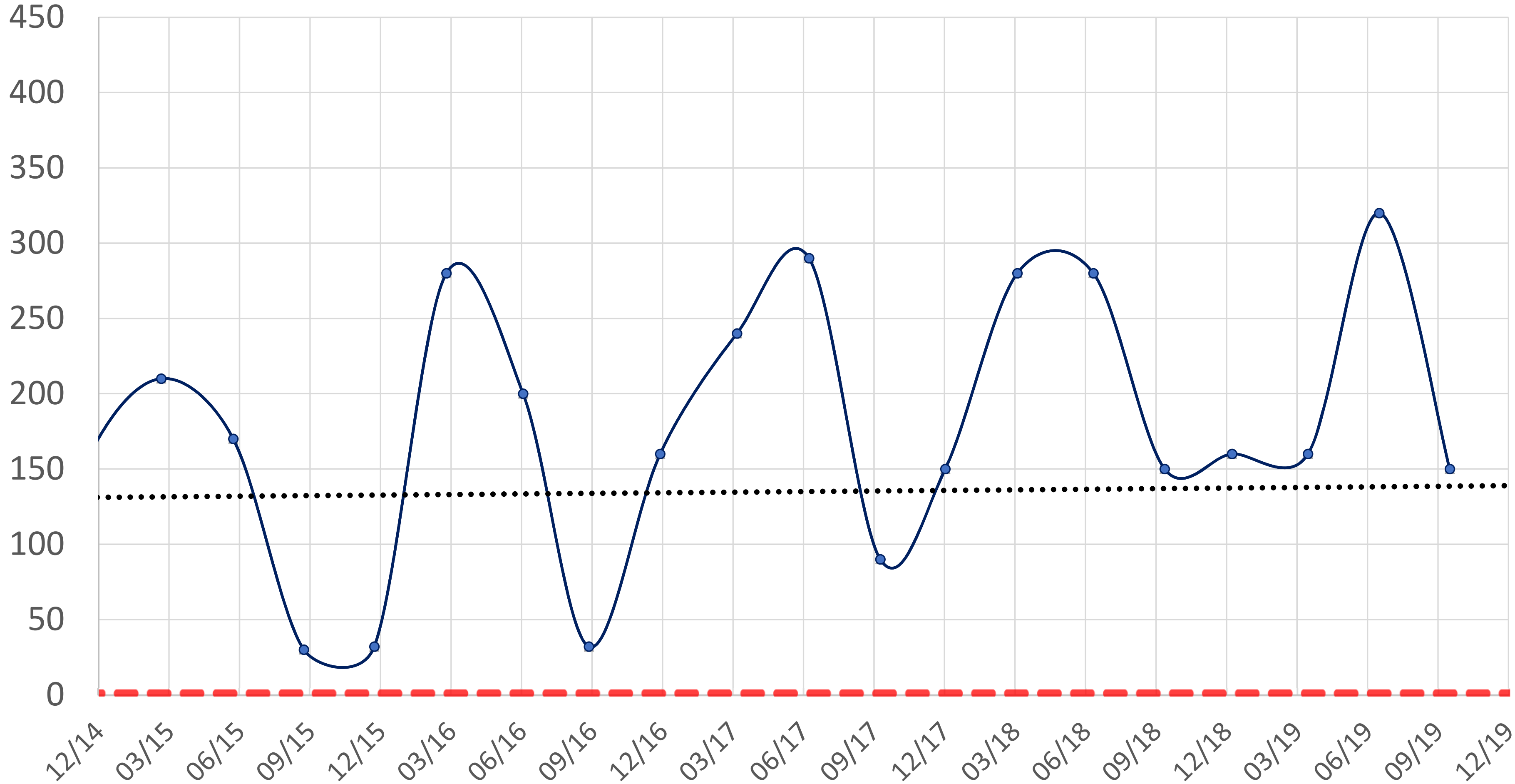
1,4-Dioxane –Slide B

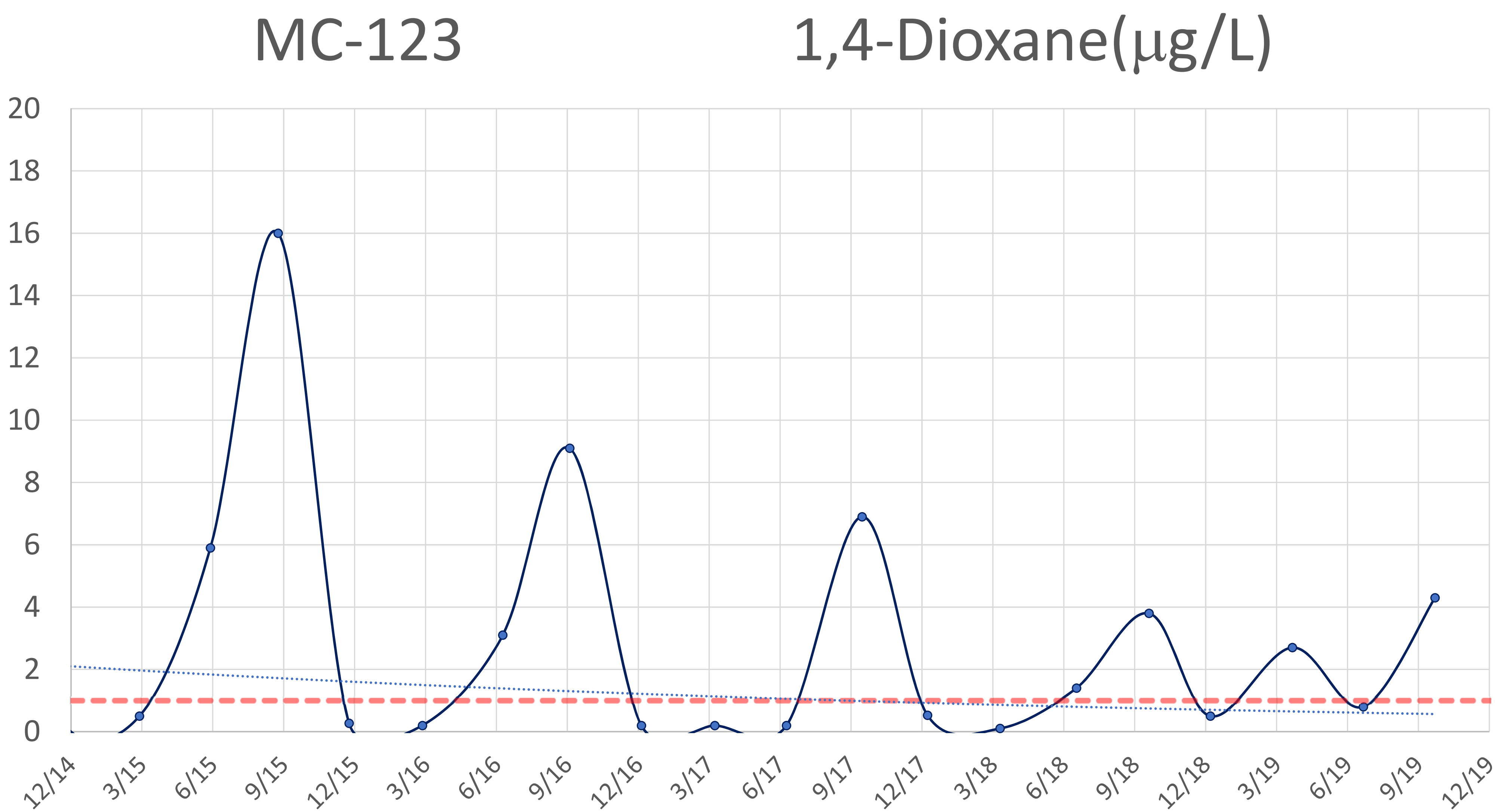
Current Groundwater Concentrations - Shallow

DALTON OLMSTED FUGLEVAND

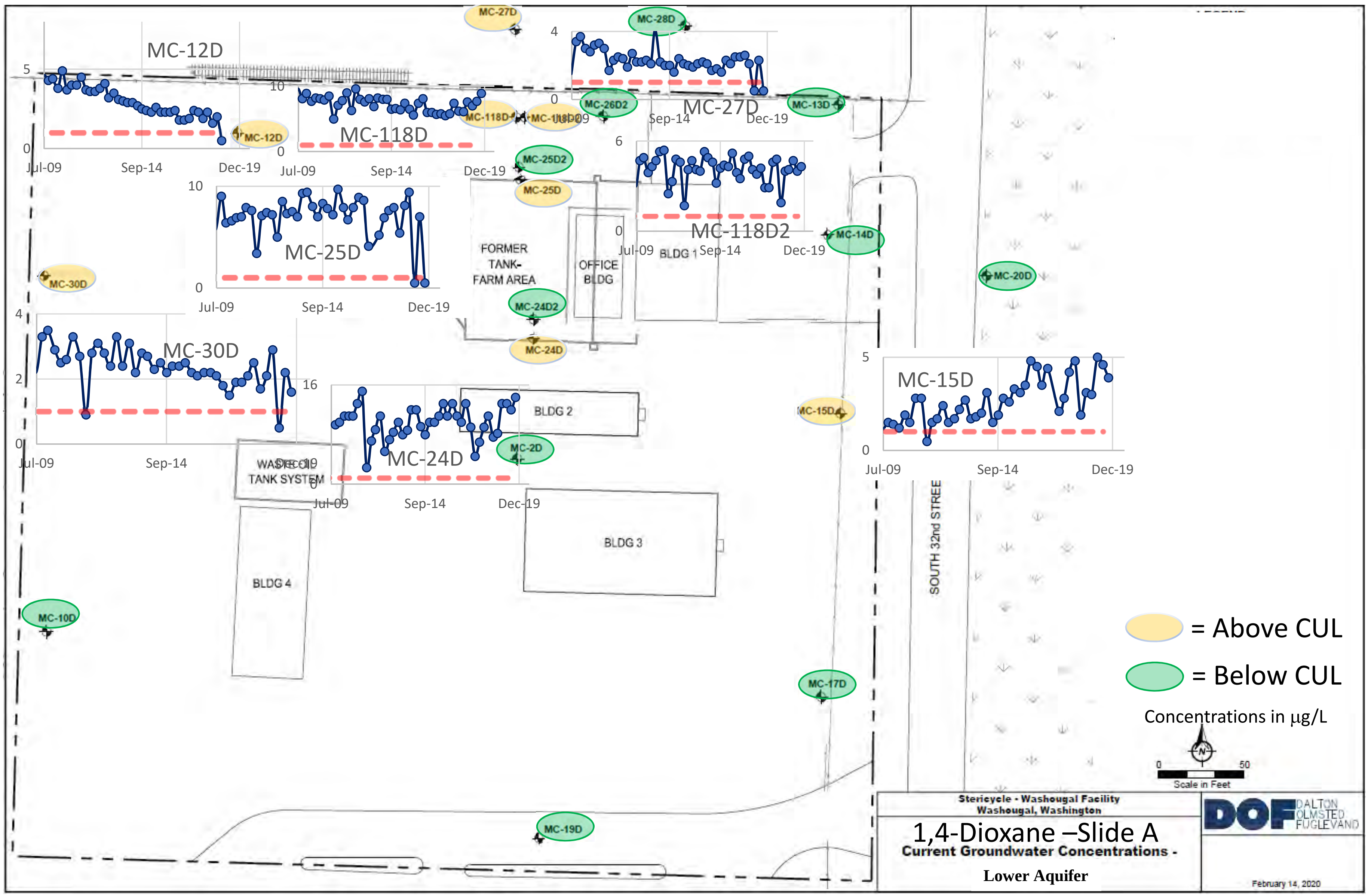
February 14, 2020

MC-14 1,4-Dioxane (µg/L)

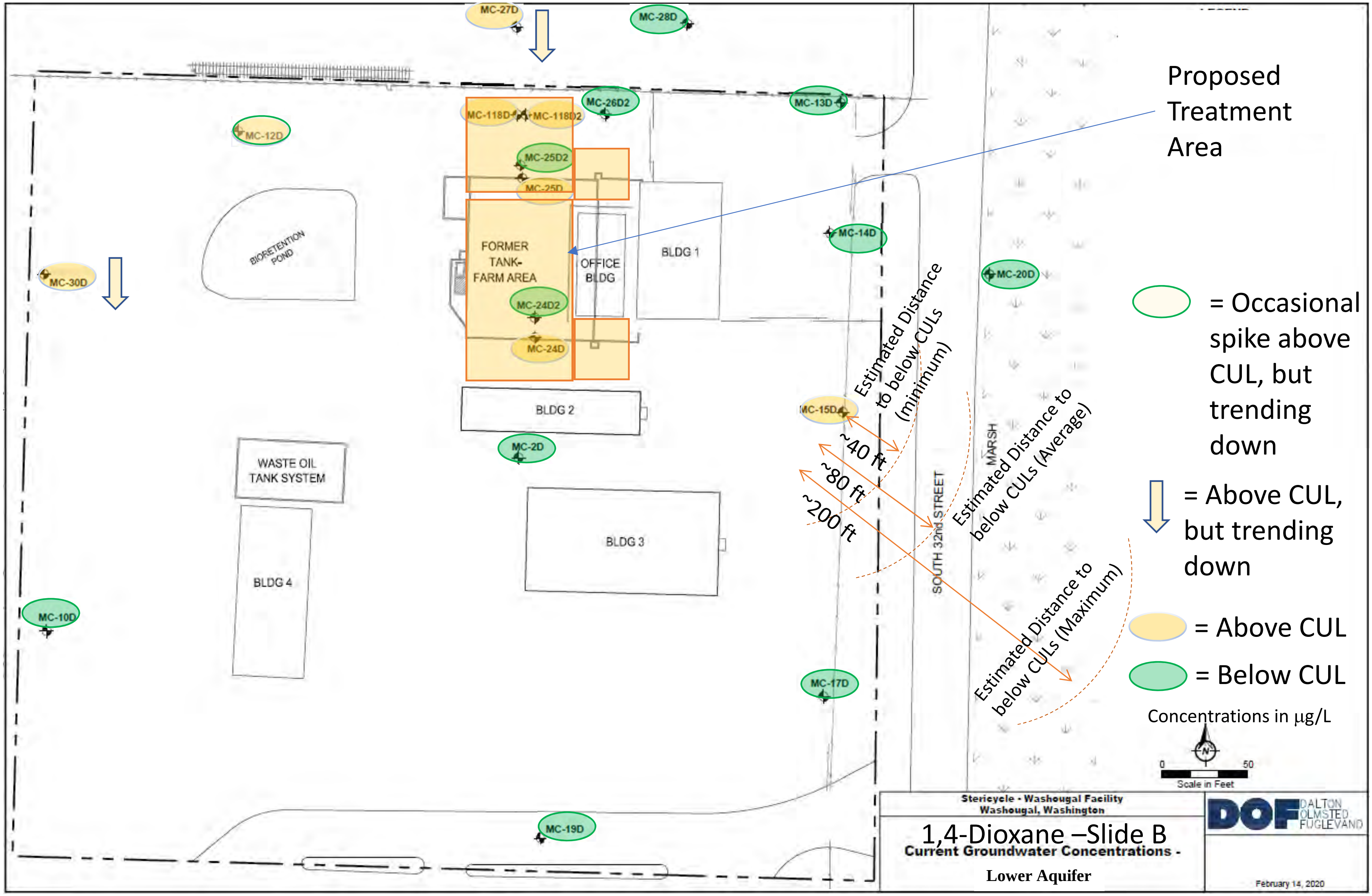




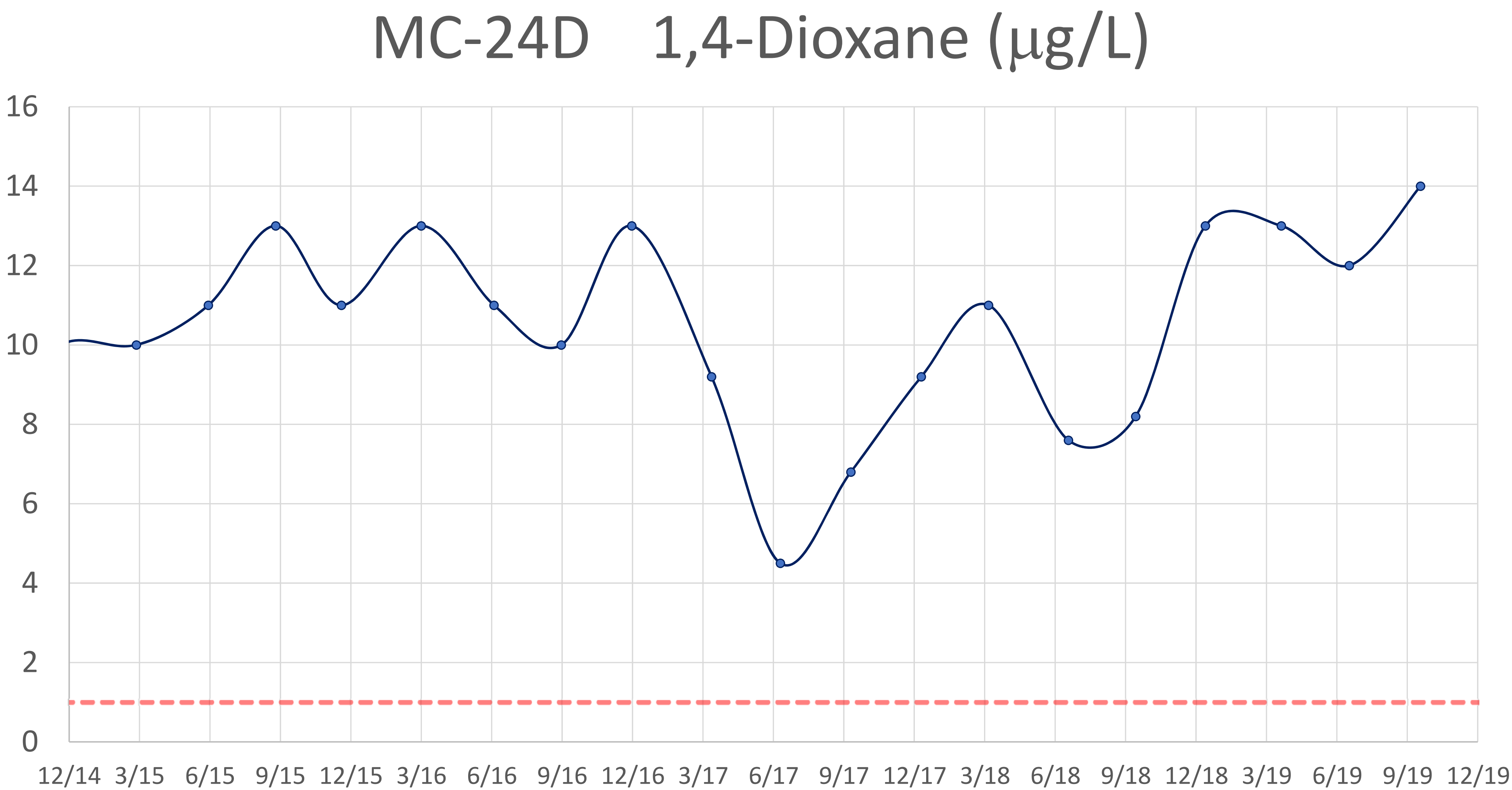
MC-123
1,4-Dioxane(µg/L)
20
18
16
14
12
10
8
6
4
2
0
12/14
3/15
6/15
9/15
12/15
3/16
6/16
9/16
12/16
3/17
6/17
9/17
12/17
3/18
6/18
9/18
12/18
3/19
6/19
9/19
12/19

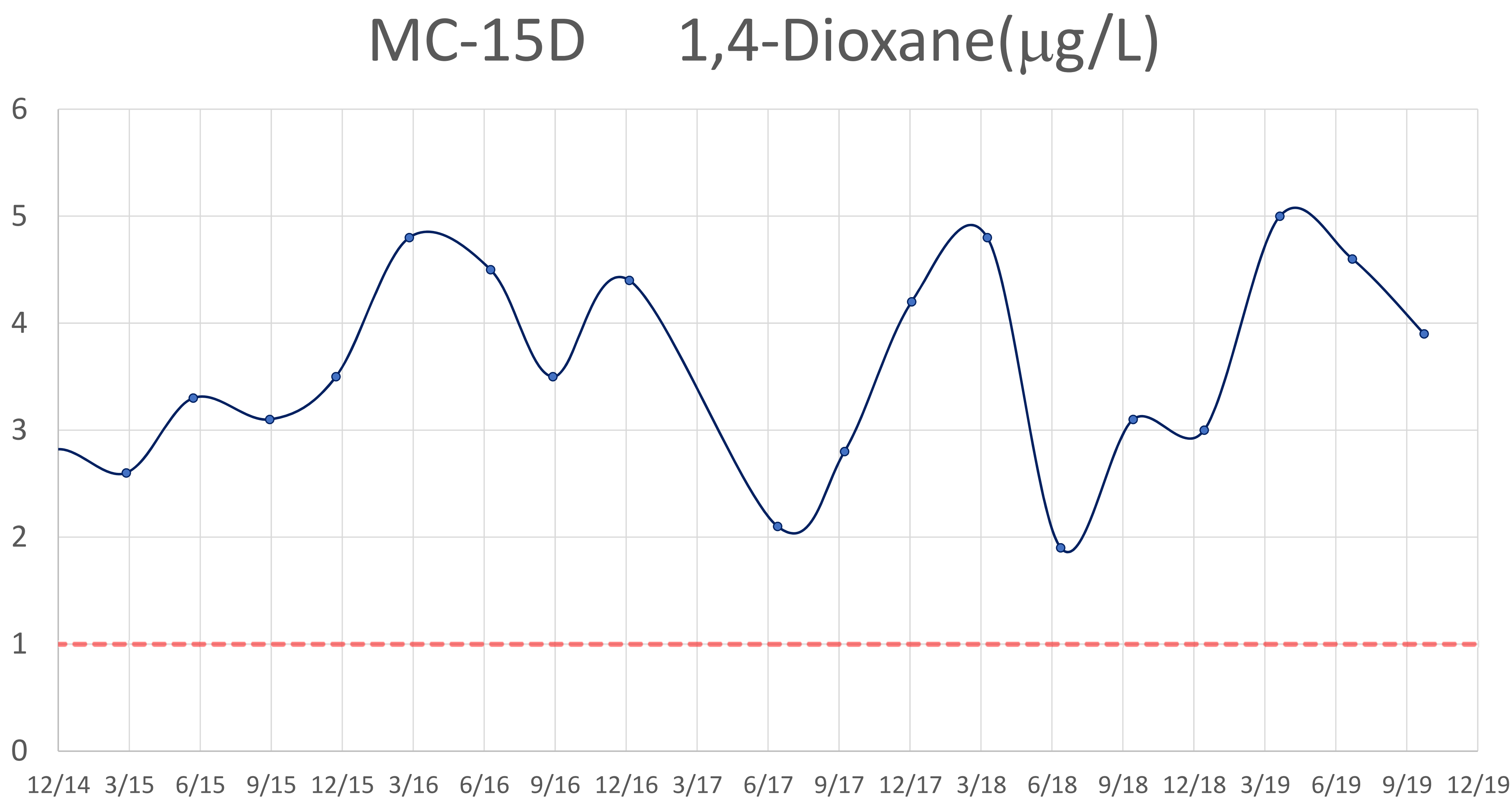


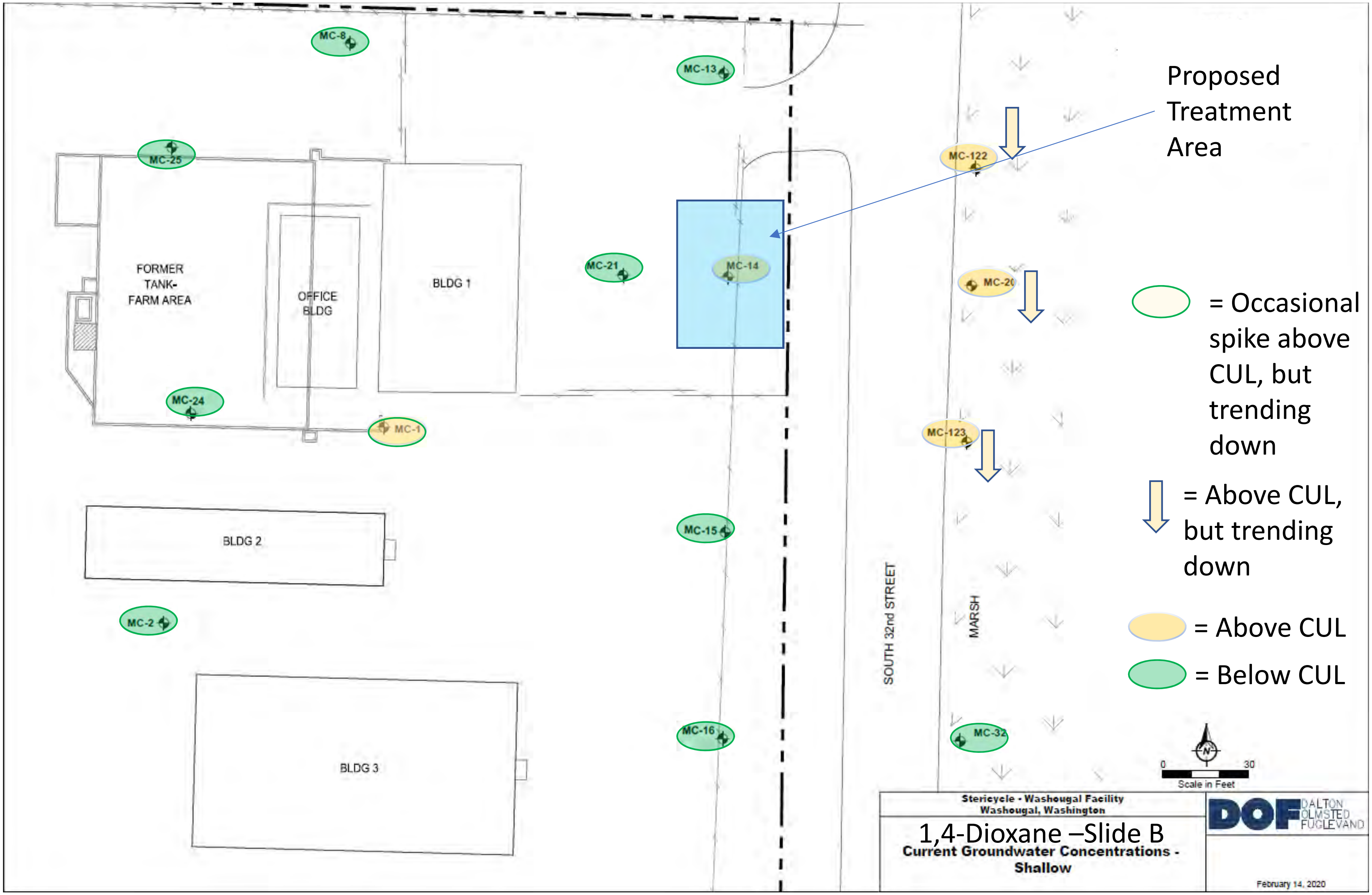
MC-12D
MC-118D
MC-27D
MC-25D
MC-118D2
MC-30D
MC-24D
MC-15D
Jul-09
Sep-14
Dec-19
MC-27D
MC-28D
MC-26D2
MC-13D
MC-12D
MC-118D
MC-118D2
MC-25D2
MC-25D
MC-14D
MC-30D
MC-20D
MC-24D2
MC-24D
MC-15D
MC-2D
MC-10D
MC-17D
MC-19D
FORMER TANK-FARM AREA
OFFICE BLDG
BLDG 1
BLDG 2
BLDG 3
BLDG 4
WASTE OIL TANK SYSTEM
SOUTH 32nd STREET
= Above CUL
= Below CUL
Concentrations in µg/L
0
50
Scale in Feet
Stericycle - Washougal Facility
Washougal, Washington
1,4-Dioxane –Slide A
Current Groundwater Concentrations -
Lower Aquifer
DOF DALTON OLMSTED FUGLEVAND
February 14, 2020

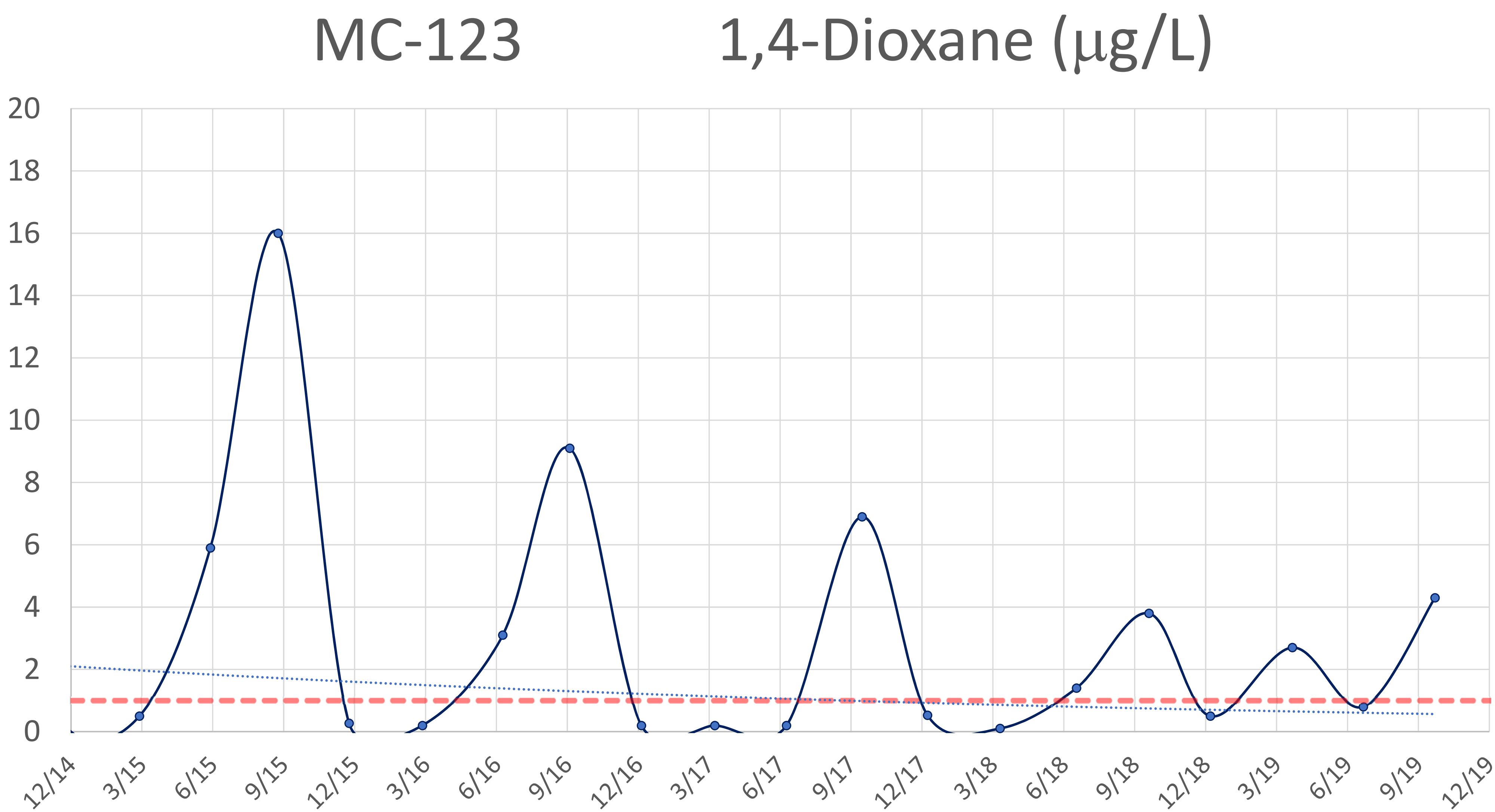


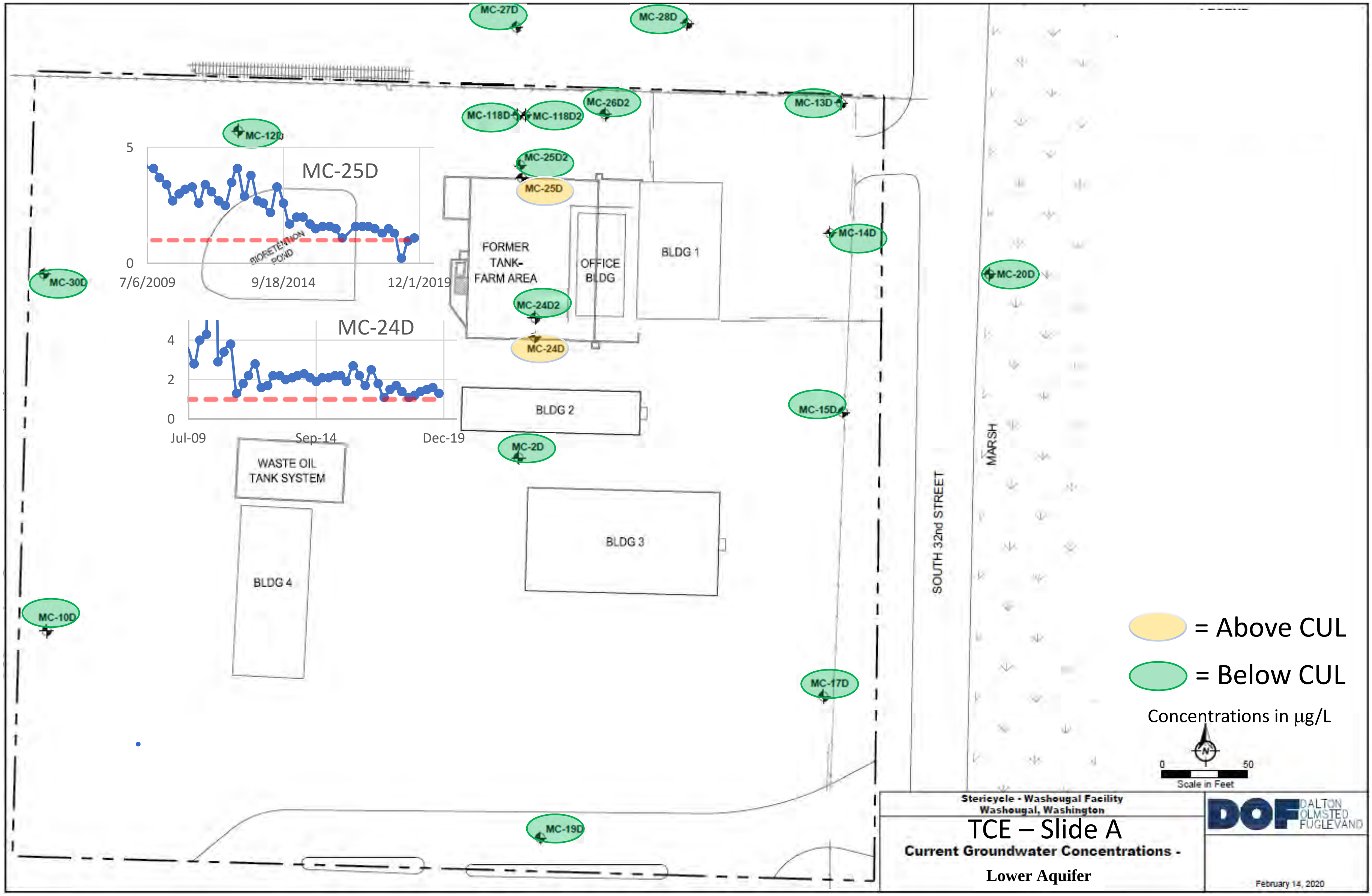
Proposed
Treatment
Area
MC-27D
MC-28D
MC-118D
MC-118D2
MC-26D2
MC-13D
MC-12D
MC-25D2
MC-25D
MC-14D
MC-20D
MC-30D
BIORETENTION POND
FORMER TANK-FARM AREA
OFFICE BLDG
BLDG 1
MC-24D2
MC-24D
BLDG 2
MC-15D
MC-2D
WASTE OIL TANK SYSTEM
BLDG 3
BLDG 4
MC-10D
MC-17D
MC-19D
Estimated Distance to below CULs (minimum)
Estimated Distance to below CULs (Average)
Estimated Distance to below CULs (Maximum)
~40 ft
~80 ft
~200 ft
SOUTH 32nd STREET
MARSH
= Occasional spike above CUL, but trending down
= Above CUL, but trending down
= Above CUL
= Below CUL
Concentrations in µg/L
0
50
Scale in Feet
Stericycle - Washougal Facility
Washougal, Washington
1,4-Dioxane –Slide B
Current Groundwater Concentrations -
Lower Aquifer
DOF DALTON OLMSTED FUGLEVAND
February 14, 2020


MC-24D 1,4-Dioxane (µg/L)
16
14
12
10
8
6
4
2
0
12/14 3/15 6/15 9/15 12/15 3/16 6/16 9/16 12/16 3/17 6/17 9/17 12/17 3/18 6/18 9/18 12/18 3/19 6/19 9/19 12/19

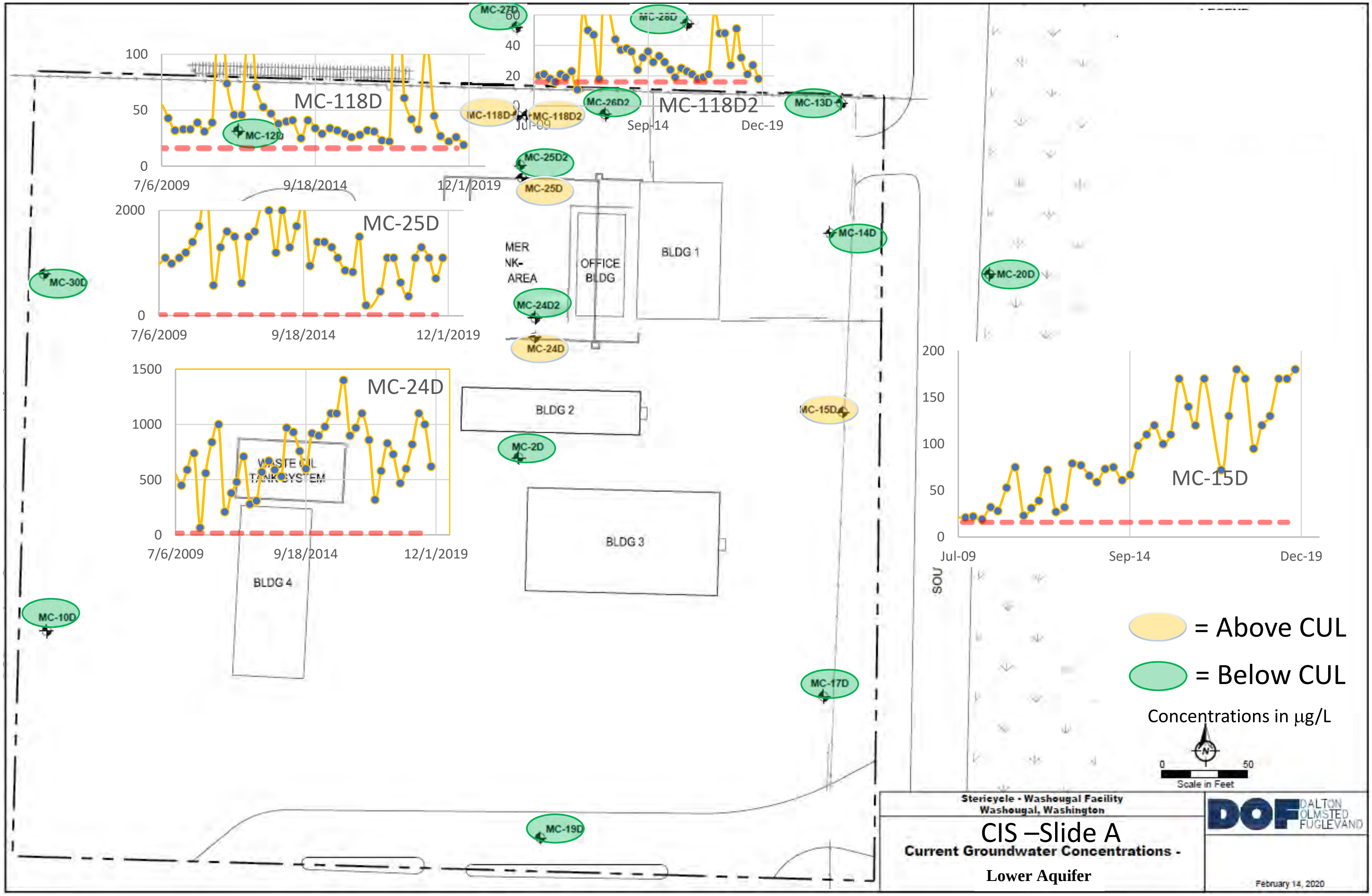

MC-15D 1,4-Dioxane(µg/L)
6
5
4
3
2
1
0
12/14
3/15
6/15
9/15
12/15
3/16
6/16
9/16
12/16
3/17
6/17
9/17
12/17
3/18
6/18
9/18
12/18
3/19
6/19
9/19
12/19


MC-8
MC-13
MC-25
FORMER TANK-FARM AREA
OFFICE BLDG
BLDG 1
MC-21
MC-14
MC-24
MC-1
MC-122
MC-20
MC-123
BLDG 2
MC-15
MC-2
BLDG 3
MC-16
MC-32
SOUTH 32nd STREET
MARSH
Proposed Treatment Area
= Occasional spike above CUL, but trending down
= Above CUL, but trending down
= Above CUL
= Below CUL
0
30
Scale in Feet
Stericycle - Washougal Facility
Washougal, Washington
1,4-Dioxane –Slide B
Current Groundwater Concentrations - Shallow
DOF DALTON OLMSTED FUGLEVAND
February 14, 2020


MC-123
1,4-Dioxane (µg/L)
0
2
4
6
8
10
12
14
16
18
20
12/14
3/15
6/15
9/15
12/15
3/16
6/16
9/16
12/16
3/17
6/17
9/17
12/17
3/18
6/18
9/18
12/18
3/19
6/19
9/19
12/19


MC-27D
MC-28D
MC-118D
MC-118D2
MC-26D2
MC-13D
MC-12D
MC-25D2
MC-25D
MC-14D
MC-20D
MC-30D
MC-24D2
MC-24D
MC-15D
MC-2D
MC-10D
MC-17D
MC-19D
MC-25D
5
0
7/6/2009
9/18/2014
12/1/2019
MC-24D
4
2
0
Jul-09
Sep-14
Dec-19
BIORETENTION POND
FORMER TANK-FARM AREA
OFFICE BLDG
BLDG 1
BLDG 2
BLDG 3
BLDG 4
WASTE OIL TANK SYSTEM
SOUTH 32nd STREET
MARSH
= Above CUL
= Below CUL
Concentrations in µg/L
0
50
Scale in Feet
Stericycle - Washougal Facility
Washougal, Washington
TCE – Slide A
Current Groundwater Concentrations -
Lower Aquifer
DOF
DALTON OLMSTED FUGLEVAND
February 14, 2020


Proposed
Treatment
Area
MC-27D
MC-28D
MC-118D
MC-118D2
MC-26D2
MC-13D
MC-12D
MC-25D2
MC-25D
BIORETENTION POND
FORMER TANK-FARM AREA
OFFICE BLDG
BLDG 1
MC-14D
MC-30D
MC-20D
MC-24D2
MC-24D
BLDG 2
MC-15D
MC-2D
MARSH
WASTE OIL TANK SYSTEM
BLDG 3
BLDG 4
SOUTH 32nd STREET
MC-10D
MC-17D
MC-19D
= Above CUL
= Below CUL
Concentrations in µg/L
0
50
Scale in Feet
Stericycle - Washougal Facility
Washougal, Washington
TCE –Slide B
Current Groundwater Concentrations -
Lower Aquifer
DOF
DALTON OLMSTED FUGLEVAND
February 14, 2020



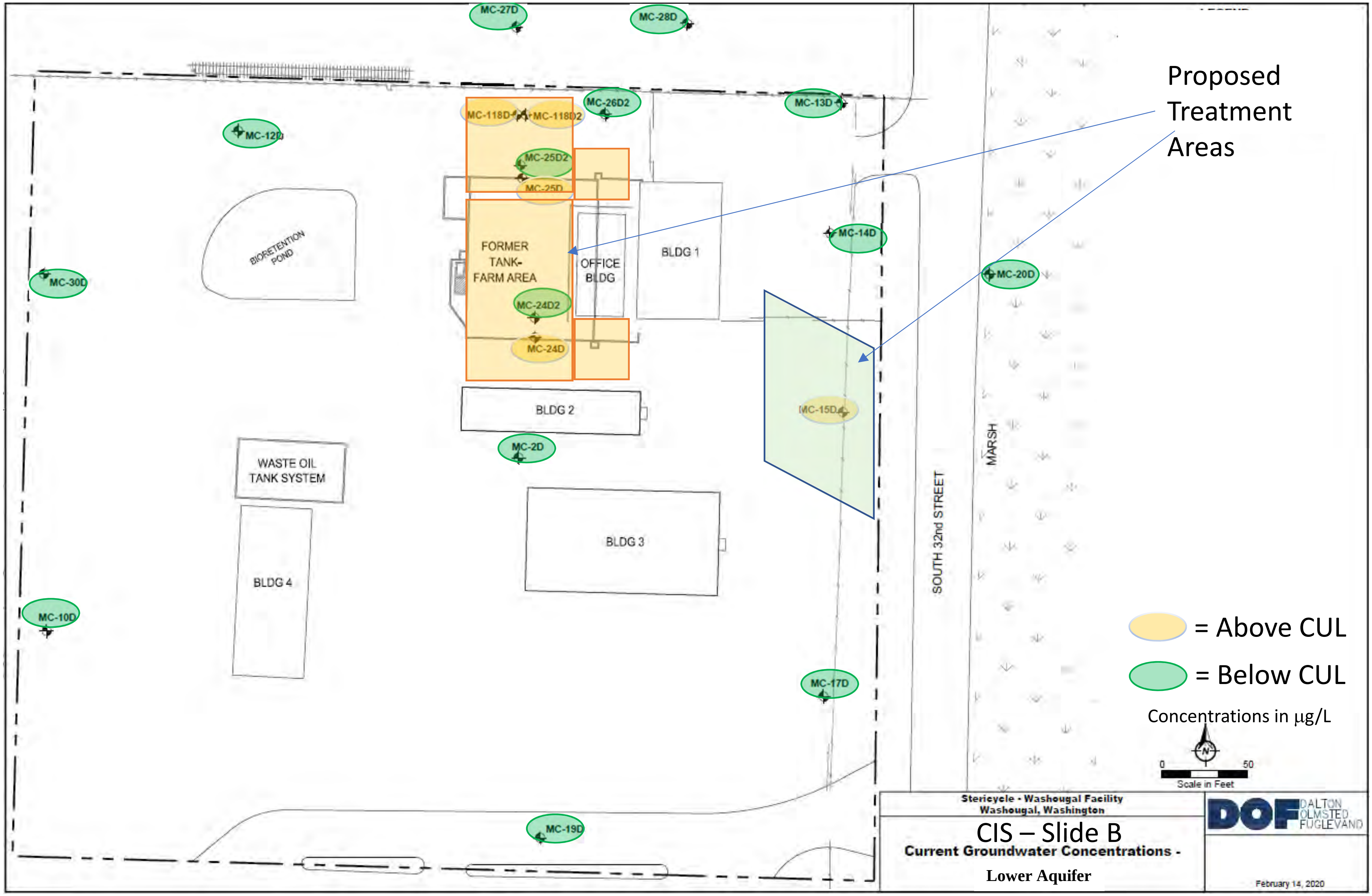
Stericycle - Washougal Facility
Washougal, Washington

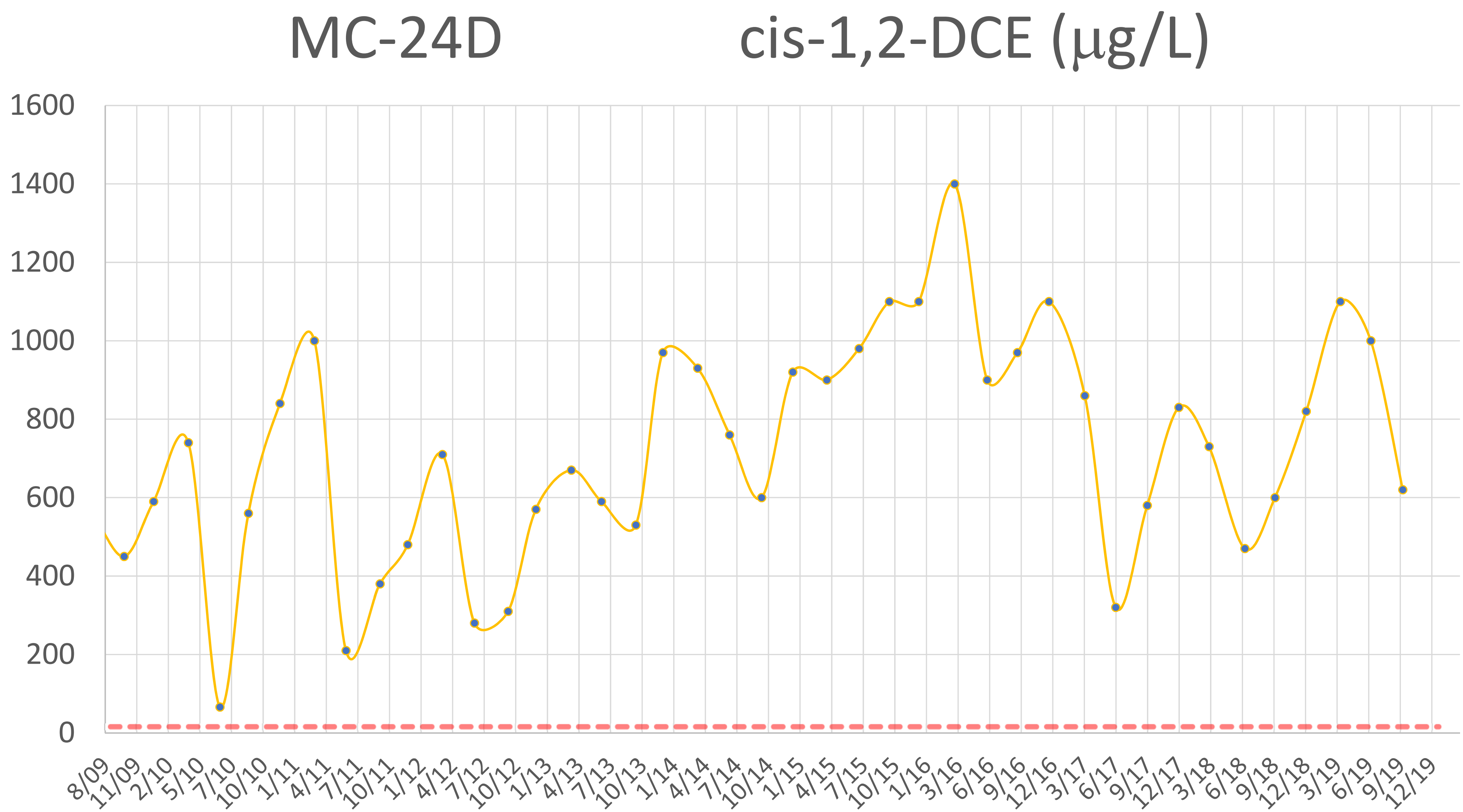
CIS –Slide A

Current Groundwater Concentrations - Lower Aquifer

DOF DALTON OLMSTED FUGLEVAND

February 14, 2020


MC-27D
MC-28D
MC-26D2
MC-13D
MC-118D
MC-118D2
MC-12D
MC-25D2
MC-25D
FORMER TANK-FARM AREA
OFFICE BLDG
BLDG 1
MC-14D
MC-20D
BIORETENTION POND
MC-30D
MC-24D2
MC-24D
BLDG 2
MC-15D
MARSH
MC-2D
WASTE OIL TANK SYSTEM
BLDG 3
BLDG 4
SOUTH 32nd STREET
MC-10D
MC-17D
MC-19D
Proposed Treatment Areas
= Above CUL
= Below CUL
Concentrations in µg/L
0
50
Scale in Feet
Stericycle - Washougal Facility
Washougal, Washington
CIS – Slide B
Current Groundwater Concentrations -
Lower Aquifer
DOF
DALTON OLMSTED FUGLEVAND
February 14, 2020


MC-24D
cis-1,2-DCE (μg/L)
1600
1400
1200
1000
800
600
400
200
0
8/09
11/09
2/10
5/10
7/10
10/10
1/11
4/11
7/11
10/11
1/12
4/12
7/12
10/12
1/13
4/13
7/13
10/13
1/14
4/14
7/14
10/14
1/15
4/15
7/15
10/15
1/16
3/16
6/16
9/16
12/16
3/17
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12/17
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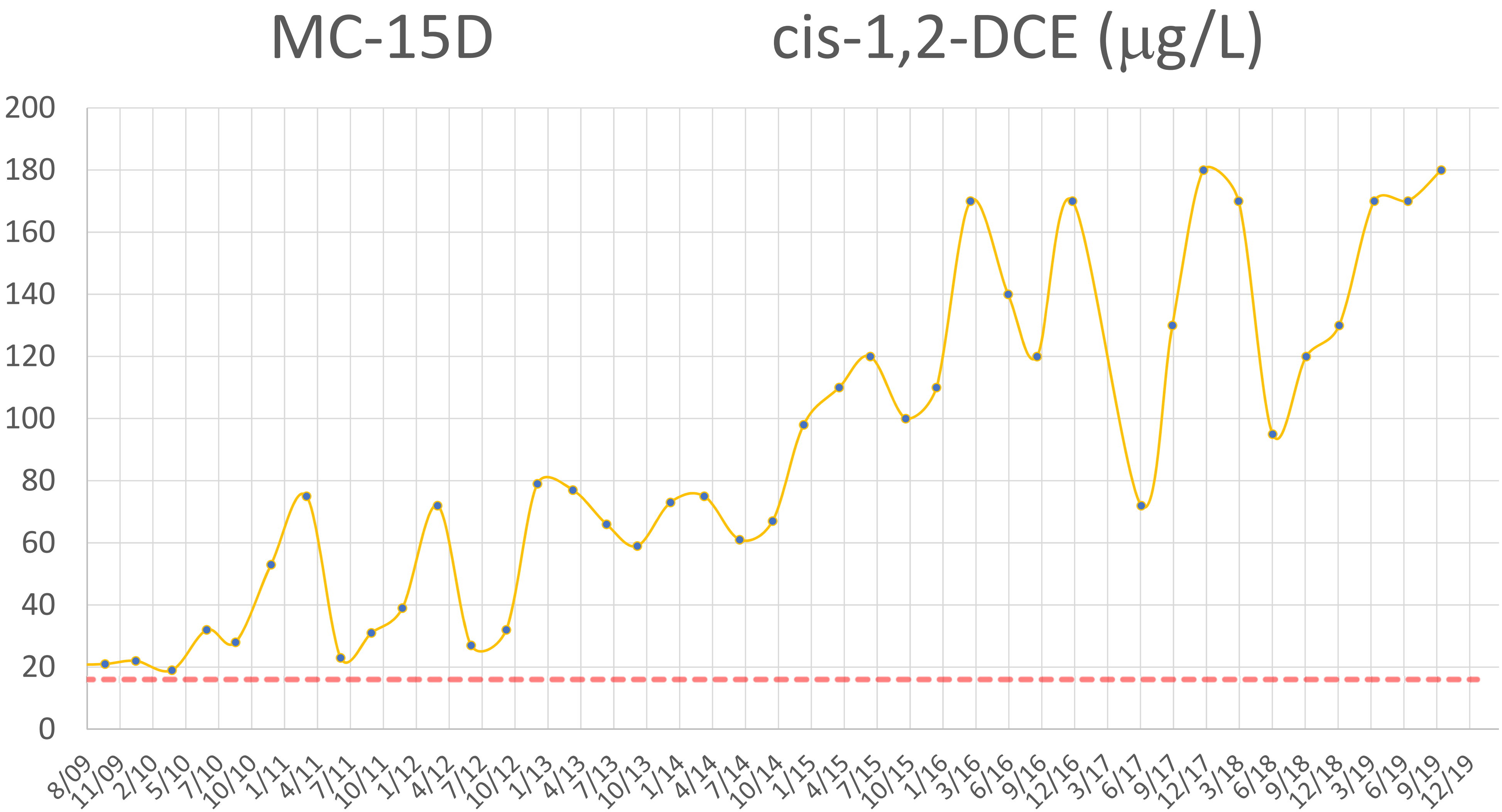
12/18
3/19
6/19
9/19
12/19



MC-15D
cis-1,2-DCE (μg/L)
200
180
160
140
120
100
80
60
40
20
0
8/09
11/09
2/10
5/10
7/10
10/10
1/11
4/11
7/11
10/11
1/12
4/12
7/12
10/12
1/13
4/13
7/13
10/13
1/14
4/14
7/14
10/14
1/15
4/15
7/15
10/15
1/16
3/16
6/16
9/16
12/16
3/17
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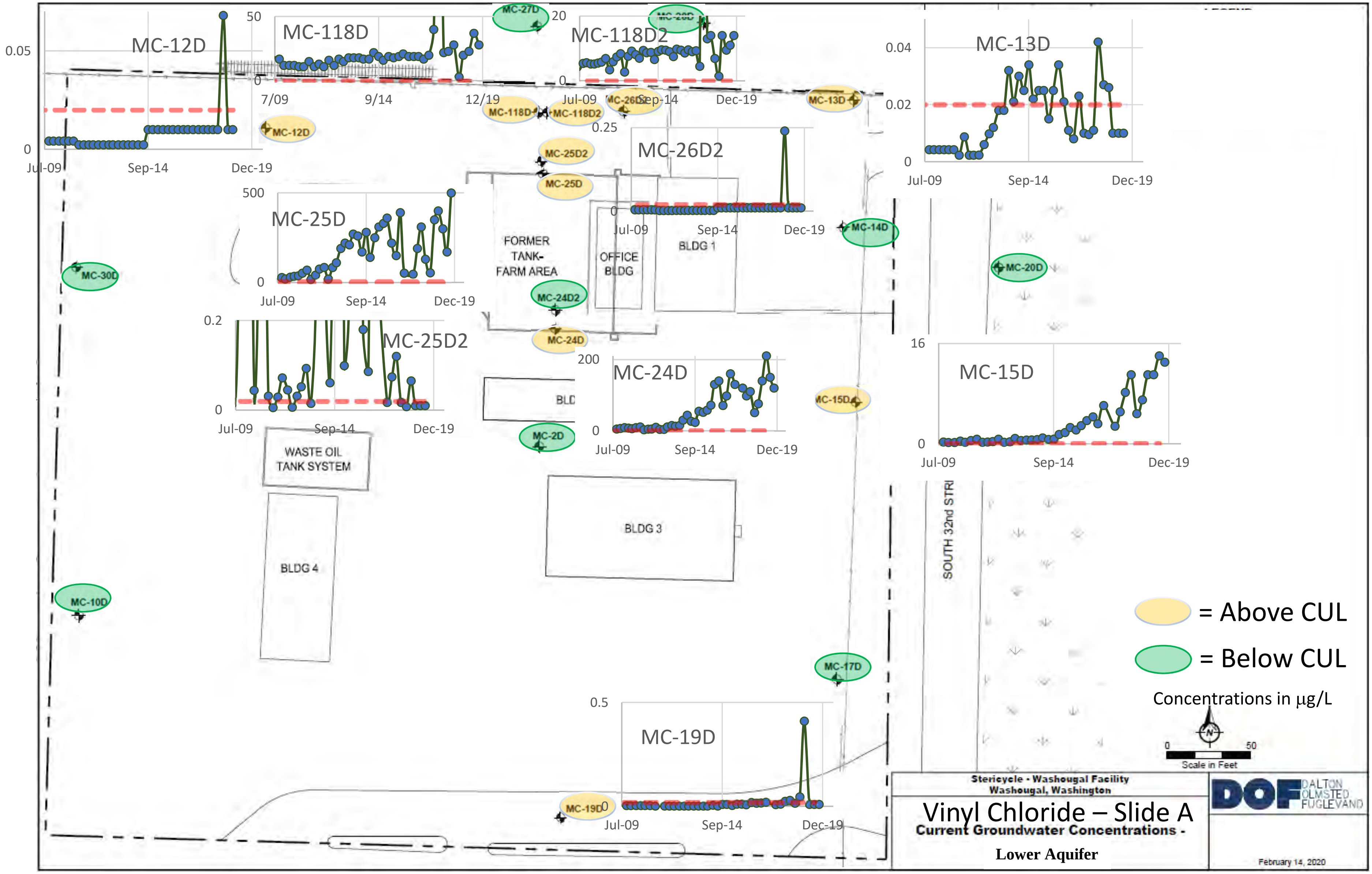
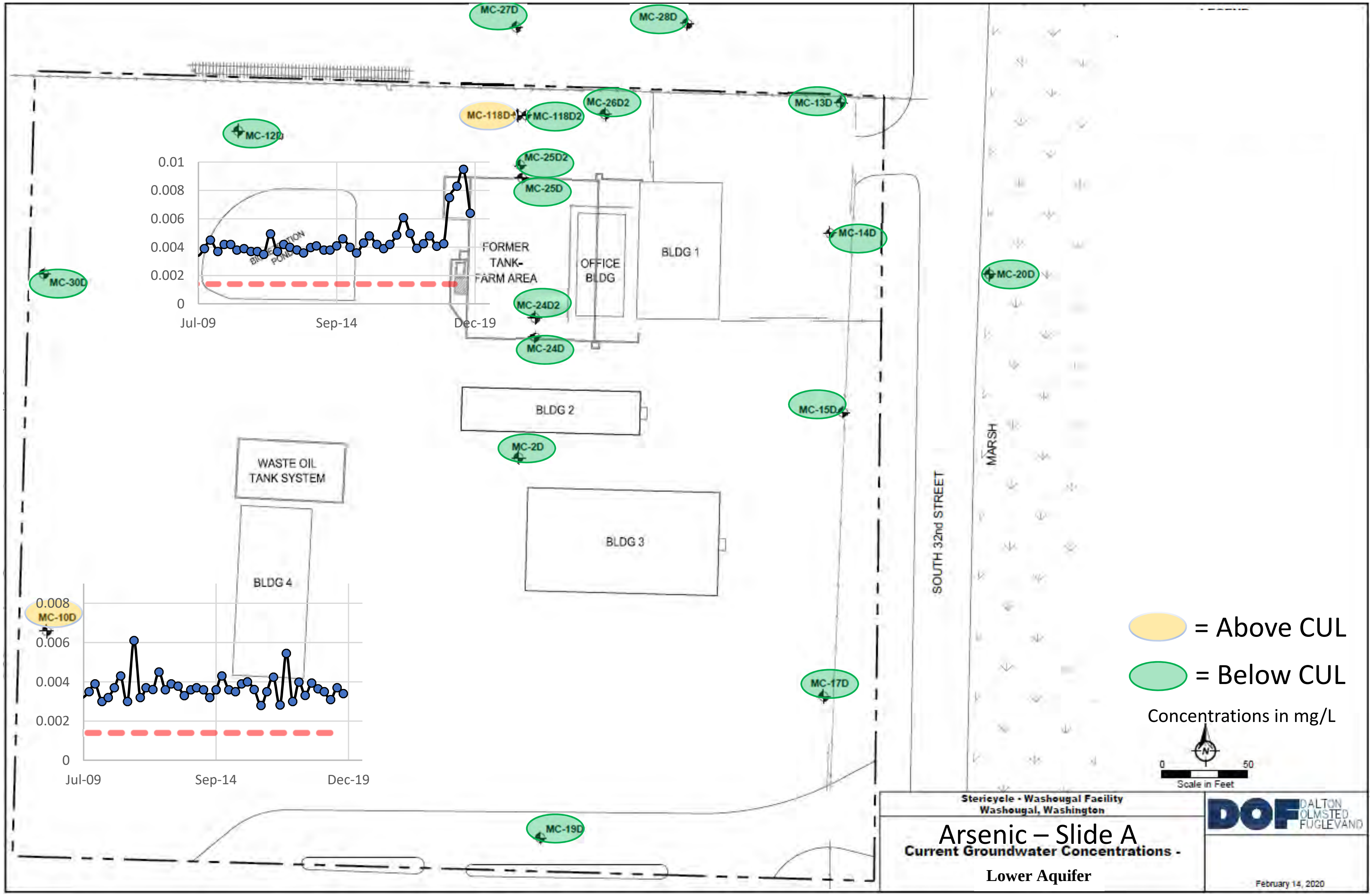
6/19
9/19
12/19

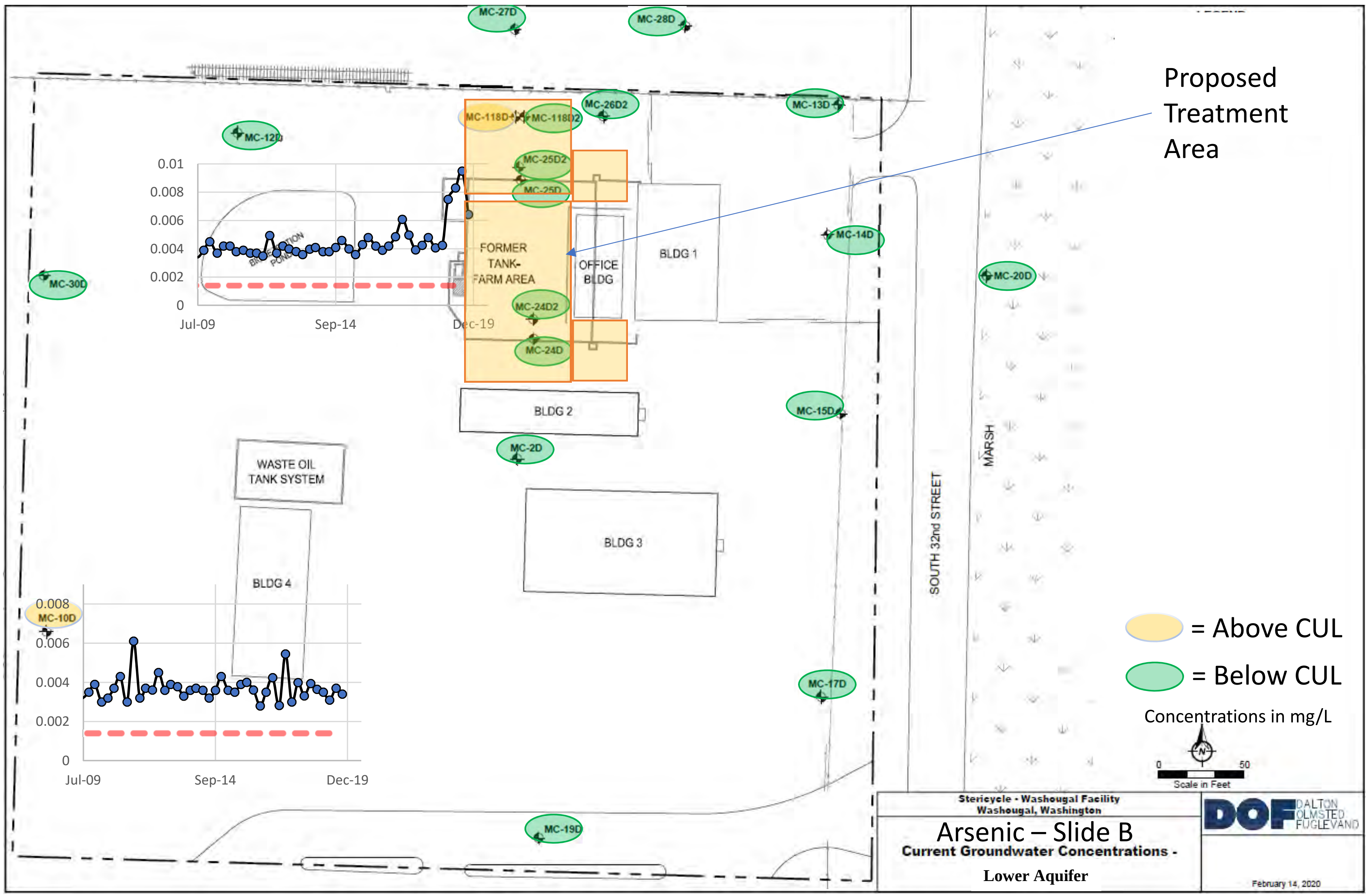


MC-12D
MC-118D
MC-118D2
MC-13D
MC-26D2
MC-25D
MC-25D2
MC-24D
MC-15D
MC-19D
Jul-09
Sep-14
Dec-19
7/09
9/14
12/19
MC-12D
MC-118D
MC-118D2
MC-27D
MC-28D
MC-26D
MC-13D
MC-25D2
MC-25D
MC-14D
MC-30D
MC-20D
MC-24D2
MC-24D
MC-15D
MC-2D
MC-10D
MC-17D
MC-19D
FORMER TANK-FARM AREA
OFFICE BLDG
BLDG 1
WASTE OIL TANK SYSTEM
BLDG 3
BLDG 4
SOUTH 32nd STR
= Above CUL
= Below CUL
Concentrations in µg/L
Scale in Feet
Stericycle - Washougal Facility
Washougal, Washington
Vinyl Chloride – Slide A
Current Groundwater Concentrations -
Lower Aquifer
DALTON OLMSTED FUGLEVAND
February 14, 2020

MC-27D
MC-28D
MC-118D
MC-118D2
MC-26D2
MC-13D
MC-12D
MC-25D2
MC-25D
BIORETENTION POND
FORMER TANK-FARM AREA
OFFICE BLDG
BLDG 1
MC-14D
MC-20D
MC-30D
MC-24D2
MC-24D
BLDG 2
MC-15D
MC-2D
WASTE OIL TANK SYSTEM
BLDG 3
BLDG 4
SOUTH 32nd STREET
MARSH
MC-10D
MC-17D
MC-19D
Proposed Treatment Areas
= Occasional spike above CUL, but trending down
= Above CUL
= Below CUL
Concentrations in µg/L
0
50
Scale in Feet
Stericycle - Washougal Facility
Washougal, Washington
Vinyl Chloride – Slide B
Current Groundwater Concentrations -
Lower Aquifer
DOF DALTON OLMSTED FUGLEVAND
February 14, 2020



MC-27D
MC-28D
MC-118D
MC-118D2
MC-26D2
MC-13D
MC-12D
MC-25D2
MC-25D
MC-14D
MC-20D
MC-30D
FORMER TANK-FARM AREA
OFFICE BLDG
BLDG 1
MC-24D2
MC-24D
BLDG 2
MC-15D
MC-2D
WASTE OIL TANK SYSTEM
BLDG 3
BLDG 4
SOUTH 32nd STREET
MARSH
MC-10D
MC-17D
MC-19D
0.01
0.008
0.006
0.004
0.002
0
Jul-09
Sep-14
Dec-19
= Above CUL
= Below CUL
Concentrations in mg/L
0
50
Scale in Feet
Stericycle - Washougal Facility
Washougal, Washington
Arsenic – Slide A
Current Groundwater Concentrations -
Lower Aquifer
DOF
DALTON OLMSTED FUGLEVAND
February 14, 2020



Proposed Treatment Area
MC-27D
MC-28D
MC-26D2
MC-13D
MC-118D
MC-118D2
MC-12D
MC-25D2
MC-25D
MC-14D
MC-20D
MC-30D
MC-24D2
MC-24D
FORMER TANK-FARM AREA
OFFICE BLDG
BLDG 1
BLDG 2
MC-15D
MC-2D
WASTE OIL TANK SYSTEM
BLDG 3
BLDG 4
MC-10D
MC-17D
MC-19D
SOUTH 32nd STREET
MARSH
0.01
0.008
0.006
0.004
0.002
0
Jul-09
Sep-14
Dec-19
= Above CUL
= Below CUL
Concentrations in mg/L
0
50
Scale in Feet
Stericycle - Washougal Facility
Washougal, Washington
Arsenic – Slide B
Current Groundwater Concentrations -
Lower Aquifer
DOF DALTON OLMSTED FUGLEVAND
February 14, 2020

<u>Appendix F</u>

Remedial Alternatives Cost Estimates

APPENDIX F
REMEDIAL ALTERNATIVE COST ESTIMATES

Stericycle Washougal Facility

Washougal, Washington

August 25, 2020

Prepared by:
DALTON, OLMSTED, & FUGLEVAND
1001 SW Klickitat Way, Suite 200B
Seattle, Washington 98134

Prepared for:
STERICYCLE ENVIRONMENTAL SOLUTIONS
CORRECTIVE ACTION GROUP, NOW PART OF CLEAN EARTH/HARSO

DALTON
OLMSTED
FUGLEVAND

Table of Contents

TABLES

TABLE OF CONTENTS
(Continued)

FIGURES

ACRONYMS & ABBREVIATIONS

bgs	below ground surface
COC	constituent of concern
DOF	Dalton, Olmsted, and Fuglevand, Inc.
DSM	deep soil mixing
Ecology	Washington State Department of Ecology
EPA	Environmental Protection Agency
ERH	electrical resistive heating
FS	Feasibility Study
GAC	granular activated carbon
HMA	hot mix asphalt
IPIM	inhalation pathway interim measure
ISB	In-situ bioremediation
ISCO	in situ chemical oxidation
KMNO	potassium permanganate
MA	monitored attenuation
MNA	monitored natural attenuation
NPV	net present value
POTW	publicly owned treatment works
PRB	permeable reactive barrier
SPOC	standard point of compliance
VOC	volatile organic compound
ZVI	zero-valent iron

1.0 INTRODUCTION

This appendix has been prepared on behalf of Burlington Environmental, LLC, a wholly owned subsidiary of PSC Environmental Services, LLC, which is a wholly owned subsidiary of Stericycle Environmental Solutions, Inc. (hereafter referred to as Stericycle). This appendix presents detailed cost estimates for each of the remedial alternatives developed for the Stericycle site in Washougal, Washington. The cost estimates were developed based on the conceptual designs for the alternatives described in Section 7 and shown in Figures 7-1, through 7-7 of the Feasibility Study (FS) Report. The cost estimates were prepared in accordance with the methods developed by the U.S. Environmental Protection Agency (EPA, 2000). General assumptions and details applied for preparation of the costs estimates for all of the remedial alternatives are presented in Section 2.0. Specific assumptions applied to individual alternatives are described in detail in Section 3.0. The seven alternatives are:

- Alternative A-1- Capping and Monitored Natural Attenuation (MNA);
- Alternative A-2- Capping, In-Situ Bioremediation (ISB), In-Situ Chemical Oxidation (ISCO) and Monitored Attenuation (MA);
- Alternative A-3- Capping, Deep Soil Mixing, ISCO, ISB and MA;
- Alternative A-4- Capping, Electrical Resistive Heating, ISB and MA;
- Alternative A-5- Capping, Permeable Reactive Barrier with zero-valent iron (ZVI), ISCO, and MA;
- Alternative A-6- Capping, ISB, ISCO, Hydraulic Control, and MA; and
- Alternative A-7- Capping, Full Scale ISCO, ISB, and MA.

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2.0 GENERAL ASSUMPTIONS

Net present value (NPV) cost estimates were prepared for each alternative. A summary of the estimated NPV cost for each remedial alternative is presented in Table F-1. The NPV cost estimates combine initial implementation costs (Year 0) as well as long-term recurring costs (Years 1 to the end of remedy). NPV discount rates were applied to recurring costs only. The initial implementation costs involve the cost to design, build, and implement the remedial alternative, and include permitting, engineering design, purchase of facilities and equipment, pilot studies, construction, and construction management costs. Recurring costs are the costs that would be incurred over the life of the remedial action and would include costs for operation, project management, repair and maintenance, compliance and confirmational monitoring, property access, materials, and replacement of equipment that may become worn out.

The NPV cost for each alternative (Table F-1) was calculated using a net discount (interest) rate of 2.5 percent based on recommendations provided by the Washington State Department of Ecology (Ecology), although EPA guidance recommends a net discount rate of 7 percent. Additional discussion of the discount rate is provided in the sensitivity analysis in Section 4.0.

Each alternative has three tables that show how the total NPV cost was calculated (Tables F-2 through F-22).

- Implementation Costs- costs in Year 0, for permitting, design, construction and implementation of the remedial action.
- Recurring Operational Costs- ongoing remedial actions, maintenance, monitoring, and project management.
- NPV Costs- Costs shown for each year of the remedy, with costs pulled into each year as appropriate from the first two tables.
    - A 10% contingency was applied to each column and added to the total for each year.
    - The total cost without NPV rates applied is provided.
    - NPV discount rates are applied on Years 1 through alternative completion to produce an NPV Total cost.

All costs in the tables are presented in constant 2020 dollars. The total NPV costs shown in Table F-1 are rounded to the nearest thousand.

The quantities shown in the cost tables were estimated based on the assumed scope of the remedial alternatives and preliminary conceptual designs, as described in Section 3. The cost estimates are based on the areas where remedial actions would occur as shown in Figures 7-1 through 7-7. Reasonable assumptions based on professional judgment were made as appropriate to estimate quantities for individual line items. The cost estimates based on these quantities are, therefore, preliminary estimates suitable for use in this FS Report to compare the alternatives only. These cost estimates are not suitable for final design or for budgeting.

The unit prices for most of the line items presented in the cost estimate tables were based on vendor quotes and experience with similar work. Technology vendors were consulted for costing on their specific technology's physical layout requirements and potential complications that could arise during implementation. Dalton, Olmsted, and Fuglevand, Inc. (DOF) then reviewed vendor supplied information against site specific trend data and layout to build the costs for each alternative.

The following general assumptions were made in estimating costs for each of the alternatives.

- Production rates and prices would be based on a standard 40-hour work week; no overtime or shift differential were included.
- The personal protective equipment would be Level D, unless otherwise noted.
- Any waste generated would be non-hazardous solid waste, except as otherwise noted.
- Any surface asphalt and concrete removed as part of remediation would be uncontaminated and would be recycled.
- Costs for potable water have not been estimated and have not been included in the remediation cost estimates.
- No security guards would be required.
- Work would be performed without interruptions or multiple mobilizations and setups, unless noted otherwise.
- No prevailing wage or union standby labor costs have been included.
- Costs for legal fees associated with gaining access for remedial construction have not been included.

The implementation cost estimates include the consultant cost (professional technical services) for individual tasks. The professional technical services were estimated as a specified percentage of the remediation construction cost (see detailed cost estimates for each alternative). The specific line items for professional technical services have been divided into permitting, remedial design, construction management, and project management, as appropriate. The assigned percentages for remedial design, construction management, and project management were obtained from EPA guidance (EPA, 2000) and from professional experience for permitting.

The following assumptions were made in estimating recurring costs :

- The unit prices used for recurring cost estimates include consultant and contractor costs, as appropriate.
- Recurring cost rates were kept flat over the time of remediation (e.g. if analysis for copper was $15 in Year 1, it was assumed to still cost $15 in Year 30).
- Annual project management costs were estimated as $10,000 for all the alternatives. The recurring project management costs include costs related to the planning, designing, coordinating implementation, and reporting of groundwater monitoring, annual site and cap inspections, inhalation pathway interim measure (IPIM) operation, and maintenance items detailed in the recurring cost tables for each alternative.
  - Alternatives A-2 and A-6 are an exception to this, since a second round of enhanced bioremediation is included as a recurring cost. Discussion of the assumptions for these recurring costs are included in sections 3.2 and 3.6.
  - Project management costs were increased to $15,000 during year 1 to account for the second round of enhanced bioremediation injections. Project management costs related to the three years of hydraulic containment in Alternative A-6 are included under operations of the system instead of adding additional project management separately.
- Groundwater monitoring recurring costs included the following:
  - Labor costs were based on current dedicated staff providing the sampling labor.
  - Analytical costs were based on current sampling costs and the same analyte list for analysis.
  - No annual increase in costs for laboratory analysis or data validation.
  - No reduction in analytes would be applied over the time of the remedial action.
  - A slow reduction in number of wells sampled and sample events over time to reflect the different stages of remediation.

Timing for each alternative was based on the average of trends in existing shallow groundwater zone and lower aquifer wells (Appendix E). Once source area remediation is complete, natural degradation rates were assumed to be on the same approximate time scale of existing wells that have declining contaminant of concern (COC) trends.

For the FS, that means the most aggressive technologies had a restoration time frame of 10 years, with the first five years comprising of active remediation and polishing by monitored attenuation, and the last five years as confirmation monitoring. The moderately aggressive technologies had a restoration time frame of 15 years with the first ten years comprising of active remediation and polishing by monitored attenuation, and the last five years as confirmation monitoring. For Alternative A-1 (MNA) the mostly passive remedial action, the timeline was assumed to be 30 years based on a number of wells in slow decline, but this assumes that the flat or increasing trends in some wells (Appendix E) start to decline by year 15.

3.0 SPECIFIC ASSUMPTIONS

Specific, detailed assumptions made for each remedial alternative are described in the following subsections.

3.1 Assumptions for Alternative A-1

Alternative A-1 includes:

- Grouting of the potential groundwater conduit, the utility trench under the stormwater piping to the east of the Stericycle property in four locations;
- Continued operation of the existing IPIM under Building 1;
- Augmenting existing surface cover by paving select areas of the Site with 4-inches of hot mix asphalt pavement;
- Long-term monitoring and maintenance of the pavement cover;
- Monitored natural attenuation of groundwater downgradient of source areas;
- Groundwater monitoring; and
- Institutional controls

Detailed cost estimates for Alternative A-1 are presented in Tables F-2 through F-4. Detailed assumptions were made as follows for remedial Alternative A-1.

- A standard point of compliance (SPOC) would be utilized for soil and groundwater for this alternative.
- The utility trench would be grouted at four locations (from near PZU-4 to between MC-16 and MC-17) to prevent groundwater from using the stormwater piping backfill as a conduit to surface waters.
- Additional capping in the vicinity of GP-109 and GP-93, west of Building 1, around Building 3, and along the northern fence line will be completed through placement of hot mix asphalt (HMA) pavement. Some portions of these areas are already paved and the areas will need to be maintained.
- IPIM operational costs would be negligible.
- Groundwater monitoring would be necessary for at least 30 years with the following number of monitoring wells for monitoring time intervals:
    - Years 0-5, 40 wells, sampled quarterly
    - Years 6-10, 40 wells, sampled semi-annually
    - Years 11-15; 30 wells, sampled semi-annually
    - Years > 15; 23 wells, sampled annually

3.2 Assumptions for Alternative A-2

Alternative A-2 includes:

- Grouting the utility trench under the stormwater piping to the east of the Stericycle property in four locations;
- Continued operation of the existing IPIM under Building 1;
- Augmenting the existing surface cover by paving select areas of the Site with 4-inches of hot mix asphalt pavement;
- Long-term monitoring and maintenance of the pavement cover;
- Treatment near MC-14 - two rounds of ISCO injections to treat 1,4-dioxane and volatile organic compounds (VOCs) in the Shallow Groundwater Zone;
- Treatment in the former tank farm area and near the north fence line (near MC-118D) - two rounds of ISB injections utilizing carbohydrates and emulsified ZVI targeting chlorinated VOCs remaining in the Silt Layer and the upper portion of the Lower Aquifer;
- Treatment in the Lower Aquifer upgradient of and near MC-15D - ISB injection of carbohydrates near MC-15D to reduce risk of off-site migration of chlorinated VOCs in the upper portion of the Lower Aquifer;
- Monitored attenuation of the groundwater downgradient of the remediation areas;
- Groundwater monitoring would be used to evaluate ISB/ISCO effectiveness for the duration of the restoration timeframe (15 years based on vendor experience and the extrapolation of groundwater monitoring data trends once source area remediation is complete). Once groundwater monitoring indicates ISB/ISCO and MA has permanently destroyed COCs to below cleanup levels, remediation would be considered complete; and
- Institutional controls.

Detailed cost estimates for Alternative A-2 are presented in Tables F-5 through F-7. Detailed assumptions were made as follows for remedial Alternative A-2.

- A SPOC would be utilized for soil and groundwater for this alternative.
- The utility trench would be grouted at four locations (from near PZU-4 to between MC-16 and MC-17) to prevent groundwater from using the stormwater piping backfill as a conduit to surface waters.
- Additional capping in the vicinity of GP-109 and GP-93, west of Building 1, around building 3, and along the northern fence line will be completed through placement of HMA pavement. Some portions of these areas are already paved and the areas will need to be maintained.
- IPIM operational costs would be negligible.
- Enhanced bioremediation with multiple injection depths per point would be employed across the site. 19 injection points would be employed for the Silt Layer below the former tank farm and seven injection points would be employed in the silty gravels in the upper 10 feet of the Lower Aquifer below the former tank farm. Two injection events spaced 6 months to a year apart have been included in the cost to allow adjustment of the location or substrate to be injected in order to deal with difficulties

resulting from injecting into the low-permeability Silt Layer. The second injection event is assumed to be 50% of the initial dose and effort. These injections are expected to enhance degradation of COCs in groundwater as they migrate from the former tank farm area toward MC-15D.

- Enhanced bioremediation at four injection locations with multiple injection depths per point would be employed in the upper 10 feet of the Lower Aquifer around MC-15D.
- Treatment using ISCO would be performed in year zero for the area near MC-14 to destroy 1,4-dioxane and any remaining COCs in the Shallow Groundwater Zone east of the former tank farm area, with additional injections six months later. Nine injection points with multiple injection depths would be used and injections would be performed in a grid pattern across the area with 15-foot spacing between locations. The second injection event is assumed to be 50% of the initial dose and effort.
- Groundwater monitoring would be necessary for only 15 years, due to the destruction of the remaining 1,4-dioxane plume by ISCO and the degradation of other COCs by enhanced bioremediation. It is assumed that 40 monitoring wells would be used for the first 2 years, 30 monitoring wells for years 3 to 5, and reduced to 23 wells for the remainder of the monitoring period after year 5.

3.3 Assumptions for Alternative A-3

Alternative A-3 includes:

- Grouting the utility trench under the stormwater piping to the east of the Stericycle property in four locations;
- Continued operation of the existing IPIM under Building 1;
- Augmenting the existing surface cover by paving select areas of the Site with 4-inches of hot mix asphalt pavement;
- Long-term monitoring and maintenance of the pavement cover;
- Treatment near MC-14 - two rounds of ISCO injections to treat the 1,4-dioxane and VOCs in the Shallow Groundwater Zone;
- Treatment in the former tank farm area using deep soil mixing (DSM) with ZVI;
- Treatment along the North Fence Line (near MC-118D) using ISCO of the silt and Lower Aquifer;
- Treatment in the Lower Aquifer upgradient of and near MC-15D - ISB by injection of carbohydrates near MC-15D to reduce risk of off-site migration of chlorinated VOCs in the upper portion of the Lower Aquifer;
- Monitored attenuation of the groundwater downgradient of source remediation areas;
- Groundwater monitoring would be used to evaluate DSM/ISCO/ISB effectiveness for the duration of the restoration timeframe (10 years based on vendor experience and the extrapolation of groundwater monitoring data trends once source area remediation is complete). Once groundwater monitoring indicates DSM/ISCO/ISB and MA has permanently destroyed COCs to below cleanup levels, remediation would be considered complete; and

- Institutional controls

Detailed cost estimates for Alternative A-3 are presented in Tables F-8 through F-10. Detailed assumptions were made as follows for remedial Alternative A-3.

- A SPOC would be utilized for soil and groundwater for this alternative.
- The utility trench would be grouted at four locations (from near PZU-4 to between MC-16 and MC-17) to prevent groundwater from using the stormwater piping backfill as a conduit to surface waters.
- Additional capping in the vicinity of GP-109 and GP-93, west of Building 1, around building 3, and along the northern fence line will be completed through placement of HMA pavement. Some portions of these areas are already paved and the areas will need to be maintained.
- IPIM operational costs would be negligible.
- An initial treatment using ISCO would be performed in year zero, with additional injections six months later. Nine injection points with multiple injection depths would be targeted near MC-14 to destroy 1,4-dioxane and any remaining COCs in the Shallow Groundwater Zone east of the former tank farm area. In order to treat the remaining source area while still allowing facility traffic to use the driveway along the north fence line, an additional 16 points with multiple injection depths would be placed along the northern fence line to treat COCs in the area of MC-118 in the Silt Layer (11 injection locations) and Lower Aquifer (5 injection locations). Injections would be performed in a grid pattern across the areas with 15-foot spacing between locations for the Shallow Groundwater Zone and 10-foot for the Silt Layer. The second injection event is assumed to be 50% of the initial dose and effort.
- Enhanced bioremediation at four injection locations with multiple injection depths per point would be employed in the upper 10 feet of the Lower Aquifer around MC-15D.
- DSM would be used to treat the source area in the former tank farm area. Soil would be excavated to just above the top of the water table (5 feet below ground surface [bgs]). It was assumed this soil would be clean (since clean backfill was placed following the 1997 excavation) and could be hauled off site as non-hazardous soils. DSM would be performed using standard track-hoe equipment for soils at depths from 5 feet to 20 feet, with addition of a clay/ZVI mixture. Following mixing of the clay/ZVI, the uppermost 5 feet of the mixing area would be mixed with Portland cement at a 10% by mass to decrease the amount of time to stabilize the material for facility use. The increase in soil volume ("swell") resulting from the DSM technique would provide sufficient soil volume to bring the DSM area back to its original grade and it is assumed the area could be paved within 3 months following treatment. To verify subsurface stability and to evaluate whether conditions are optimal for paving the DSM area to allow for truck traffic on the site, a geotechnical evaluation is included in the cost estimate.
- For DSM, six monitoring wells in the former tank farm area (MC-1, MC-24, MC-24D, MC-24D2, MC-25, MC-25D, and MC-25D2) would need to be abandoned but would be replaced with a single well screened in the Shallow Groundwater Zone and two wells in the Lower Aquifer to monitor for any possible release of COCs in the former tank farm area into the Shallow Groundwater Zone or Lower

Aquifer. Since the treated area would be stabilized with clay, groundwater flow in this zone would be negligible.

- Groundwater monitoring would be necessary for only 10 years, due to the destruction of the remaining 1,4-dioxane plume by ISCO and remediation in the source area with using deep soil mixing with ZVI. Annual monitoring costs would be lower than for Alternative A-2 due to the reduced number of monitoring wells as a result of well abandonment and the need for fewer downgradient monitoring wells after implementation of DSM, since the mixing action of DSM would allow direct contact of ZVI to contaminants.

3.4 Assumptions for Alternative A-4

Alternative A-4 includes:

- Grouting the utility trench under the stormwater piping to the east of the Stericycle property in four locations;
- Short term operation of the existing IPIM under Building 1;
- Augmenting the existing surface cover by paving select areas of the Site with 4-inches of hot mix asphalt pavement;
- Long-term monitoring and maintenance of the pavement cover;
- Treatment of the former tank farm area, the north fence line area (near MC-118D) via electrical resistive heating (ERH) of the shallow zone, Silt Layer and upper portion of the Lower Aquifer;
- Treatment of the area under Building 1 and around well MC-14 via ERH of the Shallow Groundwater Zone;
- Treatment in the Lower Aquifer upgradient of and near MC-15D via ISB by injection of carbohydrates to reduce risk of off-site migration of chlorinated VOCs;
- Monitored attenuation of groundwater downgradient of source area remediation area;
- Groundwater monitoring would be used to evaluate ERH/ISB effectiveness for the duration of the restoration timeframe (10 years based on vendor experience and the extrapolation of groundwater monitoring data trends once source area remediation is complete). Once groundwater monitoring indicates ERH/ISB and MA has permanently destroyed COCs to below cleanup levels, remediation would be considered complete; and
- Institutional controls.

Detailed cost estimates for Alternative A-4 are presented in Tables F-11 through F-13. Detailed assumptions were made as follows for remedial Alternative A-4.

- A SPOC would be utilized for soil and groundwater for this alternative.
- The utility trench would be grouted at four locations (from near PZU-4 to between MC-16 and MC-17) to prevent groundwater from using the stormwater piping backfill as a conduit to surface waters.

- Additional capping in the vicinity of GP-109 and GP-93, around building 3, and along the northern fence line will be completed through placement of HMA pavement. Some portions of these areas are already paved and the areas will need to be maintained.
- IPIM operational costs would be negligible.
- Enhanced bioremediation at four injection locations with multiple injection depths per point would be employed in the upper 10 feet of the Lower Aquifer around MC-15D.
- A quote for ERH was based on destruction of 99 percent of COCs. The treatment area would include the former tank farm area (from 10 to 18 feet bgs), under the south end of Building 1, along the north fence line around GP-97, and around MC-14 (from 2-10 feet). Removal and replacement of existing utility lines made of plastic was not included in the cost, but would be necessary. The specific locations to be removed and the estimated costs for removal would be determined in the field prior to final design.
- For ERH, 11 monitoring wells in the treatment area would need to be abandoned but would be replaced with 10 monitoring wells following treatment. Shallow Groundwater Zone monitoring wells would be replaced as follows, one along the northern fence line, two in the former tank farm area and replacement of MC-14. Three Silt Layer wells would be installed, one along the northern fence line and two in the former tank farm area to monitor COC concentrations remaining within the treated area. Three Lower Aquifer wells would be necessary, one well along the northern fence line and two in the former tank farm area to monitor for any possible release of COCs in the former tank farm area into the Lower Aquifer.
- Groundwater monitoring would be necessary for only 10 years, due to the destruction of the remaining 1,4-dioxane plume by electrical resistive heating. Monitoring costs would be slightly more than Alternative A-3 due to the number of monitoring wells that would result following well abandonment and the reduced number of reinstalled monitoring wells downgradient after implementation of ERH, since this technology is not limited by the permeability of the Silt Layer (unlike Alternative A-2).

3.5 Assumptions for Alternative A-5

Alternative A-5 includes:

- Grouting the utility trench under the stormwater piping to the east of the Stericycle property;
- Continued operation of the existing IPIM under Building 1;
- Augmenting the existing surface cover by paving select areas of the Site with 4-inches of hot mix asphalt pavement;
- Long-term monitoring and maintenance of the pavement cover;
- Treatment near MC-14 - two rounds of ISCO injections to treat 1,4-dioxane and VOCs in Shallow Groundwater Zone;
- Treatment in the former tank farm area and the north fence line (near MC-118D) via placement of

permeable reactive barriers (PRBs) by hydraulic fracturing of coarse grained ZVI using direct push methods, through the lower portion of the shallow zone (11 feet bgs) into the Silt Layer (10 to 20 feet bgs) and the upper portion of the Lower Aquifer (18 to 23 feet bgs) within the footprint of the former tank farm excavation and around the MC-118 well cluster.

- Treatment in the Lower Aquifer upgradient of and near MC-15D via placement of a PRB using hydraulic fracturing injection of fine grained ZVI through cased hole injections within the upper 10 feet of the Lower Aquifer (18 to 28 feet bgs) around MC-15D;
- Monitored attenuation of groundwater downgradient of remediation areas;
- Groundwater monitoring would be used to evaluate PRB/ISCO effectiveness for the duration of the restoration timeframe (10 years based on vendor experience and the extrapolation of groundwater monitoring data trends once source area remediation is complete). Once groundwater monitoring indicates PRB/ISCO and MA has permanently destroyed COCs to below cleanup levels, remediation would be considered complete; and
- Institutional controls.

Detailed cost estimates for Alternative A-5 are presented in Tables F-14 through F-16. Detailed assumptions were made as follows for remedial Alternative A-5.

- A SPOC would be utilized for soil and groundwater for this alternative.
- The utility trench would be grouted at four locations (from near PZU-4 to between MC-16 and MC-17) to prevent groundwater from using the stormwater piping backfill as a conduit to surface waters.
- Additional capping in the vicinity of GP-109 and GP-93, west of Building 1, around building 3, and along the northern fence line will be completed through placement of HMA pavement. Some portions of these areas are already paved and the areas will need to be maintained.
- IPIM operational costs would be negligible.
- A PRB utilizing ZVI will be installed in the former tank farm area and the downgradient area near MC-15D using specialized high-pressure hydraulic fracturing technologies. The PRB installed in the former tank farm area will be installed in the upper portion of the Lower Aquifer and the Shallow Groundwater Zone, effectively “sandwiching” the Silt Layer. Placement of the PRB in the former tank farm area will be completed by performing 84 fractures and placing 168,000 pounds of ZVI on 15 foot spacing across the area. The downgradient area near MC-15D will be completed by performing 16 fractures and placing 32,000 pounds of ZVI on 13 foot spacing across the area. Direct push drilling technologies will be used to place ZVI in the former tank farm area, but due to depth of the downgradient area, sonic drilling technologies will be needed for the downgradient fractures.
- Treatment using ISCO would be performed in year zero for the area near MC-14 to destroy 1,4-dioxane and any remaining COCs in the Shallow Groundwater Zone east of the former tank farm area, with additional injections six months later. Nine injection points with multiple injection depths would be used and injections would be performed in a grid pattern across the area with 15-foot spacing between locations. The second injection event is assumed to be 50% of the initial dose and effort.

- Groundwater monitoring would be necessary for only 10 years, due to the destruction of the remaining 1,4-dioxane plume by ISCO and the degradation of other COCs through the PRB. It is assumed that 40 monitoring wells would be used for the first 2 years, 30 monitoring wells for years 3 to 5, and reduced to 23 wells for the remainder of the monitoring period after year 5.

3.6 Assumptions for Alternative A-6

Alternative A-6 includes:

- Grouting the utility trench under the stormwater piping to the east of the Stericycle property in four locations;
- Continued operation of the existing IPIM under Building 1;
- Augmenting the existing surface cover by paving select areas of the Site with 4-inches of hot mix asphalt pavement;
- Long-term monitoring and maintenance of the pavement cover;
- Treatment near MC-14 - two rounds of ISCO injections to treat 1,4-dioxane and VOCs in the Shallow Groundwater Zone;
- Treatment in the former tank farm area and near the north fence line (near MC-118D) - two rounds of ISB injections utilizing carbohydrates and emulsified ZVI targeting chlorinated VOCs remaining in the Silt Layer and the upper portion of the Lower Aquifer;
- Short Term Hydraulic control of the Lower Aquifer;
- Treatment in the Lower Aquifer upgradient of and near MC-15D - ISB injection of carbohydrates near MC-15D to reduce risk of off-site migration of chlorinated VOCs in the upper portion of the Lower Aquifer;
- Monitored attenuation of the groundwater downgradient of the remediation areas;
- Groundwater monitoring would be used to evaluate ISB/ISCO effectiveness for the duration of the restoration timeframe (15 years based on vendor experience and the extrapolation of groundwater monitoring data trends once source area remediation is complete). Once groundwater monitoring indicates ISB/ISCO and MA has permanently destroyed COCs to below cleanup levels, remediation would be considered complete; and
- Institutional controls.

Detailed cost estimates for Alternative A-6 are presented in Tables F-17 through F-19. Detailed assumptions were made as follows for remedial Alternative A-6.

- A SPOC would be utilized for soil and groundwater for this alternative.
- The utility trench would be grouted at four locations (from near PZU-4 to between MC-16 and MC-17) to prevent groundwater from using the stormwater piping backfill as a conduit to surface waters.

- Additional capping in the vicinity of GP-109 and GP-93, west of Building 1, around building 3, and along the northern fence line will be completed through placement of hot HMA pavement. Some portions of these areas are already paved and the areas will need to be maintained.
- IPIM operational costs would be negligible.
- Enhanced bioremediation with multiple injection depths per point would be employed across the site. 19 injection points would be employed for the Silt Layer below the former tank farm and seven injection points would be employed in the silty gravels in the upper 10 feet of the Lower Aquifer below the former tank farm. Two injection events spaced 6 months to a year apart have been included in the cost to allow adjustment of the location or substrate to be injected in order to deal with difficulties resulting from injecting into the low-permeability Silt Layer. The second injection event is assumed to be 50% of the initial dose and effort. These injections are expected to enhance degradation of COCs in groundwater as they migrate from the former tank farm area toward MC-15D.
- Enhanced bioremediation at four injection locations with multiple injection depths per point would be employed in the upper 10 feet of the Lower Aquifer around MC-15D.
- Hydraulic containment would be performed in the areas of enhanced bioremediation discussed above. For the former tank farm area, pumping from the Silt Layer and Lower Aquifer would be necessary and the downgradient area would require pumping from the Lower Aquifer only. Four pumping wells would be needed to contain groundwater in the former tank farm area and two wells in the downgradient area. The six pumping wells are expected to produce an average combined flow of 33.5 gallons per minute and treatment would be required prior to discharge. Treatment would include air stripping and treatment of air stripping vapor through granular activated carbon (GAC) and potassium permanganate (KMNO) to treat volatiles. The treated groundwater would be discharge to the locally owned publicly owned treatment works (POTW). The treatment system would need to be housed in a newly constructed building on the property and would operate for a duration of three years. Regular maintenance would be necessary to operate the treatment system and annual replacement of the treatment media would be required to meet permit requirements.
- Treatment using ISCO would be performed in year zero for the area near MC-14 to destroy 1,4-dioxane and any remaining COCs in the Shallow Groundwater Zone east of the former tank farm area, with additional injections six months later. Nine injection points with multiple injection depths would be used and injections would be performed in a grid pattern across the area with 15-foot spacing between locations. The second injection event is assumed to be 50% of the initial dose and effort.
- Groundwater monitoring would be necessary for only 15 years, due to the destruction of the remaining 1,4-dioxane plume by ISCO and the degradation of other COCs by enhanced bioremediation. It is assumed that 40 monitoring wells would be used for the first 2 years, 30 monitoring wells for years 3 to 5, and reduced to 23 wells for the remainder of the monitoring period after year 5.

3.7 Assumptions for Alternative A-7

Alternative A-7 includes:

- Grouting the utility trench under the stormwater piping to the east of the Stericycle property in four locations;

- Continued operation of the existing IPIM under Building 1;
- Augmenting the existing surface cover by paving select areas of the Site with 4-inches of hot mix asphalt pavement;
- Long-term monitoring and maintenance of the pavement cover;
- Treatment near MC-14 via two rounds of ISCO injections to treat the 1,4-dioxane and VOCs in the Shallow Groundwater Zone;
- Treatment in the former tank farm area and the north fence line area (near MC-118D) via two rounds of ISB injections utilizing carbohydrates and emulsified ZVI targeting chlorinated VOCs remaining in the Silt Layer and the upper portion of the Lower Aquifer;
- Short Term Hydraulic control of the Lower Aquifer;
- Treatment in the Lower Aquifer upgradient of and near MC-15D via ISB by injection of carbohydrates to reduce risk of off-site migration of chlorinated VOCs in the Lower Aquifer;
- Monitored attenuation of the groundwater downgradient of the remediation areas;
- Groundwater monitoring would be used to evaluate ISB/ISCO effectiveness for the duration of the restoration timeframe (15 years based on vendor experience and the extrapolation of groundwater monitoring data trends once source area remediation is complete). Once groundwater monitoring indicates ISB/ISCO and MA has permanently destroyed COCs to below cleanup levels, remediation would be considered complete; and
- Institutional controls.

Detailed cost estimates for Alternative A-7 are presented in Tables F-20 through F-22. Detailed assumptions were made as follows for remedial Alternative A-7.

- A SPOC would be utilized for soil and groundwater for this alternative.
- The utility trench would be grouted at four locations (from near PZU-4 to between MC-16 and MC-17) to prevent groundwater from using the stormwater piping backfill as a conduit to surface waters.
- Additional capping in the vicinity of GP-109 and GP-93, west of Building 1, around building 3, and along the northern fence line will be completed through placement of HMA pavement. Some portions of these areas are already paved and the areas will need to be maintained.
- IPIM operational costs would be negligible.
- An initial treatment using ISCO would be performed in year zero in the former tank farm area and along the northern fence line, with additional injections six months later. 102 injection points with multiple injection depths would be completed within the former tank farm area and 26 injections along the northern fence line to treat the Silt Layer and the Lower Aquifer. The second injection event

is assumed to be 50% of the initial dose and effort. Injections would be performed in a grid pattern across the area with 15-foot spacing between locations.

- An additional treatment using ISCO would be performed in year zero for the area near MC-14 to destroy 1,4-dioxane and any remaining COCs in the Shallow Groundwater Zone east of the former tank farm area, with additional injections six months later. Nine injection points with multiple injection depths would be used and injections would be performed in a grid pattern across the area with 15-foot spacing between locations. The second injection event is assumed to be 50% of the initial dose and effort.
- Enhanced bioremediation at four injection locations with multiple injection depths per point would be employed in the upper 10 feet of the Lower Aquifer around MC-15D.
- Groundwater monitoring would be necessary for only 10 years, due to the destruction of the remaining COCs and 1,4-dioxane plume by ISCO. It is assumed that 40 monitoring wells would be used for the first 2 years, 30 monitoring wells for years 3 to 5, and reduced to 23 wells for the remainder of the monitoring period after year 5.

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4.0 SENSITIVITY ANALYSIS

During revision of the FS, Ecology asked for additional analysis of the alternatives costing to clarify the effects of various assumptions on the relative costs of the alternatives.

- Net discount rate

  Stericycle had negotiated the net discount rate of 2.5% with Ecology previously for use at their other facilities with ongoing remediation in Washington. DOF reviewed market conditions and found that 2.5% was still a reasonable rate to use given current inflation and return rates. In addition, DOF provided a comparison of different net discount rates from 2.5 to 6.5 % and found that a change in rates had limited impact on the relative costs for the alternatives (Table F-23). As could be expected, the biggest impact as for Alternative A-1 (MNA) with the longest time frame of 30 years (two or three times longer than the other alternatives). However, Alternatives A-2 (ISB) and A-5 (PRB) are the least costly remedial alternatives regardless of net discount rate.

- Groundwater Monitoring and contingency

  Stericycle currently performs most of the groundwater monitoring with dedicated sampling personnel and equipment. Stericycle directly contracts with laboratories for analytical results. This limits variability in costs and reduces the contingency necessary.

  Costs for groundwater monitoring were based on a percentage of the annual labor cost for full time Stericycle personnel that perform groundwater monitoring for all of Stericycle's Washington facilities. Typical cost varies little year to year and increases are minor (due to monitoring well damage and occasional need for resampling due to cooler loss or damage during shipment). Well replacement costs were included as a line item every 10 years. Re-sampling does not result in higher lab charges or additional labor costs to Stericycle, only additional shipping charges and minor additional costs for waste disposal of purge water.

  Upon Ecology's suggestion, groundwater monitoring was included in the contingency cost for this revision of the FS. Changes in personnel or contractual services for groundwater monitoring could affect the reliability, efficiency, and costs of groundwater monitoring in the future; and therefore, a contingency factor was used in estimating future costs. While the costs with groundwater monitoring in the contingency are higher than if excluded, the change does not impact the ranking of the majority of alternatives with Alternatives A-2 (ISB) and A-5 (PRB) costing the least regardless (Table F-23). The greatest impact is on making the cost of Alternative A-1 (MNA) higher.

- Contingency costs in general

  Ecology asked for review of contingency costs in general, noting that a 10% contingency applied across all alternatives may be low and does not account for differing levels of risk for each remedial alternative.

  DOF agrees that each alternative has differing levels of risk, but risks for each specific alternative were addressed with additional line item costs for each of the alternatives. Based on current Site data, it was assumed that each technology would behave per average performance as for sites with similar characteristics, so line item costs were based on typical expected outcomes. For example, Alternatives A-2 (ISB) includes substantial additional injection events precisely because injection is not as reliable as physically mixing soils as in Alternative A-3 (DSM). To raise the contingency percentage would effectively double count the contingency already built into the remedy for Alternative A-2 (ISB).

  To show a representation of contingency built into each alternative, DOF combined the built in line item costs [based on vendor recommendations and engineering experience] with the 10% contingency cost on a NPV basis (Table F-24). True contingency percentages range from 9.1% [Alternative A-1 (MNA) and A-5 (PRB)] to 22% [Alternative A-7 (Full Scale ISCO)].

  The lowest true contingency costs are for either the least active measures [Alternative A-1 (MNA)] or the most aggressive active measures [Alternatives A-3 (DSM), A-4 (ERH) and A-5 (PRB)] which include a higher likelihood of success by design. Alternative A-5 (PRB) may seem like an exception, as it doesn't immediately reduce COCs during implementation like DSM or ERH. However, while the PRB technology may not immediately treat COCs to below CULs, it is expected to leave in place long lasting treatment (at least 10 years) which allows more time for material to desorb from lower permeability units and be treated, even if not directly treated during implementation.

  ISB does not require direct contact and provides longer lasting treatment (1 to 3 years, enough time for COCs to desorb from finer grained units and degrade), but effective distribution does take more than one injection for low permeability aquifers. So, a higher contingency was built into implementation for Alternative A-2 (ISB) totaling 16.1% for true contingency.

  ISCO is dependent on direct contact with contaminants and only typically lasts for a few weeks, so contact can be difficult to attain in low permeability soils. A higher contingency was built into implementation for Alternative A-7 (Full scale ISCO) which uses ISCO as the primary treatment mechanism for the low permeability units resulting in a true contingency of approximately 22%.

- Performance Scenario Variability

As noted above and in the main text, costs were based on the assumption that each technology would behave per average performance as for sites with similar characteristics. This is a reasonable way to compare average costs of the different remedial alternatives. However, the remedial alternatives have differing error bars on cost, (i.e. some have higher or lower floors and some have higher or lower ceilings). For example, if bench testing shows it is particularly hard for effective direct contact of ISCO chemicals with site COCs, then the average cost for ISCO used for comparison of alternatives is actually optimistic.

In order to better illustrate the variability of the floor and ceiling performance across alternatives, DOF created an additional set of remedial scenarios for each alternative based on reasonable assumptions for implementation of treatment going better or worse than expected (Table F-25). For example, there are several items that may change the ERH costs and it is impossible to know without further bench or pilot scale testing. Vendor TRS Group, Inc. provided a range of costs for ERH used in the FS for Alternative A-4 (ERH). Alternative A-4 (ERH) could cost significantly less if the treatment area were reduced (by performing additional direct push sampling investigation) and if groundwater infiltration were on the lower end. On the other hand, DOF chose the lower end of the range for the cost per cubic yard treated in the FS ($208/CY). If water generation and conductor spacing needed to be tighter, the higher end range in the quote ($280/CY) would more accurately reflect the cost of ERH.

The variability in costs for each alternative under better performance and worse performance scenarios on Table F-26. In all cases, Alternatives A-2 (ISB) and A-5 (PRB) are the top two alternatives. In addition, even if Alternative A-2 (ISB) performs as per the worse scenario, the total cost is still less than the best case scenarios for the most aggressive remedial Alternatives A-3 (DSM) and A-4 (ERH),

This analysis also shows that pilot and bench scale testing could substantively change the relative costs for Alternative A-2 (ISB), A-5 (PRB) and A-7 (Full scale ISCO). For Alternative A-7 (ISCO), in particular, the better performance scenario could be substantially less costly while the worse case scenario is much more costly than the worse case scenarios for Alternative A-2 (ISB) or A-5 (PRB).

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5.0 REFERENCES

ENTACT, Deep soil mixing with a clay ZVI mixture for treatment of low permeability aquifers, December 2019.

EPA, (U.S. Environmental Protection Agency), 2000, A Guide to Developing and Documenting Cost Estimates During the Feasibility Study.

FRx, Permeable reactive barrier with sand ZVI installation for treatment of low permeability aquifers, December 2019.

ISOTEC, , In-situ bioremediation and In-situ chemical oxidation for treatment of low permeability aquifers, December 2019.

TRS, Thermal remediation for treatment of VOCs and 1,4-dioxane in low permeability aquifers, March 2020.

Tables

TABLE F-1

SUMMARY OF COSTS AND TIMING FOR REMEDIAL ALTERNATIVES

Stericycle Washougal Facility
Washougal, Washington

Alternatives	Initial Implementation Cost	Net Present Value Cost [1]	Start of Significant COC Reduction (years)	Active Remediation Duration (years) [2]	Restoration Time Frame (years)
A-1: Capping and MNA	$46,600	$2,742,000	10+	30	30 +
A-2: Bioremediation and Targeted ISCO	$638,300	$2,532,000	1	3 to 5	15
A-3: Deep Soil Mixing with ZVI and Targeted ISCO	$2,283,500	$3,688,000	1	1	10
A-4: Electrical Resistive Heating	$3,549,000	$5,034,000	1	1	10
A-5: ZVI Permeable Reactive Barrier and Targeted ISCO	$971,500	$2,447,000	1	3 to 10	10
A-6: Hydraulic Control with Bioremediation and Targeted ISCO	$1,099,400	$3,722,000	1	3 to 5	15
A-7: Full Scale ISCO Treatment	$1,614,000	$2,963,000	1	1	10

Notes
1. Color gradation from green (low cost) to red (high cost) indicates relative cost between alternatives
2. Active remediation indicates the expected duration of accelerated degradation rates, except in the case of MNA which has no active component, a passive timeframe was used.

Abbreviations
ISCO = in situ chemical oxidation
MNA = monitored natural attenuation
ZVI = zero-valent iron

TABLE F-2

IMPLEMENTATION COSTS FOR ALTERNATIVE A-1
Stericycle Washougal Facility
Washougal, Washington

Item	Unit	Unit Cost	Quantity	Cost	Sources/Notes
1 **Cap Construction**					
Mobilization/Demobilization	LS	$2,500	1	$2,500	Engineer estimate
Asphalt Paving	Ton	$200	113	$22,700	2019 facility stormwater improvements paving unit rate
Equipment	day	$95	1	$100	PID rental, DOF standard rate
Task 1 Subtotal				**$25,300**	
2 **Grouting of Storm Drain (4 locations)**					
Mobilization/Demobilization	LS	$500	1	$500	Engineer estimate
Test Pits & Soil Transport/Disposal	BCY	$250	9	$2,400	Estimate from similar project
Concrete	CY	$150	9	$1,400	Engineer estimate
Equipment	day	$95	1	$100	PID rental, DOF standard rate
Task 2 Subtotal				**$4,400**	
Implementation Subtotal				**$29,700**	
Professional Technical Services					
Permitting	LS	$3,500	1	$3,500	Engineer estimate based on similar project
Remedial Design	%	20%		$5,900	from EPA, 2000, Exhibit 5-8
Construction Management	%	15%		$4,500	from EPA, 2000, Exhibit 5-8
Project Management	%	10%		$3,000	from EPA, 2000, Exhibit 5-8
Subtotal, Professional Services				**$16,900**	
TOTAL INITIAL IMPLEMENTATION COST				**$46,600**	

Abbreviations
BCY = bank cubic yard
CY = cubic yard
PID = photoionization detector
LS = Lump Sum
EPA = Environmental Protection Agency

TABLE F-3

RECURRING COSTS FOR ALTERNATIVE A-1[1,2]
Stericycle Washougal Facility
Washougal, Washington

	Item	Unit	Unit Cost	Annual Quantity	Annual Cost	Sources
1	**INSPECTION**					
	Site Inspection	each	$575	1	$580	DOF Staff 1/2 Day
	Subtotal				**$580**	
2	**Groundwater Monitoring**					
	40 wells - Quarterly Compliance Monitoring	each	$1,162	160	$185,850	Current GW monitoring costs with validation
	40 wells - Semi-Annual Compliance Monitoring	each	$1,162	80	$92,930	after 5 years
	30 wells - Semi-Annual Compliance Monitoring	each	$1,162	60	$69,700	after 10 years
	23 wells - Annual Confirmational Monitoring	each	$1,162	23	$26,720	after 25 years
						Wells remaining include three depths[3]
3	**Repairs**					
	Pavement replacement every 10 years	Lump sum	$25,300	1	$25,300	Engineer Estimate
	Well replacement/fouling every 10 years	Lump sum	$3,500	2	$7,000	Engineer Estimate
	IPIM repairs/replacement parts (every 10 years)	Lump sum	$1,000	1	$1,000	Engineer Estimate
					$33,300	
4	**Well Abandonment**					
	Monitoring Well Abandonment (after 10 years)	each	$800	10	$8,000	Cascade Drilling abandonment estimate
	Monitoring Well Abandonment (after 25 years)	each	$800	7	$5,600	Cascade Drilling abandonment estimate
5	**PROJECT MANAGEMENT**					
	Project Management	year	$10,000	1	$10,000	Engineer Estimate
	Subtotal				**$10,000**	

Notes:
1. Assumes 40-hour work week.
2. No taxes have been included.
3. Wells consist of: MC-8,-10D,-12,-13,-13D,-14,-14D,-15,-15D,-17,-17D,-19D,-24,-24D,-24D2,-25,-25D,-25D2,-30,-30D,-31,-118D, and -118D2.

Abbreviations
IPIM = inhalation pathway interim measure
GW = groundwater

TABLE F-4

NET PRESENT VALUE FOR ALTERNATIVE A-1
Stericycle Washougal Facility
Washougal, Washington

Year	Implementation Cost/Repairs	Inspection & Project Management	Groundwater Monitoring[1]	10% Contingency[2]	Yearly Total
0	$46,600		$185,850	$23,245	$256,000
1		$10,580	$185,850	$19,643	$216,000
2		$10,580	$185,850	$19,643	$216,000
3		$10,580	$185,850	$19,643	$216,000
4		$10,580	$185,850	$19,643	$216,000
5		$10,580	$185,850	$19,643	$216,000
6		$10,580	$92,930	$10,351	$114,000
7		$10,580	$92,930	$10,351	$114,000
8		$10,580	$92,930	$10,351	$114,000
9		$10,580	$92,930	$10,351	$114,000
10	$33,300	$10,580	$92,930	$13,681	$150,000
11		$10,580	$77,700	$8,828	$97,000
12		$10,580	$69,700	$8,028	$88,000
13		$10,580	$69,700	$8,028	$88,000
14		$10,580	$69,700	$8,028	$88,000
15		$10,580	$69,700	$8,028	$88,000
16		$10,580	$69,700	$8,028	$88,000
17		$10,580	$69,700	$8,028	$88,000
18		$10,580	$69,700	$8,028	$88,000
19		$10,580	$69,700	$8,028	$88,000
20	$33,300	$10,580	$69,700	$11,358	$125,000
21		$10,580	$69,700	$8,028	$88,000
22		$10,580	$69,700	$8,028	$88,000
23		$10,580	$69,700	$8,028	$88,000
24		$10,580	$69,700	$8,028	$88,000
25		$10,580	$69,700	$8,028	$88,000
26		$10,580	$32,320	$4,290	$47,000
27		$10,580	$26,720	$3,730	$41,000
28		$10,580	$26,720	$3,730	$41,000
29		$10,580	$26,720	$3,730	$41,000
30		$10,580	$26,720	$3,730	$41,000
TOTAL	$113,000	$317,000	$2,772,000	$320,000	$3,519,000

Net Discount rate: 2.5% **NPV** **$2,742,000**

Notes
1. Groundwater monitoring costs include costs for monitoring well abandonment.
2. Contingency estimate is included for implementation costs, repairs, inspection, project management, and groundwater monitoring.

TABLE F-5

IMPLEMENTATION COSTS FOR ALTERNATIVE A-2
Stericycle Washougal Facility
Washougal, Washington

Item	Unit	Unit Cost	Quantity	Cost	Sources/Notes
1 **Cap Construction**					
Mobilization/Demobilization	Lump Sum	$2,000	1	$2,000	Engineer estimate
Asphalt Paving	Ton	$200	101	$20,300	2019 facility stormwater improvements paving unit rate
Equipment	day	$95	1	$100	PID rental, DOF standard rate
Task 1 Subtotal				**$22,400**	
2 **Grouting of Storm Drain (4 locations)**					
Mobilization/Demobilization	LS	$500	1	$500	Engineer estimate
Test Pits & Soil Transport/Disposal	BCY	$250	9	$2,400	Estimate from similar project
Concrete	CY	$150	9	$1,400	Engineer estimate
Equipment	day	$95	1	$100	PID rental, DOF standard rate
Task 2 Subtotal				**$4,400**	
3 **In Situ Chemical Oxidation (ISCO) (near MC-14)**					
Round 1					
Bench scale test	LS	$15,000	1	$15,000	ISOTEC discussion, 12/10/2019
Geoprobe Rig	day	$2,500	4	$10,000	Cascade Drilling Quote
ISOTEC Injection Services	day	$6,000	4	$24,000	ISOTEC Estimate, 12/13/2019
6% Hydrogen Peroxide + MFR Solution	gal	$2.50	3,950	$9,900	440 lbs per point, price ISOTEC Estimate, 12/13/2019
Transport & Disposal, State Dangerous Waste (Geoprobe)	drum	$192	1	$200	Stericycle Quote for Portland Broker, 12/13/2019
Equipment	day	$95	4	$400	PID rental, DOF standard rate
Surveying	day	$195	1	$200	GPS rental, DOF standard rate
Round 2 (Half of first round treatment)					
Geoprobe Rig	day	$2,500	2	$5,000	Cascade Drilling Quote
ISOTEC Injection Services	day	$6,000	2	$12,000	ISOTEC Estimate, 12/13/2019
6% Hydrogen Peroxide + MFR Solution	gal	$2.50	1,975	$4,900	440 lbs per point, price ISOTEC Estimate, 12/13/2019
Transport & Disposal, State Dangerous Waste (Geoprobe)	drum	$192	1	$200	Stericycle Quote for Portland Broker, 12/13/2019
Equipment	day	$95	2	$200	PID rental, DOF standard rate
Surveying	day	$195	1	$200	GPS rental, DOF standard rate
Task 3 Subtotal				**$82,200**	
4 **Former Tank Farm Area Enhanced Bioremediation**					
Bench scale test	LS	$15,000	1	$15,000	ISOTEC discussion, 12/10/2019
Geoprobe Rig	day	$2,500	7	$17,500	Cascade Drilling Quote
ISOTEC Injection Services	day	$6,000	7	$42,000	ISOTEC Estimate, 12/13/2019
Emulsified Vegetable Oil & Zero-Valent Iron Substrate	gal	$50	5,000	$250,000	ISOTEC Estimated cost, 12/13/2019. ESTCP Estimator for volume.
Transport & Disposal, State Dangerous Waste (Geoprobe)	drum	$192	1	$200	Stericycle Quote for Portland Broker, 12/13/2019
Equipment	day	$95	7	$700	PID rental, DOF standard rate
Surveying	day	$195	1	$200	GPS rental, DOF standard rate
Task 4 Subtotal				**$325,600**	
5 **Downgradient Area Enhanced Bioremediation (MC-15D)**					
Geoprobe Rig	day	$2,500	4	$10,000	Cascade Drilling Quote
ISOTEC Injection Services	day	$6,000	4	$24,000	ISOTEC Estimate, 12/13/2019
Emulsified Vegetable Oil or Lactate	gal	$10	300	$3,000	Recent EVO purchase for other Stericycle site. ESTCP Estimator for volume.
Transport & Disposal, State Dangerous Waste (Geoprobe)	drum	$192	1	$200	Stericycle Quote for Portland Broker, 12/13/2019
Equipment	day	$95	4	$400	PID rental, DOF standard rate
Surveying	day	$195	1	$200	GPS rental, DOF standard rate
Task 5 Subtotal				**$37,800**	
Implementation Subtotal				**$472,400**	
Professional Technical Services					
Permitting	LS	$10,000	1	$10,000	Engineer estimate based on similar project
Remedial Design	%	15%		$70,900	from EPA, 2000, Exhibit 5-8
Construction Management	%	10%		$47,200	from EPA, 2000, Exhibit 5-8
Project Management	%	8%		$37,800	from EPA, 2000, Exhibit 5-8
Subtotal, Professional Services				**$165,900**	
TOTAL INITIAL IMPLEMENTATION COST				**$638,300**	

Abbreviations
BCY = bank cubic yard
CY = cubic yards
PID = photoionization detector
GPS = global positioning system
EPA = Environmental Protection Agency
MFR = Modified Fenton's Reagent
ESTCP = Environmental Security Technology Certification Program
EVO = emulsified vegetable oil

TABLE F-6

RECURRING COSTS FOR ALTERNATIVE A-2[1,2]

Stericycle Washougal Facility

Washougal, Washington

	Item	Unit	Unit Cost	Annual Quantity	Annual Cost	Sources
1	**INSPECTION (15 YEARS)**					
	Site Inspection	EA	$575	1	$580	DOF Staff 1/2 Day
	Subtotal				**$580**	
2	**Groundwater Monitoring**					
	40 wells - Quarterly Compliance Monitoring	each	$1,162	160	$185,850	Current GW monitoring costs with validation
	30 wells - Quarterly Compliance Monitoring	each	$1,162	120	$139,390	after 2 years
	23 wells - Semi-Annual Confirmational Monitoring	each	$1,162	46	$53,430	after 5 years
						Wells remaining include three depths[3]
3	**Repeat Tank Farm Area Enhanced Bioremediation[4]**					
	Geoprobe Rig	day	$2,500	4	$8,800	Cascade Drilling Quote
	ISOTEC Injection Services	day	$6,000	4	$21,000	ISOTEC Estimate, 12/13/2019
	Emulsified Vegetable Oil & Zero-Valent Iron Substrate	gal	$50	2,500	$125,000	440 gal per point, price ISOTEC Estimate, 12/13/2019
	Transport & Disposal, State Dangerous Waste (Geoprobe)	drum	$192	1	$200	Stericycle Quote for Portland Broker, 12/13/2019
	Construction Oversight	day	$1,150	4	$4,000	1 engineer/scientist, DOF staff rate
	Equipment	day	$95	4	$300	PID rental, DOF standard rate
	Surveying	day	$195	1	$200	GPS rental, DOF standard rate
	Subtotal				**$159,500**	
4	**Well Abandonment**					
	Monitoring Well Abandonment (after 5 yrs)	each	$800	17	$13,600	Cascade Drilling abandonment estimate
5	**Repairs**					
	Pavement replacement every 10 years	Lump sum	$25,300	1	$25,300	Engineer Estimate
	Well replacement/fouling every 10 years	Lump sum	$3,500	2	$7,000	Engineer Estimate
	IPIM repairs/replacement parts (every 10 years)	Lump sum	$1,000	1	$1,000	Engineer Estimate
	Subtotal				**$33,300**	
6	**PROJECT MANAGEMENT (15 YEARS)**					
	Project Management	year	$10,000	1	$10,000	Engineer Estimate
	Subtotal				**$10,000**	

Notes

1. Assumes 40-hour work week.
2. No taxes have been included.
3. Wells consist of: MC-8,-10D,-12,-13,-13D,-14,-14D,-15,-15D,-17,-17D,-19D,-24,-24D,-24D2,-25,-25D,-25D2,-30,-30D,-31,-118D, and -118D2.
4. Repeat Enhanced Bioremediation treatment in Tank Farm Area is assumed to be 50% of initial dose and effort for a single event.

Abbreviation

PID = photoionization detector

GW = groundwater

IPIM = inhalation pathway interim measure

GPS = global positioning system

ISOTEC = In-Situ Oxidation Technologies, Inc.

TABLE F-7

NET PRESENT VALUE FOR ALTERNATIVE A-2

Stericycle Washougal Facility
Washougal, Washington

Year	Implementation Cost/Repairs	Inspection & Project Management	Groundwater Monitoring[1]	10% Contingency[2]	Yearly Total
0	$638,300		$185,850	$82,415	$907,000
1	$159,500	$15,580	$185,850	$36,093	$397,000
2		$10,580	$185,850	$19,643	$216,000
3		$10,580	$139,390	$14,997	$165,000
4		$10,580	$139,390	$14,997	$165,000
5		$10,580	$139,390	$14,997	$165,000
6		$10,580	$67,030	$7,761	$85,000
7		$10,580	$53,430	$6,401	$70,000
8		$10,580	$53,430	$6,401	$70,000
9		$10,580	$53,430	$6,401	$70,000
10	$33,300	$10,580	$53,430	$9,731	$107,000
11		$10,580	$53,430	$6,401	$70,000
12		$10,580	$53,430	$6,401	$70,000
13		$10,580	$53,430	$6,401	$70,000
14		$10,580	$53,430	$6,401	$70,000
15		$10,580	$53,430	$6,401	$70,000
TOTAL	$831,000	$164,000	$1,524,000	$252,000	$2,767,000

Net Discount rate: 2.5% **NPV** **$2,531,800**

Notes
1. Groundwater monitoring costs include costs for monitoring well abandonment.
2. Contingency estimate is included for implementation costs, repairs, inspection, project management, and groundwater monitoring.

Abbrevation
ISCO = in situ chemical oxidation

TABLE F-8

IMPLEMENTATION COSTS FOR ALTERNATIVE A-3

Stericycle Washougal Facility

Washougal, Washington

Item	Unit	Unit Cost	Quantity	Cost	Sources/Notes
1 **Cap Construction**					
Mobilization/Demobilization	Lump Sum	$2,000	1	$2,000	Engineer estimate
Asphalt Paving	Ton	$200	99	$19,800	2019 facility stormwater improvements paving unit rate
Equipment	day	$95	1	$100	PID rental, DOF standard rate
Task 1 Subtotal				**$21,900**	
2 **Grouting of Storm Drain (4 locations)**					
Mobilization/Demobilization	LS	$500	1	$500	Engineer estimate
Test Pits & Soil Transport/Disposal	BCY	$250	9	$2,400	Estimate from similar project
Concrete	CY	$150	9	$1,400	Engineer estimate
Equipment	day	$95	1	$100	PID rental, DOF standard rate
Task 2 Subtotal				**$4,400**	
3 **Deep Soil Mixing (DSM) with Zero-Valent Iron (ZVI)**					
Mobilization/Demobilization (Excavation Only)	Lump Sum	$37,500	1	$37,500	Price from similar job (Contractor tasks related to excavation only - 10%)
Excavation	BCY	$8	2,358	$18,900	Based on previous project units costs
Deep Soil Mixing wih ZVI	BCY	$97	7,074	$683,000	Cost per ENTACT call 12/16/2019
Cementitious Surface Treatment of DSM area (5' depth)	CY	$58	2,358	$136,800	Cost per ENTACT call 12/16/2019
Confirmation Soil Sampling	day	$1,150	1	$1,200	1 engineer/scientist, DOF field rate
Analytical Testing of Soil Samples	Lump Sum	$3,000	1	$3,000	Non-hazardous overburden soil pile testing
Off Site Transport & Disposal of Non-hazardous Overburden Soils	Ton	$45	3,773	$169,800	Recent Washougal project unit rate
Geothechnical Evaluation	Lump Sum	$15,000	1	$15,000	Engineer estimate
Asphalt Paving	Ton	$200	934	$186,800	2019 facility stormwater improvements paving unit rate
Equipment	day	$95	30	$2,900	PID rental, DOF standard rate, duration per ENTACT call 12/16/2019
Geoprobe Rig (Confirmation sampling)	day	$2,500	3	$7,500	Cascade Drilling Quote
DSM Confirmation Sampling	day	$1,150	3	$3,500	1 engineer/scientist, DOF field rate
DSM Confirmation Sampling, Analytical Testing	Lump Sum	$5,000	1	$5,000	Engineer estimate based on similar projects
Monitoring Well Abandonment	each	$800	7	$5,600	Abandon- MC-1,24,24D,24D2,25,25D,25D2
Monitoring Well Replacement - Shallow	each	$3,500	1	$3,500	Replace one shallow well downgradient of DSM area.
Monitoring Well Replacement - Deep	each	$6,400	2	$12,800	Replace two deep wells in former tank farm area.
Task 3 Subtotal				**$1,292,800**	
4 **In Situ Chemical Oxidation (ISCO) (near MC-14)**					
Round 1					
Bench scale test	LS	$15,000	1	$15,000	ISOTEC discussion, 12/10/2019
Geoprobe Rig	day	$2,500	4	$10,000	Cascade Drilling Quote
ISOTEC Injection Services	day	$6,000	4	$24,000	ISOTEC Estimate, 12/13/2019
6% Hydrogen Peroxide + MFR Solution	gal	$2.50	3,950	$9,900	440 lbs per point, price ISOTEC Estimate, 12/13/2019
Transport & Disposal, State Dangerous Waste (Geoprobe)	drum	$192	1	$200	Stericycle Quote for Portland Broker, 12/13/2019
Equipment	day	$95	4	$400	PID rental, DOF standard rate
Surveying	day	$195	1	$200	GPS rental, DOF standard rate
Round 2 (Half of first round treatment)					
Geoprobe Rig	day	$2,500	2	$5,000	Cascade Drilling Quote
ISOTEC Injection Services	day	$6,000	2	$12,000	ISOTEC Estimate, 12/13/2019
6% Hydrogen Peroxide + MFR Solution	gal	$2.50	1,975	$4,900	440 lbs per point, price ISOTEC Estimate, 12/13/2019
Transport & Disposal, State Dangerous Waste (Geoprobe)	drum	$192	1	$200	Stericycle Quote for Portland Broker, 12/13/2019
Equipment	day	$95	2	$200	PID rental, DOF standard rate
Surveying	day	$195	1	$200	GPS rental, DOF standard rate
Task 4 Subtotal				**$82,200**	

TABLE F-8

IMPLEMENTATION COSTS FOR ALTERNATIVE A-3

Stericycle Washougal Facility
Washougal, Washington

Item	Unit	Unit Cost	Quantity	Cost	Sources/Notes
5 **In Situ Chemical Oxidation (ISCO) (North Source Area)**					
Round 1					
Geoprobe Rig	day	$2,500	14	$35,000	Cascade Drilling Quote
ISOTEC Injection Services	day	$6,000	14	$84,000	ISOTEC Estimate, 12/13/2019
6% Hydrogen Peroxide + MFR Solution	gal	$2.50	37,180	$93,000	440 gal per point, price ISOTEC Estimate, 12/13/2019
Transport & Disposal, State Dangerous Waste (Geoprobe)	drum	$192	4	$800	Stericycle Quote for Portland Broker, 12/13/2019
Equipment	day	$95	14	$1,300	PID rental, DOF standard rate
Surveying	day	$195	1	$200	GPS rental, DOF standard rate
Round 2 (Half of first round treatment)					
Geoprobe Rig	day	$2,500	7	$17,500	Cascade Drilling Quote
ISOTEC Injection Services	day	$6,000	7	$42,000	ISOTEC Estimate, 12/13/2019
6% Hydrogen Peroxide + MFR Solution	gal	$2.50	18,590	$46,500	440 lbs per point, price ISOTEC Estimate, 12/13/2019
Transport & Disposal, State Dangerous Waste (Geoprobe)	drum	$192	2	$400	Stericycle Quote for Portland Broker, 12/13/2019
Equipment	day	$95	7	$700	PID rental, DOF standard rate
Surveying	day	$195	1	$200	GPS rental, DOF standard rate
Task 5 Subtotal				**$321,600**	
6 **Downgradient Area Enhanced Bioremediation (MC-15D)**					
Geoprobe Rig	day	$2,500	4	$10,000	Cascade Drilling Quote
ISOTEC Injection Services	day	$6,000	4	$24,000	ISOTEC Estimate, 12/13/2019
Emulsified Vegetable Oil or lactate	gal	$10	300	$3,000	Recent EVO purchase for other Stericycle site. ESTCP Estimator for volume.
Transport & Disposal, State Dangerous Waste (Geoprobe)	drum	$192	1	$200	Stericycle Quote for Portland Broker, 12/13/2019
Equipment	day	$95	4	$400	PID rental, DOF standard rate
Surveying	day	$195	1	$200	GPS rental, DOF standard rate
Task 6 Subtotal				**$37,800**	
Implementation Subtotal				**$1,760,700**	
Professional Technical Services					
Permitting	LS	$ 65,000	1	$65,000	Engineer estimate
Remedial Design	%	12%		$211,284	from EPA, 2000, Exhibit 5-8
Construction Management	%	8%		$140,856	from EPA, 2000, Exhibit 5-8
Project Management	%	6%		$105,642	from EPA, 2000, Exhibit 5-8
Subtotal, Professional Services				**$522,782**	
TOTAL INITIAL IMPLEMENTATION COST				**$2,283,500**	

Abbreviations

BCY = bank cubic yards
CY = cubic yards
PID = photoionization detector
GPS = global positioning system
ISOTEC = In-Situ Oxidation Technologies, Inc.
EPA = Environmental Protection Agency
MFR = Modified Fenton's Reagent
EVO = emulsified vegetable oil
ESTCP = Environmental Security Technology Certification Program

TABLE F-9

RECURRING COSTS FOR ALTERNATIVE A-3[1,2]

Stericycle Washougal Facility

Washougal, Washington

	Item	Unit	Unit Cost	Annual Quantity	Annual Cost	Sources
1	**INSPECTION (10 YEARS)**					
	Site Inspection	each	$575	1	$580	DOF Staff 1/2 Day
	Subtotal				**$580**	
2	**Groundwater Monitoring**					
	40 wells - Quarterly Compliance Monitoring	each	$1,162	160	$185,850	Current GW monitoring costs with validation
	37 wells - Quarterly Compliance Monitoring	each	$1,162	148	$171,910	after remediation implementation
	30 wells - Semi-Annual Compliance Monitoring	each	$1,162	60	$69,700	after 2 years
	19 wells - Semi-Annual Confirmational Monitoring	each	$1,162	38	$44,140	after 5 years
						Wells remaining include all three depths[3]
3	**Well Abandonment**					
	Monitoring Well Abandonment (after 5 yrs)	each	$800	21	$16,800	Cascade Drilling abandonment estimate
4	**Repairs**					
	Pavement replacement every 5 years	Lump sum	$25,300	1	$25,300	Engineer Estimate, based on increased subsurface settling.
	Well replacement/fouling every 5 years	Lump sum	$3,500	1	$3,500	Engineer Estimate
	IPIM repairs/replacement parts (every 10 years)	Lump sum	$1,000	1	$1,000	Engineer Estimate
					$29,800	
5	**PROJECT MANAGEMENT (10 YEARS)**					
	Project Management	year	$10,000	1	$10,000	Engineer Estimate
	Subtotal				**$10,000**	

Notes

1. Assumes 40-hour work week.
2. No taxes have been included.
3. Wells consist of: MC-8,-10D,-12,-13,-13D,-14,-14D,-15,-15D,-17,-17D,-19D,-24D-R,-24D2-R,-30,-30D,-31,-118D, and -118D2.

Abbreviation

GW = groundwater

IPIM = inhalation pathway interim measure

TABLE F-10

NET PRESENT VALUE FOR ALTERNATIVE A-3

Stericycle Washougal Facility
Washougal, Washington

Year	Implementation Cost/Repairs	Inspection & Project Management	Groundwater Monitoring[1]	10% Contingency[2]	Yearly Total
0	$2,283,500		$185,850	$246,935	$2,716,000
1		$10,580	$171,910	$18,249	$201,000
2		$10,580	$171,910	$18,249	$201,000
3		$10,580	$69,700	$8,028	$88,000
4		$10,580	$69,700	$8,028	$88,000
5	$57,600	$10,580	$69,700	$13,788	$152,000
6		$10,580	$60,940	$7,152	$79,000
7		$10,580	$44,140	$5,472	$60,000
8		$10,580	$44,140	$5,472	$60,000
9		$10,580	$44,140	$5,472	$60,000
10	$29,800	$10,580	$44,140	$8,452	$93,000
TOTAL	$2,371,000	$106,000	$976,000	$345,000	$3,798,000

Net Discount rate: 2.5% **NPV** **$3,687,700**

Notes
1. Groundwater monitoring costs include costs for monitoring well abandonment.
2. Contingency estimate is included for implementation costs, repairs, inspection, project management, and groundwater monitoring.

TABLE F-11

IMPLEMENTATION COSTS FOR ALTERNATIVE A-4

Stericycle Washougal Facility

Washougal, Washington

Item	Unit	Unit Cost	Quantity	Cost	Sources/Notes
1 Cap Construction					
Mobilization/Demobilization	Lump Sum	$2,000	1	$2,000	Engineer estimate
Asphalt Paving	Ton	$200	68	$13,600	2019 facility stormwater improvements paving unit rate
Equipment	day	$95	1	$100	PID rental, DOF standard rate
Task 1 Subtotal				**$15,700**	
2 Grouting of Storm Drain (4 locations)					
Mobilization/Demobilization	LS	$500	1	$500	Engineer estimate
Test Pits & Soil Transport/Disposal	BCY	$250	9	$2,400	Estimate from similar project
Concrete	CY	$150	9	$1,400	Engineer estimate
Equipment	day	$95	1	$100	PID rental, DOF standard rate
Task 2 Subtotal				**$4,400**	
3 Electrical Resistive Heating					
Thermal Remediation Services Quote	CY	$208	13,400	$2,785,500	Quote for Source Area Treatment from TRS, 03/27/2020
Monitoring Well Abandonment	each	$800	11	$8,800	Abandon MC-1,14, 14D, 24, 24D, 24D2, 25, 25D, 25D2,118D,118D2. Price from simliar job.
Shallow Zone Monitoring Well Replacement	each	$3,500	4	$14,000	Replace a shallow zone well for a well cluster at northern fence line, 2 wells in former tank farm area, and former MC-14. Previous quote from CDI.
Silt Zone Monitoring Well Replacement	each	$4,000	3	$12,000	Place a silt zone well for a well cluster at northern fenceline and 2 wells in former tank farm area. Previous quote from CDI.
Deep Aquifer Monitoring Well Replacement	each	$6,400	3	$19,200	Place a deep aquifer well for a well cluster at northern fenceline and 2 wells in former tank farm area. Quote from CDI.
Surveying	day	$195	1	$200	GPS rental, DOF standard rate
Equipment	day	$95	1	$100	PID rental, DOF standard rate
Task 3 Subtotal				**$2,839,800**	
4 Downgradient Area Enhanced Bioremediation (MC-15D)					
Bench Scale Test	LS	$15,000	1	$15,000	ISOTEC discussion, 12/10/2019
Geoprobe Rig	day	$2,500	4	$10,000	Cascade Drilling Quote
ISOTEC Injection Services	day	$6,000	4	$39,000	ISOTEC Estimate, 12/13/2019. plus mobilization charges of $15,000
Emulsified Vegetable Oil or Lactate	gal	$10	300	$3,000	Recent EVO purchase for other Stericycle site. ESTCP Estimator for volume.
Transport & Disposal, State Dangerous Waste (Geoprobe)	drum	$192	1	$200	Stericycle Quote for Portland Broker, 12/13/2019
Equipment	day	$95	4	$400	PID rental, DOF standard rate
Surveying	day	$195	1	$200	GPS rental, DOF standard rate
Task 4 Subtotal				**$67,800**	
Implementation Subtotal				**$2,927,700**	
Professional Technical Services					
Permitting	LS	$ 65,000	1	$65,000	Engineer estimate
Remedial Design	%	8%		$234,216	from EPA, 2000, Exhibit 5-8
Construction Management	%	6%		$175,662	from EPA, 2000, Exhibit 5-8
Project Management	%	5%		$146,385	from EPA, 2000, Exhibit 5-8
Subtotal, Professional Services				**$621,263**	
TOTAL INITIAL IMPLEMENTATION COST				**$3,549,000**	

Abbreviations

BCY = bank cubic yards

CY = cubic yard

PID = photoionization detector

GPS = global positioning system

EPA = Environmental Protection Agency

EVO = emulsified vegetable oil

ISOTEC = In-Situ Oxidation Technologies, Inc.

ESTCP = Environmental Security Technology Certification Program

TABLE F-12

RECURRING COSTS FOR ALTERNATIVE A-4[1,2]

Stericycle Washougal Facility
Washougal, Washington

	Item	Unit	Unit Cost	Annual Quantity	Annual Cost	Sources
1	**INSPECTION (10 YEARS)**					
	Site Inspection	EA	$575	1	$580	DOF Staff 1/2 Day
	Subtotal				**$580**	
2	**Groundwater Monitoring**					
	40 wells - Quarterly Compliance Monitoring	each	$1,162	160	$185,850	Current GW monitoring costs with validation
	39 wells - Quarterly Compliance Monitoring	each	$1,162	156	$181,210	after remediation implementation
	30 wells - Semi-Annual Compliance Monitoring	each	$1,162	60	$69,700	after 2 years
	20 wells - Semi-Annual Confirmational Monitoring	each	$1,162	40	$46,460	after 5 years
						Wells remaining include all three depths[3]
3	**Well Abandonment**					
	Monitoring Well Abandonment (after 2 yrs)	each	$800	9	$7,200	Cascade Drilling abandonment estimate
	Monitoring Well Abandonment (after 5 yrs)	each	$800	10	$8,000	Cascade Drilling abandonment estimate
4	**Repairs**					
	Well replacement/fouling every 5 years	Lump sum	$3,500	1	$3,500	Engineer Estimate
5	**PROJECT MANAGEMENT (10 YEARS)**					
	Project Management	year	$10,000	1	$10,000	Engineer Estimate
	Subtotal				**$10,000**	

Notes:
1. Assumes 40-hour work week.
2. No taxes have been included.
3. Wells consist of: MC-8,-10D,-12, -13,-13D,-14-R,-14D-R,-15,-15D,-17,-17D,-19D,-24-R,-24D-R,-24D2-R,-30,-30D,-31, -118D-R, and -118D2-R.

Abbreviations
GW = groundwater

TABLE F-13

NET PRESENT VALUE FOR ALTERNATIVE A-4

Stericycle Washougal Facility
Washougal, Washington

Year	Implementation Cost/Repairs	Inspection & Project Management	Groundwater Monitoring[1]	10% Contingency[2]	Yearly Total
0	$3,549,000		$185,850	$373,485	$4,108,000
1		$10,580	$181,210	$19,179	$211,000
2		$10,580	$181,210	$19,179	$211,000
3		$10,580	$76,900	$8,748	$96,000
4		$10,580	$69,700	$8,028	$88,000
5	$3,500	$10,580	$69,700	$8,378	$92,000
6		$10,580	$54,460	$6,504	$72,000
7		$10,580	$46,460	$5,704	$63,000
8		$10,580	$46,460	$5,704	$63,000
9		$10,580	$46,460	$5,704	$63,000
10	$3,500	$10,580	$46,460	$6,054	$67,000
TOTAL	$3,556,000	$106,000	$1,005,000	$467,000	$5,134,000

Net Discount rate: 2.5% **NPV** **$5,034,000**

Notes

1. Groundwater monitoring costs include costs for monitoring well abandonment.
2. Contingency estimate is included for implementation costs, repairs, inspection, project management, and groundwater monitoring.

TABLE F-14

IMPLEMENTATION COSTS FOR ALTERNATIVE A-5
Stericycle Washougal Facility
Washougal, Washington

Item	Unit	Unit Cost	Quantity	Cost	Sources/Notes
1 **Cap Construction**					
Mobilization/Demobilization	LS	$2,000	1	$2,000	Engineer estimate
Asphalt Paving	Ton	$200	98	$19,600	2019 facility stormwater improvements paving unit rate
Equipment	day	$95	1	$100	PID rental, DOF standard rate
Task 1 Subtotal				**$21,700**	
2 **Grouting of Storm Drain (4 locations)**					
Mobilization/Demobilization	LS	$500	1	$500	Engineer estimate
Test Pits & Soil Transport/Disposal	BCY	$250	9	$2,400	Estimate from similar project
Concrete	CY	$150	9	$1,400	Engineer estimate
Equipment	day	$95	1	$100	PID rental, DOF standard rate
Task 2 Subtotal				**$4,400**	
3 **Permeable Reactive Barrier**					
Pilot Study	LS	$28,369	1	$28,400	Test area in both source area and downgradient with direct-push rig
Mobilization/Demobilization	LS	$125,000	1	$125,000	FRx Quote from 12/13/2019
Fracture crew	day	$774	22	$17,000	FRx Quote from 12/13/2019
Surveying	day	$195	1	$200	GPS rental, DOF standard rate
Equipment	day	$95	22	$2,100	PID rental, DOF standard rate
Source Area					
Geoprobe Rig	day	$2,500	14	$35,000	Cascade Drilling Quote
Fractures	ea	$2,500	84	$210,000	FRx Quote from 12/13/2019
Zero-Valent Iron	lb	$0.62	168,000	$104,900	Compass Remediation Chemicals Quote 12/17/2019
Downgradient Area					
Drilling & Well Construction	LF	$115	280	$32,200	FRx Quote from 12/13/2019
Fractures	ea	$4,500	16	$72,000	FRx Quote from 12/13/2019
Zero-Valent Iron	lb	$0.62	32,000	$20,000	Compass Remediation Chemicals Quote 12/17/2019
Task 3 Subtotal				**$646,800**	
4 **In Situ Chemical Oxidation (ISCO) (near MC-14)**					
Round 1					
Bench scale test	LS	$15,000	1	$15,000	ISOTEC discussion, 12/10/2019
Geoprobe Rig	day	$2,500	4	$10,000	Cascade Drilling Quote
ISOTEC Injection Services	day	$6,000	4	$24,000	ISOTEC Estimate, 12/13/2019
6% Hydrogen Peroxide + MFR Solution	gal	$2.50	3,950	$9,900	440 lbs per point, price ISOTEC Estimate, 12/13/2019
Transport & Disposal, State Dangerous Waste (Geoprobe)	drum	$192	1	$200	Stericycle Quote for Portland Broker, 12/13/2019
Equipment	day	$95	4	$400	PID rental, DOF standard rate
Surveying	day	$195	1	$200	GPS rental, DOF standard rate
Round 2 (Half of first round treatment)					
Geoprobe Rig	day	$2,500	2	$5,000	Cascade Drilling Quote
ISOTEC Injection Services	day	$6,000	2	$12,000	ISOTEC Estimate, 12/13/2019
6% Hydrogen Peroxide + MFR Solution	gal	$2.50	1,975	$4,900	440 lbs per point, price ISOTEC Estimate, 12/13/2019
Transport & Disposal, State Dangerous Waste (Geoprobe)	drum	$192	1	$200	Stericycle Quote for Portland Broker, 12/13/2019
Equipment	day	$95	2	$200	PID rental, DOF standard rate
Surveying	day	$195	1	$200	GPS rental, DOF standard rate
Task 4 Subtotal				**$82,200**	
Implementation Subtotal				**$755,100**	
Professional Technical Services					
Permitting	LS	$ 20,000	1	$20,000	Engineer estimate
Remedial Design	%	12%		$90,612	from EPA, 2000, Exhibit 5-8
Construction Management	%	8%		$60,408	from EPA, 2000, Exhibit 5-8
Project Management	%	6%		$45,306	from EPA, 2000, Exhibit 5-8
Subtotal, Professional Services				**$216,326**	
TOTAL INITIAL IMPLEMENTATION COST				**$971,500**	

Abbreviations
BCY = bank cubic yards
CY = cubic yard
PID = photoionization detector
GPS = global positioning system
EPA = Environmental Protection Agency
MFR = Modified Fenton's Reagent
ISOTEC = In-Situ Oxidation Technologies, Inc.

TABLE F-15

RECURRING COSTS FOR ALTERNATIVE A-5[1,2]
Stericycle Washougal Facility
Washougal, Washington

	Item	Unit	Unit Cost	Annual Quantity	Annual Cost	Sources
1	**INSPECTION (10 YEARS)**					
	Site Inspection	each	$575	1	$580	DOF Staff 1/2 Day
	Subtotal				**$580**	
2	**Groundwater Monitoring**					
	40 wells - Quarterly Compliance Monitoring	each	$1,162	160	$185,850	Current GW monitoring costs with validation
	30 wells - Quarterly Compliance Monitoring	each	$1,162	120	$139,390	after 2 years
	23 wells - Semi-Annual Confirmational Monitoring	each	$1,162	46	$53,430	after 5 years
						Wells remaining include all three depths[3]
3	**Well Abandonment**					
	Monitoring Well Abandonment (after 2 yrs)	each	$800	10	$8,000	Cascade Drilling abandonment estimate
	Monitoring Well Abandonment (after 5 yrs)	each	$800	7	$5,600	Cascade Drilling abandonment estimate
4	**Repairs**					
	Well replacement/fouling every 5 years	Lump sum	$3,500	1	$3,500	Engineer Estimate
	IPIM repairs/replacement parts (every 10 years)	Lump sum	$1,000	1	$1,000	Engineer Estimate
					$4,500	
5	**PROJECT MANAGEMENT (10 YEARS)**					
	Project Management	year	$10,000	1	$10,000	Engineer Estimate
	Subtotal				**$10,000**	

Notes:
1. Assumes 40-hour work week.
2. No taxes have been included.
3. Wells consist of: MC-8,-10D,-12,-13,-13D,-14,-14D,-15,-15D,-17,-17D,-19D,-24,-24D,-24D2,-25,-25D,-25D2,-30,-30D,-31,-118D, and -118D2.

Abbreviations
IPIM = inhalation pathway interim measure
GW = groundwater

TABLE F-16

NET PRESENT VALUE FOR ALTERNATIVE A-5

Stericycle Washougal Facility
Washougal, Washington

Year	Implementation Cost/Repairs	Inspection & Project Management	Groundwater Monitoring[1]	10% Contingency[2]	Yearly Total
0	$971,500		$185,850	$115,735	$1,273,000
1		$10,580	$185,850	$19,643	$216,000
2		$10,580	$185,850	$19,643	$216,000
3		$10,580	$147,390	$15,797	$174,000
4		$10,580	$139,390	$14,997	$165,000
5	$3,500	$10,580	$139,390	$15,347	$169,000
6		$10,580	$59,030	$6,961	$77,000
7		$10,580	$53,430	$6,401	$70,000
8		$10,580	$53,430	$6,401	$70,000
9		$10,580	$53,430	$6,401	$70,000
10	$4,500	$10,580	$53,430	$6,851	$75,000
TOTAL	$980,000	$106,000	$1,256,000	$234,000	$2,575,000

Net Discount rate: 2.5% **NPV** **$2,447,000**

Notes
1. Groundwater monitoring costs include costs for monitoring well abandonment.
2. Contingency estimate is included for implementation costs, repairs, inspection, project management, and groundwater monitoring.

TABLE F-17

IMPLEMENTATION COSTS FOR ALTERNATIVE A-6
Stericycle Washougal Facility
Washougal, Washington

Item	Unit	Unit Cost	Quantity	Cost	Sources/Notes
1 **Cap Construction**					
Mobilization/Demobilization	Lump Sum	$2,000	1	$2,000	Engineer estimate
Asphalt Paving	Ton	$200	101	$20,300	2019 facility stormwater improvements paving unit rate
Equipment	day	$95	1	$100	PID rental, DOF standard rate
Task 1 Subtotal				**$22,400**	
2 **Grouting of Storm Drain (4 locations)**					
Mobilization/Demobilization	LS	$500	1	$500	Engineer estimate
Test Pits & Soil Transport/Disposal	BCY	$250	9	$2,400	Estimate from similar project
Concrete	CY	$150	9	$1,400	Engineer estimate
Equipment	day	$95	1	$100	PID rental, DOF standard rate
Task 2 Subtotal				**$4,400**	
3 **In Situ Chemical Oxidation (ISCO) (near MC-14)**					
Round 1					
Bench scale test	LS	$15,000	1	$15,000	ISOTEC discussion, 12/10/2019
Geoprobe Rig	day	$2,500	4	$10,000	Cascade Drilling Quote
ISOTEC Injection Services	day	$6,000	4	$24,000	ISOTEC Estimate, 12/13/2019
6% Hydrogen Peroxide + MFR Solution	gal	$2.50	3,950	$9,900	440 lbs per point, price ISOTEC Estimate, 12/13/2019
Transport & Disposal, State Dangerous Waste (Geoprobe)	drum	$192	1	$200	Stericycle Quote for Portland Broker, 12/13/2019
Equipment	day	$95	4	$400	PID rental, DOF standard rate
Surveying	day	$195	1	$200	GPS rental, DOF standard rate
Round 2 (Half of first round treatment)					
Geoprobe Rig	day	$2,500	2	$5,000	Cascade Drilling Quote
ISOTEC Injection Services	day	$6,000	2	$12,000	ISOTEC Estimate, 12/13/2019
6% Hydrogen Peroxide + MFR Solution	gal	$2.50	1,975	$4,900	440 lbs per point, price ISOTEC Estimate, 12/13/2019
Transport & Disposal, State Dangerous Waste (Geoprobe)	drum	$192	1	$200	Stericycle Quote for Portland Broker, 12/13/2019
Equipment	day	$95	2	$200	PID rental, DOF standard rate
Surveying	day	$195	1	$200	GPS rental, DOF standard rate
Task 3 Subtotal				**$82,200**	
4 **Former Tank Farm Area Enhanced Bioremediation**					
Bench scale test	LS	$15,000	1	$15,000	ISOTEC discussion, 12/10/2019
Geoprobe Rig	day	$2,500	7	$17,500	Cascade Drilling Quote
ISOTEC Injection Services	day	$6,000	7	$42,000	ISOTEC Estimate, 12/13/2019
Emulsified Vegetable Oil & Zero-Valent Iron Substrate	gal	$50	5,000	$250,000	ISOTEC Estimated cost, 12/13/2019. ESTCP Estimator for volume.
Transport & Disposal, State Dangerous Waste (Geoprobe)	drum	$192	1	$200	Stericycle Quote for Portland Broker, 12/13/2019
Equipment	day	$95	7	$700	PID rental, DOF standard rate
Surveying	day	$195	1	$200	GPS rental, DOF standard rate
Task 4 Subtotal				**$325,600**	
5 **Downgradient Area Enhanced Bioremediation (MC-15D)**					
Geoprobe Rig	day	$2,500	4	$10,000	Cascade Drilling Quote
ISOTEC Injection Services	day	$6,000	4	$24,000	ISOTEC Estimate, 12/13/2019
Emulsified Vegetable Oil or lactate	gal	$10	300	$3,000	Recent EVO purchase for other Stericycle site. ESTCP Estimator for volume.
Transport & Disposal, State Dangerous Waste (Geoprobe)	drum	$192	1	$200	Stericycle Quote for Portland Broker, 12/13/2019
Equipment	day	$95	4	$400	PID rental, DOF standard rate
Surveying	day	$195	1	$200	GPS rental, DOF standard rate
Task 5 Subtotal				**$37,800**	

TABLE F-17

IMPLEMENTATION COSTS FOR ALTERNATIVE A-6
Stericycle Washougal Facility
Washougal, Washington

Item	Unit	Unit Cost	Quantity	Cost	Sources/Notes
6 **Hydraulic Control (Source Area & Downgradient)**					
Extraction Well Installation	each	$15,000	6	$90,000	Cascade Drilling Estimate for conductor cased 6 inch wells with sonic.
Transport & Disposal, State Dangerous Waste (Geoprobe)	drum	$192	35	$6,700	Stericycle Quote for Portland Broker, 12/13/2019
Treatment building installation	LS	$100,000	1	$100,000	Steel pre-fab building with containment foundation
Treatment system equipment, piping, & installation	LS	$150,000	1	$150,000	Air stripper and vapor GAC to treat volatiles. Discharge to POTW.
System Start-up	day	$1,150	5	$5,800	1 engineer/scientist, DOF field rate
Task 6 Subtotal				**$352,500**	
Implementation Subtotal				**$824,900**	
Professional Technical Services					
Permitting	LS	$60,000	1	$60,000	Engineer estimate based on similar project
Remedial Design	%	12%		$98,988	from EPA, 2000, Exhibit 5-8
Construction Management	%	8%		$65,992	from EPA, 2000, Exhibit 5-8
Project Management	%	6%		$49,494	from EPA, 2000, Exhibit 5-8
Subtotal, Professional Services				**$274,474**	
TOTAL INITIAL IMPLEMENTATION COST				**$1,099,400**	

Abbreviations
BCY = bank cubic yards
CY = cubic yards
PID = photoionization detector
GPS = global positioning system
ISOTEC = In-Situ Oxidation Technologies, Inc.
EPA = Environmental Protection Agency
ESTCP = Environmental Security Technology Certification Program

TABLE F-18

RECURRING COSTS FOR ALTERNATIVE A-6[1,2]
Stericycle Washougal Facility
Washougal, Washington

	Item	Unit	Unit Cost	Annual Quantity	Annual Cost	Sources
1	**INSPECTION (20 YEARS)**					
	Site Inspection	EA	$575	1	$580	DOF Staff 1/2 Day
	Subtotal				**$580**	
2	**Groundwater Monitoring**					
	40 wells - Quarterly Compliance Monitoring	each	$1,162	160	$185,850	Current GW monitoring costs with validation
	30 wells - Quarterly Compliance Monitoring	each	$1,162	120	$139,390	after 2 years
	23 wells - Semi-Annual Confirmational Monitoring	each	$1,162	46	$53,430	after 5 years
						Wells remaining include three depths[3]
3	**GW Pump and Treat O&M**					
	POTW Discharge Costs	Yearly	$92,000	1	$92,000	Assumes average flow of ~34 gallons per minute (GPM)
	Lab (water and air sampling)	Yearly	$15,000	1	$15,000	Engineer Estimate, based on O&M at similar facilities
	Water Treatment Chemicals	Yearly	$20,000	1	$20,000	Engineer Estimate, based on O&M at similar facilities
	Biosolids cleanout and disposal	Yearly	$5,000	1	$5,000	Engineer Estimate, based on O&M at similar facilities
	GAC/KMNO air treatment media	Yearly	$15,000	1	$15,000	Engineer Estimate, based on O&M at similar facilities
	Labor for air stripper cleaning	Quarterly	$5,000	4	$20,000	Engineer Estimate, based on O&M at similar facilities
	Consultant Support	Yearly	$50,000	1	$50,000	Engineer Estimate, based on O&M at similar facilities
	Subtotal				**$217,000**	
4	**Repeat Tank Farm Area Enhanced Bioremediation[4]**					
	Geoprobe Rig	day	$2,500	4	$8,800	Cascade Drilling Quote
	ISOTEC Injection Services	day	$6,000	4	$21,000	ISOTEC Estimate, 12/13/2019
	Emulsified Vegetable Oil & Zero-Valent Iron Substrate	gal	$50	2,500	$125,000	440 gal per point, price ISOTEC Estimate, 12/13/2019
	Transport & Disposal, State Dangerous Waste (Geoprobe)	drum	$192	1	$192	Stericycle Quote for Portland Broker, 12/13/2019
	Construction Oversight	day	$1,150	4	$4,000	1 engineer/scientist, DOF staff rate
	Equipment	day	$95	4	$300	PID rental, DOF standard rate
	Surveying	day	$195	1	$200	GPS rental, DOF standard rate
	Subtotal				**$159,500**	
5	**Well Abandonment**					
	Monitoring Well Abandonment (after 2 yrs)	each	$800	10	$8,000	Cascade Drilling abandonment estimate
	Monitoring Well Abandonment (after 5 yrs)	each	$800	7	$5,600	Cascade Drilling abandonment estimate
6	**Repairs**					
	Pavement replacement every 10 years	Lump sum	$25,300	1	$25,300	Engineer Estimate
	Well replacement/fouling every 10 years	Lump sum	$3,500	2	$7,000	Engineer Estimate
	IPIM repairs/replacement parts (every 10 years)	Lump sum	$1,000	1	$1,000	Engineer Estimate
					$33,300	
7	**PROJECT MANAGEMENT (20 YEARS)**					
	Project Management	year	$10,000	1	$10,000	Engineer Estimate
	Subtotal				**$10,000**	

Notes
1. Assumes 40-hour work week.
2. No taxes have been included.
3. Wells consist of: MC-8,-10D,-12,-13,-13D,-14,-14D,-15,-15D,-17,-17D,-19D,-24,-24D,-24D2,-25,-25D,-25D2,-30,-30D,-31,-118D, and -118D2.
4. Repeat Enhanced Bioremediation treatment in Tank Farm Area is assumed to be 50% of initial dose and effort for a single event.

Abbreviations
IPIM = inhalation pathway interim measure
GW = groundwater
PID = photoionization detector
GPS = global positioning system
ISOTEC = In-Situ Oxidation Technologies, Inc.

TABLE F-19

NET PRESENT VALUE FOR ALTERNATIVE A-6

Stericycle Washougal Facility
Washougal, Washington

Year	Implementation Cost/Repairs	Inspection & Project Management	GWPT O&M	Groundwater Monitoring[1]	10% Contingency[2]	Yearly Total
0	$1,099,400			$185,850	$128,525	$1,414,000
1	$159,500	$15,580	$217,000	$185,850	$57,793	$636,000
2		$10,580	$217,000	$185,850	$41,343	$455,000
3		$10,580	$217,000	$147,390	$37,497	$412,000
4		$10,580		$139,390	$14,997	$165,000
5		$10,580		$139,390	$14,997	$165,000
6		$10,580		$59,030	$6,961	$77,000
7		$10,580		$53,430	$6,401	$70,000
8		$10,580		$53,430	$6,401	$70,000
9		$10,580		$53,430	$6,401	$70,000
10	$33,300	$10,580		$53,430	$9,731	$107,000
11		$10,580		$53,430	$6,401	$70,000
12		$10,580		$53,430	$6,401	$70,000
13		$10,580		$53,430	$6,401	$70,000
14		$10,580		$53,430	$6,401	$70,000
15		$10,580		$53,430	$6,401	$70,000
TOTAL	$1,292,000	$164,000	$651,000	$1,524,000	$363,000	$3,991,000

Net Discount rate: 2.5% **NPV** **$3,722,000**

Notes
1. Groundwater monitoring costs include costs for monitoring well abandonment.
2. Contingency estimate is included for implementation costs, repairs, inspection, project management, and groundwater monitoring.

Abbrevation
ISCO = in situ chemical oxidation

TABLE F-20

IMPLEMENTATION COSTS FOR ALTERNATIVE A-7
Stericycle Washougal Facility
Washougal, Washington

	Item	Unit	Unit Cost	Quantity	Cost	Sources/Notes
1	**Cap Construction**					
	Mobilization/Demobilization	Lump Sum	$2,000	1	$2,000	Engineer estimate
	Asphalt Paving	Ton	$200	101	$20,300	2019 facility stormwater improvements paving unit rate
	Equipment	day	$95	1	$100	PID rental, DOF standard rate
	Task 1 Subtotal				**$22,400**	
2	**Grouting of Storm Drain (4 locations)**					
	Mobilization/Demobilization	LS	$500	1	$500	Engineer estimate
	Test Pits & Soil Transport/Disposal	BCY	$250	9	$2,400	Estimate from similar project
	Concrete	CY	$150	9	$1,400	Engineer estimate
	Equipment	day	$95	1	$100	PID rental, DOF standard rate
	Task 2 Subtotal				**$4,400**	
3	**In Situ Chemical Oxidation (ISCO) (near MC-14)**					
	Round 1					
	Bench scale test	LS	$15,000	1	$15,000	ISOTEC discussion, 12/10/2019
	Geoprobe Rig	day	$2,500	4	$10,000	Cascade Drilling Quote
	ISOTEC Injection Services	day	$6,000	4	$24,000	ISOTEC Estimate, 12/13/2019
	6% Hydrogen Peroxide + MFR Solution	gal	$2.50	3,950	$9,900	440 lbs per point, price ISOTEC Estimate, 12/13/2019
	Transport & Disposal, State Dangerous Waste (Geoprobe)	drum	$192	1	$200	Stericycle Quote for Portland Broker, 12/13/2019
	Equipment	day	$95	4	$400	PID rental, DOF standard rate
	Surveying	day	$195	1	$200	GPS rental, DOF standard rate
	Round 2 (Half of first round treatment)					
	Geoprobe Rig	day	$2,500	2	$5,000	Cascade Drilling Quote
	ISOTEC Injection Services	day	$6,000	2	$12,000	ISOTEC Estimate, 12/13/2019
	6% Hydrogen Peroxide + MFR Solution	gal	$2.50	1,975	$4,900	440 lbs per point, price ISOTEC Estimate, 12/13/2019
	Transport & Disposal, State Dangerous Waste (Geoprobe)	drum	$192	1	$200	Stericycle Quote for Portland Broker, 12/13/2019
	Equipment	day	$95	2	$200	PID rental, DOF standard rate
	Surveying	day	$195	1	$200	GPS rental, DOF standard rate
	Task 4 Subtotal				**$82,200**	
4	**In Situ Chemical Oxidation (ISCO) (North Source Area and Tank Farm)**					
	Round 1					
	Geoprobe Rig	day	$2,500	45	$112,500	Cascade Drilling Quote
	ISOTEC Injection Services	day	$6,000	45	$270,000	Based on ISOTEC Estimate 12/13/2019 and recent Seattle injection
	6% Hydrogen Peroxide + MFR Solution	gal	$2.50	138,160	$345,400	440 gal per point, price ISOTEC Estimate, 12/13/2019
	Transport & Disposal, State Dangerous Waste (Geoprobe)	drum	$192	10	$1,900	Stericycle Quote for Portland Broker, 12/13/2019
	Equipment	day	$95	45	$4,300	PID rental, DOF standard rate
	Surveying	day	$195	4	$800	GPS rental, DOF standard rate
	Round 2 (Half of first round treatment)					
	Geoprobe Rig	day	$2,500	23	$56,300	Cascade Drilling Quote
	ISOTEC Injection Services	day	$6,000	23	$135,000	ISOTEC Estimate, 12/13/2019
	6% Hydrogen Peroxide + MFR Solution	gal	$2.50	69,080	$172,700	440 lbs per point, price ISOTEC Estimate, 12/13/2019
	Transport & Disposal, State Dangerous Waste (Geoprobe)	drum	$192	5	$1,000	Stericycle Quote for Portland Broker, 12/13/2019
	Equipment	day	$95	23	$2,100	PID rental, DOF standard rate
	Surveying	day	$195	2	$400	GPS rental, DOF standard rate
	Task 5 Subtotal				**$1,102,400**	

TABLE F-20

IMPLEMENTATION COSTS FOR ALTERNATIVE A-7
Stericycle Washougal Facility
Washougal, Washington

Item	Unit	Unit Cost	Quantity	Cost	Sources/Notes
5 Downgradient Area Enhanced Bioremediation (MC-15D)					
Geoprobe Rig	day	$2,500	4	$10,000	Cascade Drilling Quote
ISOTEC Injection Services	day	$6,000	4	$24,000	ISOTEC Estimate, 12/13/2019
Emulsified Vegetable Oil or lactate	gal	$10	300	$3,000	Recent EVO purchase for other Stericycle site. ESTCP Estimator for volume.
Transport & Disposal, State Dangerous Waste (Geoprobe)	drum	$192	1	$200	Stericycle Quote for Portland Broker, 12/13/2019
Equipment	day	$95	4	$400	PID rental, DOF standard rate
Surveying	day	$195	1	$200	GPS rental, DOF standard rate
Task 6 Subtotal				**$37,800**	
Implementation Subtotal				**$1,249,200**	
Professional Technical Services					
Permitting	LS	$ 40,000	1	$40,000	Engineer estimate
Remedial Design	%	12%		$149,904	from EPA, 2000, Exhibit 5-8
Construction Management	%	8%		$99,936	from EPA, 2000, Exhibit 5-8
Project Management	%	6%		$74,952	from EPA, 2000, Exhibit 5-8
Subtotal, Professional Services				**$364,792**	
TOTAL INITIAL IMPLEMENTATION COST				**$1,614,000**	

Abbreviations
BCY = bank cubic yards
CY = cubic yards
PID = photoionization detector
GPS = global positioning system
EPA = Environmental Protection Agency
EVO = emulsified vegetable oil
ESTCP = Environmental Security Technology Certification Program

TABLE F-21

RECURRING COSTS FOR ALTERNATIVE A-7[1,2]

Stericycle Washougal Facility
Washougal, Washington

	Item	Unit	Unit Cost	Annual Quantity	Annual Cost	Sources
1	**INSPECTION (10 YEARS)**					
	Site Inspection	each	$575	1	$580	DOF Staff 1/2 Day
	Subtotal				**$580**	
2	**Groundwater Monitoring**					
	40 wells - Quarterly Compliance Monitoring	each	$1,162	160	$185,850	Current GW monitoring costs with validation
	40 wells - Quarterly Compliance Monitoriing	each	$1,162	160	$185,850	after remediation implementation
	30 wells - Semi-Annual Compliance Monitoring	each	$1,162	60	$69,700	after 2 years
	23 wells - Semi-Annual Confirmational Monitoring	each	$1,162	46	$53,430	after 5 years
						Wells remaining include all three depths[3]
3	**Well Abandonment**					
	Monitoring Well Abandonment (after 2 yrs)	each	$800	10	$8,000	Cascade Drilling abandonment estimate
	Monitoring Well Abandonment (after 5 yrs)	each	$800	7	$5,600	Cascade Drilling abandonment estimate
4	**Repairs**					
	Pavement replacement every 5 years	Lump sum	$25,300	1	$25,300	Engineer Estimate, based on increased subsurface settling.
	Well replacement/fouling every 5 years	Lump sum	$3,500	1	$3,500	Engineer Estimate
	IPIM repairs/replacement parts (every 10 years)	Lump sum	$1,000	1	$1,000	Engineer Estimate
					$29,800	
5	**PROJECT MANAGEMENT (10 YEARS)**					
	Project Management	year	$10,000	1	$10,000	Engineer Estimate
	Subtotal				**$10,000**	

Notes
1. Assumes 40-hour work week.
2. No taxes have been included.
3. Wells consist of: MC-8,-10D,-12,-13,-13D,-14,-14D,-15,-15D,-17,-17D,-19D,-24,-24D,-24D2,-25,-25D,-25D2,-30,-30D,-31,-118D, and -118D2.

Abbreviation
GW = groundwater
IPIM = inhalation pathway interim measure

TABLE F-22

NET PRESENT VALUE FOR ALTERNATIVE A-7

Stericycle Washougal Facility
Washougal, Washington

Year	Implementation Cost/Repairs	Inspection & Project Management	Groundwater Monitoring[1]	10% Contingency[2]	Yearly Total
0	$1,614,000		$185,850	$179,985	$1,980,000
1		$10,580	$185,850	$19,643	$216,000
2		$10,580	$185,850	$19,643	$216,000
3		$10,580	$77,700	$8,828	$97,000
4		$10,580	$69,700	$8,028	$88,000
5		$10,580	$69,700	$8,028	$88,000
6		$10,580	$59,030	$6,961	$77,000
7		$10,580	$53,430	$6,401	$70,000
8		$10,580	$53,430	$6,401	$70,000
9		$10,580	$53,430	$6,401	$70,000
10	$29,800	$10,580	$53,430	$9,381	$103,000
TOTAL	$1,644,000	$106,000	$1,047,000	$280,000	$3,075,000

Net Discount rate: 2.5% **NPV $2,963,000**

Notes
1. Groundwater monitoring costs include costs for monitoring well abandonment.
2. Contingency estimate is included for implementation costs, repairs, inspection, project management, and groundwater monitoring.

TABLE F-23

Sensitivity Analysis: Groundwater Monitoring Contingency and Net Discount Rate [1,2]
Stericycle Washougal Facility
Washougal, Washington

Alternatives	Net Present Value Cost	Net Present Value Cost	Net Present Value Cost	Net Present Value Cost	Net Present Value Cost	Net Present Value Cost
	10% Contingency **includes** GW monitoring	10% Contingency without GW monitoring	10% Contingency without GW monitoring	10% Contingency without GW monitoring	10% Contingency without GW monitoring	10% Contingency without GW monitoring
A-1: Capping and MNA	$2,742,000	$2,522,000	$2,312,000	$2,133,000	$1,980,000	$1,847,000
A-2: Bioremediation and Targeted ISCO	$2,532,000	$2,399,000	$2,325,000	$2,258,000	$2,196,000	$2,140,000
A-3: Deep Soil Mixing with ZVI and Targeted ISCO	$3,688,000	$3,600,000	$3,563,000	$3,529,000	$3,498,000	$3,468,000
A-4: Electrical Resistive Heating	$5,034,000	$4,941,000	$4,909,000	$4,879,000	$4,850,000	$4,824,000
A-5: ZVI Permeable Reactive Barrier and Targeted ISCO	$2,447,000	$2,332,000	$2,290,000	$2,251,000	$2,214,000	$2,180,000
A-6: Hydraulic Control with Bioremediation and Targeted ISCO	$3,722,000	$3,589,000	$3,502,000	$3,422,000	$3,349,000	$3,281,000
A-7: Full Scale ISCO Treatment	$3,020,000	$2,923,000	$2,884,000	$2,847,000	$2,813,000	$2,781,000
Net discount rate=	2.5%	2.5%	3.5%	4.5%	5.5%	6.5%

Notes
1 Color gradation from green (low cost) to red (high cost) indicates relative cost between alternatives
2 The sensitivity analysis calculations have not been revised since the May 2020 submission of the FS. Ecology pointed out in a July 8, 2020 comment letter an approximately $60,000 discrepancy in costs applied for paving replacement between Alternative A-2 and A-7. This resulted in a minor reduction in the total NPV cost for Alternative A-7 from $3,020,000 to $2,963,000. Since this change is minor and would not affect the conclusions of the sensitivity analysis, the calculations for the sensitivity analysis were not re-run. The total NPV cost for Alternative A-7 has been left at $3,020,000 for the sensitivity analysis.

TABLE F-24

Sensitivity Analysis: True Contingency [1,2]
Stericycle Washougal Facility
Washougal, Washington

Alternatives	Net Present Value Cost		
	Baseline Performance Scenario	**True Contingency Cost (NPV)**	**True Contingency %**
A-1: Capping and MNA	$2,742,000	$250,000	9.1%
A-2: Bioremediation and Targeted ISCO	$2,531,800	$408,500	16.1%
A-3: Deep Soil Mixing with ZVI and Targeted ISCO	$3,687,700	$465,100	12.6%
A-4: Electrical Resistive Heating	$5,034,000	$458,000	9.1%
A-5: ZVI Permeable Reactive Barrier and Targeted ISCO	$2,447,000	$245,000	10.0%
A-6: Hydraulic Control with Bioremediation and Targeted ISCO	$3,722,000	$517,000	13.9%
A-7: Full Scale ISCO Treatment	$3,020,000	$665,000	22.0%
Net discount rate=	2.5%		

Notes
1 True Contingency Cost (NPV) is a total of the 10% contingency line items each year plus the implementation cost line items that were included to supplement initial treatment, e.g. second round injections/treatments, in NPV dollars.
2 The sensitivity analysis calculations have not been revised since the May 2020 submission of the FS. Ecology pointed out in a July 8, 2020 comment letter an approximately $60,000 discrepancy in costs applied for paving replacement between Alternative A-2 and A-7. This resulted in a minor reduction in the total NPV cost for Alternative A-7 from $3,020,000 to $2,963,000. Since this change is minor and would not affect the conclusions of the sensitivity analysis, the calculations for the sensitivity analysis were not re-run. The total NPV cost for Alternative A-7 has been left at $3,020,000 for the sensitivity analysis.

Abbreviations
NPV = Net Present Value
ISCO = in situ chemical oxidation
MNA = monitored natural attenuation
ZVI = zero-valent iron

TABLE F-25

Sensistivity Analysis: Performance Scenario Variability
Stericycle Washougal Facility
Washougal, Washington

Alternatives	Better Performance Scenario	Baseline Performance Scenario	Worse Performance Scenario
A-1: Capping and MNA	No 10% contingency on GW monitoring	10% GW contingency included	Double remedial time frame to 60 years
A-2: Bioremediation and Targeted ISCO	No 10% contingency on GW monitoring, 2nd injections reduced by half, 10 year time frame	10% GW contingency included, 15 year time frame	10% contingency on GW monitoring, 2nd injections increased by 50% & third round of ISB, polish round of ISCO
A-3: Deep Soil Mixing (DSM) with ZVI and Targeted ISCO	No 10% contingency on GW monitoring, 2nd injections reduced by half, smaller DSM area by 25% (reduced by extra push probe sampling)	10% GW contingency included	10% contingency on GW monitoring, 2nd injections increased by 50%, 25% contingency on DSM
A-4: Electrical Resistive Heating	No 10% contingency on GW monitoring, 25% smaller Area requiring treatment	10% GW contingency included Cost ~$208 per CY	10% contingency on GW monitoring, Cost per CY increased to $280/CY
A-5: ZVI Permeable Reactive Barrier (PRB) and Targeted ISCO	No 10% contingency on GW monitoring, 2nd injections reduced by half, 25% smaller Area requiring treatment	10% GW contingency included	10% contingency on GW monitoring, 2nd injections increased by 50%, 25% contingency on PRB 15 year time frame
A-6: Hydraulic Control with Bioremediation and Targeted ISCO	No 10% contingency on GW monitoring, 2nd injections reduced by half, 10 year time frame, 16 GPM for hydraulic control	10% contingency on GW monitoring, 15 year time frame, 33.5 GPM for hydraulic control	10% contingency on GW monitoring, 2nd injections increased by 50% & 3rd round of ISB polish round of ISCO 60 GPM for hydraulic control
A-7: Full Scale ISCO Treatment	No 10% contingency on GW monitoring, 2nd injections reduced by half, 25% smaller tank farm Area requiring treatment	10% GW contingency included	10% contingency on GW monitoring, 2nd injections increased by 50% & 3rd round of ISCO in Former Tank Farm Area (50% of initial injection)

Abbreviations
MNA = monitored natural attenuation
GW = groundwater
ISCO = in situ chemical oxidation
ZVI = zero-valent iron
ISB = in-situ bioremediation
GPM = gallons per minute

TABLE F-26

Sensitivity Analysis: Cost Comparison for Performance Variability [1,2]

Stericycle Washougal Facility

Washougal, Washington

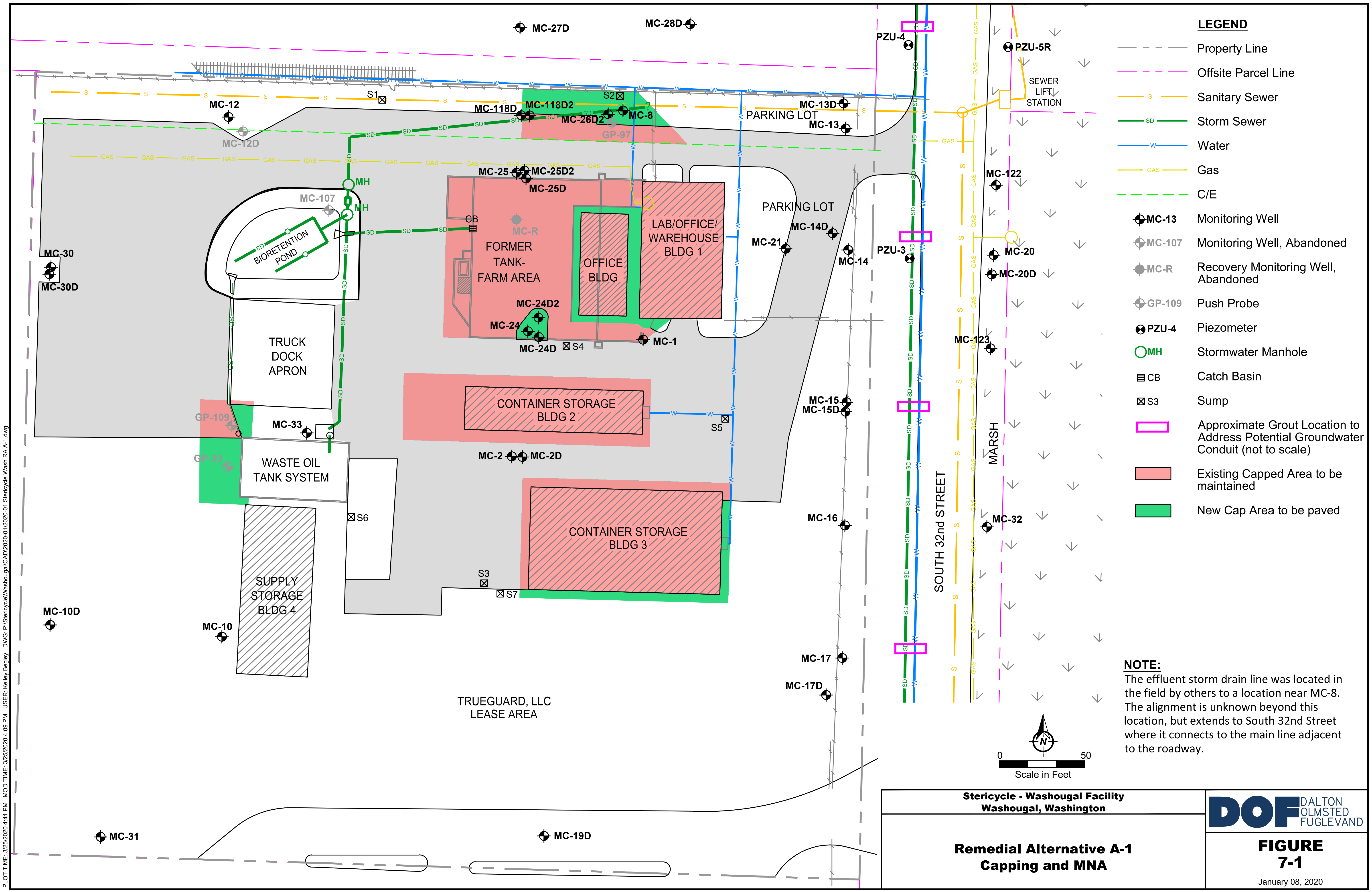
Alternatives	Net Present Value Cost			% Change in Cost from Baseline	
	Better Performance Scenario	Baseline Performance Scenario	Worse Performance Scenario	Better Performance Scenario	Worse Performance Scenario
A-1: Capping and MNA	$2,522,000	$2,742,000	$3,682,000	-8%	+34%
A-2: Bioremediation and Targeted ISCO	$2,062,000	$2,532,000	$2,859,000	-19%	+13%
A-3: Deep Soil Mixing with ZVI and Targeted ISCO	$3,180,000	$3,688,000	$4,213,000	-14%	+14%
A-4: Electrical Resistive Heating	$4,127,000	$5,034,000	$6,322,000	-18%	+26%
A-5: ZVI Permeable Reactive Barrier and Targeted ISCO	$2,206,000	$2,447,000	$2,931,000	-10%	+20%
A-6: Hydraulic Control with Bioremediation and Targeted ISCO	$2,983,000	$3,722,000	$4,475,000	-20%	+20%
A-7: Full Scale ISCO Treatment	$2,437,000	$3,020,000	$3,684,000	-19%	+22%
Net discount rate=	2.5%	2.5%	2.5%		

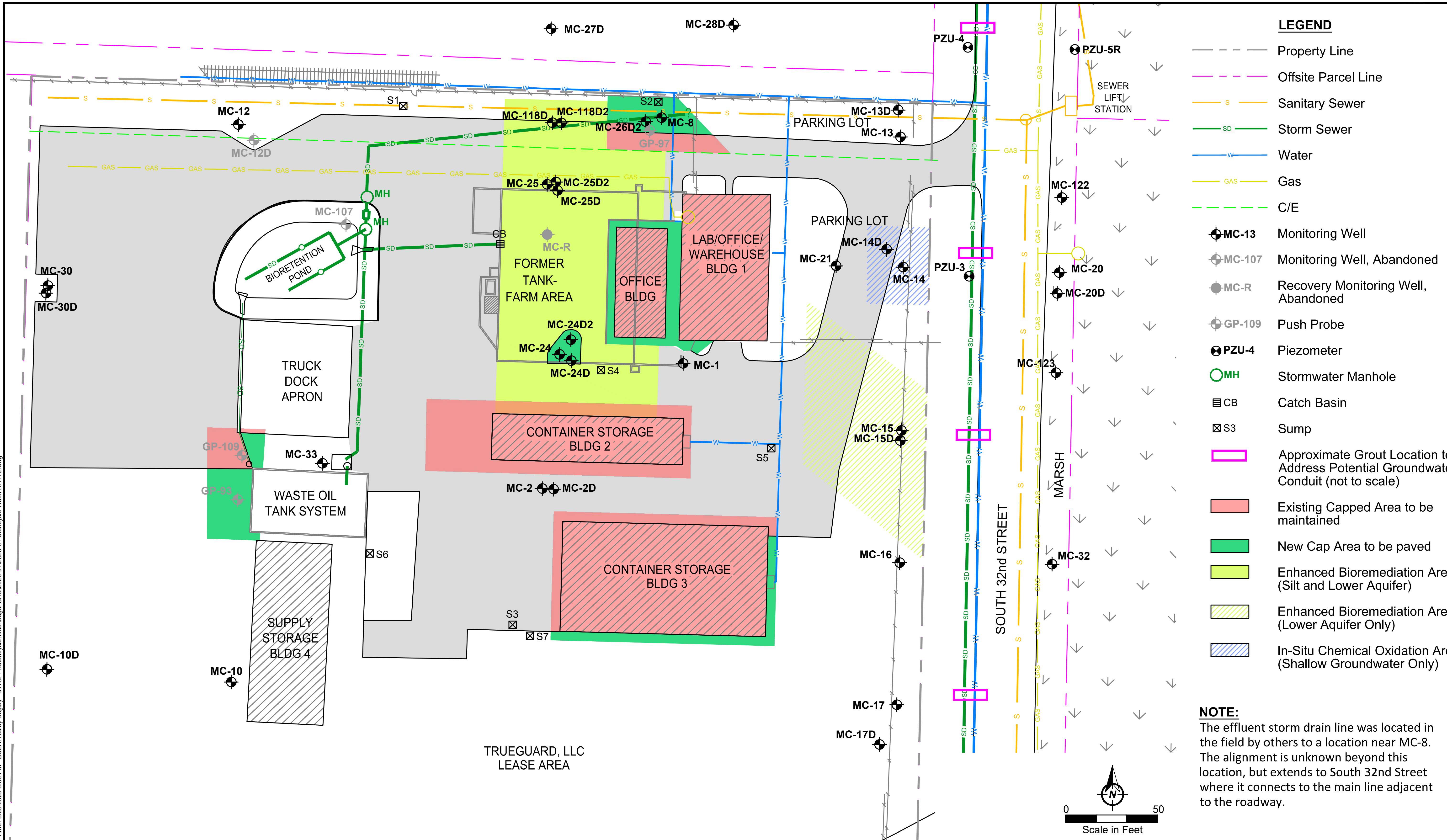
Notes

1 Color gradation from green (low cost) to red (high cost) indicates relative cost between alternatives

2 The sensitivity analysis calculations have not been revised since the May 2020 submission of the FS. Ecology pointed out in a July 8, 2020 comment letter an approximately $60,000 discrepancy in costs applied for paving replacement between Alternative A-2 and A-7. This resulted in a minor reduction in the total NPV cost for Alternative A-7 from $3,020,000 to $2,963,000. Since this change is minor and would not affect the conclusions of the sensitivity analysis, the calculations for the sensitivity analysis were not re-run. The total NPV cost for Alternative A-7 has been left at $3,020,000 for the sensitivity analysis.

Figures


LEGEND
Property Line
Offsite Parcel Line
Sanitary Sewer
Storm Sewer
Water
Gas
C/E
MC-13 Monitoring Well
MC-107 Monitoring Well, Abandoned
MC-R Recovery Monitoring Well, Abandoned
GP-109 Push Probe
PZU-4 Piezometer
MH Stormwater Manhole
CB Catch Basin
S3 Sump
Approximate Grout Location to Address Potential Groundwater Conduit (not to scale)
Existing Capped Area to be maintained
New Cap Area to be paved
MC-27D
MC-28D
PZU-4
PZU-5R
SEWER LIFT STATION
S1
S2
MC-12
MC-12D
MC-118D
MC-118D2
MC-26D2
MC-8
GP-97
MC-13D
MC-13
PARKING LOT
MC-107
MH
BIORETENTION POND
MC-25
MC-25D2
MC-25D
MC-R
CB
FORMER TANK-FARM AREA
OFFICE BLDG
LAB/OFFICE/ WAREHOUSE BLDG 1
PARKING LOT
MC-14D
MC-21
MC-14
PZU-3
MC-122
MC-20
MC-20D
MC-30
MC-30D
TRUCK DOCK APRON
MC-24D2
MC-24
MC-24D
S4
MC-1
MC-123
GP-109
MC-33
CONTAINER STORAGE BLDG 2
S5
MC-15
MC-15D
GP-53
WASTE OIL TANK SYSTEM
MC-2
MC-2D
S6
CONTAINER STORAGE BLDG 3
MC-16
MC-32
SOUTH 32nd STREET
MARSH
S3
S7
SUPPLY STORAGE BLDG 4
MC-10D
MC-10
MC-17
MC-17D
TRUEGUARD, LLC LEASE AREA
N
0
50
Scale in Feet
MC-31
MC-19D
NOTE:
The effluent storm drain line was located in the field by others to a location near MC-8. The alignment is unknown beyond this location, but extends to South 32nd Street where it connects to the main line adjacent to the roadway.
Stericycle - Washougal Facility
Washougal, Washington
Remedial Alternative A-1
Capping and MNA
DOF DALTON OLMSTED FUGLEVAND
FIGURE 7-1
January 08, 2020
PLOT TIME: 3/25/2020 4:41 PM MOD TIME: 3/25/2020 4:09 PM USER: Kelley Begley DWG: P:\Stericycle\Washougal\CAD\2020-01\2020-01 Stericycle Wash RA A-1.dwg



Stericycle - Washougal Facility
Washougal, Washington

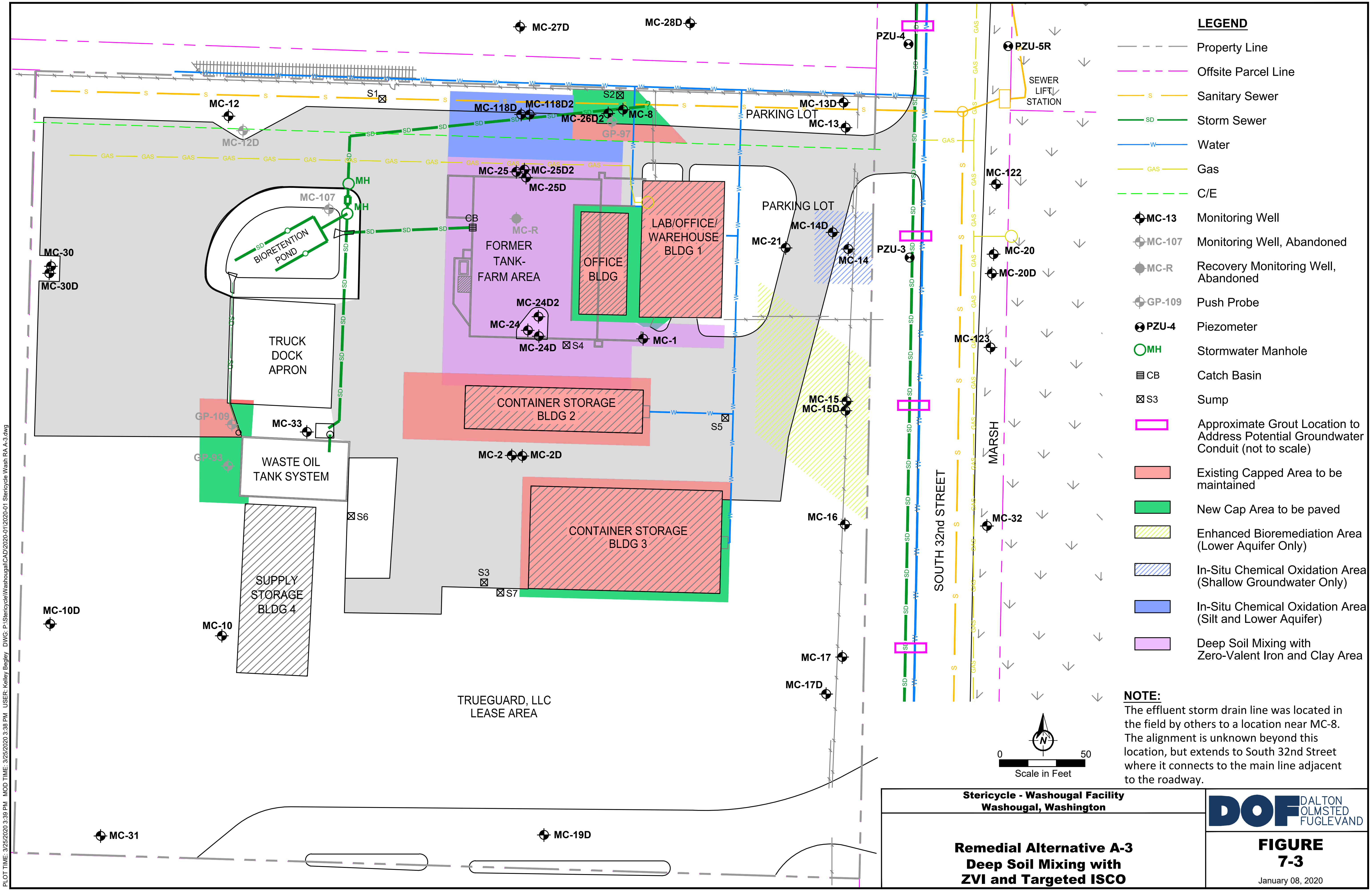
Remedial Alternative A-2
Bioremediation and Targeted ISCO

DALTON OLMSTED FUGLEVAND

FIGURE 7-2

January 08, 2020

PLOT TIME: 3/25/2020 3:33 PM MOD TIME: 3/25/2020 3:30 PM USER: Kelley Begley DWG: P:\Stericycle\Washougal\CAD\2020-01\2020-01 Stericycle Wash RA A-2.dwg



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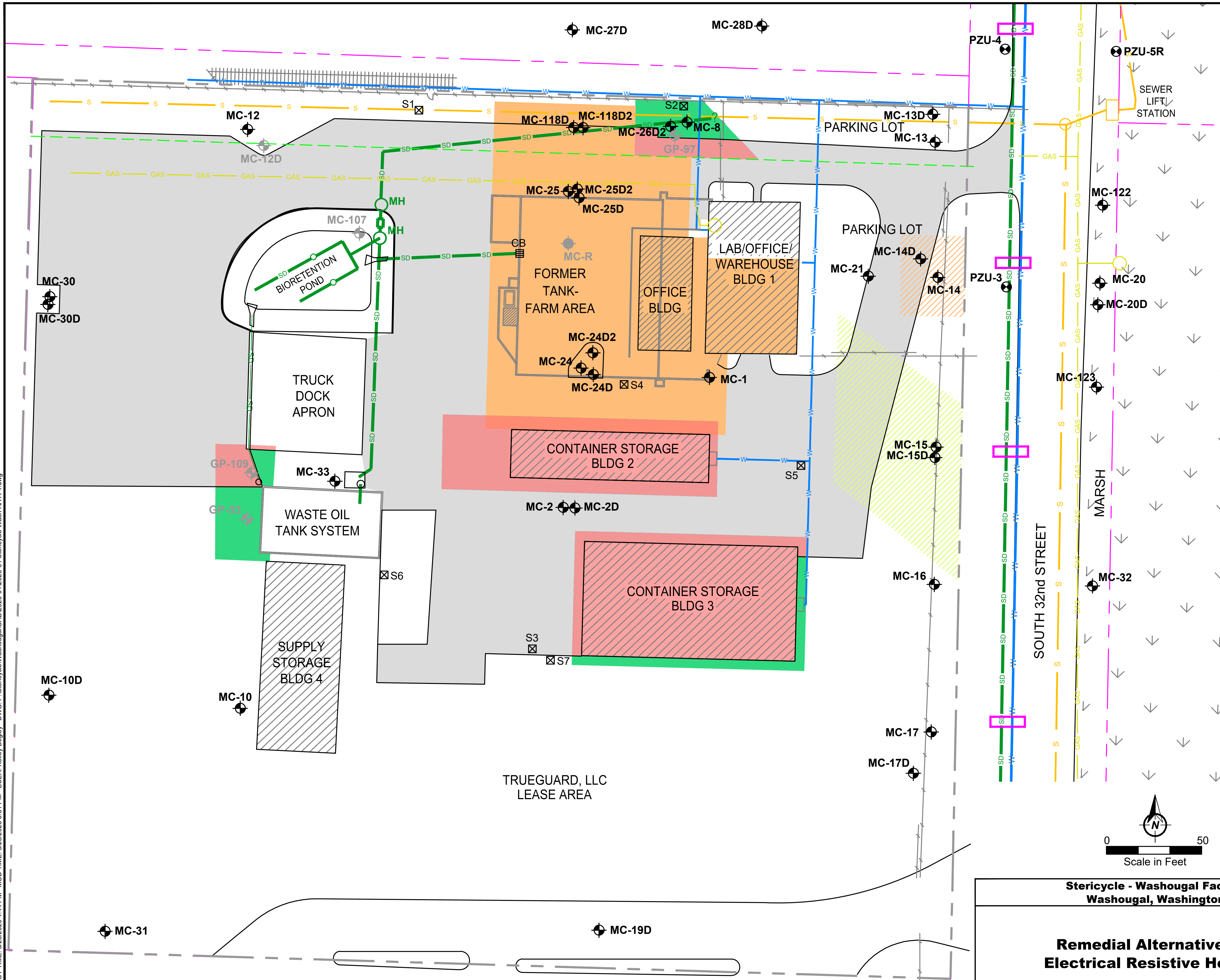


LEGEND

- Property Line
- Offsite Parcel Line
- Sanitary Sewer
- Storm Sewer
- Water
- Gas
- C/E
- MC-13 Monitoring Well
- MC-107 Monitoring Well, Abandoned
- MC-R Recovery Monitoring Well, Abandoned
- GP-109 Push Probe
- PZU-4 Piezometer
- MH Stormwater Manhole
- CB Catch Basin
- S3 Sump
- Approximate Grout Location to Address Potential Groundwater Conduit (not to scale)
- Existing Capped Area to be maintained
- New Cap Area to be paved
- Enhanced Bioremediation Area (Lower Aquifer Only)
- Electrical Resistance Heating Area (Shallow Groundwater Only)
- Electrical Resistance Heating Area (Shallow Sand Unit and Silt)

NOTE:
The effluent storm drain line was located in the field by others to a location near MC-8. The alignment is unknown beyond this location, but extends to South 32nd Street where it connects to the main line adjacent to the roadway.

Stericycle - Washougal Facility
Washougal, Washington

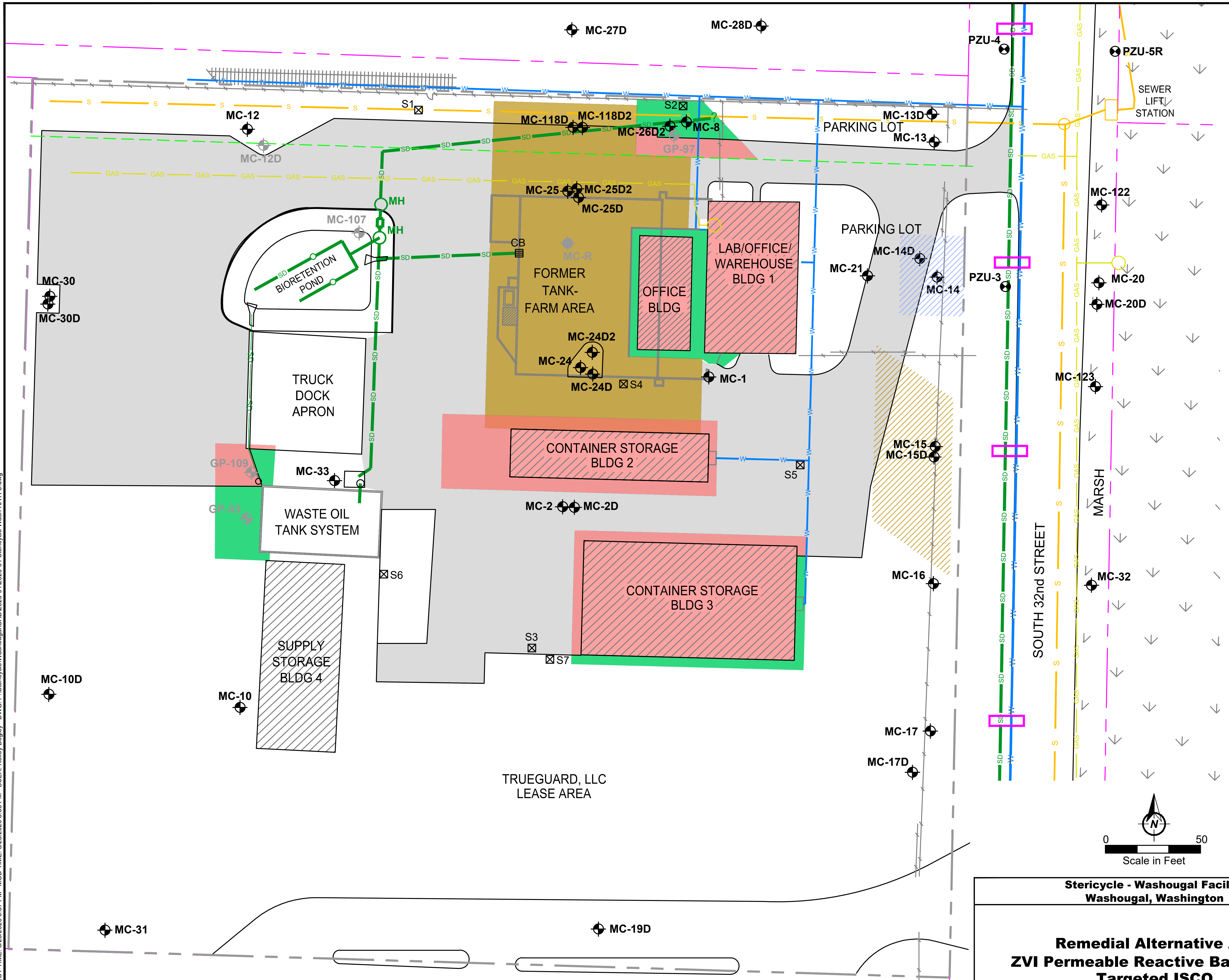
Remedial Alternative A-4
Electrical Resistive Heating

DALTON OLMSTED FUGLEVAND

FIGURE 7-4

January 08, 2020

PLOT TIME: 3/25/2020 4:44 PM MOD TIME: 3/25/2020 3:51 PM USER: Kelley Begley DWG: P:\Stericycle\Washougal\CAD\2020-01\2020-01 Stericycle Wash RA A-4.dwg



PLOT TIME: 3/25/2020 3:57 PM MOD TIME: 3/25/2020 3:56 PM USER: Kelley Begley DWG: P:\Stericycle\Washougal\CAD\2020-01\2020-01 Stericycle Wash RA A-5.dwg

LEGEND

- Property Line
- Offsite Parcel Line
- Sanitary Sewer
- Storm Sewer
- Water
- Gas
- C/E
- MC-13 Monitoring Well
- MC-107 Monitoring Well, Abandoned
- MC-R Recovery Monitoring Well, Abandoned
- GP-109 Push Probe
- PZU-4 Piezometer
- MH Stormwater Manhole
- CB Catch Basin
- S3 Sump
- Approximate Grout Location to Address Potential Groundwater Conduit (not to scale)
- Existing Capped Area to be maintained
- New Cap Area to be paved
- In-Situ Chemical Oxidation Area (Shallow Groundwater Only)
- Permeable Reactive Barrier (Silt and Lower Aquifer)
- Permeable Reactive Barrier (Lower Aquifer Only)

NOTE:
The effluent storm drain line was located in the field by others to a location near MC-8. The alignment is unknown beyond this location, but extends to South 32nd Street where it connects to the main line adjacent to the roadway.

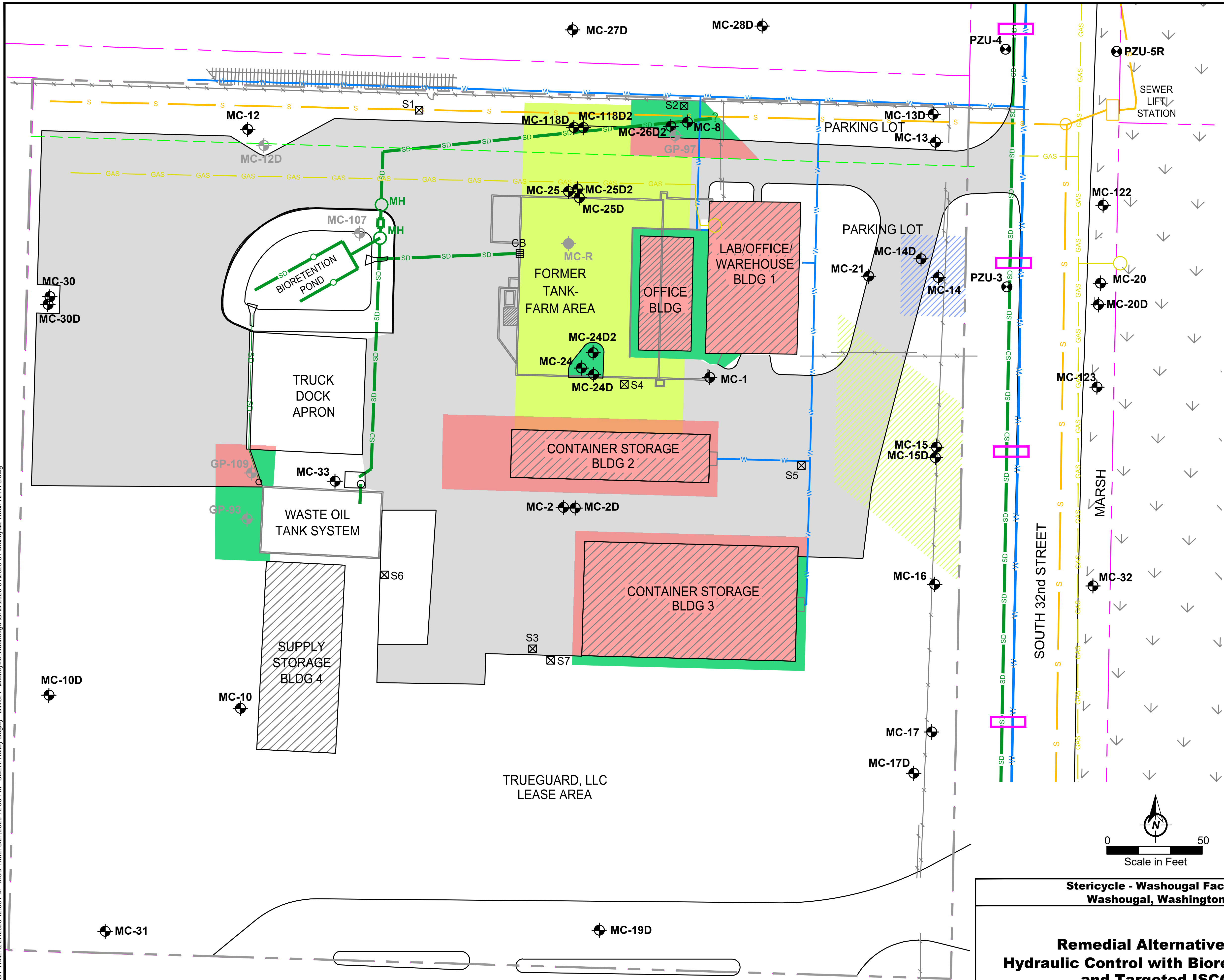
Stericycle - Washougal Facility
Washougal, Washington

Remedial Alternative A-5
ZVI Permeable Reactive Barrier and Targeted ISCO

DALTON OLMSTED FUGLEVAND

FIGURE 7-5

January 08, 2020



LEGEND

- Property Line
- Offsite Parcel Line
- Sanitary Sewer
- Storm Sewer
- Water
- Gas
- C/E
- MC-13 Monitoring Well
- MC-107 Monitoring Well, Abandoned
- MC-R Recovery Monitoring Well, Abandoned
- GP-109 Push Probe
- PZU-4 Piezometer
- MH Stormwater Manhole
- CB Catch Basin
- S3 Sump
- Approximate Grout Location to Address Potential Groundwater Conduit (not to scale)
- Existing Capped Area to be maintained
- New Cap Area to be paved
- Hydraulic Containment and Enhanced Bioremediation Area (Silt and Lower Aquifer)
- Hydraulic Containment and Enhanced Bioremediation Area (Lower Aquifer Only)
- In-Situ Chemical Oxidation Area (Shallow Groundwater Only)

NOTE:
The effluent storm drain line was located in the field by others to a location near MC-8. The alignment is unknown beyond this location, but extends to South 32nd Street where it connects to the main line adjacent to the roadway.

Stericycle - Washougal Facility
Washougal, Washington

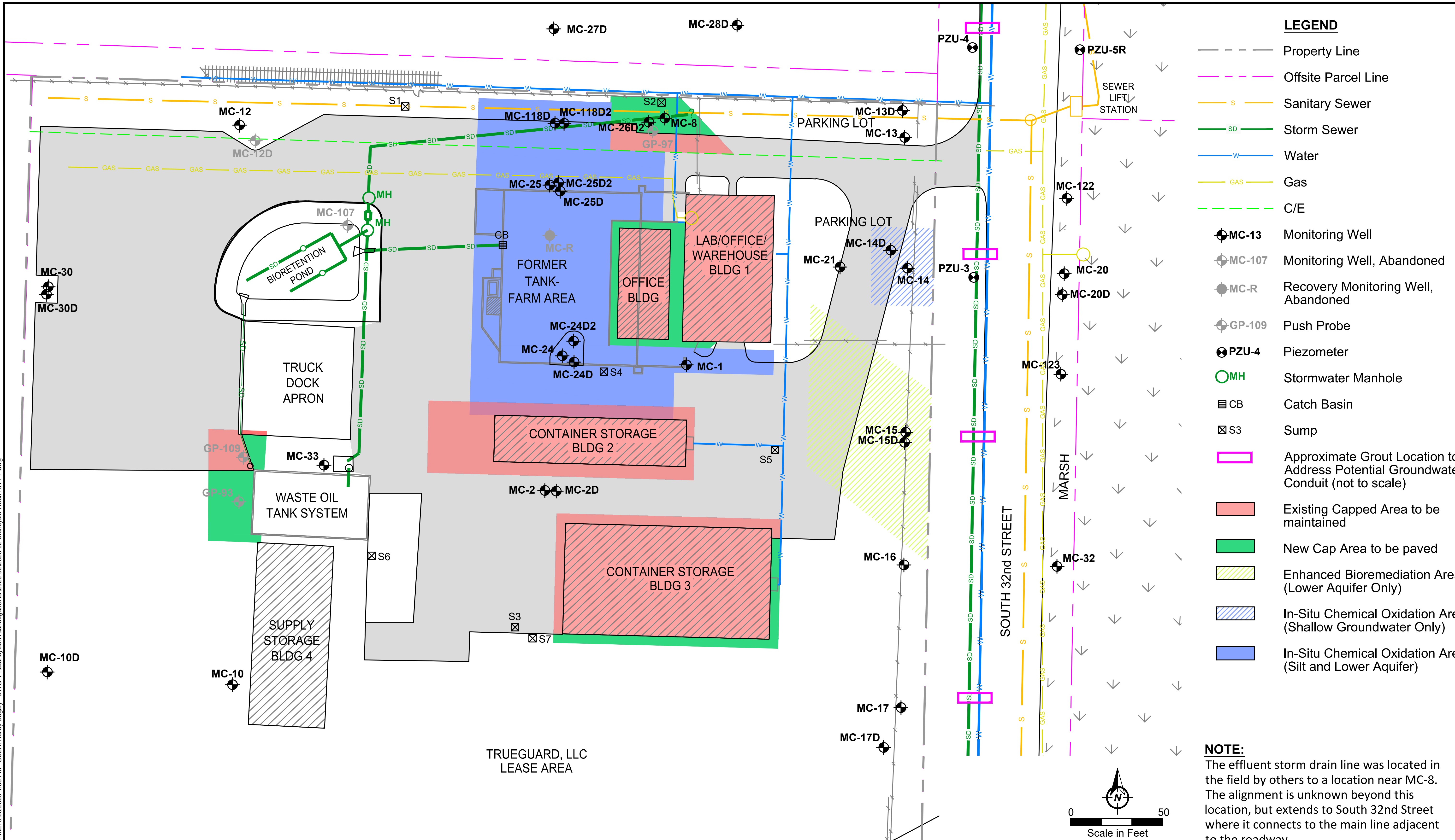
Remedial Alternative A-6
Hydraulic Control with Bioremediation and Targeted ISCO

DALTON OLMSTED FUGLEVAND

FIGURE 7-6

January 08, 2020

PLOT TIME: 3/27/2020 12:06 PM MOD TIME: 3/27/2020 12:05 PM USER: Kelley Begley DWG: P:\Stericycle\Washougal\CAD\2020-01\2020-01 Stericycle Wash RA A-6.dwg



Stericycle - Washougal Facility
Washougal, Washington

Remedial Alternative A-7
Full Scale ISCO Treatment

FIGURE 7-7

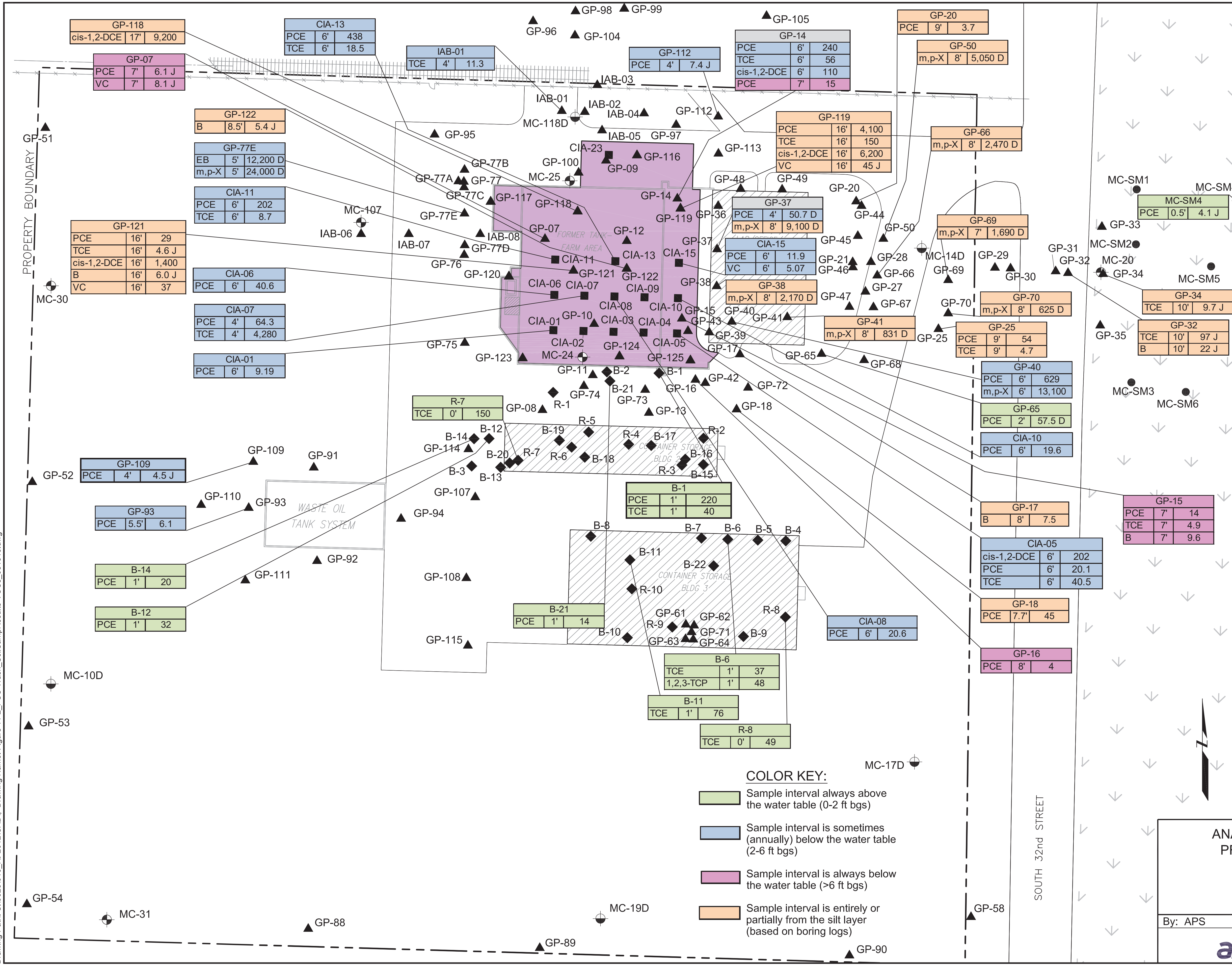
February 14, 2020

PLOT TIME: 3/25/2020 4:34 PM MOD TIME: 3/25/2020 4:33 PM USER: Kelley Begley DWG: P:\Stericycle\Washougal\CAD\2020-02\2020-02 Stericycle Wash RA 7-7.dwg

Appendix G

Relevant Remedial Investigation

Tables and Figures



EXPLANATION

- R-8 ◆ RCRA Closure Sample
- CIA-05 ■ Historic Tank Farm Excavation Soil Confirmation Sample
- GP-32 ▲ Direct-Push Sample Location
- MC-20 ⊕ Shallow Groundwater Zone Monitoring Well
- MC-118D ⊕ Lower Aquifer Monitoring Well
- MC-SM4 ● Sediment/Pore Water Sample Location
- Area of 1997 Excavation

DATABOX KEY

B	Benzene
cis-1,2-DCE	cis-1,2-Dichloroethene
EB	Ethylbenzene
m,p-X	m,p-Xylenes
PCE	Tetrachloroethene
TCE	Trichloroethene
TCP	Trichloropropane
VC	Vinyl Chloride

GP-65 — Location I.D.
PCE 2' 57.5 D
Detected Concentration above preliminary cleanup level (µg/kg)
depth (feet bgs)

Data Qualifiers

D = Value shown is result from dilution of field sample.
J = Value shown is estimated concentration.

Results shown only for analytes that were detected at concentration above the respective preliminary cleanup level.

Note:

Analytical results for soil samples collected at all depths are shown, including those samples collected below the water table that are representative of groundwater conditions.

0 25 50
APPROXIMATE SCALE IN FEET

COLOR KEY:

- Sample interval always above the water table (0-2 ft bgs)
- Sample interval is sometimes (annually) below the water table (2-6 ft bgs)
- Sample interval is always below the water table (>6 ft bgs)
- Sample interval is entirely or partially from the silt layer (based on boring logs)

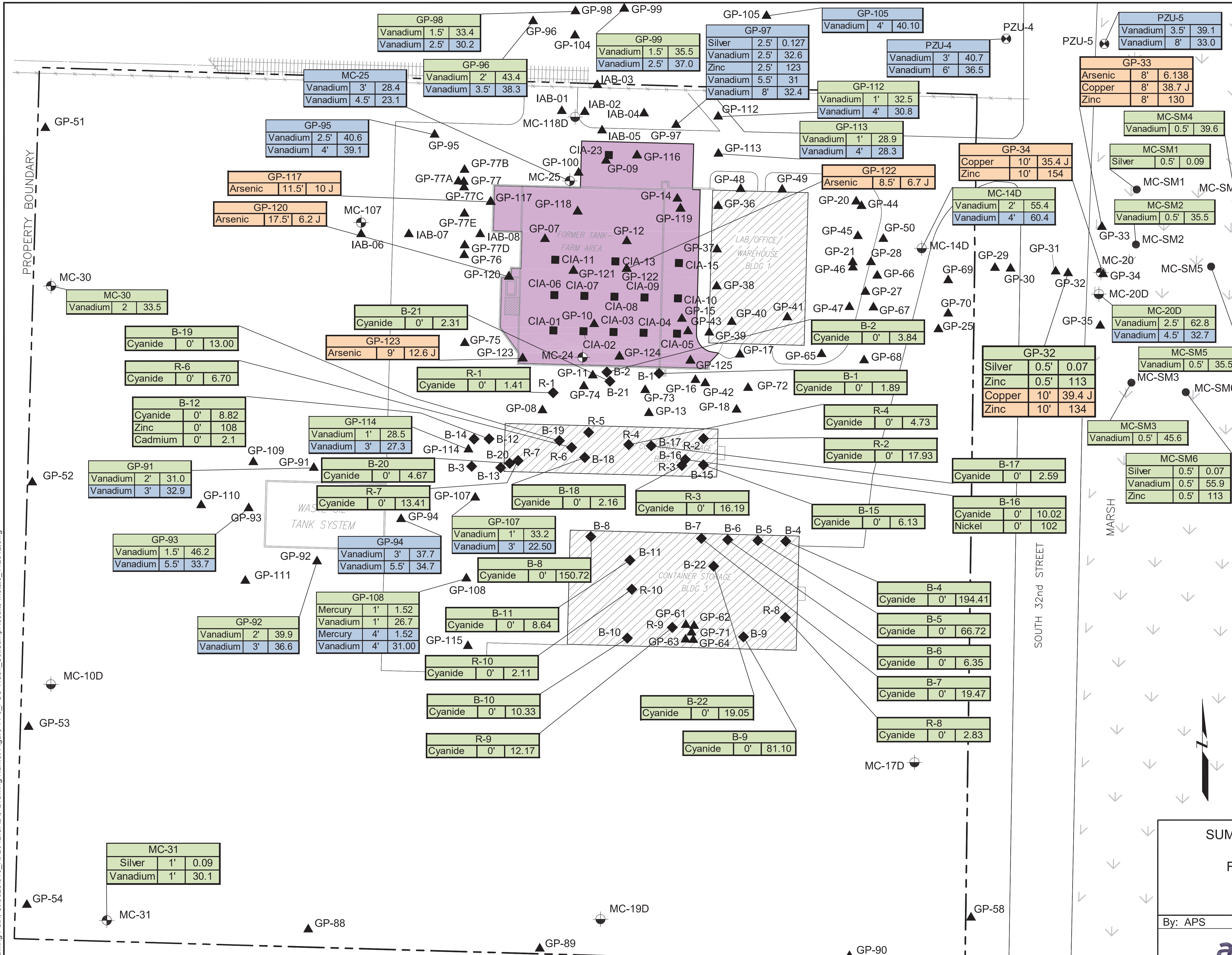
ANALYTICAL RESULTS EXCEEDING PRELIMINARY CLEANUP LEVELS FOR VOCs IN SOIL
PSC Washougal Facility
Washougal, Washington

By: APS | Date: 08/15/13 | Project No. 9625

amec

Figure 11-2

Plot Date: 08/15/13 - 9:07pm, Plotted by: adam.stenberg
Drawing Path: S:\9625\010_RI-2012\CAD\, Drawing Name: Figure 11-2_PSC-Wash_SoilSampResults-VOCs_081513.dwg



EXPLANATION

R-8 ◆	RCRA Closure Sample
CIA-05 ■	Historic Tank Farm Excavation Soil Confirmation Sample
GP-101 ▲	Direct-Push Sample Location
MC-20	Shallow Groundwater Zone Monitoring Well
MC-118D	Lower Aquifer Monitoring Well
PZU-5	Piezometer
MC-SM1 ●	Sediment/Pore Water Sample Location
	Area of 1997 Excavation

DATABOX KEY

B-1		
Cyanide	0'	1.89

Location I.D.
Detected Concentration above preliminary cleanup level (mg/kg)
depth (feet bgs)

Data Qualifiers

D= Value shown is result from dilution of field sample.
J = Value shown is estimated concentration.

Results shown only for analytes that were detected at concentration above the respective preliminary cleanup level.

Note:

Analytical results for soil samples collected at all depths are shown, including those samples collected below the water table that are representative of groundwater conditions.

COLOR KEY:

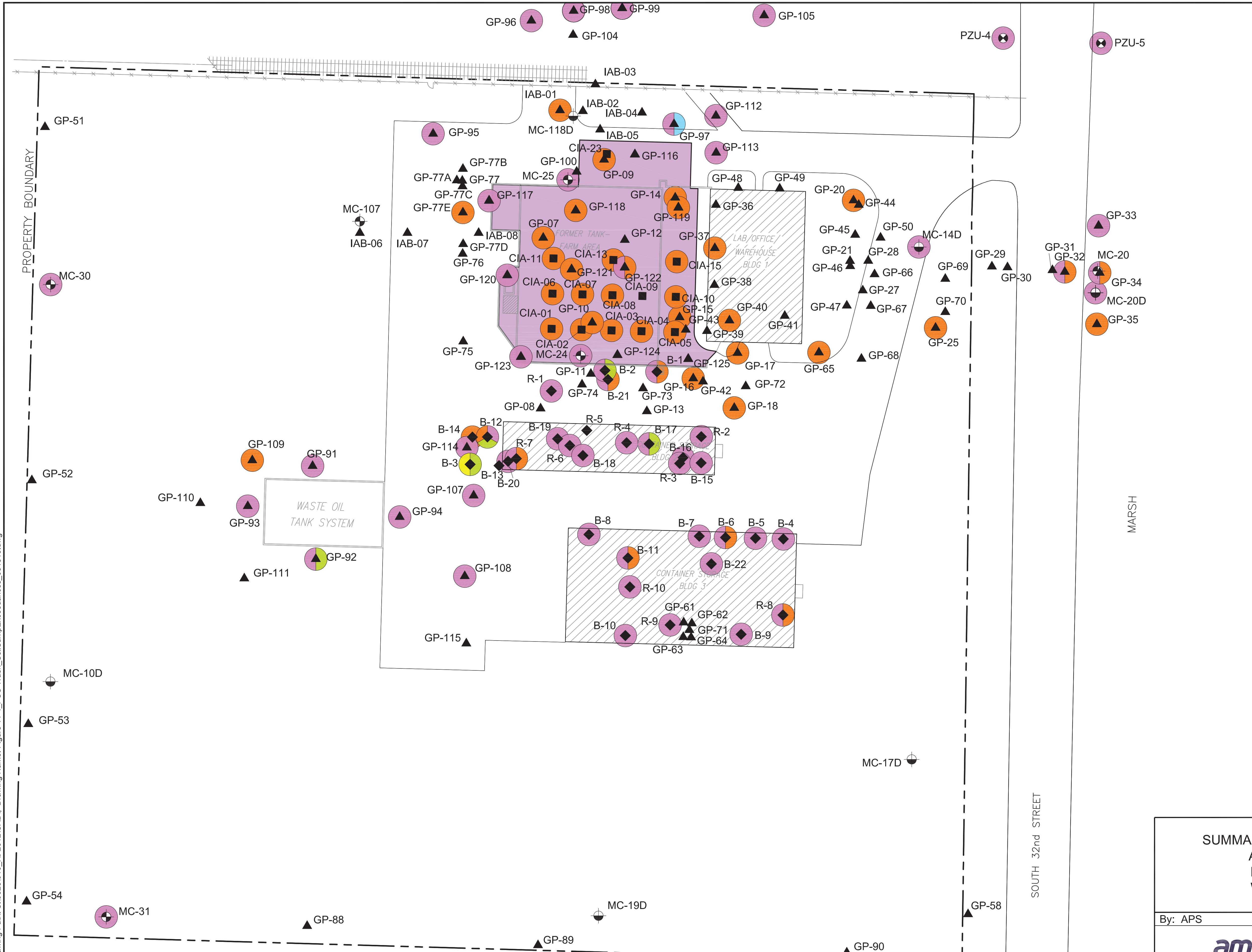
- Sample interval always above the water table (0-2 ft bgs)
- Sample interval is sometimes (annually) below the water table (2-6 ft bgs)
- Sample interval is entirely or partially from the silt layer (based on boring logs)

SUMMARY OF ANALYTICAL RESULTS
EXCEEDING PCLs
FOR INORGANIC COCs IN SOIL
PSC Washougal Facility
Washougal, Washington

By: APS | Date: 12/10/12 | Project No. 9625

amec | Figure 11-3

Plot Date: 12/10/12 - 9:30am, Plotted by: adam.stenberg
Drawing Path: S:\9625\010_RI-2012\CAD\, Drawing Name: Figure 11-3_PSC-Wash_SoilSampResults-Metals_112612.dwg



EXPLANATION

R-8 ◆ RCRA Closure Sample

CIA-05 ■ Historic Tank Farm Excavation Soil Confirmation Sample

GP-105 ▲ Direct-Push Sample Location

MC-20 Shallow Groundwater Zone Monitoring Well

MC-118D Lower Aquifer Monitoring Well

PZU-4 Piezometer

Area of 1997 Excavation

KEY

Locations where soil samples exceed preliminary cleanup levels for:

- VOCs
- Inorganics
- Pesticides
- SVOCs
- TPH

Unshaded samples did not exceed preliminary cleanup level for any analyte tested for that sample.

Note:

Results shown include results for samples collected below the water table, which are representative of groundwater conditions.

SUMMARY OF ANALYTICAL RESULTS ABOVE PCLs FOR SOIL

PSC Washougal Facility
Washougal, Washington

By: APS	Date: 08/15/13	Project No. 9625
amec		Figure 11-4

Plot Date: 08/15/13 - 9:09pm, Plotted by: adam.stenberg
Drawing Path: S:\9625\010_RI-2012\CAD\, Drawing Name: Figure 11-4_PSC-Wash_SoilSampExceedances_081513.dwg

TABLE 11-1

SOIL VOC RESULTS MTCA METHOD C CLEANUP LEVEL COMPARISON SUMMARY

PSC Washougal Facility
Washougal, Washington

Analyte	Maximum Concentration (mg/Kg)	Calculated Maximum Concentration (mg/Kg)	MTCA Method C Carcinogenic Screening Level (mg/Kg)	MTCA Method C Non Carcinogenic Screening Level (mg/Kg)
1,1,1-Trichloroethane	13	130	NE	7,000,000
1,1,2,2-Tetrachloroethane	1.7	17	656	NE
1,1,2-Trichloroethane	1.8	18	2,303	NE
1,1,2-Trichlorotrifluoroethane	0.027	0.27	NE	105,000,000
1,1-dichloroethane	0.291	2.91	NE	700,000
1,1-Dichloroethene	0.0027	0.027	NE	175,000
1,2,3-Trichlorobenzene	0.018	0.18	NE	NE
1,2,3-Trichloropropane	0.048	0.48	4	NE
1,2,4-Trichlorobenzene	0.0102	0.102	4,530	NE
1,2,4-Trimethylbenzene	63	630	NE	NE
1,2-Dibromo-3-chloropropane	0.012	0.12	164	NE
1,2-dichlorobenzene	2.88	28.8	NE	315,000
1,2-Dichloropropane	0.00487	0.0487	NE	NE
1,3,5-Trimethylbenzene	23	230	NE	35,000
1,3-dichlorobenzene	0.16	1.6	NE	NE
1,4-Dichlorobenzene	0.35	3.5	NE	NE
2-Butanone	0.04	0.4	NE	2,100,000
2-Butanone (MEK)	9.47	94.7	NE	2,100,000
2-Chlorotoluene	4.4	44	NE	70,000
2-Hexanone	8.4	84	NE	NE
2-methylpentane	1.6	16	NE	NE
3-methylpentane	1.22	12.2	NE	NE
4-Chlorotoluene	0.0714	0.714	NE	NE
4-Methyl-2-Pentanone (MIBK)	87	870	NE	280,000
Acetone	890	8900	NE	3,150,000
benzene	0.546	5.46	2,386	NE
Bromobenzene	0.0023	0.023	NE	NE
Carbon disulfide	0.106	1.06	NE	350,000
Chloroethane	6.7	67	NE	NE
Chloroform	0.0021	0.021	NE	35,000
Chloromethane	0.025	0.25	NE	NE
cis-1,2-dichloroethene	0.593	5.93	NE	7,000
Dichlorodifluoromethane	0.0202	0.202	NE	700,000
Ethylbenzene	18	180	NE	350,000
Isopropylbenzene	3.9	39	NE	350,000
m,p-Xylene	78	780	NE	700,000
methylcyclopentane	2.02	20.2	NE	NE
Methylene chloride	2.1	21	17,500	NE
naphthalene	19.8	198	NE	70,000
n-Butylbenzene	5.8	58	NE	NE
n-propylbenzene	12	120	NE	350,000

TABLE 11-1

SOIL VOC RESULTS MTCA METHOD C CLEANUP LEVEL COMPARISON SUMMARY

PSC Washougal Facility
Washougal, Washington

Analyte	Maximum Concentration (mg/Kg)	Calculated Maximum Concentration (mg/Kg)	MTCA Method C Carcinogenic Screening Level (mg/Kg)	MTCA Method C Non Carcinogenic Screening Level (mg/Kg)
o-Xylene	42	420	NE	700,000
p-Cymene	3.3	33	NE	NE
p-isopropyltoluene	2.46	24.6	NE	NE
sec-Butylbenzene	3.6	36	NE	NE
Styrene	1.4	14	NE	700,000
tert-Butylbenzene	8.1	81	NE	NE
Tetrachloroethene	74	740	NE	21,000
Toluene	21	210	NE	280,000
trans-1,2-Dichloroethene	0.0391	0.391	NE	70,000
Trichloroethene	8.4	84	NE	1,750
Vinyl Chloride	0.037	0.37	NE	10,500

Abbreviations
NE = Not Established
mg/Kg = milligrams per kilogram