Aspect
CONSULTING

August 11, 2016

Mr. Ed Jones
Washington State Department of Ecology, NWRO
3190 160th Avenue SE
Bellevue, Washington 98008-5452

Re: West of 4th Site Agreed Order #DE10402
Feasibility Study Report, West of 4th Site Unit 2

Dear Mr. Jones:

Please find enclosed the Feasibility Study Report, West of 4th Site Unit 2. This report was prepared by Pacific Groundwater Group and Farallon Consulting on behalf of the four potentially liable persons (PLPs) [Art Brass Plating, Blaser Die Casting, Capital Industries, and PSC Environmental Services, LLC] identified by Ecology in the Agreed Order #DE10402 for the West of 4th Site.

The W4 consultants would like to meet with Ecology to discuss revisions made to the report and the adaptive performance approach proposed with the recommended cleanup action. I will email shortly to coordinate a meeting time and location.

Sincerely,

Aspect consulting, LLC

Dana Cannon

Dana Cannon, LHG
W4 Project Coordinator
dcannon@aspectconsulting.com

Attachments: Feasibility Study Report, West of 4th Site Unit 2

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WEST OF FOURTH SITE UNIT 2
FEASIBILITY STUDY
SEATTLE, WASHINGTON

August 2016

WEST OF FOURTH SITE UNIT 2
FEASIBILITY STUDY
SEATTLE, WASHINGTON

Prepared for:

West of Fourth Joint Agreed Order
Art Brass Plating
Blaser Die Casting
Capital Industries
Stericycle
Seattle, Washington

Prepared by:

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August 11, 2016
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SU2FeasibilityStudy 8-11-16.docx

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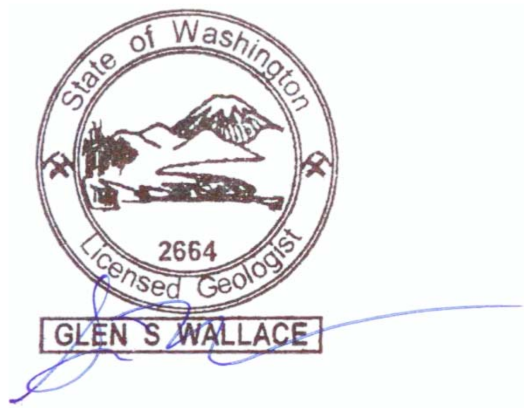
SIGNATURE

This report, and Pacific Groundwater Group and Farallon Consulting's work contributing to this report, were reviewed by the undersigned and approved for release.



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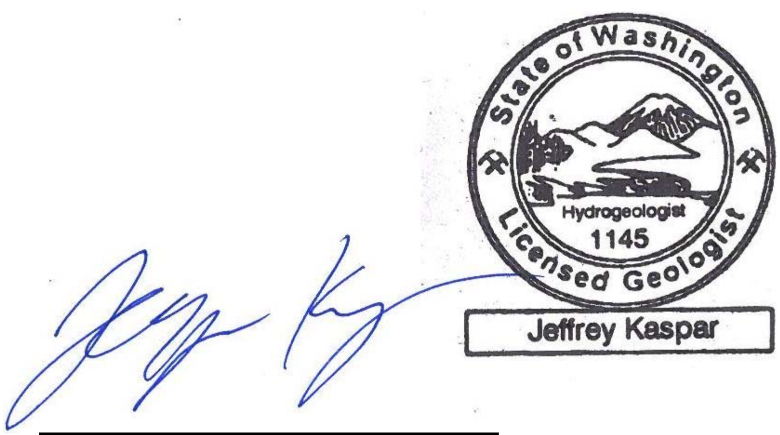

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1.0 INTRODUCTION

This Draft Feasibility Study (FS) was prepared on behalf of the potentially liable parties (PLPs) [Blaser Die Casting (BDC), Capital Industries (CI), Art Brass Plating (ABP)[1], and Burlington Environmental, LLC [1]] identified by the Washington State Department of Ecology (Ecology) in Agreed Order (AO) No. DE10402 for the West of 4th (W4) Site. The AO requires the four PLPs (the W4 Group) to complete a Feasibility Study (FS) and prepare a draft Cleanup Action Plan (dCAP) for the W4 Site. This report is the FS for Site Unit 2 within the W4 site. The environmental consultants addressing technical aspects of the FS and dCAP on behalf of the W4 Group (W4 Consultants) are: Aspect Consulting (Aspect) for ABP; Farallon Consulting (Farallon) for CI; Pacific Groundwater Group (PGG) for BDC; and Pacific Crest Environmental (Pacific Crest) for Stericycle Environmental Solutions, Inc. (Stericycle) [2].

The W4 Site is located in the Georgetown neighborhood of Seattle, between 4th Avenue South and the Duwamish Waterway (the Waterway). For the purposes of the FS, the Site has been divided into two site units, Site Unit 1 (SU1) and Site Unit 2 (SU2), as described in the AO. In this document, "site" refers to the SU2 area unless otherwise specified. This SU2 FS develops and evaluates remedial alternatives to address contaminated media at SU2 in accordance with Washington Administration Code (WAC) 173-340-350(8). These remedial alternatives are compared to Model Toxics Control Act (MTCA) threshold criteria and compared to each other through the disproportionate cost analysis (DCA) framework. The DCA analysis supports selection of a preferred alternative. Modeling in support of some technical elements of the FS are included in Appendix A. Cost basis tables in support of DCA evaluations are included in Appendix B.

The FS integrates and builds upon information developed in previous tech memos, including:

- Site Conceptual Model Technical Memorandum (Revised) (Aspect, 2014)
- Revised Preliminary Site Cleanup Standards (Farallon, 2014)
- Revised Fate and Transport Modeling Plan (PGG, 2014)
- Revised Technology Screening FS Technical Memorandum (PGG, 2015)
- Draft Fate and Transport Summary Memo for SU2 (PGG, 2015)
- Revised Vapor Intrusion Assessment, Monitoring, and Mitigation Plan (Farallon, 2015a)
- Remedial Alternatives for Site Unit 2 (Farallon, 2015)

[1] ABP is located in Site Unit 1 or the West of Fourth site.
[2] Burlington Environmental, LLC is a wholly owned subsidiary of PSC Environmental Services, LLC, which is a wholly owned subsidiary of Stericycle Environmental Solutions, Inc., hereafter referred to in this document as "Stericycle" for simplicity.

This report assumes that the reader has access to, and is familiar with, these documents[3]. The supporting technical memoranda are included in Appendix C. Appendix C also includes one additional technical memorandum:

- Beneficial Use Evaluation of Groundwater as a Drinking Water Source (PGG, 2016)

Additional investigation and groundwater monitoring has occurred following completion of the SU2 RI reports. This data collection has included:

- Groundwater monitoring at SU2 monitoring wells, with data included in quarterly progress reports and Appendix D.
- Installation of monitoring well BDC-13-40[4] (PGG, 2015), which targeted vinyl chloride in the shallow interval.
- Remedial Investigation Data Gap Resolution at Capital Industries (Farallon, 2016)

Please refer to the Data summary tables for samples collected after the respective RIs are included in Appendix D.

1.1 CONSTITUENTS OF CONCERN

As defined in the Remedial Investigation Reports for the BDC, CI, and/or Stericycle facility, the constituents of concern (COCs) for SU2 are:

- Tetrachloroethene (PCE)
- Trichloroethene (TCE)
- cis-1,2-Dichloroethene (DCE), trans-1,2-DCE, and 1,1-DCE
- Vinyl chloride
- 1,4-dioxane (groundwater only)
- Iron
- Manganese

Iron and manganese are categorized as naturally occurring and are not targeted for cleanup in the alternatives presented. The evaluation of alternatives considers how the alternatives will affect the behavior of iron and manganese in the groundwater intervals.

The presence of 1,4-dioxane in SU1 groundwater is due to migration of contaminated groundwater originating from areas east of 4th Avenue South (East of 4th Area) and is being addressed by Stericycle under AO DE 7347. 1,4-dioxane is a colorless, volatile, cyclic ether that has primarily been used as a metal inhibitor and an acid acceptor to maximize the effectiveness of 1,1,1-trichloroethane (1,1,1-TCA) as a cleaning and degreasing agent. It is miscible with water, most organic solvents, aromatic hydrocarbons, and oils

[3] These reports are available from Ecology and are also currently posted on the internet at: http://clients.aspectconsulting.com/W4/

[4] Monitoring well BDC-13-40 is co-located with direct push investigation location BDC-9. Earlier letters refer to a planned well named BDC-12-40. The well was named BDC-13-40 to prevent confusion with earlier direct push data from similar depth intervals.

and is characterized by a low affinity for sorption to soils and organic matter. It readily leaches from and through soil following its release to the environment and is highly mobile and persistent in groundwater.

Stericycle is in the process of designing a contingent remedy (Remedial Design) to reduce concentrations of 1,4-dioxane in groundwater (Amec Foster Wheeler, 2015). The highest concentrations of 1,4-dioxane in groundwater have been detected in samples collected east of 4th Avenue South and south of South Lucile Street. The technologies being evaluated as part of the Remedial Design include: in-situ chemical oxidation (ISCO) implemented by injecting of a slurry of water and chemical oxidant (PersulfOx™, a proprietary formulation of sodium persulfate and chemical activator) into groundwater; and in-situ enhanced anaerobic bioremediation (EAB) implemented by injecting a slurry of water and microorganisms and substrate into groundwater. Although the Remedial Design focuses on the area with the highest concentrations of 1,4-dioxane in the East of 4th Area, the remedial objective is to attain cleanup level for 1,4-dioxane both east and west of 4th Avenue South within the reasonable restoration timeframe established in Agreed Order DE 7347 as 2032. The evaluation of alternatives presented in the SU2 FS Report will consider the potential effects on 1,4-dioxane.

1.2 MEDIA OF CONCERN

The confirmed media of concern for SU2 are:

- Soil
- Groundwater in the water table, shallow, and intermediate Groundwater Intervals
- Air

Media of concern include media in which COCs have been detected in remedial investigation sampling above screening levels. Empirical groundwater data and fate and transport modeling results support that neither surface water nor sediment is a medium of concern for SU2. Therefore, sediment and surface water are considered media of potential future concern to allow for the possibility of a future change in site conditions.

1.3 SU2 SUB AREAS

SU2 is divided into five sub-areas including three source areas and two commingled downgradient groundwater plume areas. Source areas are locations with releases to soil and/or groundwater, which are co-located with model source areas (Appendices A and C). Downgradient areas include groundwater plume areas that are downgradient from source areas. Vinyl chloride in the shallow and intermediate Zones is co-mingled from the BDC, CI and Stericycle sources.

1.3.1 Source Areas

Identified source areas within SU2include:

- Blaser Die Casting (BDC)
- Capital Industries (CI) Plant 2

- Capital Industries (CI) Plant 4

Groundwater contamination at and east of 4th Avenue is also a contributing source of groundwater COCs within SU2.

Supplemental soil investigation work completed by CI in 2015 was required by Ecology to address data gaps regarding the nature and extent and distribution of COCs at CI Plants 2 and 4. The supplemental soil investigation results are summarized in the *Remedial Investigation Data Gap Resolution Summary Report* dated February 12, 2016 (Farallon 2016). An objective of the soil investigation work at CI Plant 4 was to assess the potential for a source of PCE and/or TCE east of CI Plant 4 at the east adjacent Pacific Food Systems property. The results of the soil investigation conducted were inconclusive. Farallon and Ecology concluded that additional soil investigation at the Pacific Food Systems property would be required to evaluate whether a source of PCE and/or TCE existed. At this time CI has elected to proceed with cleanup of soil at CI Plant 4 that contains COCs that exceed the PCULs. The technologies for soil cleanup presented in Alternatives 1 through 3 include ISCO and soil excavation, which address soil cleanup at CI Plant 4 only. Application of SVE under Alternative 4 would include a system design that would extend beneath Pacific Food Systems and remediate affected soil as well as serve as a vapor intrusion mitigation measure.

1.3.2 Downgradient Areas

- Capital Industries (CI) Plant 4 Downgradient Area
- Blaser Die Casting (BDC)/Capital Industries (CI)/Stericycle Downgradient Area

These areas are described in the remedial alternatives memo (Farallon, 2015). Implementation of remedial technologies is dependent on the characteristics of each of the sub areas. Therefore, the evaluation of alternatives will include evaluation at the level of individual sub areas in the selection of remedial alternatives (Section 1.4).

Surface water is not included as a sub area because available data indicates that groundwater discharging to surface water does not exceed screening levels within SU2.[5]

1.4 EVALUATION FRAMEWORK

Remedial alternatives are evaluated based on the MTCA criteria for selection of cleanup actions described in WAC 173-340-360. Under these criteria a cleanup must meet minimum threshold requirements, beyond which alternatives are selected based on a disproportionate cost analysis (DCA).

Threshold requirements state that a cleanup action shall:

- Protect human health and the environment;

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- Comply with cleanup standards
- Comply with applicable state and federal laws
- Provide for compliance monitoring

The purpose of the DCA is to determine whether a cleanup action uses permanent solutions to the maximum extent practicable. Within the DCA, the FS alternatives are ranked from most to least permanent. The most permanent practicable alternative becomes the baseline cleanup action alternative and the alternative against which the other alternatives are compared. Additional costs are disproportionate to benefits if the incremental costs of one alternative over that of a lower cost alternative exceed the incremental degree of benefits achieved by the alternative over that of the other lower cost alternative.

In practice, there are several ways to conduct a DCA consistent with MTCA. For this DCA, the benefits of each alternative are assigned a score on a scale of 1 to 10 with a commonly-applied weighting factor to calculate an overall benefit score (Table 3). The estimated cost for each alternative is divided by 100,000 and divided by the benefit score to calculate a cost-benefit ratio. The preferred alternative is the remedial alternative with the lowest cost-benefit ratio[6].

2.0 REMEDIAL ACTION OBJECTIVES

General remedial action objectives (RAOs) for the W4 area include reducing concentrations of COCs to acceptable levels. Acceptable levels are the preliminary cleanup levels (PCULs) for each media, as defined in either the Revised Preliminary Site Cleanup Standards Technical Memorandum or in an interim mitigation measure plan to reduce exposure to levels protective of receptors (Farallon, 2014a). Acceptable levels of risk are the risks and/or hazard quotients corresponding to these preliminary media cleanup levels.

General Site-wide RAOs for the W4 area were provided in the *Revised Technology Screening Memo* (PGG, 2015b), including reducing concentrations of COCs to acceptable levels. Acceptable levels are the PCULs for each media, as defined in either the *Revised Preliminary Site Cleanup Standards Technical Memorandum* or in an interim mitigation measure plan to reduce exposure to levels protective of receptors (Farallon, 2014). Acceptable levels of risk are the risks and/or hazard quotients corresponding to these PCULs. General Site-wide RAOs include:

- **RAO 1:** Reduce soil COC concentrations posing a potentially unacceptable direct contact health risk to acceptable levels. Or, if this is not practicable, reduce risks associated with contacting surface or subsurface soils to acceptable levels through the use of institutional controls or engineered barriers.
- **RAO 1A:** Reduce soil COC concentrations posing a potentially unacceptable health risk via dust inhalation to acceptable levels. Or, if this is not practicable, reduce risks

[6] Ecology site managers may prefer to use a more qualitative or other approach consistent with MTCA in their evaluation of alternatives.

associated with inhaling contaminated dust to acceptable levels through the use of institutional controls or engineered barriers.

- **RAO 2:** Reduce soil and shallow groundwater HVOC concentrations posing a potentially unacceptable vapor intrusion health risk to acceptable levels. Or, if this is not practicable, reduce risks associated with inhaling contaminated indoor air to acceptable levels through the use of institutional controls or engineered controls.
- **RAO 3:** Within a reasonable timeframe, reduce soil and groundwater COC concentrations posing a potentially unacceptable health risk to human and ecological surface water receptors to acceptable levels. Or, if this is not practicable, reduce the health risks associated with COC exposure to acceptable levels through the use of institutional controls or engineered barriers.
- RAO 4: Reduce COC concentrations in groundwater discharging to surface water to acceptable levels.

RAOs in SU2 include addressing impacted soil, groundwater, and air. The following sections present the RAOs for each medium of concern.

2.1 SOIL

RAOs for soil in SU2 are:

- Groundwater Protection Pathway: Meeting the preliminary cleanup levels (PCULs) for groundwater protection, or immobilizing/containing soil to achieve the same degree of groundwater protection throughout the Site (Table 1).
- Air Pathway: Reducing VOC concentrations in soil to meet MTCA Method B cleanup levels protective of indoor and outdoor air quality, or using engineering controls to protect receptors.

2.2 GROUNDWATER

RAOs for groundwater in SU2 include:

- Reducing COC concentrations to achieve applicable Method B surface water criteria, vapor intrusion criteria, or the natural background[7] at the point of compliance within a reasonable restoration time frame if practicable;
- Protecting Lower Duwamish Waterway receptors by ensuring that groundwater discharging to the Waterway does not contain COCs at concentrations exceeding Method B surface water criteria at the point of compliance;
- Reducing COC concentrations in the water table Groundwater Interval to meet Method B vapor intrusion-based groundwater PCULs at and down-gradient of the BDC and CI facilities; and
- Applying engineered barriers and non-engineered institutional controls to protect receptors until vapor intrusion-based Method B PCULs are attained.

[7] Background metals concentrations in groundwater have not been established for SU2.

2.3 AIR

Soil and groundwater concentrations in SU2 exceed PCULs protective of air. The RAO for air is reducing COCs in soil and groundwater to concentrations less than PCULs protective of air quality.

2.4 ARAR EVALUATION

WAC 173-340-710 lists general requirements for complying with applicable local, state, and federal laws (Applicable or Relevant and Appropriate Requirements [ARARs]) applicable to cleanup actions under MTCA. ARARs applicable to cleanup actions often include various construction-related permits, air emission requirements, water discharge requirements, offsite-disposal requirements including both solid waste and highway department transport regulations, and other issues related to impacts in and around the site. For cleanup actions conducted under Agreed Order or Consent Decree, certain permit requirements may be waived while maintaining the requirement to meet the standards in the applicable ARARs (WAC 173-340-710(9)).

The MTCA Cleanup Regulation (Chapter 173-340 WAC) authorizes Ecology to adopt cleanup standards for groundwater, soil, surface water, and air at sites where hazardous substances are present, and establishes processes for identifying, investigating, and cleaning up these sites.

Other potentially applicable regulatory requirements for SU2 cleanup actions include:

- The federal Clean Water Act (33 United States Code [USC] Section 1251);
- The Washington Water Pollution Control Act (Chapter 90.48 RCW; Chapter 173 201A WAC; Chapter 173-200 WAC);
- Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and All Appropriate Inquiries (AAI) (40 Code of Federal Regulations [CFR] Part 312);
- The Resource Conservation and Recovery Act (RCRA);
- Sediment Management Standards (Chapter 173-204 WAC);
- Washington Hazardous Waste Management Act (Chapter 70.105 RCW; Chapter 173 303 WAC);
- Federal and state Clean Air Acts (42 USC 7401 et seq.; 40 CFR 50; RCW 70.94; WAC 173-400, 403);
- The State Environmental Policy Act (SEPA) (RCW 43.21C; WAC 197-11);
- The Occupational Safety and Health Act (OSHA) (Part 1910 of Title 29 of the Code of Federal Regulations [29 CFR 1910]);
- General Occupational Health Standards (Chapter 296-62 WAC);
- Safety Standards for Construction Work (Chapter 296-155 WAC);

- Minimum Standards for Construction and Maintenance of Wells (Chapter 173-160 WAC);
- Underground Injection Control Program (Chapter 173-218 WAC); and
- Permits from local municipalities as required for activities at the Site. Examples include King County and City of Seattle permits for sewer discharges, and City of Seattle grading permits, street-use permits, or shoreline permits.

ARARs typically applicable to particular remediation technologies were identified in the Revised Technology Screening Memo (PGG, 2015b). Many ARARs are commonly addressed through standard industry practices. For instance, construction of monitoring or remediation wells will be conducted by a Washington State licensed driller, and construction work is conducted under site-specific health and safety plans in compliance with applicable safety regulations.

Once a preferred cleanup action is selected and approved by Ecology for the Site, a State Environmental Policy Act (SEPA) checklist will be completed and Ecology will make a SEPA threshold determination. This typically occurs prior to soliciting public comment on the draft Cleanup Action Plan (CAP). The public is then asked to comment on both the proposed CAP and the threshold determination.

2.5 POINTS OF COMPLIANCE

This section describes preliminary points of compliance (POC) for the site as they relate to RAOs. Conditional points of compliance (CPOC) are not established in an FS, and are not included in the descriptions of remedial alternatives because they do not influence the selection of a preferred remedy. At this time, the need for CPOCs is not foreseen for a preferred remedy to be protective. If CPOCs are incorporated into the selected remedy, they will be formally established in the CAP.

2.5.1 Soil

For the purpose of evaluating the remedial alternatives herein, the POC for soil will be the standard POC. Cleanup actions may also be considered to meet cleanup objectives if they satisfy the requirements of WAC 173-340-740(6)(f).

2.5.2 Groundwater

For the purpose of evaluating the remedial alternatives herein, the POC for groundwater will be the standard POC (WAC 173-340-720[8]). The groundwater POC for indoor air protection is limited to the water table interval.

2.5.3 Air

For the purpose of evaluating the remedial alternatives herein, the POC for air includes indoor and outdoor ambient air throughout the site (WAC 173-340-750).

3.0 SCREENING OF REMEDIAL TECHNOLOGIES

Remedial technologies and preliminary alternatives were reviewed in previous technical memos (Farallon, 2015; PGG, 2015). This FS uses the previous screening as the basis for development of remedial alternatives in Section 5.

4.0 INTERIM AND MITIGATION MEASURES

Several interim remedial actions have been completed or are underway in source areas contributing to groundwater contamination in the W4 SU2 area. These remedial actions include:

- Interim excavation action in the BDC Source Area (PGG, 2009)
- Excavation in Capital Industries Plant 2 following 2004 fire (Farallon, 2012)
- Installation of sub-slab depressurization (SSD) systems in multiple structures throughout the W4 site including both SU1 and SU2 (Farallon, 2015)
- Hydraulic Control Interim Measure – Stericycle implements a hydraulic control interim measure (HCIM) at their facility located east of 4th Avenue.

Art Brass Plating has also installed and operated an AS/SVE system at their facility location that is a source area in SU1 (Aspect, 2016). Mass removal in this treatment area may reduce groundwater concentrations downgradient and near the SU1-SU2 boundary in the future and is part of the larger W4 site.

5.0 DESCRIPTION OF REMEDIAL ALTERNATIVES

This section provides details on the implementation, development of planning-level cost estimates, and quantitative comparison to remedial action objectives for specific remedial alternatives. The description of remedial alternatives will discuss how remedial alternatives could be applied within each SU2 subarea. Remedial layouts are shown in Figure 3a through 3d with additional location specific details shown in Figure 4.

Remedial alternatives are developed with planning level cost estimates based on typical or expected costs per cubic yard for implementation of remedial technologies. These costs and assumptions are detailed in Appendix B. Each cost element includes a 25% contingency to capture uncertainty in cost estimates. Specific cost estimates have not been obtained from vendors for implementation of remedial alternative elements, as those details will be refined during development of the Cleanup Action Plan and Engineering Design Report. The level of detail presented here is intended to be appropriate for internally-consistent comparison and ranking of remedial alternatives.

Appendix A includes additional calculations and modeling used to support evaluation of alternatives, based on the *Draft Site Unit 2 Fate and Transport Memorandum* (PGG 2015). The calculations in Appendix A are used to:

- Estimate remediation levels applicable at specific source areas that are protective of surface water criteria at the point of discharge to the Duwamish River (Table 1). Re-

mediation levels are greater than PCULs and trigger remedial actions to achieve protective of surface water receptors if exceeded.
- Estimate the time required to achieve groundwater PCULs at source areas and along modeled groundwater flow paths.

The BIOCHLOR modeling approach and analytical calculations necessarily involve simplifying assumptions about the geochemistry and fate and transport of contaminants. While the selected input parameters are intended to be conservative (biased toward slower achievement of PCULs, for example), the calculations should be considered approximate. In some cases, time estimates may be adjusted based on professional judgment to account for conditions that cannot be incorporated into the modeling and calculations. Adjustments are clearly discussed in the restoration time frame section for each alternative and in Section 6.2.3.

All alternatives would include evaluation of underground utilities and infrastructure during the design process. The design process would consider both potential adverse interactions such as physical short-circuiting of remedial actions, damaging or dangerous chemical reactions, or physical blockage, and would consider possible effects of utilities and buried infrastructure on contaminant fate and transport, which may influence final dosing or layout design.

5.1.1 Groundwater Monitoring Assumptions

Post-CAP groundwater monitoring will be guided by a West of 4th Compliance Monitoring Plan (CMP), and all remedial alternatives are assumed to include groundwater monitoring. Groundwater monitoring is divided into:

- **Performance Monitoring**: groundwater monitoring at the full selected network to track remedial progress in targeted areas, at sentinel locations, and compliance monitoring wells.
- **Compliance Monitoring**: groundwater monitoring at specific wells that target either sensitive receptors or key centerline plume concentration locations.

Groundwater monitoring is assumed to be more frequent early in the remedial actions, with decreasing frequency over time. Groundwater monitoring frequency is assumed to decrease over time for all alternatives as concentrations decrease and the understanding of plume stability improves. Groundwater monitoring assumptions include:

- Compliance groundwater monitoring will be conducted at least annually
- There will be 15 compliance wells and 35 performance wells, with compliance wells a subset of the performance wells.
- Performance monitoring is reduced to biennial monitoring after year 10 or 15 of the monitoring program, depending on the alternative.
- Performance monitoring is either quarterly or semi-annual over the first decade of monitoring.
- Groundwater monitoring concludes with one year of quarterly performance monitoring.

The groundwater monitoring assumptions do not include changes in the number of wells over time. As the groundwater plume contracts and areas within SU2 meet PCULs, individual wells may meet criteria to discontinue monitoring. Those criteria will be described in the CMP. Therefore, the number of wells may also decrease over time with Ecology approval.

5.1.2 Vapor Intrusion

Vapor intrusion is a potential issue in downgradient structures. Vapor intrusion is addressed through continued mitigation of buildings with potential VI issues until the selected remedial action reduces water table groundwater concentrations to acceptable levels to meet vapor intrusion related RAOs. This approach assumes that building owners allow mitigation in their structures and that the mitigation measures are operated continuously to maintain protection of human health. Additional information, including maps showing buildings with mitigation systems, is included in Appendix C (Farallon, 2015a).

5.2 ALTERNATIVE 1

Alternative 1 focuses on natural attenuation of COCs in groundwater with targeted soil remediation by in-situ chemical oxidation (ISCO) in selected source area hot spots (Table 2). Alternative 1 has been revised from the Ecology Review Draft W4 SU2 Feasibility Study (PGG, 2016) to include groundwater treatment within the Capital Industries Plant 4 area and more specific contingency options, as discussed in Section 7.

RAOs would be met for groundwater by the permanent destruction of groundwater HVOCs through natural attenuation, and combined engineered and institutional controls where contaminated soil is inaccessible. Vapor intrusion RAOs would be met through interim mitigation measures and eventually through reduction in soil and groundwater contaminant mass and controls. Existing interim vapor intrusion assessment, monitoring, and mitigation measures presented in the Revised Vapor Intrusion Assessment, Monitoring, and Mitigation Plan (Farallon 2015a) will remain in force through completion of the CAP. Final vapor intrusion assessment, monitoring, and mitigation measures will be integrated will be integrated as a part of the selected alternative, and are included in cost estimates.

The alternative includes an assumed 60 years of groundwater monitoring with 2 years of semi-annual monitoring, followed by 10 years of annual monitoring, and then biennial monitoring. The monitoring program would be completed with quarterly compliance monitoring for 1 year to demonstrate compliance with PCULs. A detailed schedule is included in Appendix B.

5.2.1 Blaser Die Casting

The interim action conducted in 2008 has reduced groundwater water table source area HVOC concentrations by more than 95%. Groundwater concentrations in water table interval wells at the source area (BDC-3-WT and BDC-2-WT) are continuing to decline at rates higher than the site-wide average (Appendix A). The higher source decay rates (SDR) in these water table interval wells likely reflect both relatively low concentrations entering the source area from upgradient and the removal of sorbed source mass that would consume more of the assimilative capacity of the groundwater influx. Due to the lack of a commingled water table interval TCE plume at this location, source decay rates for TCE are expected to remain higher than the site wide average. Downgradient water table interval monitoring wells north of Mead Street have SDRs similar to the site-wide average, consistent with a mid-plume position. SDRs are unlikely to significantly increase at these wells absent a plume cutoff and increased assimilative capacity in this area. Monitoring will provide date regarding the continued effects of the interim action in the water table interval and continued degradation of COCs through natural attenuation mechanisms in the water table, shallow, and intermediate intervals. Groundwater RAOs will be met through reductions in COCs concentrations in groundwater.

Soil RAOs were largely met through the interim removal action (PGG 2009). Remaining impacted soil that was inaccessible during the interim action will be addressed through implementation of institutional controls and maintenance of hard impermeable surfaces over the remaining soil area. Remaining impacted soil is currently underneath a concrete slab and asphalt paving. These surfaces will serve as engineered controls to meet the direct contact criteria for soil RAOs. A restrictive covenant is expected for the Blaser property to be protective of utility workers who may encounter contaminated groundwater and associated vapor intrusion issues[8].

Implementation of monitored natural attenuation in the BDC source area will include groundwater monitoring to confirm the decline of groundwater concentrations PCULs. BIOCHLOR modeling of groundwater concentrations indicates that PCULs will be achieved through natural attenuation in wells located between BDC and Mead Street in (Appendix A; Table 4):

- the water table interval in approximately 23 years; (16 to 22 years based on analytical solutions);
- the shallow interval in 51 years; (86 to 432 years based on analytical solutions); and
- the intermediate interval in 48 years; (18 to 739 years based on analytical solutions).

The variability in expected remediation times reflects a combination of total concentration, and observed decay rates at those locations.

5.2.2 Capital Industries Plant 2

Soil sampling was conducted during the CI Remedial Investigation (Farallon, 2012) and supplemental Remedial Investigation Data Gap work (Farallon, 2016) in areas of CI Plant 2 where historical information indicated the potential for sources of COCs or utilities that could convey COCs beneath the Plant existed (Figure 4A)(Appendix D). The results of the soil sampling indicated that concentrations of COCs are less than all PCULs and no further remedial actions are necessary for soil cleanup. Soil beneath CI Plant 2 was excavated for the foundation and utility trenches for reconstruction of CI Plant 2 in 2004 following the destruction of the building by a fire. The fire, soil excavation, and recon-

[8] Regardless of the selected remedy, a restrictive covenant is expected to be filed within the schedule in the consent decree or order for implementation of the selected remedy. Due to decreasing water table concentrations, it is possible that a restrictive covenant will not be necessary at that time if empirical data indicate that the receptor pathway is not complete.

struction activities appear to have remediated soil with the potential for impacting groundwater. Residual concentrations of COCs in soil, if present, are expected to attenuate with time.

The COC that exceeds PCULs in the water table interval is TCE. COC concentration trends in groundwater monitoring wells screened within the water table interval, including MW-2, MW-4, and CI-137-WT (Figure 2) have been decreasing or stable since BDC completed an interim action in 2008. The 2008 interim action removed the majority of the water table interval source mass feeding groundwater impacts that migrated from BDC downgradient beneath CI Plant 2 and commingling with impacted groundwater beneath CI Plant 2 associated with the former CI Plant 2 source(s).

COC concentrations in groundwater within the shallow and intermediate intervals that exceed PCULs include vinyl chloride. Historical groundwater sampling results indicate that vinyl chloride concentrations have been decreasing. Evaluations of natural attenuation potential have included BIOCHLOR modeling and collecting geochemical parameters during semiannual groundwater sampling events. Both the modeling and groundwater sampling data confirm that natural attenuation is occurring in all groundwater intervals, including a biodegradation component that is supported by the presence of ethene concentrations in groundwater. Modeling of groundwater concentrations (Appendix A) indicates that PCULs will be achieved through natural attenuation in wells located at CI Plant 2 in (Table 4):

- the water table interval in approximately 20 years; (22 to 26 years based on analytical solutions);
- the shallow interval in 27 years; (34 to 40 years based on analytical solutions); and
- the intermediate interval in 40 to 85 years; (9 to 99 years based on analytical solutions) (Appendix A)

Limitations associated with the BIOCHLOR model resulted in a remediation timeframe for the intermediate interval that is likely bias high. The analytical solution timeframe of approximately 40 years is considered more reasonable based on historical groundwater monitoring results.

Historical vapor intrusion air sampling data has indicated that residual COCs in soil and in groundwater within the water table interval are not a risk to indoor air quality under current site use. Active remediation of soil and groundwater is therefore unnecessary for protection of air quality at CI Plant 2. Vapor intrusion monitoring and mitigation measures are currently being performed at the Olympic Medical Building located downgradient of the commingled water table interval plumes where concentrations of TCE persist at concentrations exceeding the PCUL for protection of air quality. These measures will continue until groundwater PCULs protective of air quality are achieved and air sampling data confirm that vapor intrusion monitoring and mitigation measures are no longer required.

Monitored natural attenuation is a technically feasible remedial alternative for groundwater in all three groundwater intervals. Implementation of monitored natural attenuation at CI Plant 2 would include groundwater monitoring to confirm the decline of COC concentrations in groundwater to PCULs.

Institutional and engineering controls to mitigate direct contact with groundwater and potential exposure to vapors from groundwater will also be implemented at and downgradient of CI Plant 2 and would remain until PCULs are achieved. These controls include but are not limited to: maintaining the CI building and other hard surfaces at the CI property to mitigate vapor intrusion and contact with groundwater; placing an environmental covenant on the CI property; notifying utility providers of the presence of contaminated media locations and depths; and notifying landowners within the contaminated water table interval plume area. Notification procedures will be presented to and approved by Ecology.

5.2.3 Capital Industries Plant 4

Soil sampling was conducted during the CI Remedial Investigation (Farallon, 2012) and supplemental Remedial Investigation Data Gap work (Farallon, 2016) in areas of CI Plant 4 where historical information indicated the potential for sources of COCs or utilities that could convey COCs beneath the Plant existed. The results of the soil sampling indicated that concentrations of PCE and TCE exceeding PCULs for protection of air and/or groundwater protective of surface water exist between approximately 1 and 6 feet bgs. Results of historical groundwater sampling and vapor intrusion investigation work at CI Plant 4 and the east adjacent Pacific Food Systems buildings have indicated the potential for an additional source of PCE and/or TCE to exist east of CI Plant 4 that is contributing to groundwater contamination and air quality impacts at the Pacific Food Systems Buildings (Farallon 2015c, 2016). However, the soil investigation work completed to evaluate the nature and extent of COCs at CI Plant 4 (Farallon 2016) were inconclusive regarding whether a contributing source of PCE and/or TCE east of CI Plant 4 exists. Soil sampling has not been conducted at the Pacific Food Systems property to evaluate whether a source of PCE and TCE exists and is not planned at this time. Currently a vapor intrusion subslab depressurization system is operating at the Pacific Food Systems North Building to mitigate COCs in soil and groundwater from affecting air quality. Remedial alternatives herein focus on cleanup of soil and groundwater impacts confirmed and associated with CI Plant 4.

CI Plant 4 includes active paint booths that occupy the majority of the plant (Figure 4a). Plant 4 is a highly active and integral part of the CI business. Injection of a chemical oxidant would involve injection of a liquid chemical oxidant such as permanganate via direct-push drilling into affected soil. Soil consists of approximately 1 foot of silty sand underlain by silt to depths ranging from approximately 6 to 7.5 feet bgs, underlain by sand with silt to approximately 10 feet bgs. A pilot and/or bench-scale testing would be performed to determine the details for applying the ISCO technology including dosage and injection radius.

Application of chemical oxidant would target locations within the area depicted on Figure 4A where soil sampling results indicate PCE and/or TCE exceed the PCULs. The target injection depth for affected soil is estimated to be up to 6 feet bgs. However, application of ISCO also has the potential to treat groundwater at this source area. The injection depth is proposed to extend to a depth of 25 feet bgs to reduce COCs in the water table interval. The effectiveness of the technology would be assessed by drilling direct-push borings following sufficient time to allow the chemical oxidant to react and analyzing soil samples for COCs to evaluate whether the RAOs have been achieved.

Injection of a chemical oxidant at CI Plant 4 will target known areas of soil and groundwater contamination beneath CI Plant 4 only. Vapor intrusion monitoring at the Pacific Food Systems property will continue and will include periodic subslab and soil gas sampling to evaluate whether the cleanup action at CI Plant 4 has had an effect on soil gas concentrations at the North and South Buildings, and if the data supports a source at Pacific Foods.

COC concentration trends in groundwater monitoring wells screened within the water table interval, including MW-6 and MW-7 are fluctuating with an overall decreasing trend (Appendix A) based on molar mass estimates. COCs that exceed the current PCULs for groundwater in the water table interval include TCE. BIOCHLOR modeling results indicate that the relatively low concentrations of TCE and other COCs with the water table interval do not represent a potential risk to surface water at the Lower Duwamish Waterway. Vapor intrusion investigation work at buildings downgradient of the CI Plant 4 plume have indicated that COCs in groundwater are not resulting in a vapor intrusion condition requiring mitigation measures. The ISCO injections within the water table interval will decrease the timeframe for cleanup of groundwater at and downgradient of CI Plant 4 that are described below.

COCs that exceed the current PCULs for groundwater in the shallow groundwater interval include vinyl chloride, which has been detected at a maximum concentration of 1.7 µg/l within the past two years, slightly exceeding the PCUL of 1.6 µg/l. COCs in the intermediate groundwater interval are all less than the PCULs. The low concentrations of vinyl chloride are associated with upgradient source(s) commingled with the CI Plant 4 source. ISCO injections within the shallow groundwater interval will not be conducted due to low concentrations of vinyl chloride present and because without treating the upgradient source, recontamination would occur following depletion of the chemical oxidant.

Evaluation of natural attenuation potential has included BIOCHLOR modeling and collecting geochemical parameters during semiannual groundwater sampling events. Both the modeling and groundwater sampling data confirm that natural attenuation is occurring. The water table interval is the least conducive to natural attenuation via biodegradation based on groundwater geochemistry and historical COC concentration trends. However, the total molar mass data indicate an overall decreasing trend in COC mass (Appendix A). Groundwater geochemistry within the shallow and intermediate groundwater intervals are more conducive to biodegradation of PCE and TCE and is supported by the presence of the degradation compounds vinyl chloride and ethene. Modeling of groundwater concentrations (Appendix A) indicates that PCULs will be achieved through natural attenuation in wells located at CI Plant 4 in (Table 4):

- the water table interval in approximately 35 years; (42 to 116 years based on analytical solutions);
- the shallow interval in 40 years; (71 years based on analytical solutions); The greater than expected time frame is due to influx of vinyl chloride associated with upgradient source(s); and
- the intermediate interval is compliant with PCULs.

Monitored natural attenuation is a technically feasible remedial alternative for groundwater in all three groundwater intervals at CI Plant 4. Implementation of monitored natural attenuation at CI Plant 4 would include groundwater monitoring to confirm the decline of COC concentrations in groundwater to PCULs. ISCO injections within the water table interval will further reduce the timeframe for cleanup and reduce vapor intrusion risk at and downgradient of CI Plant 4. Institutional and engineering controls to mitigate direct contact with groundwater and potential exposure to vapors from groundwater described under CI Plant 2 will also be implemented at CI Plant 4 and would remain until PCULs are achieved.

5.2.4 Downgradient Groundwater

Compliance monitoring will confirm continued reduction in downgradient plume mass and concentrations as the effects of upgradient source control actions propagate through the groundwater system.

5.2.5 Evaluation of Time frames

Estimates of remediation time frames for Alternative 1 indicate that PCULs will be achieved at different rates in different portions of the site ranging from approximately 20 to 50 years, as discussed in the individual sections above and Appendix A.

Within the water table interval, vapor intrusion screening levels are expected to be attained within approximately 16 to 26 years (Table 4).

These estimates are based on modeling and while intended to be conservative, the estimates do include uncertainty. A reasonable expectation is that the majority of the groundwater plume(s) will conform to the modeling predictions. However, SU2 groundwater is expected to remain protective of surface water and the time estimates are appropriate for ranking of alternatives. Additional refinement of remediation time estimates and appropriate contingency actions would be included in the CAP for the selected alternative. The alternative is costed conservatively assuming 60 years of groundwater monitoring based on these time estimates.

5.2.6 Cost Estimate

The combined cost estimate for implementation of Alternative 1 is $2,130,000 million (Table 3 and Appendix B). This cost estimate includes 60 years of compliance monitoring (Table B5), with documentation including reporting, treatability studies, and implementation of source area actions with a 25% contingency on implementation costs. This cost estimate does not include costs for implementation of contingency actions undertaken in the event of partial remedy failure or discovery of additional contamination. Contingency remedial actions and estimated scenario costs are discussed in Section 7.

5.3 ALTERNATIVE 2A

Alternative 2A focuses on targeted remediation by enhanced anaerobic biodegradation (EAB) in selected source area soil and groundwater hot spots and downgradient groundwater locations (Table 2 and Figure 3b). EAB would be implemented as lines of injections of compounds designed to enhance degradation such as electron donor substances or nano-scale granular activated carbon. ISCO would be the selected technology for treating shallow soil and water table interval groundwater at CI Plant 4.

EAB will both reduce COC concentrations in groundwater in water passing through the lines or treatment injections and increase source decay decay rates in immediately downgradient areas. Decay rates will increase due to both flushing and limited migration of electron donor substances through the aquifer. EAB would be implemented through direct-push injections of electron donor substances to increase metabolic degradation of chlorinated ethenes. The goal of the injections is to reduce the time to meet groundwater RAOs. The limitation on achievement of groundwater RAOs will be the time required to achieve groundwater concentrations in the interval downgradient from and between the EAB injection lines (Appendix B). This timeline is controlled by the time lag for groundwater advection to downgradient locations and the subsequent change in source decay rate at those locations. Injections are expected to have little leverage on improvement in remediation times in the intermediate zone because of the slow seepage velocities. Therefore, Alternative 2A focuses on treatment in the water table and shallow intervals where treatments will be more effective and TCE and vinyl chloride concentrations are higher. For the purposes of this FS, literature implementation costs per cubic yard are assumed for costing purposes and the number of injection events is not specified, though typical applications include 1 to 3 rounds of injections. An injection schedule would be addressed in the CAP, if selected for implementation.

Vinyl chloride production is a potential issue with the use of EAB. While HVOCs naturally degrade through vinyl chloride, the use of EAB may cause vinyl chloride concentrations to transiently increase at downgradient wells as TCE and DCE degrade. The increased vinyl chloride would still be protective of surface water because increased vinyl chloride will be generated further from the point of discharge than under the currently protective conditions, allowing more time for natural biodegradation. The addition of electron donors will also marginally accelerate degradation of vinyl chloride. Injection design may also include a hydrogen release compound, or bioammendment, to target vinyl chloride if bench testing suggests that vinyl chloride treatment from EAB compounds alone are not adequate.

Dissolved metals concentrations may increase due to the reducing conditions generated by EAB implementation. COCs such as manganese may increase immediately downgradient of injections. However, the reducing conditions are not expected to extend far downgradient and are not expected to result in elevated metals concentrations at the Duwamish River.

Compliance monitoring plans developed concurrent with the CAP or Engineering Design Report (if required) would address possible transient increases in vinyl chloride and metals as a possible result of EAB implementation, and specify acceptable statistical and concentration thresholds to prevent unnecessary triggering of contingency actions.

RAOs would be met for groundwater through the permanent destruction of groundwater HVOCs through both natural attenuation and targeted EAB. Soil RAOs would be met through excavation and offsite disposal in the CI source areas, and combined engineered and institutional controls where soil was inaccessible. Vapor intrusion RAOs would be met through interim mitigation measures and eventually through reduction in soil and groundwater contaminant mass. Existing interim vapor intrusion assessment, monitoring, and mitigation measures presented in the Revised Vapor Intrusion Assessment, Monitoring, and Mitigation Plan (Farallon 2015a) will remain in force through completion of the CAP. Final vapor intrusion assessment, monitoring, and mitigation measures will be integrated as a part of the selected alternative, and are included in cost estimates.

The alternative includes an assumed 40 years of groundwater monitoring with 5 years of quarterly monitoring, 5 years of semi-annual monitoring, 5 years of annual monitoring, and followed by biennial performance monitoring with annual compliance monitoring. The monitoring program would be completed with quarterly performance monitoring for 1 year to demonstrate compliance with PCULs. A detailed schedule is included in Appendix B.

5.3.1 Blaser Die Casting

Remedial actions in the BDC source area would include EAB of groundwater in the water table and shallow zones. EAB injections would be arranged in two lines transecting the plume forming plume cutoff features intended to reduce groundwater TCE concentrations by approximately 90% or to meet PCULs (Figure 3b). BD Line 1 would be located at the BDC source area. BD Line 2 would be located south of the Mead Street Building. Loading rates would be based on the flow rate and concentration range in each location.

Soil RAOs were largely met through the interim removal action (PGG 2009). Remaining soil that was inaccessible during the interim action will be addressed through implementation of institutional controls and maintenance of hard impermeable surfaces over the remaining soil area. A restrictive covenant is expected for the Blaser property to be protective of utility workers who may encounter contaminated groundwater and associated vapor intrusion issues.. Remaining impacted soil is currently underneath a concrete slab and asphalt paving. These surfaces meet the direct contact criteria for soil RAOs.

5.3.2 Capital Industries Plant 2

As previously stated under Alternative 1, no further remedial action is required at CI Plant 2 with respect to soil. The objective of applying EAB at CI Plant 2 would be to work in conjunction with the BDC Line 2 EAB injection (Figures 3b and 4b) to reduce the mass and concentrations of COCs in the water table and shallow groundwater intervals below the PCULs, or to the maximum extent practicable. The intermediate groundwater interval is not being targeted due to concentrations of vinyl chloride at and downgradient of CI Plant 2 being low and continuing to biodegrade. Engineering and Institutional controls cited under Alternative 1 would also be implemented under Alternative 2A.

Application of EAB would include a single line of injection across the width of the TCE plume exceeding the current PCUL of 7 µg/l (Figure 4B). This line of injection is estimated to be approximately 240 feet in length and a target injection depth that would extend from approximately 35 feet bgs to 8 feet bgs. The estimated injection radius is currently estimated at 10 feet resulting in an estimated 15 to 20-foot thickness of the injection line width. There would be an estimated 13 points of injection at a 20-foot spacing. Pilot testing will likely be necessary to evaluate the final injection geometry and volume of EAB substrate that can be injected at each injection boring. At this time, the EAB substrate is assumed to be injected using direct-push drilling rather than dedicated injection wells. Groundwater sampling events for performance monitoring purposes would include analysis of COCs, key geochemical indicators of biodegradation, microbial analysis, and organic acids. These data would be used to evaluate the effectiveness of EAB, the distance the release of the soluble electron donor disperses via groundwater downgradient of the injection line, and when the substrate is expended.

At this time bioaugmentation, the injection of bacteria capable of fully biodegrading TCE to ethene, is not anticipated to be necessary. However, microbial testing will be performed as a component of pilot testing to evaluate whether bioaugmentation will be performed as a component of the EAB substrate injection. The presence of vinyl chloride and ethene in the shallow and intermediate groundwater intervals indicate that there are likely sufficient indigenous bacteria capable of fully biodegrading TCE and that the injection of an EAB substrate in the water table interval may be sufficient to enhance the growth of the beneficial bacteria capable of completing the degradation of TCE to ethene.

If the initial injection of EAB substrate is expended prior to achieving the RAO, current conditions in the groundwater intervals will be evaluated to assess whether a second injection event is necessary or monitored natural attenuation will be sufficient to achieve the RAOs.

5.3.3 Capital Industries Plant 4

Application of ISCO would target locations within the area depicted on Figure 4B. Application of the technology would be the same as described under Alternative 1 and will target both soil and water table interval groundwater within the footprint of CI Plant 4. The chemical oxidant that would be pilot tested would likely be potassium permanganate, an oxidant that is effective at destroying the COCs present, has a relatively short lifespan (days to weeks) depending on the oxidant demand of the subsurface media and COCs, and results in byproducts such as chloride and potassium that will not impact EAB. Application of ISCO will temporarily result in a reduction of populations of bacteria that are beneficial to biodegradation of PCE and TCE but will not completely eliminate the bacteria. The ISCO application also will temporarily result in a localized shift from anaerobic to aerobic conditions. However, influx of anaerobic groundwater from upgradient of CI Plant 4 following depletion of the selected chemical oxidant will return the ISCO injection areas to their native anoxic to anaerobic state and result in reestablishment of beneficial bacteria. Historical groundwater data for COCs and geochemistry indicate that the water table interval is not sufficiently anaerobic to complete biodegradation of PCE and TCE to ethene indicating a deficiency or dormancy of the types of beneficial bacteria. Subsequent application of EAB with possible bioaugmentation are expected to successfully restore and improve conditions in the water table interval for biodegradation of residual COCs.

Implementing and monitoring of EAB for groundwater remediation would be completed in a manner consistent with the criteria at CI Plant 2. However, the water table groundwater interval would be the only groundwater interval targeted by EAB at CI Plant 4. A single line of injection of an EAB substrate would be located on the south sides of CI Plants 3 and 4 across the estimated width of the PCE and TCE plumes (Figure 4b). This line of injection is estimated to be approximately 210 feet in length and a target injection depth that would extend from approximately 25 feet bgs to 8 feet bgs. The estimated injection radius is currently estimated at 10 feet resulting in an estimated 15 to 20-foot thickness of the injection line width. There would be an estimated 11 points of injection at 20-foot spacing.

Application of EAB at CI Plant 4 would remediate COCs that may be emanating from an alternative source east of CI Plant 4 but without remediation of the source in soil there is the potential for concentrations of COCs to persist in groundwater following remediation of COCs in soil at CI Plant 4. Compliance groundwater monitoring results would be used to evaluate whether further investigation of an alternative source of PCE and/or TCE east of CI Plant 4 exists and requires identification and subsequent remediation to meet soil and groundwater RAOs throughout SU2. Engineering and Institutional controls cited under Alternative 1 would also be implemented under Alternative 2A.

5.3.4 Downgradient Groundwater

Implementation of EAB in the downgradient area of CI Plant 2 would include a line of injections immediately south of the Olympic Medical building (Downgradient line 1), assuming access is granted (Figure 3b). An alternate alignment would parallel 1st Avenue South. Injections would target the water table and shallow aquifer intervals to provide a plume cutoff feature. The TCE concentrations are close to PCULs for surface water in this area and the primary risk to surface water receptors is degradation to vinyl chloride, which is occurring by natural biodegradation. HVOC degradation may be associated with transient increases in vinyl chloride and metals downgradient of the plume cutoff feature.

Application of EAB in the downgradient area of CI Plant 4 is not proposed at this time. The effects of the EAB at the CI Plant 4 source area will be evaluated at the CI-9 well cluster. The existing downgradient monitoring well network may also be augmented with additional wells within the lateral plume boundary during pilot testing of the technology to evaluate effects of EAB. If the concentrations and mass of COCs at CI-9-WT and CI-9-40, or supplemental monitoring wells installed, remain stable EAB would be considered as a contingency action.

5.3.5 Evaluation of Time frames

Estimates of remediation time frames for Alternative 2A indicate that PCULs will be achieved within approximately[9] (Appendix A; Table 4)):

- 15 to 90 years in the BDC source area;
- 20 to 55 years in the CI Plant 2 source area; and
- 30 to 50 years in the CI Plant 4 source area.

Remediation time estimates for Alternative 2 are slightly shorter than natural attenuation times calculated using BIOCHLOR and analytical solutions. Because injected electron donor substances are often relatively immobile, the primary mechanism for increase in SDR at downgradient locations is the reduction in dissolved phase concentrations and the associated flushing effect (i.e., a detached plume). Thus, at downgradient areas in intervals where seepage velocities are slower, the additional benefit of remedial action at downgradient areas is limited by the flushing time (Appendix A).

[9] Values are rounded to 5 year increments.

5.3.6 Cost Estimate

The combined cost estimate for implementation of Alternative 2A is $5,240,000 (Table 3, Appendix B). This cost estimate includes 40 years of compliance monitoring, with documentation including reporting, treatability studies, and implementation of source area actions with a 25% contingency on implementation costs. This cost estimate does not include costs for implementation of contingency actions undertaken in the event of partial remedy failure or discovery of additional contamination. Contingency remedial actions and estimated scenario costs are discussed in Section 7.

5.4 ALTERNATIVE 2B

All elements or Alternative 2B are the same as Alternative 2A, with the exception of an additional line treatment line along First Avenue intercepting the downgradient extent of the plume in the vicinity of CI 14-35 and CI-15-60, and elevated cis-1,2 DCE and vinyl chloride in the vicinity of CG-141 (Figure 3c) and the application of excavation at CI Plant 4 (Figure 4C). Downgradient Line 2 would target the Shallow and Intermediate zones. Remediation times are expected to be similar to Alternative 2A.

Alternative 2B includes excavation and off-site disposal as the method of remediating soil exceeding the current PCULs. The soil excavation will target the southeast portion of CI Plant 4 where the concentrations of PCE and TCE are greatest and with a vertical extent that is at or near the depth to groundwater. Concentrations of TCE present in other areas of CI Plant 4 at low concentrations limited to less than 2 feet bgs will not be excavated and are expected to continue to attenuate over the duration that groundwater cleanup would be completed. The estimated limits of excavation are depicted on Figure 4C.

Excavation would require shutting down the CI Plant 4 operations and removal of equipment within the targeted excavation area. A structural and geotechnical engineering assessment of the building and underlying soil types will also be necessary to evaluate how to maintain the integrity of the building while completing excavation at and near the building walls/footings. The concrete slab would be removed from the excavation area and any structural shoring/bracing required would be implemented prior to excavation. A backhoe would be used to excavate soil to a depth of approximately 6 feet bgs. Soil would be profiled prior to excavation using existing soil data from the Remedial Investigation (Farallon 2012) and Remedial Investigation Data Gap work (Farallon 2016) to allow excavated soil to be transported directly to the designated disposal facility as excavated. The concentrations of PCE and TCE meet Ecology’s criteria for a contained-out designation allowing the soil to be transported to a Subtitle D landfill. Performance soil sampling would be conducted until the results indicate that the RAOs for soil are achieved, or excavation has been completed to the extent practicable and within the CI property limits. This alternative does not target potential contamination east of CI Plant 4.

Following confirmation sampling data that indicates the RAOs for soil have been achieved, the excavation area would be backfilled in accordance the geotechnical assessment requirements. CI Plant 4 would be restored including the building slab, equipment, and subsurface utilities affected. The estimated time frame to complete the excavation and restoration work is 15 to 20 days.

The excavation approach to soil remediation has been presented as a technically feasible technology due to its inclusion in the Remedial Alternatives Memorandum for SU2 (Farallon, 2015b). However, due to a need to interrupt an integral component of the CI operations and integrate shoring/bracing to support structural elements of the building, is ranked lower than ISCO for implementability and management of short-term risk. Termination of the ability to paint the CI manufactured products for a period of 15 to 20 days is also unsustainable regardless of the technical feasibility of soil excavation. ISCO also ranks either equal to or higher with respect to overall protectiveness, permanence, and long-term effectiveness.

5.4.1 Cost Estimate

The combined cost estimate for implementation of Alternative 2B is $8,110,000 (Table 3 and Appendix B). This cost estimate includes 40 years of compliance monitoring, with documentation including reporting, treatability studies, and a 25% contingency on implementation costs. This cost estimate does not include costs for implementation of contingency actions undertaken in the event of partial remedy failure or discovery of additional contamination. Contingency remedial actions and estimated scenario costs are discussed in Section 7.

5.5 ALTERNATIVE 3A

Alternative 3A focuses on targeted remediation by in-situ chemical reduction (ISCR) and ISCO in selected source area soil and groundwater hot spots and downgradient groundwater locations (Table 2 and Figure 3c). The general approach is similar to Alternative 2, but utilizes different chemistry to achieve COC concentration reductions.

ISCR would be implemented through direct-push injections of zero-valent iron (ZVI) solutions to enhance chemical degradation of chlorinated ethenes. ZVI is typically effective with a 0.5% amendment of the aquifer matrix. ISCR injections would be arranged in lines transecting the plume forming plume cutoff features similar to those in Alternative 2A, and shown in Figure 3c. Loading rates and zone width would be based on the flow rate, concentration range, and intended duration at each location. For the purposes of this FS, literature implementation costs per cubic yard are assumed for costing purposes (Section 5.3.6) and the number of injection events is not specified.

RAOs would be met for groundwater through the permanent destruction of groundwater HVOCs through natural attenuation and targeted ISCR. Soil RAOs would be met through ISCO in the CI source areas, and combined engineered and institutional controls where soil is inaccessible. Vapor intrusion RAOs would be met through interim mitigation measures and eventually through reduction in soil and groundwater contaminant mass. Existing interim vapor intrusion assessment, monitoring, and mitigation measures presented in the Revised Vapor Intrusion Assessment, Monitoring, and Mitigation Plan (Farallon 2015a) will remain in force through completion of the CAP. Final vapor intrusion assessment, monitoring, and mitigation measures will be integrated as a part of the selected alternative, and are included in cost estimates.

Similar to Alternative 2A, transient increases in metals due to reducing conditions or vinyl chloride due to incomplete degradation to ethene may occur. Therefore, compliance monitoring plans developed concurrent with the CAP or Engineering Design Report (if required) should address possible transient increases in vinyl chloride and metals as a possible result of ISCR implementation, and specify acceptable statistical and concentration thresholds to prevent unnecessary triggering of contingency actions.

The alternative includes an assumed 40 years of groundwater monitoring with 5 years of quarterly monitoring, 5 years of semi-annual monitoring, 5 years of annual monitoring, and followed by biennial performance monitoring and annual compliance monitoring. The monitoring program would be completed with quarterly compliance monitoring for 1 year to demonstrate compliance with PCULs. A detailed schedule is included in Appendix B.

5.5.1 Blaser Die Casting

ISCR would be implemented in the water table and shallow intervals at two locations. ISCR injections would be arranged in two lines transecting the plume forming plume cutoff features similar to those in Alternative 2 (Figure 3c). BD Line 1 would be located at the BDC source area near the BDC-3 well. BD Line 2 would be located immediately south of the Mead Street Building.

ISCR will both reduce COC concentrations in groundwater passing through and increase decay rates in downgradient areas as low-concentration groundwater migrates/flushes through the aquifer. The limitation on achievement of groundwater RAOs will be the interval downgradient from and between the ISCR injection lines. The transport times and changes in SDR should be similar to the Alternative 2 analysis for EAB with a minimum remediation time to PCULs in the area of 20 to 90 years (Appendix B Table 7).

Similarly to the implementation of EAB, ISCR may cause transient increases in vinyl chloride or metals as a result of the remediation chemistry and incomplete breakdown to ethene. However, compliance monitoring plans should address detections of vinyl chloride and metals to prevent unnecessary triggering of contingency actions.

Soil RAOs were largely met through the interim removal action (PGG 2009). Remaining soil that was inaccessible during the interim action will be addressed through implementation of institutional controls and maintenance of hard impermeable surfaces over the remaining soil area. A restrictive covenant is expected for the Blaser property to be protective of utility workers who may encounter contaminated groundwater and associated vapor intrusion issues. Remaining impacted soil is currently underneath a concrete slab and asphalt paving. These surfaces meet the direct contact criteria for soil RAOs.

5.5.2 Capital Industries Plant 2

As previously stated under Alternative 1, no further remedial action is required at CI Plant 2 with respect to soil. The objective of applying ISCR at CI Plant 2 is the same as Alternative 2 but using an alternative technology to eliminate COCs via an abiotic reaction. The ISCR at CI Plant 2 would work in conjunction with the BDC Line 2 injection (Figure 4c) to reduce the mass and concentrations of COCs in the water table and shallow groundwater intervals below PCULs, or to the maximum extent practicable. The intermediate groundwater interval is not being targeted due to concentrations of vinyl chloride at and down-gradient of CI Plant 2 being low and continuing to biodegrade. Engineering and Institutional controls cited under Alternative 1 would also be implemented under Alternative 3A.

Injection and subsequent groundwater monitoring of ISCR will be the same as the EAB substrate injections under Alternative 2A. An exception would be the analysis of organic acids, which would not be analyzed since ZVI does not release an electron donor that will generate organic acids.

5.5.3 Capital Industries Plant 4

Application of ISCO would target locations within the area depicted on Figure 4c. Application of the technology would be the same as described under Alternative 1 and will target both soil and water table interval groundwater within the footprint of CI Plant 4The chemical oxidant that would be pilot tested would be potassium permanganate, an oxidant that is effective at destroying the COCs present, has a relatively short lifespan (days to weeks) depending on the oxidant demand of the subsurface media and COCs, and results in byproducts such as chloride and potassium, which do not significantly react with ZVI. The combination of ISCO and ISCR are compatible when not applied simultaneously in the same areas. Application of ISCR would follow confirmation of depletion of the potassium permanganate.

Application of ISCO will temporarily result in a reduction of populations of bacteria that are beneficial to biodegradation of PCE and TCE but will not completely eliminate the bacteria. The ISCO application also will temporarily result in a localized shift from anaerobic to aerobic conditions. However, influx of anaerobic groundwater from upgradient of CI Plant 4 following depletion of the selected chemical oxidant will return the ISCO injection areas to their native anoxic to anaerobic state and result in reestablishment of beneficial bacteria. Historical groundwater data for COCs and geochemistry indicate that the water table interval is not sufficiently anaerobic to complete biodegradation of PCE and TCE to ethene indicating a deficiency or dormancy of the types of beneficial bacteria. The application of ISCR following depletion of the chemical oxidant will also increase the rate of anaerobic restoration and create a more anaerobic environment, promoting beneficial bacterial growth and anaerobic abiotic reactions that will destroy residual COCs that are not fully treated by ISCO. The benefit of reducing the COC mass in soil and groundwater at CI Plant 4 by ISCO injection is anticipated to outweigh the temporary delay in groundwater remediation downgradient due to the reduction of beneficial bacteria and localized changes in groundwater geochemistry to an aerobic state.

Implementing and monitoring of ISCR for groundwater remediation would be completed in a manner consistent with the criteria described in Alternative 2A. The water table groundwater interval would be the only groundwater interval targeted by ISCR at CI Plant 4. A single line of injection of the ZVI solution would be located on the south sides of CI Plants 3 and 4 across the estimated width of the PCE and TCE plumes (Figure 4b). This line of injection is estimated to be approximately 210 feet in length and a target injection depth that would extend from approximately 25 feet bgs to 8 feet bgs. The estimated injection radius is currently estimated at 10 feet resulting in an estimated 15 to 20-foot thickness of the injection line width. There would be an estimated 11 points of injection at 20-foot spacing.

Engineering and Institutional controls cited under Alternative 1 would also be implemented under Alternative 3.

Injection and subsequent groundwater monitoring of ISCR will be the same as the EAB substrate injections under Alternative 2A. As noted above elimination of analysis of organic acids would also be applicable.

5.5.4 Downgradient Groundwater

Implementation of ISCR in the downgradient area would include a line of injections immediately south of the Olympic Medical building, assuming access is granted (Figure 3c). An alternate alignment would parallel 1st Avenue South. Injections would target the Water Table and Shallow aquifer intervals to provide a plume cutoff feature. The TCE concentrations are close to PCULs for surface water in this area and the primary risk to surface water receptors is degradation to vinyl chloride, which is occurring by natural attenuation. Reduction in source mass will reduce possible vinyl chloride near the Duwamish. Even if degradation at the plume cutoff only reduces HVOCs to vinyl chloride (as opposed to complete destruction), the vinyl chloride degradation will have occurred further upgradient allowing greater time/distance for final degradation to ethene. Travel time/distance also allows groundwater oxidation-reduction potential and thus metals concentrations to return to natural conditions.

Application of ISCR in the downgradient area of CI Plant 4 is not proposed at this time. The effects of the ISCR at the CI Plant 4 source area will be evaluated at the CI-9 well cluster. The existing downgradient monitoring well network may also be augmented with additional wells within the lateral plume boundary during pilot testing of the technology to evaluate effects of ISCR. If the concentrations and mass of COCs at CI-9-WT and CI-9-40, or supplemental monitoring wells installed, remain stable ISCR would be considered as a contingency and would be applied and monitored as described for EAB under Alternative 2A.

5.5.5 Evaluation of Time frames

Estimates of remediation time frames for Alternative 3A indicate that PCULs will be similar to Alternative 2A, and achieved (Table 4):

- 15 to 90 years in the BDC source area;
- 20 to 55 years in the CI Plant 2 source area; and
- 30 to 50 years in the CI Plant 4 source area.

Remediation time estimates for Alternative 3 are slightly shorter than natural attenuation times calculated using BIOCHLOR and analytical solutions. Because injected electron donor substances are often relatively immobile, the primary mechanism for increase in SDR at downgradient locations is the reduction in dissolved phase concentrations and the associated flushing effect (i.e., a detached plume). Thus, at downgradient areas in intervals where seepage velocities are slower, the additional benefit of remedial action at downgradient areas is limited by the flushing time (Appendix A).

5.5.6 Cost Estimate

The combined cost estimate for implementation of Alternative 3A is $7,020,000 (Table 3 and Appendix B). This cost estimate includes 40 years of compliance monitoring, with documentation including reporting, treatability studies, and a 25% contingency on implementation costs. This cost estimate does not include costs for implementation of contingency actions undertaken in the event of partial remedy failure or discovery of additional contamination. Contingency remedial actions and estimated scenario costs are discussed in Section 7.

5.6 ALTERNATIVE 3B

All elements or Alternative 3B are the same as Alternative 3A, with the exception of an additional line treatment line along First Avenue intercepting the downgradient extent of the plume in the vicinity of CI 14-35 and CI-15-60, and elevated cis-1,2 DCE and vinyl chloride in the vicinity of CG-141 (Figure 3d). Downgradient Line 2 would target the Shallow and Intermediate zones. Remediation times are expected to be similar to Alternative 3A.

5.6.1 Cost Estimate

The combined cost estimate for implementation of Alternative 3B is $11,130,000 (Table 3 and Appendix B). This cost estimate includes 40 years of compliance monitoring, with documentation including reporting, treatability studies, and a 25% contingency on implementation costs. This cost estimate does not include costs for implementation of contingency actions undertaken in the event of partial remedy failure or discovery of additional contamination. Contingency remedial actions and estimated scenario costs are discussed in Section 7.

5.7 ALTERNATIVE 4

Alternative 4 is similar to Alternative 1, but evaluates Air Sparge/Soil Vapor Extraction (AS/SVE) (Table 2; Figure 3e) as technologies for soil and groundwater treatment at CI Plant 4. Elements in the Blaser source area, CI Plant 2, and downgradient groundwater areas are the same as in Alternative 1 (Section 5.1).

The alternative includes an assumed 60 years of groundwater monitoring with 5 years of quarterly monitoring, 5 years of semi-annual monitoring, 5 years of annual monitoring, and followed by biennial monitoring. The monitoring program would be completed with quarterly compliance monitoring for 1 year to demonstrate compliance with PCULs. A detailed schedule is included in Appendix B.

5.7.1 Blaser Die Casting

Implementation in the BDC source area is the same as for Alternative 1.

5.7.2 Capital Industries Plant 2

Implementation in the Plant 2 area is the same as for Alternative 1.

5.7.3 Capital Industries Plant 4

AS/SVE is being evaluated as a technically feasible remedial technology because a system could be designed to remediate COCs in soil located to the east of CI Plant 4, if present, without requiring further investigation or direct access to the Pacific Food Systems property to implement the technology. ISCO and soil excavation would require further investigation at the Pacific Food Systems property to identify the location and distribution of PCE and/or TCE in soil in order to be successfully implemented[10].

The AS component of the system would also achieve groundwater RAOs for the water table and shallow groundwater intervals at a nominal incremental cost. The estimated area of remediation of soil and groundwater that an AS/SVE system would be designed to affect is depicted on Figure 4d. An AS and SVE pilot test would need to be completed to confirm that the technology would be effective, the geometry of the treatment wells within the remediation area, the number of AS/SVE wells required, and the equipment required. It is uncertain at this time whether the shallow groundwater interval can be targeted with this technology. Silt lenses present in the subsurface may mitigate the ability to effectively capture COC vapors generated using the shallow SVE trenches. Pilot testing would need to be conducted to evaluate whether the AS technology would be restricted to the water table groundwater interval.

At this time an estimated 15 AS wells screened within the water table groundwater interval and 15 AS wells screened within the shallow groundwater interval are assumed necessary. Installation of these wells within CI Plant 4 would need to be installed on weekends or evening hours when night shifts are not operating to minimize impacts to business operations since the paint booths are critical to CI operations. Similarly, completing the trenching and piping connections would require either shutting down the plant or multiple weekends/evenings and temporary metal plates placed over trench areas to allow CI to conduct operations during normal business hours until the trenching/piping activities are completed. Where practicable piping runs would be aboveground and anchored to walls to minimize trenching needs. The equipment compound would be located either inside the northwest interior portion of CI Plant 4 or southwest interior portion of CI Plant 4. The AS compressor and SVE blower would likely need to be equipped with sound dampening equipment to minimize noise impacts for workers at the plant.

Shallow groundwater will limit the vacuum that could be applied using standard vertical SVE wells. An SVE system would consist of horizontal SVE wells to achieve the soil RAOs. The radius of influence of a horizontal SVE well is uncertain at this time and the system may not effectively treat potential soil contamination east of CI Plant 4, depending on the vacuum that can be applied. Pilot testing would be necessary to evaluate the design parameters for the horizontal SVE wells. A total of 3 shallow SVE wells are assumed at this time. Installation of the shallow horizontal SVE wells would also result in substantial impacts to CI Plant 4 operations due to trenching and piping requirements. Where possible piping runs would be aboveground and anchored to walls to minimize trenching needs. Engineering and Institutional controls cited under Alternative 1 would also be implemented under Alternative 4.

[10] See the discussion of possible source at Pacific Foods in Section 1.3.1.

Once installed, the AS/SVE system is estimated to require 1 to 5 years to meet RAOs for soil and groundwater. The estimated time frame would be refined based on monitoring results of the SVE effluent concentrations and results of groundwater sampling events. The current unknown remains whether a source of PCE and/or TCE exists at Pacific Food Systems and the potential mass of COCs present in the vadose zone. The soil analytical results at CI Plant 4 indicate that the limits and mass of PCE and TCE in the vadose zone is relatively low and is expected to be remediated within 1 to 2 years of SVE operation. However, due to the silty nature of the soil matrix this estimate may be understated. The time frame for groundwater cleanup will be dependent upon the ability to remediate adsorbed phase COCs in the silty soil matrix. Back diffusion of residual COCs is possible following shut down of the AS system based on experience at sites with similar geology and COCs, albeit, the mass of COCs will likely be reduced.

5.7.4 Downgradient Groundwater

Implementation in the downgradient groundwater area is the same as for Alternative 1. Extending the AS system into and south of CI Plant 4 and South Fidalgo Street is impracticable due to the need to install trenching and piping back to the remediation equipment compound. Extending the SVE system into the areas of influence of the southerly AS wells to capturer COC vapors that could enter ambient air or buildings. A number of utilities are present (Figure 4D) that include water, stormwater, sanitary sewer, and natural gas in the right-of-ways and South Fidalgo Street that will also likely impede trenching or installation of shallow SVE wells.

5.7.5 Evaluation of Time frames

Estimates of remediation time frames for Alternative 4 indicate that PCULs will be achieved (Table 4):

- Within 15 to 90years in the interval from the BDC source area to Plant 2;
- 10 to 40 years in the CI Plant 2 source area; and,
- Within 20 to 70 years in the CI Plant 4 source area.

Remediation time frame estimates for Alternative 4 are discussed in Section 5.1 for portions similar to Alternative 1. Time frames in the Plant 4 area are similar to Alternatives 2 and 3.

5.7.6 Cost Estimate

The combined cost estimate for implementation of Alternative 4 is $2,780,000 (Table 3 and Appendix B). This cost estimate includes 60 years of compliance monitoring, with documentation including reporting, treatability studies, and implementation of source area actions with a 25% contingency on implementation costs. This cost estimate does not include costs for implementation of contingency actions undertaken in the event of partial remedy failure or discovery of additional contamination. Contingency actions and estimated scenario costs are discussed in Section 7.Evaluation of SU2 Alternatives

This section of the FS compares Alternatives 1 through 4 to MTCA threshold requirements (WAC 173-340-360). All considered remedial alternatives meet the MTCA threshold requirements.

5.8 MTCA THRESHOLD CRITERIA

Threshold requirements are discussed in the following subsections, including:

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

5.8.1 Protect human health and the environment

All considered options are protective of human health and the environment. Alternatives 1 through 4 satisfy the RAOs described in section 2. The RAOs are satisfied through a combination of active remediation, including both that conducted as interim action and included in the Alternatives, through adoption of targeted institutional controls, and through mitigation measures. None of the remedies rely primarily on institutional controls or mitigation measures to ensure protectiveness and achieve RAOs.

The only currently complete receptor pathway in the SU2 area is vapor intrusion, which is currently mitigated and monitored under the Revised Vapor Intrusion Assessment, Monitoring, and Mitigation Plan (Farallon 2015a). Existing interim vapor intrusion mitigation measures would be integrated into the CAP as a part of the selected alternative. Vapor intrusion risk is expected to decrease regardless of the alternative selected since all alternatives will reduce the mass/concentrations of COCs.

5.8.2 Comply with cleanup standards

All considered alternatives meet the RAOs for soil and groundwater, which are based on attainment of cleanup standards. Soil RAOs may be met either by meeting cleanup standards at the point of compliance, or through use of engineering and institutional controls where reaching PCULs is impractical, and where it is consistent with WAC 173-340-200 and -360. Air RAOs will be met through interim mitigation and attainment of soil and groundwater RAOs. Methods to satisfy PCULs are described within each alternative.

5.8.3 Comply with applicable state and federal laws

All alternatives comply with applicable state and federal laws (ARARs, Section 2.4).

5.8.4 Provide for compliance monitoring

All alternatives provide for compliance monitoring consistent with MTCA (WAC 173-340-410).

5.9 ADDITIONAL MTCA CRITERIA

In addition to threshold requirements, MTCA also requires that selected actions will:

- Use permanent solutions to the maximum extent practicable;
- Consider public concerns; and

- Provide for a reasonable restoration time frame;

5.9.1 Use permanent solutions to the maximum extent practicable

All alternatives adopt remedial actions with permanent remedies. Groundwater remedies focus on the degradation and destruction of chlorinated ethenes. Soil remedies focus on removal and destruction where technically feasible and use permanent containment remedies meeting the requirements of WAC 173-340-740 (6)(f) where removal and/or destruction are not practicable.

5.9.2 Consider public concerns

The selected actions consider public concerns including vapor intrusion, potential use of groundwater as a drinking water source. Site reports and documents are available for public review, and potential impacts to offsite/downgradient receptors have been incorporated into consideration of remedial actions. Additional public concerns may be addressed after the public comment period.

5.9.3 Provide for a reasonable restoration time frame

describes the criteria for determining if a remedy provides for a reasonable time frame. Generally speaking, shorter restoration time frames are required for sites with imminent threats to human health or the environment while longer time frames may be appropriate or allowed at sites with lower risk and where it is consistent and practical with future site use and ability to monitor. Specific factors to be considered include:

- **Potential risks:** Potential risks in SU2 are generally low, or are currently mitigated as in the case of vapor intrusion. SU2 groundwater conditions are protective of human health and the environment for soil and groundwater under current site use, and VI mitigation has been implemented.
- **Practicability of achieving a shorter time frame**: Remediation time frames are variable between the selected alternatives. When compared with Alternative 1, the more aggressive Alternatives 2, 3, and 4 range in restoration time frame from no reduction to approximately half. The relative benefits of the aggressive actions are analyzed in the DCA (Section 7).
- **Current and potential future site use:** The SU2 area is currently mixed commercial, industrial, and residential. While this use type is not expected to significantly change, changes in land use would likely be associated with construction of new buildings that would likely be less susceptible to vapor intrusion due to modern vapor barrier construction, and construction may include vapor intrusion specific elements further improving effectiveness. Therefore, future land uses within SU2 are not expected to adversely impact remediation.
- **Availability of alternate water supplies:** All drinking/potable water in the SU2 area is supplied by Seattle Public Utilities and installation of wells for private use is not allowed. W4 groundwater potability is discussed in Appendix C (PGG, 2016).
- **Ability to control and monitor migration:** An extensive monitoring well network is in place in the W4 Site that will facilitate mon-+itoring of the groundwater plume. Institutional controls soil are likely to be effective because the remaining areas are diffi-

cult to access due to the configuration of buildings and pavement, and can be tied to potential future lease agreements.

- **Toxicity of the hazardous substances:** Sites with highly toxic compounds or high concentrations of COCs can be reasonably expected to adopt a faster remedial action to reduce risk to potential receptors. While SU2 COC concentrations do exceed screening levels based on protection of vapor intrusion and surface water receptors, COC concentrations do not indicate the presence of non-aqueous phase liquids, and receptor pathways are largely incomplete under current site conditions, and risks associated with COCs are acceptably addressed.
- Natural processes that reduce concentrations at the site: biodegradation of HVOCs is demonstrated by presence of degradation compounds, groundwater geochemical indicators of biodegradation, and decreasing concentrations in source areas. The time for natural processes to reduce concentrations varies by source area and aquifer interval (Appendix A).

Assessment of a reasonable time frame includes consideration of the relative rate at which alternatives can achieve RAOs, and if the selected alternatives as a group are reasonable within what is technically feasible with available technologies and site conditions. Similarly, alternatives with longer remediation times are not preferred when reasonable and practicable alternatives with shorter remediation times are available. Longer time frames may be adopted if a cleanup alternative has a greater degree of long-term effectiveness than non-destructive alternatives such as landfill disposal or containment technologies[11]. The remedial alternatives herein incorporate either naturally occurring biotic processes or in-situ technologies to reduce/eliminate COCs in soil, soil gas, and/orgroundwater, which is preferred under the MTCA threshold criteria under WAC 173-340-360(4).

Based on the factors cited above, all presented alternatives fall within acceptable criteria for a reasonable time frame. Prior and planned source control measures are expected to continue to reduce restoration timeframes for groundwater. More aggressive groundwater cleanup actions in Alternatives 2 through 4 expedite remediation, but anticipated time to achieve PCULs remains dependent on the time required to flush and degrade contaminant mass between treatment lines/areas, which would take decades to complete without a proportional reduction in risk to the affected pathways, media, and/or receptors. Some portions of the W4 Site including the shallow and intermediate groundwater intervals will take decades to achieve RAOs regardless of the alternative selected (see Section 5, Appendix A) partially due to continued influx of low levels of contamination from upgradient of the W4 Site. However, the achievement of RAOs will occur faster in other portions of the W4 Site either due to active remedies, or because natural attenuation processes are either faster or already closer to achieving PCULs. Many areas of the W4 Site are expected to achieve PCULs within 30 years, including the higher-priority water table groundwater interval, which represents an ongoing potential for vapor intrusion and direct contact risk. All alternatives presented herein include measures to: monitor the effectiveness of the alternative; refine the estimate of the restoration timeframe; evaluate potential increases or decreases in risks to various receptors; and implement contingency ac-

[11] In addition to technical feasibility of excavation in Capital Industries Plant 4 area, excavation is also less-preferred under MTCA threshold criteria relative to the in-situ remedial technologies incorporated into alternatives.

tions. The criteria set forth under WAC 173-340-360(4) are therefore met for all alternatives.

5.9.4 Effect of Alternatives on 1,4-Dioxane

In accordance with AO DE 10402, the likely effect of each of the six alternatives considered for implementation within SU2 on the concentrations of 1,4-dioxane in groundwater is discussed below:

- Alternative 1 (MNA and ISCO) – ISCO is a cleanup action element currently being evaluated by Stericycle in the Remedial Design in the East of 4th Area. Implementation of ISCO as part of Alternative 1 is focused on remediation of COCs in soil and has little potential to reduce concentrations of 1,4-dioxane in groundwater in SU2 through direct oxidation. Implementation of MNA has the potential to reduce concentrations of 1,4-dioxane in groundwater in SU2 by not interfering with the biodegradation processes that are occurring. It is unlikely that implementation of Alternative 1 would interfere with on-going attenuation of 1,4-dioxane or interfere with Stericycle's contingent remedy.
- Alternative 2 (EAB and Excavation/ISCO) and Alternative 3 (ISCR and MNA)– EAB is a cleanup action element currently being evaluated by Stericycle in the Remedial Design in the East of 4th Area. Implementation of EAB as part of Alternative 2 or EAB and ISCR as part of Alternative 3 has the potential to reduce concentrations of 1,4-dioxane in groundwater in SU2 by promoting biodegradation. It is unlikely that implementation of Alternative 2 or Alternative 3 would interfere with on-going attenuation of 1,4-dioxane or interfere with Stericycle's contingent remedy.
- Alternative 4 (AS/SVE/MNA) — The cleanup action elements of Alternative 4 (AS/SVE) are unlikely to reduce concentrations of 1,4-dioxane in groundwater, but they are also unlikely to interfere with on-going attenuation of 1,4-dioxane concentrations in groundwater or with Stericycle's contingent remedy. It is unlikely that implementation of Alternative 4 would interfere with on-going attenuation of 1,4-dioxane or interfere with Stericycle's contingent remedy.

In SU2, laboratory analysis of groundwater samples have detected 1,4-dioxane at concentrations exceeding its PCUL in wells located near 4^{th} Avenue South. The implementation of Stericycle's contingent remedy reduces the potential for future exceedances of the 1,4-dioxane PCUL in SU2 groundwater. Alternatives 1, 2, 3 and 4 either have the potential to reduce concentrations of 1,4-dioxane in groundwater or are unlikely to interfere with on-going attenuation. Implementation of the SU2 alternatives are not expected affect the timeline for attaining the cleanup level.

6.0 DISPROPORTIONATE COST ANALYSIS

The DCA ranks alternatives based on their relative costs and benefits. The evaluation criteria for the disproportionate cost analysis are specified in WAC 173-340-360(3)(f), and include the following criteria. Weightings are commonly applied values for DCAs based on professional judgement[12]:

- Overall protectiveness (30%);
- Permanence (20%);
- Long-term effectiveness (20%);
- Management of short-term risks (10%);
- Technical and administrative implementability (10%);
- Public concerns (10%); and,
- Cost (weighed against criteria above).

Scores applied for each criteria in the DCA are applied based on a qualitative assessment of each Alternative relative to the other Alternatives. The following sections discuss the relative rankings of alternatives for each of the criteria. Supporting discussion is limited to where there are significant differences between alternatives for specific criteria; how Alternatives satisfy the underlying RAOs is discussed in Section 5.

6.1 OVERALL PROTECTIVENESS

The overall protectiveness criteria considers how much existing risks are reduced, the time required to reach cleanup standards, on site and off site risk and impacts associated with implementation, and overall improvement in environmental quality. All of the alternatives have similar RAOs and residual COCs left in place.

The alternatives are similar in their overall protectiveness because site conditions are currently protective of human health and the environment. Residual COCs in soil do not exceed direct contact PCULs throughout the W4 Site. Historical VI investigation work has indicated that VI risk is nominal with very few buildings being affected by the low concentrations of COCs in water table interval groundwater. Source areas of COCs have been or will be addressed eliminating potential for VI risk that could be posed by residual low concentrations of soil. Where VI has been confirmed to be a concern, it is being mitigated through the implementation of VI mitigation systems. At this time and based on modeling results conducted for the FS, COCs are not and should not discharge to surface water at concentrations that exceed the PCULs. Alternatives 2, 3, and 4 potentially could achieve cleanup goals faster for select media and groundwater intervals through the use of active remedial technologies, and have accordingly higher short term risks and implementation challenges associated with but not limited to engineering, accessing non-PLP properties, permitting, construction, and long term monitoring.. All of the considered alternatives will require more than a decade to achieve PCULs and the RAOs.

The Revised Preliminary Cleanup Standards Memorandum dated September 12, 2014 summarized potential exposure pathways at the various facilities and off-property. The analysis indicated that the completed pathways of concern at SU2 for the FS included:

[12] The weightings in Table 3 are commonly applied in DCA analyses. However, there is no Ecology guidance on assigning benefit scores, and other methods for fulfilling the MTCA DCA requirements are commonly used.

- Direct contact with soil associated with temporary construction workers performing subsurface work. Direct contact with groundwater was not considered a complete pathway based on the average depth of groundwater being below most routine construction work for utilities in the area and that per the criteria discussed herein, groundwater is not an existing or future potable drinking water source.
- Inhalation via the vapor intrusion pathway where COCs in the water table groundwater interval posed this risk, and to a lesser degree where COCs in soil exceeded the PCULs at the CI or BDC facilities.

To summarize the protectiveness of alternatives for each pathway:

- Direct Contact – All of the alternatives are equally protective of direct contact with soil. Application of ISCO under Alternatives 1 and 3A ranks slightly higher due to this technology being completely in-situ with no exposure of the affected soil during implementing the technology.
- Inhalation – Alternatives 2A/2B and 3A/3B rank higher for protectiveness of the water table groundwater interval to air pathway. Alternative 4 with its application of SVE and AS at CI Plant 4 ranks higher for protectiveness associated with the soil to air pathway.

Although incomplete, the groundwater to surface water and sediment pathways could represent a potential future protectiveness concern should the current PCULs be adjusted downward prior to approval of the CAP. Alternatives 2A/2B and 3A/3B are more protective of this pathway since they include active remediation technologies downgradient of the source areas that would mitigate COCs from affecting surface water and sediments.

Based on these factors, the alternatives are assigned the following scores:

- Alternative 1: 7
- Alternative 2A: 8
- Alternative 2B: 8
- Alternative 3A: 8
- Alternative 3B: 8
- Alternative 4: 7

6.2 PERMANENCE

Permanence criteria considers the degree to which the alternative permanently reduces the toxicity, mobility or mass of hazardous substances. This includes consideration of the effectiveness of the alternative in destroying the hazardous substances, the reduction of source areas, and the potential for reversibility of the contaminant reductions. The destruction of the contaminants is a key differentiator from the evaluation of effectiveness (Section 7.3).

The selected alternatives all focus on the permanent, irreversible destruction of HVOCs. Source area cleanup actions have already been conducted at the BDC and Stericycle facilities, and to a limited extent, CI Plant 2 following the 2004 fire. Remediation of the source(s) of COCs in soil are also included for CI Plant 4 in all alternatives. Alternatives including plume cutoff/treatment features reduce the mobility of contaminants, though the overall impact of this reduction in mobility is tempered by the transit time and persistence of contaminants between features.

Within the overall groundwater plume, there is no significant difference between the applied groundwater remedies for permanence. Alternatives 1 and 4 primarily destroy contaminants through naturally occurring degradation processes while Alternatives 2 and 3 either enhance or supplement those processes. There are differences in the rate at which the destruction occurs, but little difference in the permanence.

In Plant 4, several types of remedial technologies are considered. Excavation removes contaminant mass for off-site disposal but does not explicitly destroy the contaminants[13]. AS/SVE has partial capture through granular activated carbon treatment of exhaust gases (or other treatment method, if adopted), but some of the VOCs would be likely to be discharged to atmosphere, and capture in activated carbon would not constitute destruction of the COCs. ISCO and ISCR would directly chemically degrade the contaminants in place with few, if any, intermediate degradation compounds as would be generated during biodegradation. Therefore, Alternatives incorporating ISCO in Plant 4 would rank slightly higher than those incorporating AS/SVE, which would rank higher than excavation.

Based on these factors, the alternatives are assigned the following scores:

- Alternative 1: 8
- Alternative 2A: 9
- Alterative 2B: 9
- Alternative 3Aa: 9
- Alternative 3B: 9
- Alternative 4: 7

6.3 LONG-TERM EFFECTIVENESS

The long-term effectiveness criteria considers the certainty that the alternative will be successful, the reliability of the alternative until PCULs are met, the magnitude of residual risk at alternative completion, and the effectiveness of controls required to manage material left in place. MTCA regulations specify a preference for cleanup action components in descending order of: reuse/recycling, destruction or detoxification, immobilization/solidification, off-site disposal in an engineered facility, on site isolation or containment with attending engineering controls, and institutional controls and monitoring. This does not consider the time required to meet this objective.

Alternatives are similar in their long-term effectiveness. All of the MTCA considered actions are included in the presented alternatives with the exception of reuse, which is not feasible for the released HVOCs. Only small amounts of vadose zone material with low concentrations of COCs will be left in place at the respective source areas where infrastructure and/or site use makes removal infeasible. Alternative 2A/2B includes excava-

[13] Soil concentrations are not high enough to require thermal destruction at an approved facility.

tion components in source areas, and Alternative 4 include SVE removal to a carbon filter media that will be similarly discarded, and are therefore slightly less preferred in the MTCA ranking of cleanup action preference.

The effectiveness of the proposed groundwater plume remedies is based on models incorporating estimated source decay rates, estimated biodegradation rates from literature values, and estimated groundwater transport and flushing times. While these parameters have generally been selected to be conservative, there is uncertainty in the predictive power of the methods. This uncertainty mostly relates to the rate at which RAOs will be achieved rather than if the mechanism is likely to effectively reduce groundwater concentrations. Implementation of more aggressive treatment is expected to increase the rate at which degradation occurs, but empirical evidence supports natural degradation throughout SU2 leading to effective destruction of contaminants. Alternatives 2B and 3B include additional treatment further down gradient, which could be more effective if concentrations in downgradient areas increased to above applicable remediation levels. However, downgradient areas do not exceed applicable remediation levels, so Alternatives 2B and 3B are not currently more effective.

The Alternatives vary in their effectiveness for addressing soil. The physical and regulatory institutional controls for residual soil are expected to effectively prevent direct contact, restrict infiltration, and meet RAOs, and there is little difference between the Alternatives. In Plant 4, Alternatives that incorporate ISCO are expected to be the most effective relative to excavation or AS/SVE. Excavation will be difficult to implement in the capillary zone and has significant access restrictions within the site constraints. AS/SVE will potentially be able to influence a larger volume of soil, but is highly susceptible to flow channelization along preferential flow pathways as well as being difficult to implement due to the need for substantial horizontal trenching in the active faciltity. AS/SVE flow channelization reduces the effectiveness of the remedial technology.

Based on these factors, the alternatives are assigned the following scores:

- Alternative 1: 6
- Alternative 2A: 7
- Alternative 2B: 8
- Alternative 3A: 8
- Alternative 3B: 8
- Alternative 4: 7

6.4 MANAGEMENT OF SHORT-TERM RISKS

The management of short-term risks criteria considers the risk to human health and the environment during construction and implementation, and the effectiveness of the measures that will be taken to manage such risks. For the considered alternatives, this includes interim VI mitigation, and risks associated with construction of active measures. Because the site conditions are currently protective of discharge to the Duwamish Waterway and the same VI mitigation plan will be implemented across all alternatives (Farallon 2015a), the primary distinction between alternatives is based on the risks associated with construction implementation. Alternative 1 has the smallest amount of construction, and therefore the least amount of short term risk. Alternatives 2A/2B and 3A/3B have similar implementation logistics, and similar short-term risk profiles for the groundwater cleanup technologies. However, the soil excavation component included in Alternative 2A/2B represents greater short-term risk due to potential impacts to the building, utilities, and adjacent properties. Alternative 4 also includes more aggressive intrusive subsurface excavation work associated with AS/SVE installation. The need for drilling and extensive horizontal trenching in the plant and to the south proximate to the water, natural gas, sanitary sewer, and stormwater utilities , has a higher risk level relative to Alternatives 1 and 3 that include ISCO.

Based on these factors, the alternatives are assigned the following scores:

- Alternative 1: 8
- Alternative 2A: 6
- Alternative 2B: 6
- Alternative 3A: 7
- Alternative 3B: 7
- Alternative 4: 6

6.5 TECHNICAL AND ADMINISTRATIVE IMPLEMENTABILITY

The implementability criteria considers the relative difficulty and uncertainty of implementing the cleanup actions. Factors considered in this evaluation include: use of innovative vs. mature technologies, the feasibility of implementing the technologies in the site conditions, and potential regulatory or permitting issues. All of the selected alternatives adopt mature technologies that can be implemented. The implementation can occur in areas that are either on public right of ways, or in facility boundaries should third party access be denied.

All of the proposed Alternatives are implementable. The primary distinction between the alternatives is the implementation-phase level of effort, and extent to which implementation requires access to third-party properties. Alternative 2A/2B is ranked lowest due to the excavation component at CI Plant 4, which is anticipated to have the highest level of effort to accommodate implementing the technology. However, if Alternative 2A/2B was selected based on the merits of EAB application for groundwater, ISCO would replace excavation at CI Plant 4 during the CAP.

Similarly, implementing AS/SVE under Alternative 4 has a relatively higher degree of effort both with engineering, construction, permitting, long-term operations/maintenance requirements, and with decommissioning of the system components once RAOs are achieved. Alternatives 2A and 3A are more implementable than Alternative 2B and 3B due to the significant challenges of working along a major arterial in the Downgradient Line 2 areas along First Avenue and the access requirements to work in front of active businesses for extended periods. Injecting EAB or ISCO agents at the depths required also pose challenges that rank Alternatives 2B and 3B higher than other alternatives.

Based on these factors, the alternatives are assigned the following scores:

- Alternative 1: 9
- Alternative 2A: 7

- Alternative 2B: 7
- Alternative 3A: 7
- Alternative 3B: 6
- Alternative 4: 7

6.6 PUBLIC CONCERNS

The SU2 PLPs anticipate receiving comments on the FS and eventual CAP. These comments will be reviewed and addressed upon receipt and may include revision of remedial alternative elements or alternative rankings. All alternatives have similar consideration of public concerns at this point because public comments have not been received on the remedial alternatives.

The alternatives are assigned the following scores:

- Alternative 1: 9
- Alternative 2A: 9
- Alternative 2B: 9
- Alternative 3A: 9
- Alternative 3B: 9
- Alternative 4: 9

6.7 COST

Cost is not given a weighting factor in the MTCA benefit score, but is instead weighed against the benefit score in a cost to benefit ratio for each alternative. The estimated cost for implementation of the alternatives, rounded to the nearest ten thousand dollars, are (Table 3):

- Alternative 1: $2,130,000
- Alternative 2A: $5,240,000
- Alternative 2B: $8,110,000
- Alternative 3A: $7,020,000
- Alternative 3B: $11,130,000
- Alternative 4: $2,780,000

Details supporting the cost estimate for each alternative are included in Appendix B and discussed in each alternative. These costs are inclusive of both the near term active remedial elements, and the long-term monitoring and reporting elements.

6.8 RANKING OF ALTERNATIVES

Alternatives are ranked by their respective cost to benefit ratios (Table 3). Cost to benefit ratios are calculated as the costs divided by 100,000 and then divided by the weighted benefit scores. Cost benefit ratios are also presented graphically in Figure 5. The cost to benefit ratio for the alternatives are:

- Alternative 1: 2.8
- Alternative 2A: 6.7
- Alternative 2B: 10.1
- Alternative 3A: 8.7
- Alternative 3B: 13.9
- Alternative 4: 3.9

Alternative 1 is the preferred remedy based on the DCA ranking of alternatives.

7.0 CONTINGENCY ACTIONS

All alternatives recognize the possibility of conditions arising that would require application of a contingency action. A contingency action would be necessary to protect human or ecologic receptors if an unexpected condition occurred resulting in the potential for exposure or impending impact to a medium currently unaffected such as surface water, air quality, or sediment. Alternatives that adopt more aggressive treatment through source control and plume treatment are less likely to require contingency action at a future date. Depending on how a contingency action may be triggered, the application of a contingency action may require a relatively rapid response. Therefore, use of technologies that are already evaluated and incorporated in the current remedial alternatives would be preferred for incorporation in a final contingency action.

The following sections describe technologies that may be incorporated as contingency actions, as general scenarios, and then as scaled examples with rough costs per alternative. The discussion of contingency actions is conceptual in that it presents possible responses to contingency scenarios. The CAP and Compliance Monitoring Plan will include specific discussion of contingency actions as they relate to the selected remedial action. The alternative-specific contingency actions and costs are necessarily conceptual at this point, and would be expected to be substantially altered in response to an actual contingency action implementation.

7.1 CONTINGENCY SCENARIOS

Vapor Intrusion

A contingency action could be required if a vapor intrusion hazard is identified through sampling, equipment not achieving adequate mitigation, or construction/utility activities. In these cases existing systems would be modified or standard vapor intrusion mitigation measures would be implemented including but not limited to sub-slab and sub-membrane vapor intrusion mitigation systems.

Surface Water Impacts

A contingency action could be required if monitoring indicated potential impacts to surface water in exceedance of surface water criteria. The selected action would depend on the proximity to the surface water receptor and magnitude of exceedance. If concentrations of COCs were approaching or slightly exceeding the cleanup levels established in the CAP, implementation of chemical and/or biodegradation based technologies to reduce concentrations may be appropriate and would be implemented as for plume interception. If concentrations of COCs are elevated and exceed cleanup levels established in the CAP representing a high risk to human health or the environment, then implementation of hydraulic controls or aggressive mass removal/destruction technologies such as AS/SVE or ISCO may be appropriate. These more aggressive technologies typically have a more intrusive footprint, and implementation would require appropriate access.

Non-HVOC Contaminants

A contingency action could be required if monitoring demonstrates that iron and/or manganese were elevated as a result of releases at SU2 source areas, and were impacting surface water (i.e. not due to background concentrations or changes). Note that reducing conditions generated by EAB, or ISCR may locally elevate downgradient metals concentrations and should not automatically trigger a contingency action. Remedial measures would likely include a chemical treatment to precipitate or adsorb and stabilize the metals through modulation of the oxidation-reduction potential, pH, or addition of a catalyst. While metals have not been a focus of SU2 remediation, metals issues have been extensively considered for SU1 metals COCs, and that work would provide a strong foundation for evaluating metals exceedances in SU2 (Aspect, 2016).

Persistent Source or Plume

A contingency action could be required if monitoring demonstrates that a source area has concentrations that persist above remedial design expectations indicating that remediation time frame objectives will not be met (time frames will be specified in the CAP). This is the most likely need for a contingency action to be encountered. The contingency action would need to dovetail with the existing remedial approach implemented through the CAP, and could either bolster the existing approach or supplement it with an additional technology. For example:

- EAB could be used to bolster an excavation remedy that left residual source material in contact with groundwater;
- AS/SVE could be used for rapid and focused treatment of affected groundwater in source areas;
- EAB or ISCR loading rates could be increased through additional injections at areas where COCs are stable or represent a risk to a receptor;
- ISCO could be applied for rapid and focused elimination of one or more COCs in soil or groundwater in a source area or other high concentration problem location

7.2 ALTERNATIVE SPECIFIC CONTINGENCY COST ESTIMATES

Cost estimates for hypothetical contingency actions are included in each cost-estimate table in Appendix B, and summarized in Table 3. For comparability and costing purposes, all contingencies implement similar groundwater plume treatment. Each contingency cost assumes:

- In-situ chemical reduction (ISCR) as the contingency technology. This technology once injected reacts with COCs faster than EAB and ranks higher for long term effectiveness. ISCR can also be implemented close to the waterway with minimal concern since the ZVI solution is not soluble and is not readily transported further than the injection radius thereby ranking higher than ISCO or EAB for short and long term risk;
- One large in-situ treatment line 250 feet long targeting the interval between 20 and 40 feet bgs for Alternatives 1 and 4 and 100 feet long for Alternatives 2A and 3A. This is assumed to be implemented along First Avenue for targeted protection of surface water.
- One hot spot in situ treatment line 50 feet long targeting the interval between 20 and 40 feet bgs.
- Assessment report and analysis based on existing data to determine the need for contingency action; this assumes no additional data gaps investigation is needed for the decision;
- Data gaps investigation to support design and possible targeted pilot testing;
- Streamlined EDR based on existing information;
- Post-implementation performance status report; and
- Costs for implementation based on the current FS unit costs without any adjustment for offset to a future date (NPV adjustment).

Contingency cost estimates by alternative are:

- Alternative 1: $1,018,000
- Alternative 2A: $637,000
- Alternative 2B: $637,000
- Alternative 3A: $637,000
- Alternative 3B: $637,000
- Alternative 4: $1,053,000

The contingency actions are selected to allow cost estimating, and do not indicate that the W4 parties expect these contingency actions to be triggered in SU2. In practice, no contingency action may be necessary during the remedial action or, if contingency remedial action is needed, the action would likely be in response to a different set of conditions than specified above, requiring a different technology application, a different layout, or some other variation on the contingency approach. Alternatives that implement more aggressive treatments are qualitatively expected to be less likely to require contingency remedial actions.

Contingency remedial action costs are not included in alternative total costs[14], and are not formally included in the DCA because they are not a required evaluation element under MTCA.

[14] For clarity: the 25% contingency included in alternative cost estimates addresses construction cost overruns and related types of unforeseen expenditures or changes in costs between estimating and presumed implementation.

7.3 FINANCIAL ASSURANCE

The W4 parties acknowledge that financial assurance will be required for implementation of the selected remedial alternative, consistent with WAC 173-340-440 (11). Financial assurance is expected to be established concurrent with implementation of the Cleanup Action Plan (CAP), and will include amounts to cover estimated costs for alternative implementation in addition to an amount for possible contingency remedial action.

Financial assurance is not a part of the MTCA DCA process, but may be considered in the alternative selection process by W4 parties as they consider their overall site strategies.

8.0 FEASIBILITY STUDY SUMMARY AND CONCLUSIONS

Alternative 1, which integrates targeted source control, long term monitoring, and natural attenuation is the preferred remedial alternative based on the DCA. All alternatives met MTCA threshold and other requirements including protection and reasonable timeframe requirements. Alternative 1 is the preferred alternative because the alternatives that included active groundwater treatment did not sufficiently expedite cleanup or reduce demonstrated risk to human health and the environment relative to the additional expense, short-term risk, and implementability.

The challenge of using of active remediation technologies to significantly reduce chlorinated solvent plume remediation times is consistent with related analyses documented in the literature (McGuire, 2004; Newell, 2006). At SU2, source areas have been or will be addressed, reducing risk to human health and the environment. Residual groundwater contamination is widespread and extends to multiple groundwater intervals extending to 60 feet below the ground surface. While the modeling method is precise, the results have variable accuracy, should be interpreted using professional judgement, and should not be strictly relied upon for establishing a firm restoration timeframe. However, the modeling results herein are adequate and appropriate to estimate and compare SU2 remediation times, which inform Alternative selection and DCA benefit scoring.

The contingency options tied to Alternative 1 are a tangible response to the modeling uncertainty. Implementing a contingency action would be data driven to address areas that do not meet RAOs. Therefore, the Cleanup Action Plan[15], will include a scheduled evaluation, such as the 5-year review, to assess remediation progress relative to RAOs[16]. This structure allows the W4 Group and Ecology to implement the alternative that the FS process set forth under MTCA (WAC 173-340-360), indicates is the best approach for existing conditions and provides an adaptive approach, if needed. Establishing financial assurances to fund a contingency action provides all parties with a mechanism to ensure protection of human health and the environment.

[15] This would also propagate through Compliance Monitoring Plans and related documents.
[16] This evaluation may also include revised remediation time estimates incorporating the additional monitoring data.

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Table 1. Preliminary Groundwater Cleanup Levels

West of Fourth, Seattle, Washington

Constituent of Concern	Carcinogen or Non-Carcinogen	Preliminary Cleanup Levels (PCULs)											
		Puget Sound Background Concentrations for Metals	Soil Cleanup Level Protective of Direct Contact Pathway (Unrestricted Land Use)[1]	Soil Cleanup Level Protective of Direct Contact Pathway (Industrial Land Use)[1]	Soil Cleanup Level Protective of Air Quality based on Protection of Groundwater as Potable Drinking Water[2]	Soil Cleanup Level Protective of Groundwater Concentrations Protective of Surface Water Quality[3]	Groundwater Cleanup Level Protective of Air Quality Water Table Zone (Unrestricted Land Use)[4]	Groundwater Cleanup Level Protective of Air Quality Water Table Zone (Industrial Land Use)[4]	Groundwater Cleanup Level Protective of Surface Water[5]	Air Cleanup Level Protective of Inhalation Pathway (Unrestricted Land Use)[1]	Air Cleanup Level Protective of Inhalation Pathway (Industrial Land Use)[1]	Surface Water Cleanup Level Protective of Human Health[6]	Surface Water Cleanup Level Protective of Aquatic Life
		(Milligrams/kilogram)					(Micrograms/liter)			(Micrograms/cubic meter)		(Micrograms/liter)	
Tetrachloroethene	Carcinogen	--	476	21,000	0.08	0.44	116	482	29	9.6	40	29	--
Trichloroethene	Carcinogen	--	12	1,750	0.03	0.057	6.9	37	7	0.37	2	7	194 [10]
cis-1,2-Dichloroethene	Non-Carcinogen	--	160	7,000	--	--	--	--	--	--	--	--	--
trans-1,2-Dichloroethene	Non-Carcinogen	--	1,600	70,000	0.59	62	559	1,224	4,000	27.4	60	4,000	--
1,1-Dichloroethene	Non-Carcinogen	--	4,000	175,000	0.055	0.025	538	1,176	3.2	91.4	200	3.2	--
Vinyl chloride	Carcinogen	--	0.67	87.5	0.002	0.010	1.3	12.7	1.6	0.28	2.8	1.6	210 [11]
1,4-Dioxane	Carcinogen	--	10	1,310	0.004	0.32	2,551	25,510	78	0.5	5	78	--
Arsenic	Carcinogen	20	20	87.5	Not Applicable	0.082	Not Applicable	Not Applicable	0.14 / 5 [8]	Not Applicable	Not Applicable	0.14 / 5 [8]	36 [12]
Barium	Non-Carcinogen	--	16,000	700,000	Not Applicable	824	Not Applicable	Not Applicable	--	Not Applicable	Not Applicable	--	--
Cadmium	Non-Carcinogen	1	80	3,500	Not Applicable	1.2	Not Applicable	Not Applicable	8.8	Not Applicable	Not Applicable	--	8.8 [13]
Copper	Non-Carcinogen	36	3,200	140,000	Not Applicable	1.1	Not Applicable	Not Applicable	3.1 [9]	Not Applicable	Not Applicable	--	3.1 [13]
Iron	Non-Carcinogen	58,700	58,700	2,450,000	Not Applicable	--	Not Applicable	Not Applicable	--	Not Applicable	Not Applicable	1,000	--
Manganese	Non-Carcinogen	1,200	11,200	490,000	Not Applicable	--	Not Applicable	Not Applicable	100	Not Applicable	Not Applicable	100	--
Nickel	Non-Carcinogen	48	1,600	70,000	Not Applicable	11	Not Applicable	Not Applicable	8.2	Not Applicable	Not Applicable	4,600	8.2 [13]
Zinc	Non-Carcinogen	85	24,000	1,050,000	Not Applicable	101	Not Applicable	Not Applicable	81	Not Applicable	Not Applicable	26,000	81 [13]

NOTES:

Preliminary cleanup levels presented represent the most stringent cleanup levels for the constituent of concern listed in the media indicated.

-- indicates no value is available. In the case of ARARs, the reference sources do not publish values for the noted chemicals. In the case of calculated values, one or more input parameters are not available.

"Not Applicable" is used where the constituent of concern will not affect the media of potential concern due to an incomplete pathway.

[1] Cleanup level is based on standard Washington State Model Toxics Control Act Cleanup Regulation (MTCA) Method B (unrestricted land use) or Method C (industrial land use) values from the Cleanup and Risk Calculations tables (CLARC).

[2] Soil cleanup levels for protection of air quality are calculated using MTCA Equation 747-1 where the potable Method B groundwater cleanup level was used as Cw. Concentrations of hazardous substances in soil that meet the potable groundwater protection standard currently are considered sufficiently protective of the air pathway for unrestricted and industrial land uses.

[3] Soil cleanup levels for protection of surface water quality are calculated using MTCA Equation 747-1 where the groundwater cleanup level protective of surface water in this table was used as Cw.

[4] Groundwater cleanup levels protective of the air pathway for unrestricted land use (residential and commercial sites) and industrial land use were derived using the following equation: Gwcul = Aircul/GIVF.

[5] Human health and marine aquatic ecologic receptors were considered. Refer to the Surface Water Cleanup Levels Protective of Human Health and Aquatic Life. The more stringent value of the two receptors has been listed for the Groundwater Cleanup Level Protective of Surface Water.

[6] The most stringent exposure pathway for human health receptors are for consumption of fish. Listed values are based on ARARs listed in CLARC with one exception. 1,4-dioxane is derived from MTCA Method B default values

[8] Arsenic Cleanup level of 5 ug/L based on background concentrations for state of Washington (MTCA Table 720-1).

[9] The surface water cleanup level for copper had previously been tabulated as 2.4ug/L; however this value is based on an approach using site-specific water effects ratio which has not been determined. We have replaced this with 3.1 ug/L, National Recommended Water Quality Criteria published by EPA under 304 of the Federal Clean Water Act - Aquatic Life Criteria Table.

[10] Oak Ridge Nation Laboratory (ORNL) Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Aquatic Biota

[11] Peer Review Literature - DeRooij et al., 2004, *Euro Chlor Risk Assessment for the Marine Environment OSPARCOM Region – North Sea – Environmental Monitoring and Assessment*

[12] WAC- 173-201A-240

[13] National Recommended Water Quality Criteria published by EPA under 304 of the Federal Clean Water Act - Aquatic Life Criteria Table

Table updated August 14, 2015 based on revisions to AWQC and July 20, 2016 based on Ecology comments on the Draft FS Reports for SU1 and SU2 (clarify footnotes, add sediment values, add surface water CULs protective of aquatic life).

Table 2. Summary of Remedial Alternatives
West of Fourth, Site Unit 2, Seattle, Washington

Target Interval	Target Media	Target Constituents of Concern	Remedial Technology Group	Remedial Technologies	Alternative 1	Alternative 2a	Alternative 2b	Alternative 3a	Alternative 3b	Alternative 4
Blaser Die Casting Source Area										
Vadose Zone/Water Table	Soil/Groundwater/Air	TCE and Vinyl Chloride	Mitigation	Capping	Protection from Direct Contact					
				Institutional Controls	Protection from Direct Contact, Ingestion of Groundwater, and/or Inhalation of Vapor					
				Sub-Slab and Sub-Membrane Depressurization	Protection from Vapor Intrusion					
			In Situ	Monitored Natural Attenuation[1]	Compliance Monitoring of Affected Media					
				In-Situ Chemical Reduction	--	--	--	Treatment of Groundwater	Treatment of Groundwater	--
				Enhanced Anaerobic Biodegradation	--	Treatment of Groundwater	Treatment of Groundwater	--	--	--
				In-Situ Chemical Oxidation	--	--	--	--	--	--
			Ex Situ	Excavation & Off-Site Disposal	Completed as Interim Action					
Shallow	Groundwater	TCE and Vinyl Chloride	In Situ	Monitored Natural Attenuation[1]	Compliance Monitoring of Affected Media					
				In-Situ Chemical Reduction	--	--	--	Treatment of Groundwater	Treatment of Groundwater	--
				Enhanced Anaerobic Biodegradation	--	Treatment of Groundwater	Treatment of Groundwater	--	--	--
Intermediate	Groundwater	Vinyl Chloride	In Situ	Monitored Natural Attenuation[1]	Compliance Monitoring of Affected Media					
				In-Situ Chemical Reduction						
				Enhanced Anaerobic Biodegradation						
Capital Industries Plant 2 Source Area										
Vadose Zone/Water Table	Soil and Groundwater	TCE and Vinyl Chloride	Mitigation	Capping	Protection from Direct Contact					
				Institutional Controls	Protection from Direct Contact, Ingestion of Groundwater, and/or Inhalation of Vapor					
				Sub-Slab and Sub-Membrane Depressurization	--					
			In Situ	Monitored Natural Attenuation[1]	Compliance Monitoring of Affected Media					
				In-Situ Chemical Reduction	--	--	--	Treatment of Groundwater	Treatment of Groundwater	--
				Enhanced Anaerobic Biodegradation	--	Treatment of Groundwater	Treatment of Groundwater	--	--	--
				Air Sparge / Soil Vapor Extraction	--	--	--	--	--	--
				In-Situ Chemical Oxidation	--	--	--	--	--	--
			Ex Situ	Excavation & Off-Site Disposal	--	--	--	--	--	--
Shallow	Groundwater	TCE and Vinyl Chloride	In Situ	Monitored Natural Attenuation[1]	Compliance Monitoring of Affected Media					
				In-Situ Chemical Reduction	--	--	--	Treatment of Groundwater	Treatment of Groundwater	--
				Enhanced Anaerobic Biodegradation	--	Treatment of Groundwater	Treatment of Groundwater	--	--	--
Intermediate	Groundwater	Vinyl Chloride	In Situ	Monitored Natural Attenuation[1]	Compliance Monitoring of Affected Media					
Capital Industries Plant 4 Source Area										
Vadose Zone/Water Table	Soil/Groundwater/Air	PCE and TCE	Mitigation	Capping	Protection from Direct Contact					
				Institutional Controls	Protection from Direct Contact, Ingestion of Groundwater, and/or Inhalation of Vapor					
				Sub-Slab and Sub-Membrane Depressurization	Protection from Vapor Intrusion					
			In Situ	Monitored Natural Attenuation[1]	Compliance Monitoring of Affected Media					
				In-Situ Chemical Reduction	--	--	--	Treatment of Groundwater	Treatment of Groundwater	--
				Enhanced Anaerobic Biodegradation	--	Treatment of Groundwater	Treatment of Groundwater	--	--	--
				Air Sparge / Soil Vapor Extraction	--	--	--	--	--	Treatment of Soil and Groundwater/Vapor Intrusion Mitigation
				In-Situ Chemical Oxidation	Treatment of Soil	Treatment of Soil	--	Treatment of Soil	Treatment of Soil	--
			Ex Situ	Excavation & Off-Site Disposal	--	--	Treatment of Soil	--	--	--
Shallow	Groundwater	Vinyl Chloride	In Situ	Monitored Natural Attenuation[1]	Compliance Monitoring of Affected Media					
				In-Situ Chemical Reduction	--	--	--	--	--	--
				Enhanced Anaerobic Biodegradation	--	--	--	--	--	--
Intermediate	Groundwater	Vinyl Chloride	In Situ	Monitored Natural Attenuation[1]	Compliance Monitoring of Affected Media					
Blaser Die Casting/Capital Industries/Stericycle Down-Gradient Area										
Vadose Zone/Water Table	Groundwater/Air	TCE and Vinyl Chloride	Mitigation	Capping	Protection from Direct Contact					
				Institutional Controls	Protection from Direct Contact, Ingestion of Groundwater, and/or Inhalation of Vapor					
				Sub-Slab and Sub-Membrane Depressurization	Protection from Vapor Intrusion					
			In Situ	Monitored Natural Attenuation[1]	Compliance Monitoring of Affected Media					
				In-Situ Chemical Reduction	--	--	--	Treatment of Groundwater at Select Areas	Treatment of Groundwater at Select Areas (expanded)	--
				Enhanced Anaerobic Biodegradation	--	Treatment of Groundwater at Select Areas	Treatment of Groundwater at Select Areas (expanded)	--	--	--
Shallow	Groundwater	TCE and Vinyl Chloride	In Situ	Monitored Natural Attenuation[1]	Compliance Monitoring of Affected Media					
				In-Situ Chemical Reduction	--	--	--	Treatment of Groundwater at Select Areas	Treatment of Groundwater at Select Areas	--
				Enhanced Anaerobic Biodegradation	--	Treatment of Groundwater at Select Areas	Treatment of Groundwater at Select Areas (expanded)	--	--	--
Intermediate	Groundwater	Vinyl Chloride	In Situ	Monitored Natural Attenuation[1] In-Situ Chemical Reduction Enhanced Anaerobic Biodegradation	Compliance Monitoring of Affected Media	Compliance Monitoring of Affected Media	Treatment of Groundwater at Select Areas[3]	Compliance Monitoring of Affected Media	Treatment of Groundwater at Select Areas[3]	Compliance Monitoring of Affected Media
Capital Industries Plant 4 Down-Gradient Area										
Vadose Zone/Water Table	Soil and Groundwater	PCE and TCE	Mitigation	Capping	Protection from Direct Contact					
				Institutional Controls	Protection from Direct Contact, Ingestion of Groundwater, and/or Inhalation of Vapor					
				Sub-Slab and Sub-Membrane Depressurization	--					
			In Situ	Monitored Natural Attenuation[1]	Compliance Monitoring of Affected Media					
				In-Situ Chemical Reduction	--	--	--	--	--	--
				Enhanced Anaerobic Biodegradation	--	--	--	--	--	--
				In-Situ Chemical Oxidation	--	--	--	--	--	--
			Ex Situ	Excavation & Off-Site Disposal	--	--	--	--	--	--
Shallow	Groundwater	Vinyl Chloride	In Situ	Monitored Natural Attenuation[1]	Compliance Monitoring of Affected Media					
				In-Situ Chemical Reduction	--	--	--	--	--	--
				Enhanced Anaerobic Biodegradation	--	--	--	--	--	--
Intermediate	Groundwater	Vinyl Chloride	In Situ	Monitored Natural Attenuation[1]	Compliance Monitoring of Affected Media					
				Summary of Total Costs	**$2,130,000**	**$5,240,000**	**$8,110,000**	**$7,020,000**	**$11,130,000**	**$2,780,000**
				Cost in Millions of Dollars	**$2.1**	**$5.2**	**$8.1**	**$7.0**	**$11.1**	**$2.8**
				Supporting Cost Table	Table B1	Table B2	Table B2	Table B3	Table B3	Table B4

Potential Contingency Remedial Action [2]

Water Table	Groundwater	PCE and TCE	In Situ	In-Situ Chemical Reduction	Treatment of Groundwater at Select Areas					
Shallow	Groundwater	PCE and TCE	In Situ	In-Situ Chemical Reduction	Treatment of Groundwater at Select Areas					
				Summary of Total Costs	**$1,018,000**	**$637,000**	**$637,000**	**$637,000**	**$637,000**	**$1,053,000**
				Cost in Millions of Dollars	**$1.0**	**$0.6**	**$0.6**	**$0.6**	**$0.6**	**$1.1**
				Supporting Cost Table	Table B1	Table B2	Table B2	Table B3	Table B3	Table B4

Notes
-- Dashes indicate action not included for that alternative.
Remedial technologies presented include those presented in the Revised Technology Screening Memorandum dated April 27, 2015. Only those technologies included in the alternatives being considered for the Feasibility Study are presented.
Contingency actions will consist of an active in situ technology applied to protect a receptor at risk.
[1] Monitored natural attenuation is assumed to be a component of all alternatives as either a primary technology or secondary technology following application of another technology listed.
PCE = Tetrachloroethene
TCE = Trichloroethene
Modified from Farallon (2015)
[2] Potential contingency remedial actions would be implemented in the event of remedy failiure in a portion of the site. Values are estimates of a conceptual implementation, and would likely be significantly revised in the event of implementation.
[3] See Figures 3c and 3d and supporting text for details.

Table 3. Disproportionate Cost Analysis and Comparison to MTCA Criteria
West of Fourth, Site Unit 2, Seattle, Washington

		Alternative 1	Alternative 2a	Alternative 2b	Alternative 3a	Alternative 3b	Alternative 4
		NA + Plant 4 ISCO	Enhanced Anaerobic + Plant 4 ISCO	Enhanced Anaerobic + Plant 4 Excavation + Downgradient Line 2	ISCR + Plant 4 ISCO	ISCR + Plant 4 ISCO + Downgradient Line 2	NA + Plant 4 AS/SVE
Weighted Benefits Ranking for Disproportionate Cost Analysis (Score 1-10)							
Weighting	*Criteria*						
30%	Overall Protectiveness	7	8	8	8	8	7
20%	Permanence	8	9	9	9	9	7
20%	Long Term Effectiveness	6	7	8	8	8	7
10%	Management of Short Term Risk	8	6	6	7	7	6
10%	Implementability	9	7	7	7	6	7
10%	Consideration of Public Concerns	9	9	9	9	9	9
MTCA Overall Benefit Score (1-10)	*Row A)*	**7.5**	**7.8**	**8**	**8.1**	**8**	**7.1**
Disproportionate Cost Analysis							
Cost Basis Table (Appendix B)		Table B1	Table B2	*no table*	Table B3	Table B3	Table B4
Estimated Remedy Cost	*Row B)*	$2,130,000	$5,240,000	$8,110,000	$7,020,000	$11,130,000	$2,780,000
Relative Cost/Benefit Ratio (divided by 100,000)	*Row C) = (Row B / 100,000) / Row A*	2.8	6.7	10.1	8.7	13.9	3.9
Estimated Time (Appendix A)		60	40	40	40	40	60
Remedy Permanent to the Maximum Extent Practicable		Yes	Yes	Yes	Yes	Yes	Yes
Meets Remediation Objectives		Yes	Yes	Yes	Yes	Yes	Yes
Estimated Contingency Amount		*$1,018,000*	*$637,000*	*$637,000*	*$637,000*	*$637,000*	*$1,053,000*

Notes:

Costs are rounded to the nearest ten thousand dollars.

Remedial Alternative cost details in Appendix B.

DCA: Disproportionate Cost Analysis

Overall Benefit Score weighting factors are commonly applied factors accepted by Ecology at similar sites. Weighting factors are not an Ecology policy and other benefit approaches are used.

Table 4. Summary of Remediation Times

West of Fourth, Seattle, Washington

Source Area	Aquifer Inverval	BIOCHLOR *(Table 6)*	Flushing *(Table 7a,b)*	SDR - All Data *(Table 7a)*	SDR - 2010+ Data *(Table 7b)*	SDR - 2011+ Data *(Table 7c)*
BD	WT	23	22	22	16	31
BD	SH	51	27	86	432	*-259*
BD	IN	48	69	18 to 47 **	15 to 739 **	47 to *-222* **
C2	WT	20	17	26	24	64
C2	SH	27	33	40	34	30
C2	IN	85	99	9	9	7
C4	WT	35	22	42	116	*-1,166*
C4	SH	40	24	71	71	41
C4	IN	0*	*	*	*	*

Notes:

Source areas

BD SW corner of Blaser Facility

C4 CI Plant 4

C2 Down gradient of Capital Industries Plant 2

Aquifer Intervals

WT Water Table Interval

SH Shallow Interval

IN Intermediate Interval

Values are the time in years to achieve PCULs.

* Location already meets PCULs.

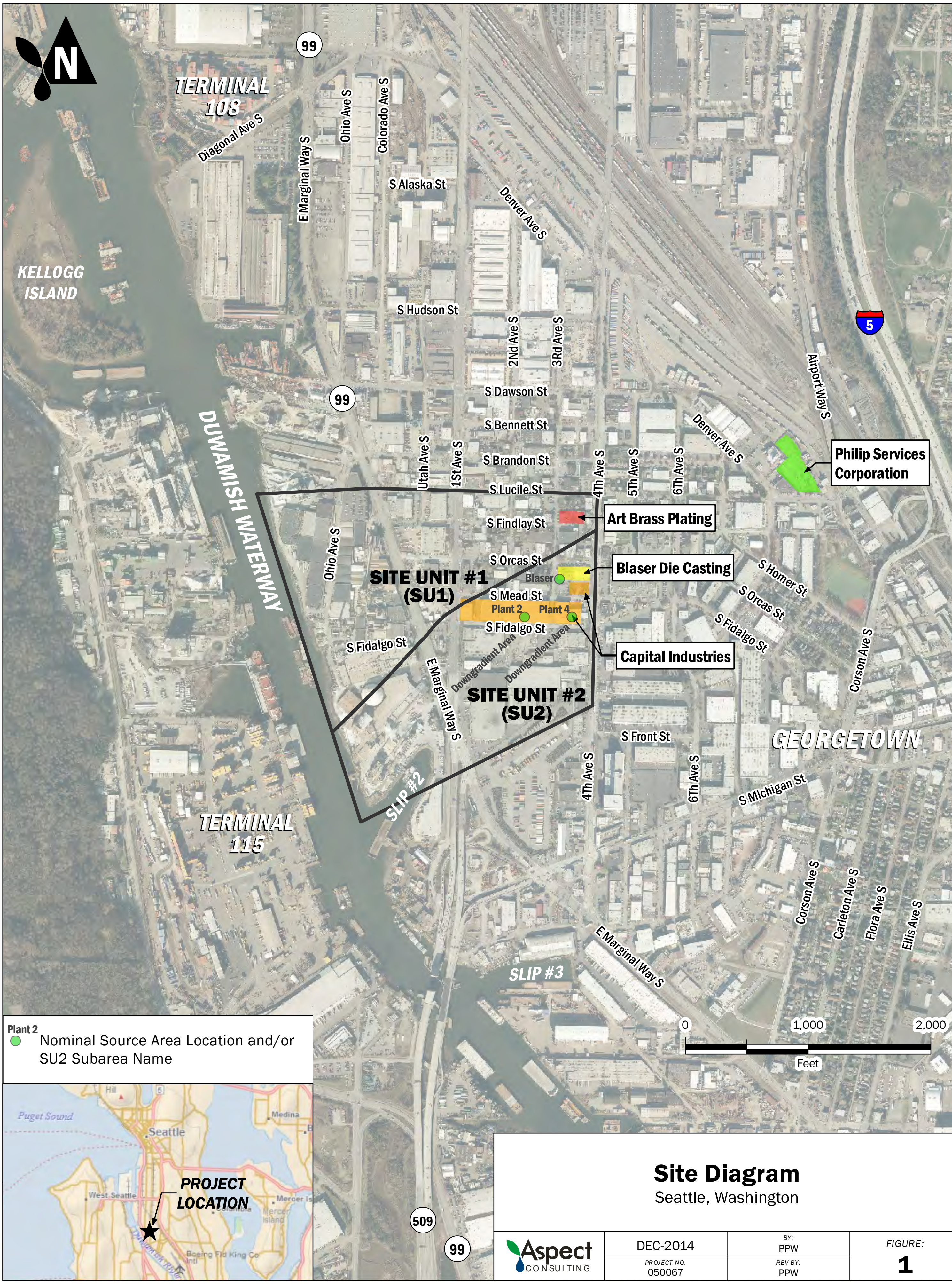
** Range brackets BIOCHLOR maximum-allowed SDR and SDR based on best-fit of available data in given date range.

SDR is the source decay rate based time to achieve PCULs.

Tables referenced in header are in Appendix A.

Negative values in *italics* indicate that the SDR is consistent with an increasing concentration. Negative values are qualitatively associated with poor-quality trend fits in Tables 3a,b,c) and there is low confidence in those SDRs and related estimated remediation times.

SDRs used in calculations for BIOCHLOR and SDR-All Data columns are consistent.



Site Diagram

Seattle, Washington

Aspect CONSULTING	DEC-2014	BY: PPW	FIGURE:
	PROJECT NO. 050067	REV BY: PPW	1

GIS Path: T:\projects_8\Artbrass\FS Working\SC Memo_Revised_Nov2014\Fig 01 Site Diagram.mxd || Coordinate System: NAD83 HARN Washington North || Date Saved: 12/12/2014 || User: pwittman || Print Date: 12/12/2014

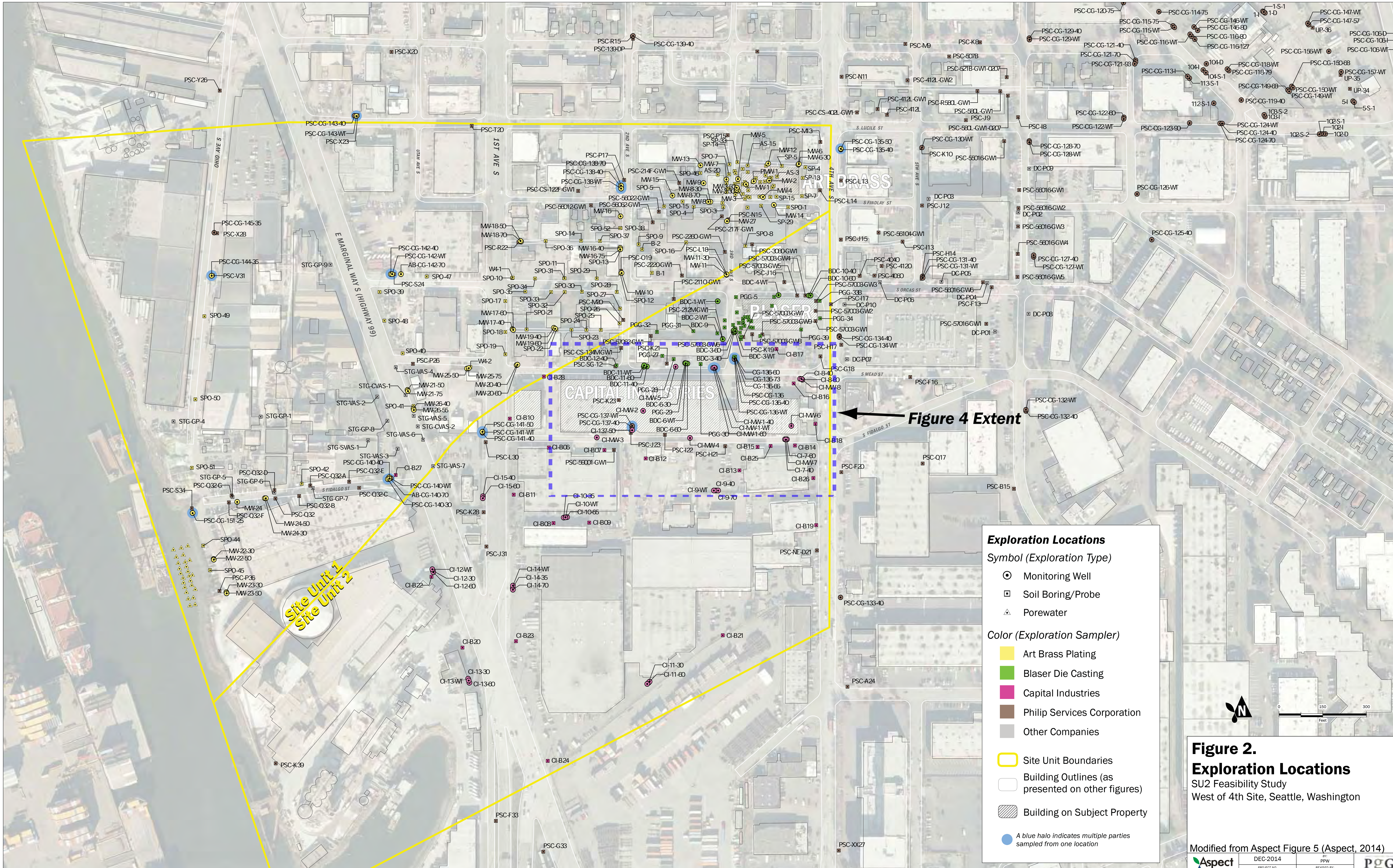
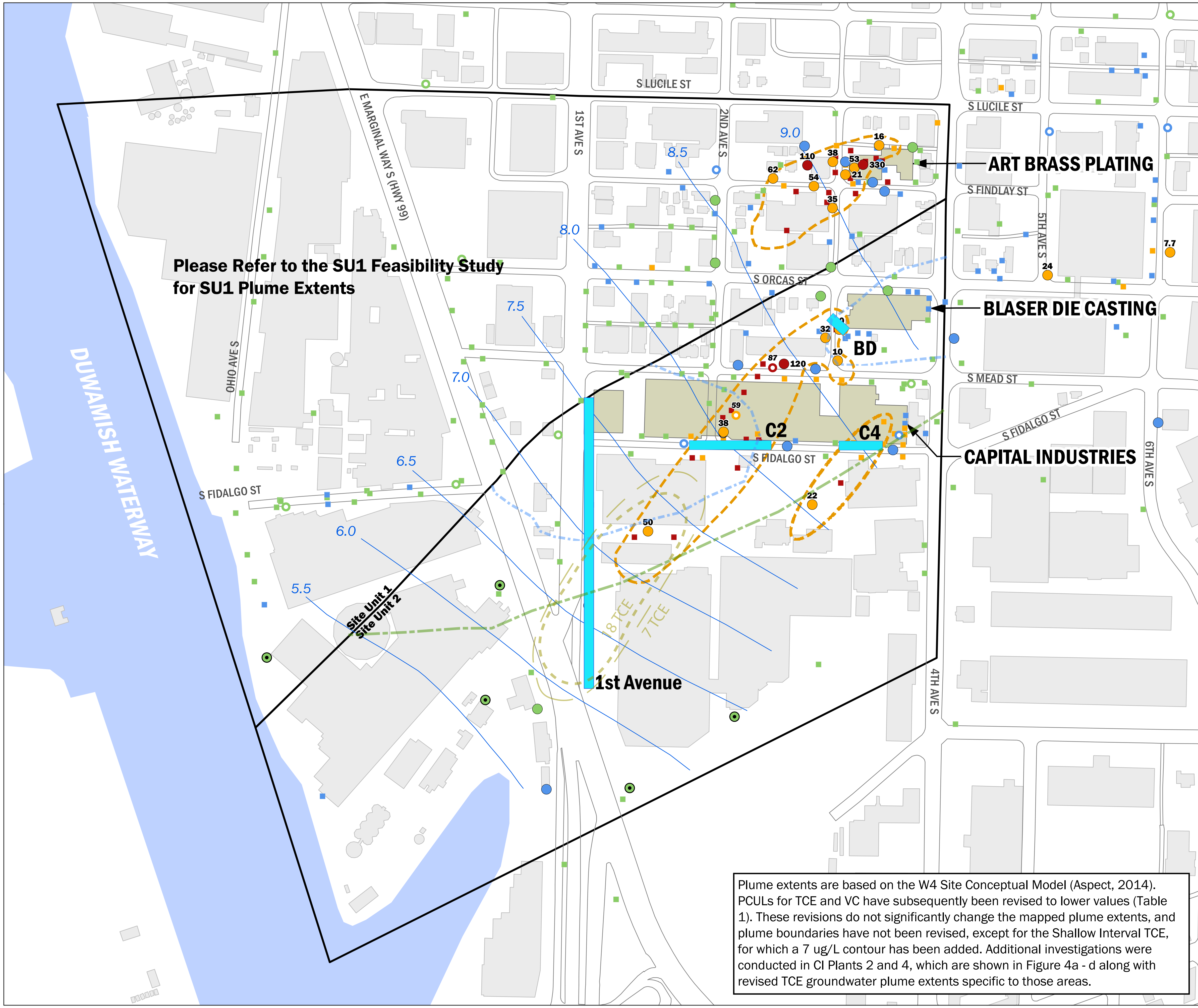


Figure 2.
Exploration Locations
SU2 Feasibility Study
West of 4th Site, Seattle, Washington

Modified from Aspect Figure 5 (Aspect, 2014)



Plume extents are based on the W4 Site Conceptual Model (Aspect, 2014). PCULs for TCE and VC have subsequently been revised to lower values (Table 1). These revisions do not significantly change the mapped plume extents, and plume boundaries have not been revised, except for the Shallow Interval TCE, for which a 7 ug/L contour has been added. Additional investigations were conducted in CI Plants 2 and 4, which are shown in Figure 4a - d along with revised TCE groundwater plume extents specific to those areas.

Figure 3a.
Remedial Alternative Conceptual Source Treatment Areas

SU2 Feasibility Study
West of 4th Site, Seattle, Washington
Modified from Aspect Figure 28.

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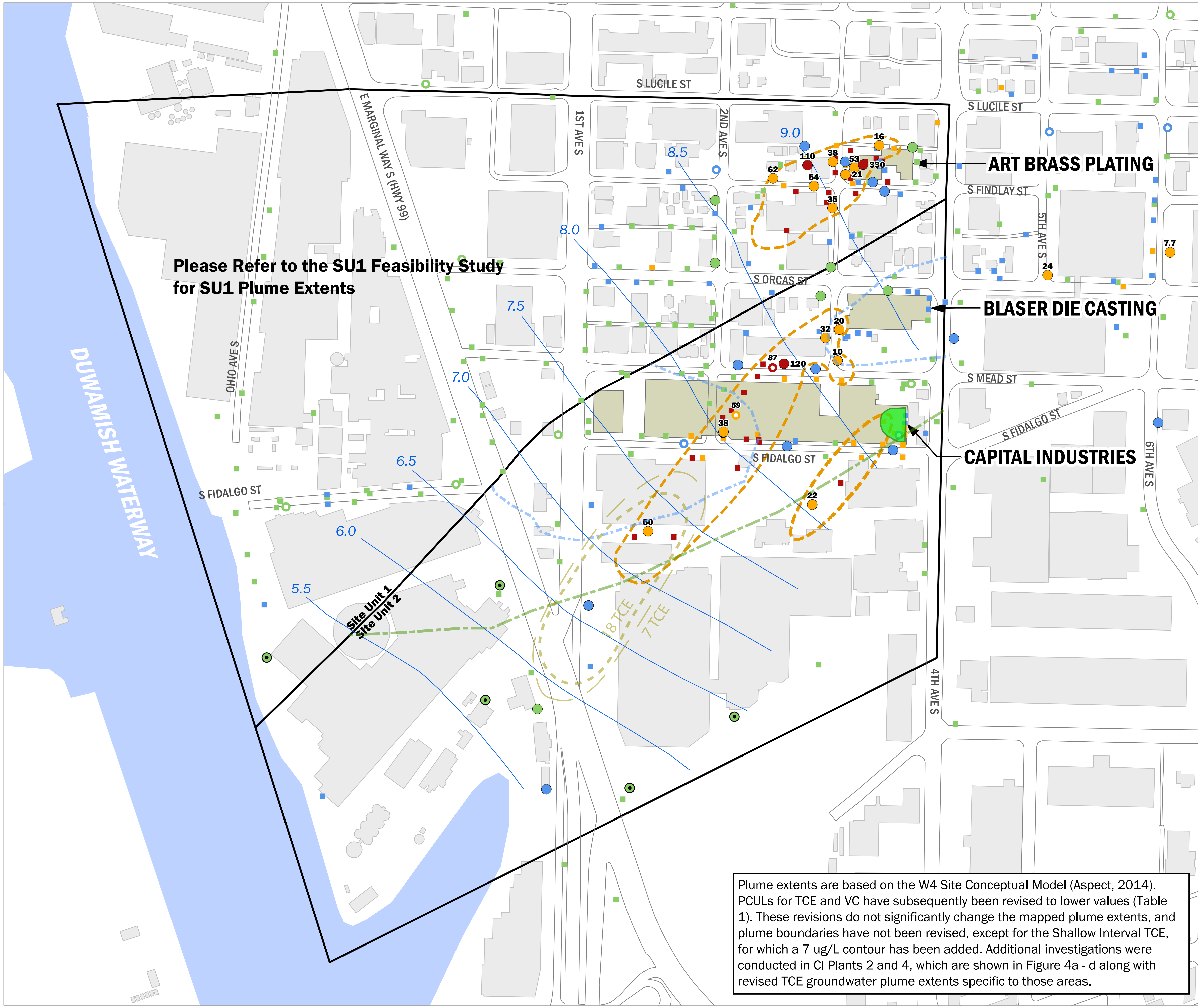

Groundwater Sample Locations:

- Well with data from Q3 2013
- Well with data Q4 2012 or after (but without data from Q3 2013)
- Well with data pre-dating Q4 2012
- Probe sample data* (reflecting the maximum concentration detected in the given interval)
- Well without data for analyte/interval

* Note: Probe data are from 2000 to 2012

WT Interval Sample Location Symbol Color
(based on TCE protective of air 6.9 ug/L):

- Detected at > 10x CUL
- Detected Above CUL
- Detected Below CUL
- Not Detected (Reporting Limit Above CUL)
- Not Detected

Well locations with CUL exceedances are labeled with the exceeding concentration:

10 ← *Trichloroethene (TCE) Concentration (in µg/L)*

- Water Table (WT) TCE Plume Extent at 6.9 ug/L
- Shallow (SH) TCE Plume Extent at 18 and 7 ug/L
- Shallow (SH) VC Plume Extent at 2.4 ug/L
- Intermediate (IN) VC Plume Extent at 2.4 ug/L
- Estimated Area of In-Situ Chemical Oxidant (ISCO) Injection (See Figure 4a)
- 8.0 Half-foot Water Table Groundwater Elevation Contours from August, 2012 Site-Wide Monitoring Event (NAVD88 Vertical Datum)

N

0 300 600
Feet

Plume extents are based on the W4 Site Conceptual Model (Aspect, 2014). PCULs for TCE and VC have subsequently been revised to lower values (Table 1). These revisions do not significantly change the mapped plume extents, and plume boundaries have not been revised, except for the Shallow Interval TCE, for which a 7 ug/L contour has been added. Additional investigations were conducted in CI Plants 2 and 4, which are shown in Figure 4a - d along with revised TCE groundwater plume extents specific to those areas.

Figure 3b.
Alternative 1 Remedial Components
SU2 Feasibility Study
West of 4th Site, Seattle, Washington

Modified from Aspect Figure 28.

Aspect CONSULTING

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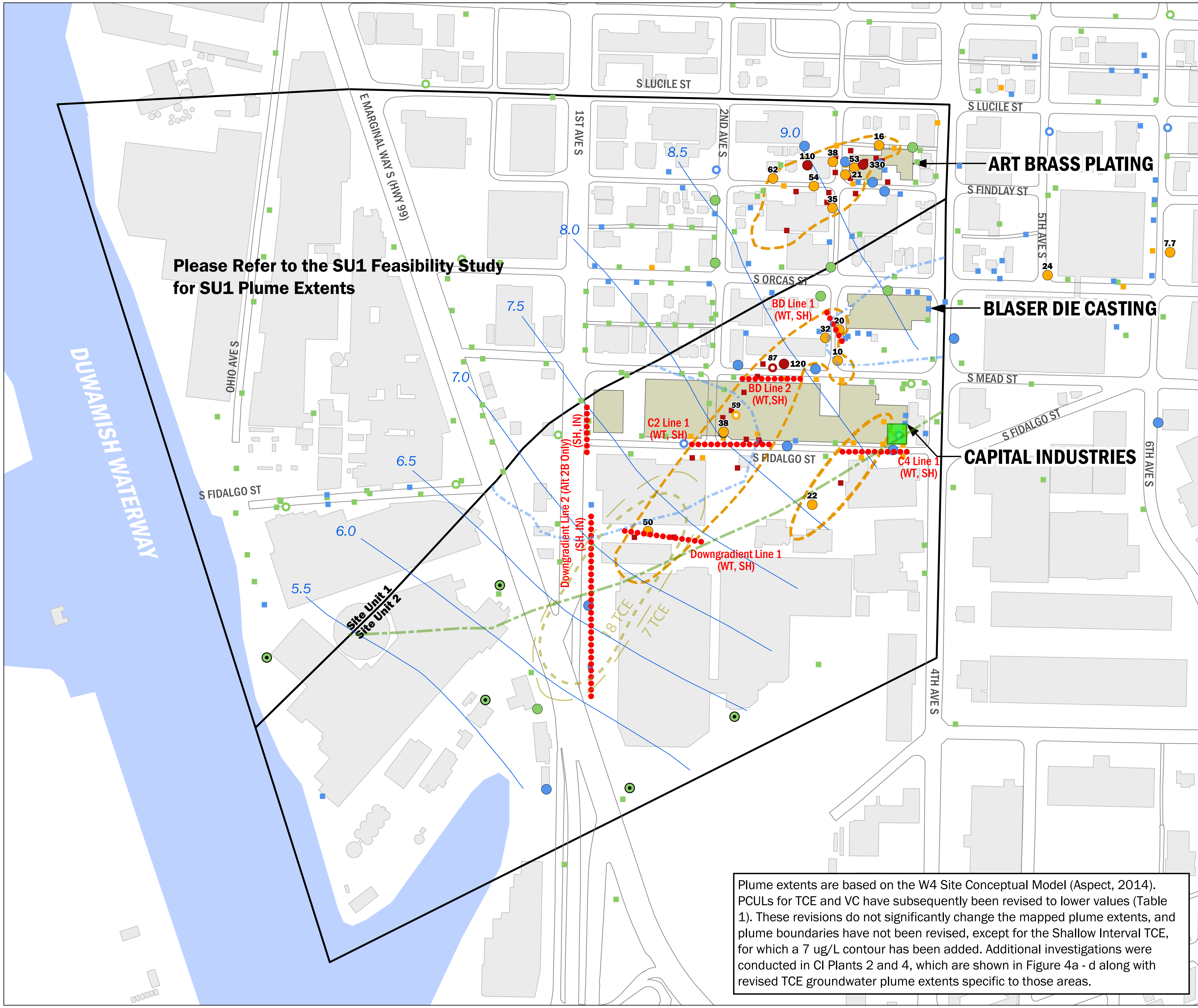

Plume extents are based on the W4 Site Conceptual Model (Aspect, 2014). PCULs for TCE and VC have subsequently been revised to lower values (Table 1). These revisions do not significantly change the mapped plume extents, and plume boundaries have not been revised, except for the Shallow Interval TCE, for which a 7 ug/L contour has been added. Additional investigations were conducted in CI Plants 2 and 4, which are shown in Figure 4a - d along with revised TCE groundwater plume extents specific to those areas.

Groundwater Sample Locations:

- Well with data from Q3 2013
- Well with data Q4 2012 or after (but without data from Q3 2013)
- Well with data pre-dating Q4 2012
- Probe sample data* (reflecting the maximum concentration detected in the given interval)
- Well without data for analyte/interval

** Note: Probe data are from 2000 to 2012*

WT Interval Sample Location Symbol Color (based on TCE protective of air 6.9 ug/L):

- Detected at > 10x CUL
- Detected Above CUL
- Detected Below CUL
- Not Detected (Reporting Limit Above CUL)
- Not Detected

Well locations with CUL exceedances are labeled with the exceeding concentration:

10 ← *Trichloroethene (TCE) Concentration (in µg/L)*

- Water Table (WT) TCE Plume Extent at 6.9 ug/L
- Shallow (SH) TCE Plume Extent at 18 and 7 ug/L
- Shallow (SH) VC Plume Extent at 2.4 ug/L
- Intermediate (IN) VC Plume Extent at 2.4 ug/L
- Estimated Area of Enhanced Anaerobic Biodegradation Injection Alignment. Injections Target WT and SH Intervals Except C4, Which Targets WT Interval. Each dot is a preliminary well or injection location at 20 foot horizontal spacing assuming a 10-15 foot radius of influence.
- Estimated Area of ISCO (Alt. 2A) or Soil Excavation and Off-Site Disposal (Alt. 2B) (See Figure 4b)
- 8.0 Half-foot Water Table Groundwater Elevation Contours from August, 2012 Site-Wide Monitoring Event (NAVD88 Vertical Datum)

N

0 300 600
Feet

Figure 3c.
Alternative 2 Remedial Components
SU2 Feasibility Study
West of 4th Site, Seattle, Washington

Modified from Aspect Figure 28.

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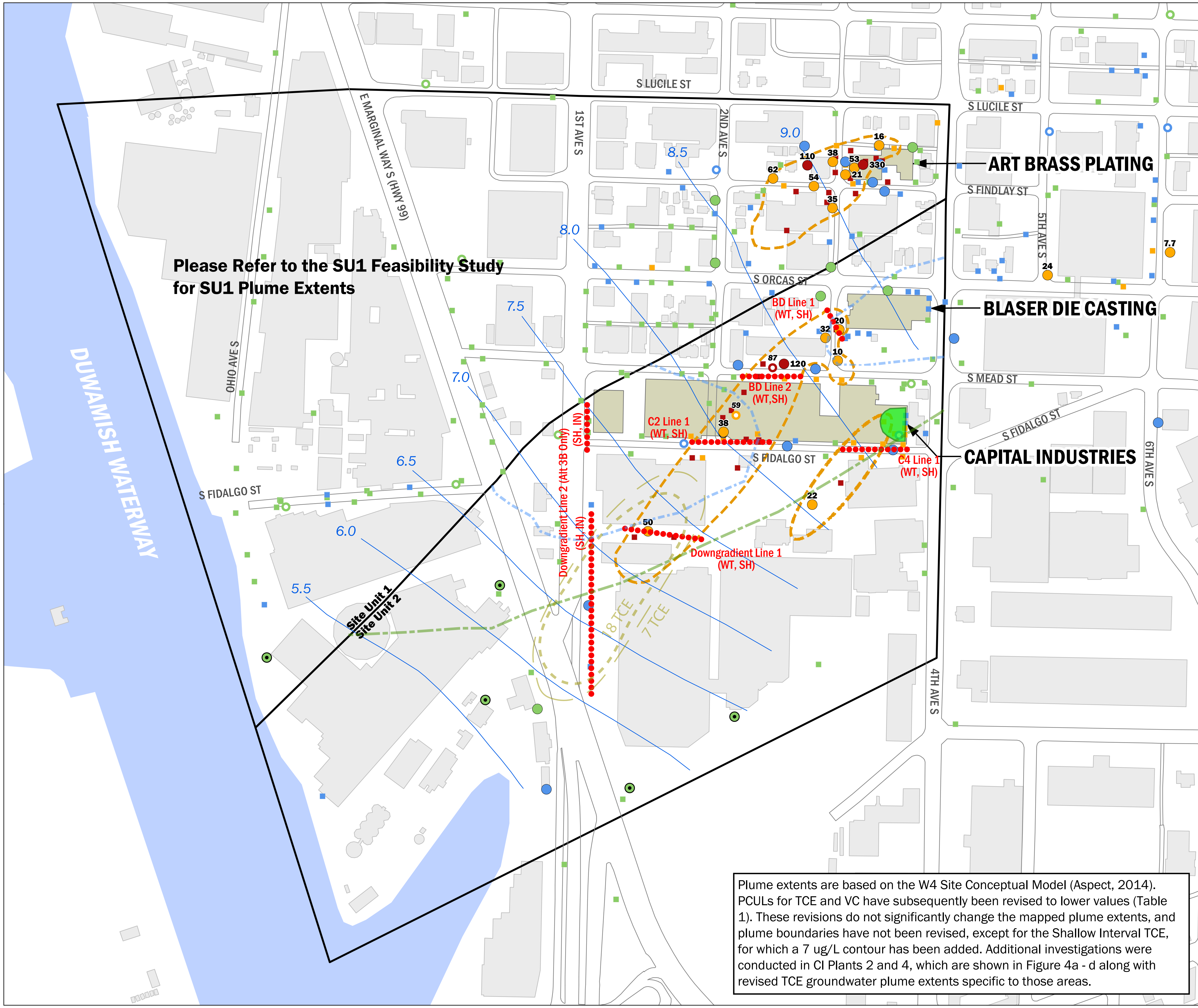

Plume extents are based on the W4 Site Conceptual Model (Aspect, 2014). PCULs for TCE and VC have subsequently been revised to lower values (Table 1). These revisions do not significantly change the mapped plume extents, and plume boundaries have not been revised, except for the Shallow Interval TCE, for which a 7 ug/L contour has been added. Additional investigations were conducted in CI Plants 2 and 4, which are shown in Figure 4a - d along with revised TCE groundwater plume extents specific to those areas.

Groundwater Sample Locations:

- Well with data from Q3 2013
- Well with data Q4 2012 or after (but without data from Q3 2013)
- Well with data pre-dating Q4 2012
- Probe sample data* (reflecting the maximum concentration detected in the given interval)
- Well without data for analyte/interval

** Note: Probe data are from 2000 to 2012*

WT Interval Sample Location Symbol Color (based on TCE protective of air 6.9 ug/L):

- Detected at > 10x CUL
- Detected Above CUL
- Detected Below CUL
- Not Detected (Reporting Limit Above CUL)
- Not Detected

Well locations with CUL exceedances are labeled with the exceeding concentration:

10 — *Trichloroethene (TCE) Concentration (in µg/L)*

- Water Table (WT) TCE Plume Extent at 6.9 ug/L
- Shallow (SH) TCE Plume Extent at 18 and 7 ug/L
- Shallow (SH) VC Plume Extent at 2.4 ug/L
- Intermediate (IN) VC Plume Extent at 2.4 ug/L
- Estimated Area of In-Situ Chemical Oxidant (ISCO) Injection (See Figure 4c)
- Estimated Area of In-Situ Chemical Reduction (ISCR) Alignment. Each dot is a preliminary well or injection location at 20 foot horizontal spacing assuming a 10-15 foot radius of influence.
- 8.0 Half-foot Water Table Groundwater Elevation Contours from August, 2012 Site-Wide Monitoring Event (NAVD88 Vertical Datum)

N

0 300 600
Feet

Figure 3d.
Alternative 3 Remedial Components

SU2 Feasibility Study
West of 4th Site, Seattle, Washington

Modified from Aspect Figure 28.

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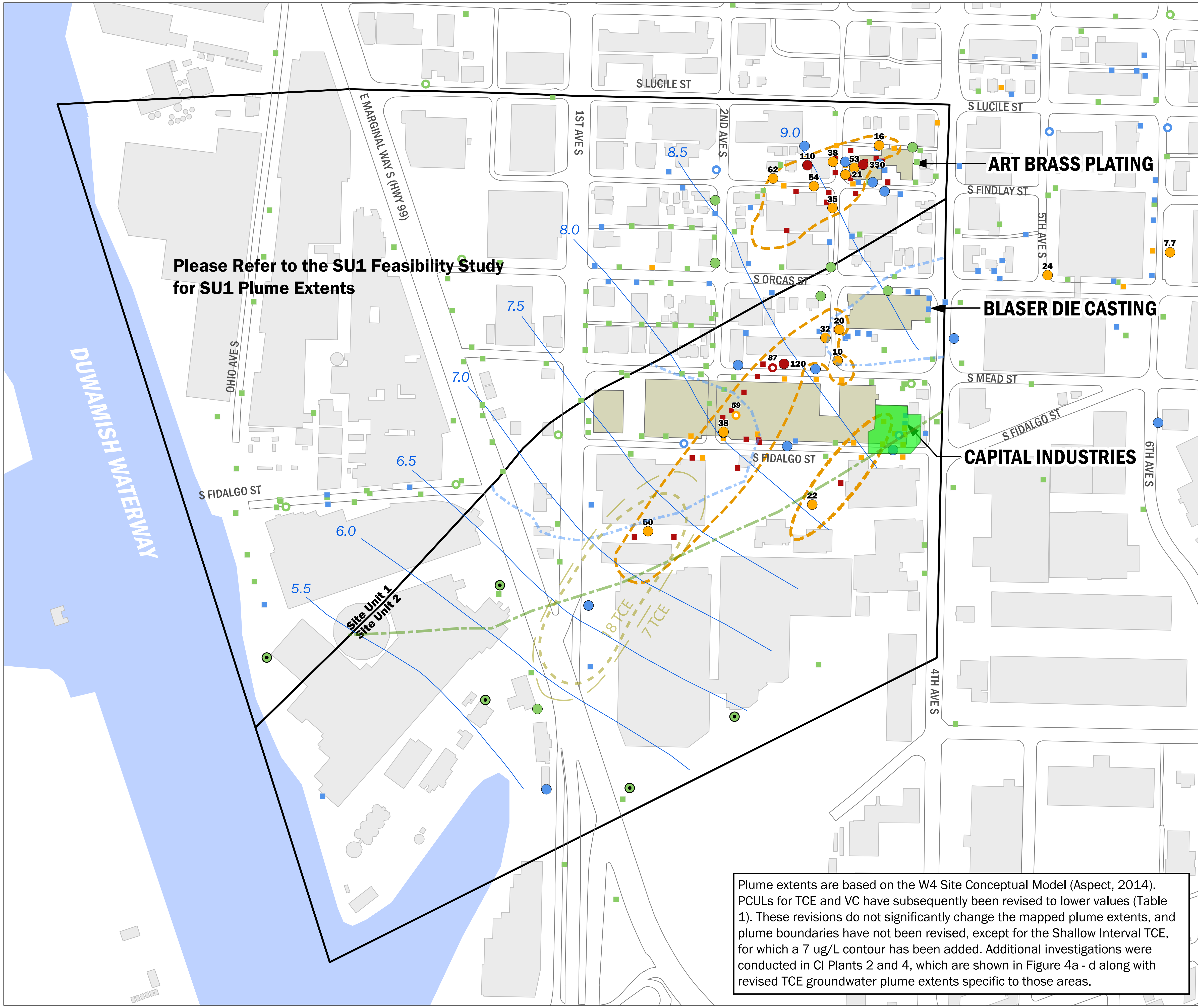

Groundwater Sample Locations:

- Well with data from Q3 2013
- Well with data Q4 2012 or after (but without data from Q3 2013)
- Well with data pre-dating Q4 2012
- Probe sample data* (reflecting the maximum concentration detected in the given interval)
- Well without data for analyte/interval

** Note: Probe data are from 2000 to 2012*

WT Interval Sample Location Symbol Color
(based on TCE protective of air 6.9 ug/L):

- Detected at > 10x CUL
- Detected Above CUL
- Detected Below CUL
- Not Detected (Reporting Limit Above CUL)
- Not Detected

Well locations with CUL exceedances are labeled with the exceeding concentration:

10 ← *Trichloroethene (TCE) Concentration (in µg/L)*

- Water Table (WT) TCE Plume Extent at 6.9 ug/L
- Shallow (SH) TCE Plume Extent at 18 and 7 ug/L
- Shallow (SH) VC Plume Extent at 2.4 ug/L
- Intermediate (IN) VC Plume Extent at 2.4 ug/L

Estimated Area of Air Sparge / Soil Vapor Extraction (AS/SVE) Treatment (See Figure 4d)

8.0 Half-foot Water Table Groundwater Elevation Contours from August, 2012 Site-Wide Monitoring Event (NAVD88 Vertical Datum)

N

0 300 600
Feet

Figure 3e.
Alternative 4 Remedial Components
SU2 Feasibility Study
West of 4th Site, Seattle, Washington

Modified from Aspect Figure 28.

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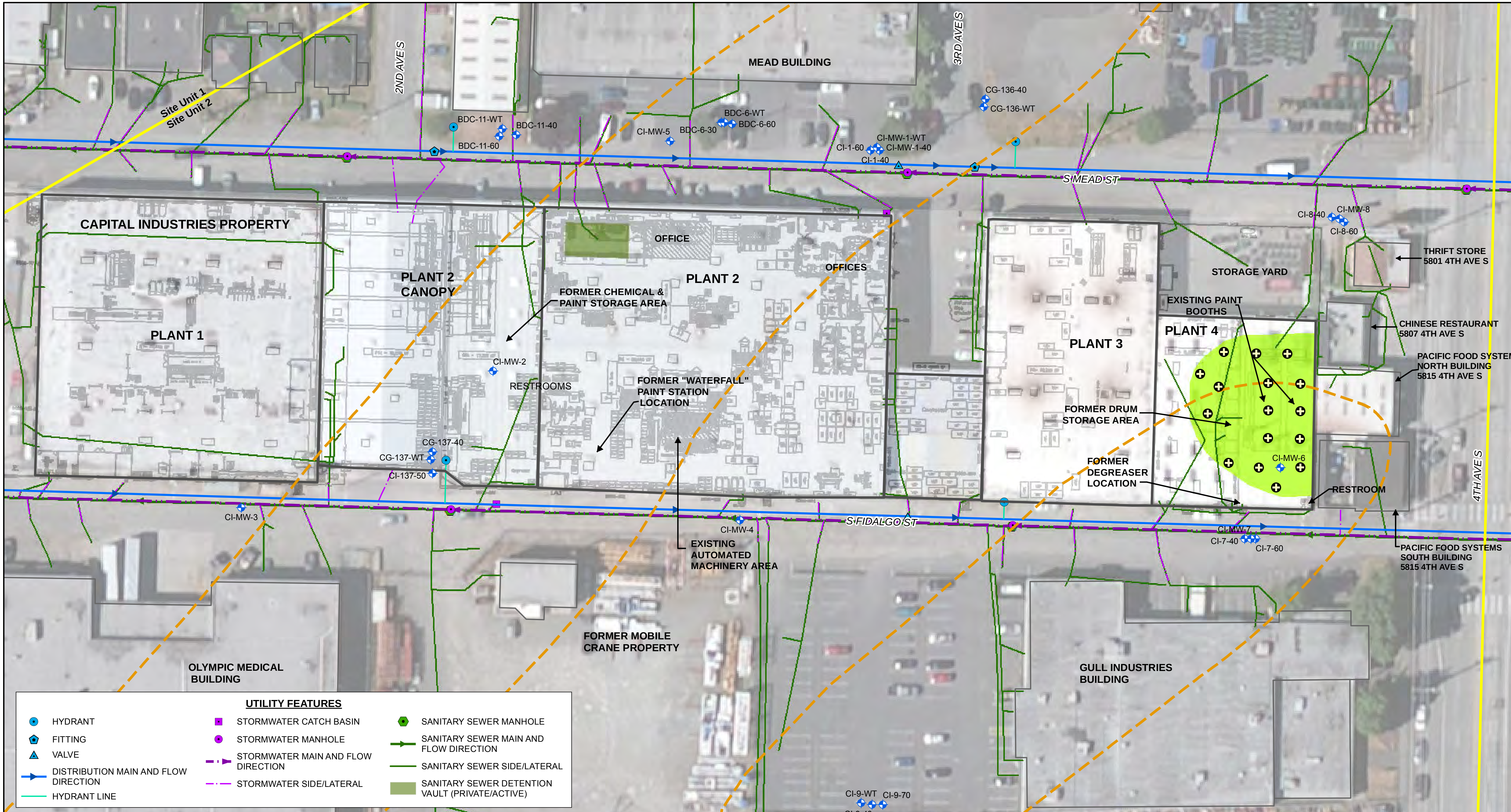

LEGEND

MW-8 EXISTING MONITORING WELL

SITE UNIT BOUNDARY

CAPITAL INDUSTRIES PROPERTY

BUILDINGS

TCE GROUNDWATER ISOCONCENTRATION LINE AT 7 µg/L CLEAN UP LEVEL

ESTIMATED AREA OF IN-SITU CHEMICAL OXIDANT INJECTION

WATER TABLE INTERVAL IN-SITU CHEMICAL OXIDANT INJECTION LOCATION

TCE = TRICHLOROETHENE
µg/L = MICROGRAMS PER LITER

N

0 60
Scale in Feet

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FIGURE 4A

ALTERNATIVE 1 REMEDIAL COMPONENTS
5815 FOURTH AVENUE SOUTH
CAPITAL INDUSTRIES
SEATTLE, WASHINGTON

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Drawn By: tperrin | Checked By: JK | Date: 7/28/2016 | Disc Reference:

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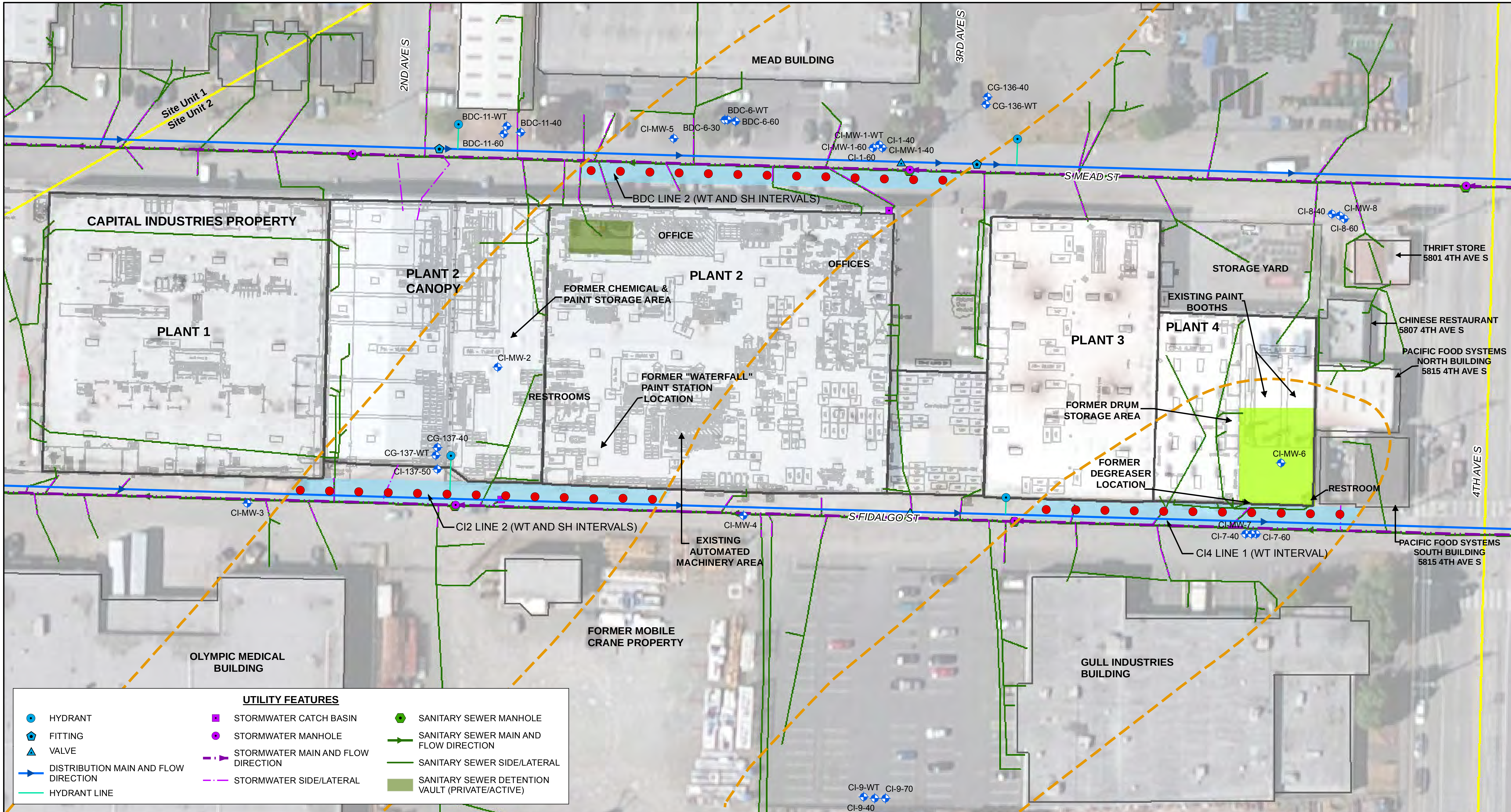

LEGEND

- MW-8 — EXISTING MONITORING WELL
- SITE UNIT BOUNDARY
- CAPITAL INDUSTRIES PROPERTY
- BUILDINGS
- TCE GROUNDWATER ISOCONCENTRATION LINE AT 7 µg/L CLEAN UP LEVEL
- ESTIMATED AREA OF SOIL EXCAVATION AND OFF-SITE DISPOSAL
- ESTIMATED AREA OF ENHANCED ANAEROBIC BIODEGRADATION INJECTION ALIGNMENT
- ESTIMATED AREA OF ENHANCED ANAEROBIC BIODEGRADATION INJECTION ALIGNMENT. INJECTIONS TARGET WT AND SH INTERVALS EXCEPT C4, WHICH TARGETS WT INTERVAL. EACH DOT IS A PRELIMINARY WELL OR INJECTION LOCATION AT 20 FOOT HORIZONTAL SPACING ASSUMING A 10-15 FOOT RADIUS OF INFLUENCE.

TCE = TRICHLOROETHENE
µg/L = MICROGRAMS PER LITER
BDC = BLASER DIE CASTING
CI = CAPITAL INDUSTRIES
CI2/CI4 = CI PLANT 2 OR PLANT 4
SH = SHALLOW
WT = WATER TABLE

N

0 — 60
Scale in Feet

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FIGURE 4B

ALTERNATIVE 2A REMEDIAL COMPONENTS
5815 FOURTH AVENUE SOUTH
CAPITAL INDUSTRIES
SEATTLE, WASHINGTON

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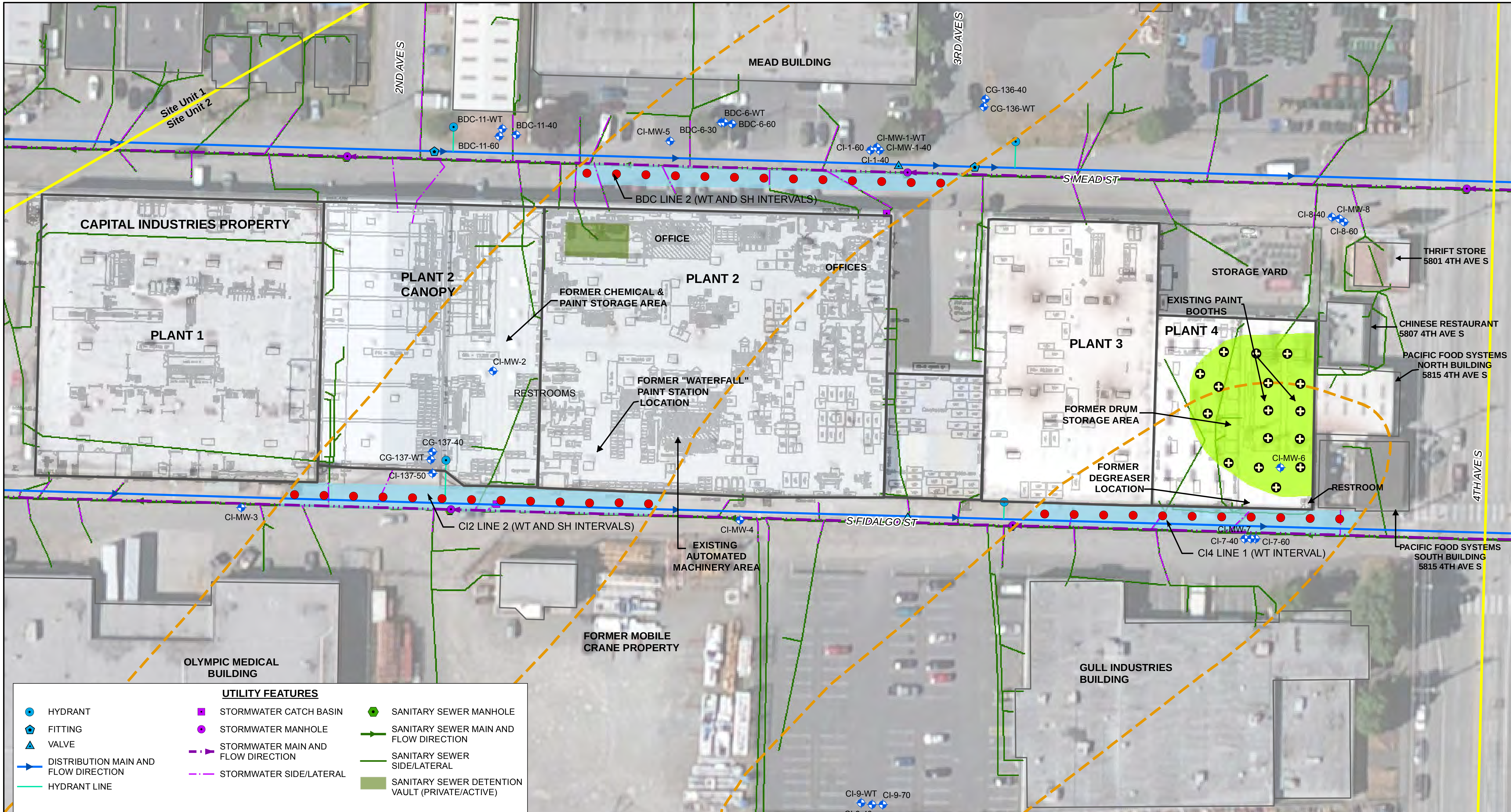

LEGEND

- MW-8 — EXISTING MONITORING WELL
- SITE UNIT BOUNDARY
- CAPITAL INDUSTRIES PROPERTY
- BUILDINGS
- TCE GROUNDWATER ISOCONCENTRATION LINE AT 7 µg/L CLEAN UP LEVEL
- ESTIMATED AREA OF IN-SITU CHEMICAL OXIDANT INJECTION
- ESTIMATED AREA OF IN-SITU CHEMICAL REDUCTION INJECTION ALIGNMENT
- WATER TABLE INTERVAL IN-SITU CHEMICAL OXIDANT INJECTION LOCATION
- ESTIMATED AREA OF IN-SITU CHEMICAL REDUCTION (ICSR) ALIGNMENT. INJECTIONS TARGET WT AND SH INTERVALS EXCEPT C4, WHICH TARGETS WT INTERVAL. EACH DOT IS A PRELIMINARY WELL OR INJECTION LOCATION AT 20 FOOT HORIZONTAL SPACING ASSUMING A 10-15 FOOT RADIUS OF INFLUENCE.

TCE = TRICHLOROETHENE
µg/L = MICROGRAMS PER LITER
BDC = BLASER DIE CASTING
CI = CAPITAL INDUSTRIES
CI2/CI4 = CI PLANT 2 OR PLANT 4
SH = SHALLOW
WT = WATER TABLE

N

0 60
Scale in Feet

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FIGURE 4C

ALTERNATIVE 3A REMEDIAL COMPONENTS
5815 FOURTH AVENUE SOUTH
CAPITAL INDUSTRIES
SEATTLE, WASHINGTON

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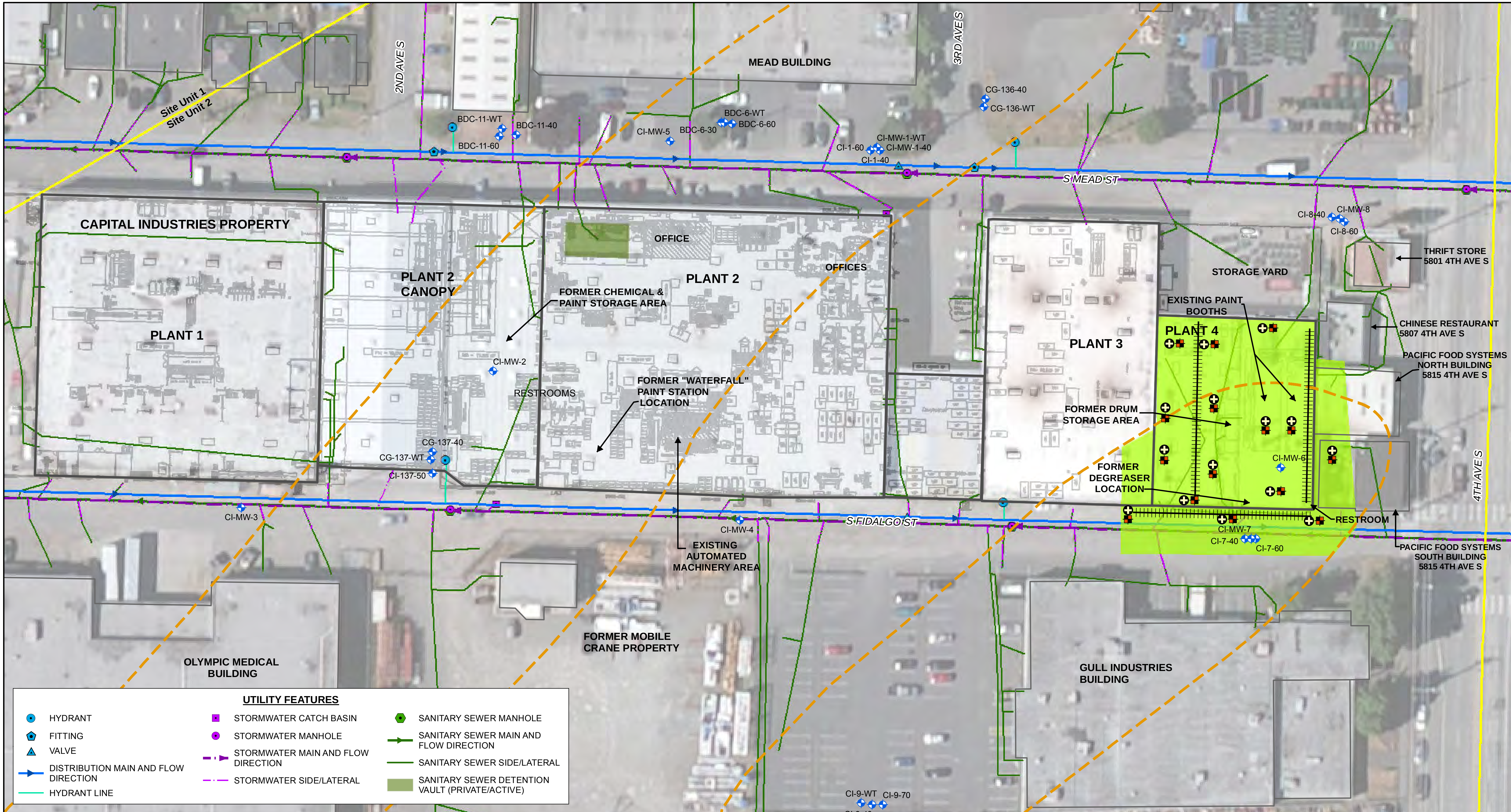
Document Path: G:\Projects\457 Capital Indust\457010 West of 4th - Site Unit 2\GIS\Fig 4C_AltRemComponents_InjDots.mxd



LEGEND

- MW-8 — EXISTING MONITORING WELL
- SITE UNIT BOUNDARY
- CAPITAL INDUSTRIES PROPERTY
- BUILDINGS
- TCE GROUNDWATER ISOCONCENTRATION LINE AT 7 µg/L CLEAN UP LEVEL
- ESTIMATED AREA OF AIRSPARGE/ SOIL VAPOR EXTRACTION TREATMENT
- SHALLOW INTERVAL AIR SPARGE WELL
- WATER TABLE INTERVAL AIR SPARGE WELL
- SHALLOW SVE WELL AND TRENCH

TCE = TRICHLOROETHENE
µg/L = MICROGRAMS PER LITER
SVE = SOIL VAPOR EXTRACTION

N

0 60
Scale in Feet

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FIGURE 4D

ALTERNATIVE 4 REMEDIAL COMPONENTS
5815 FOURTH AVENUE SOUTH
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SEATTLE, WASHINGTON

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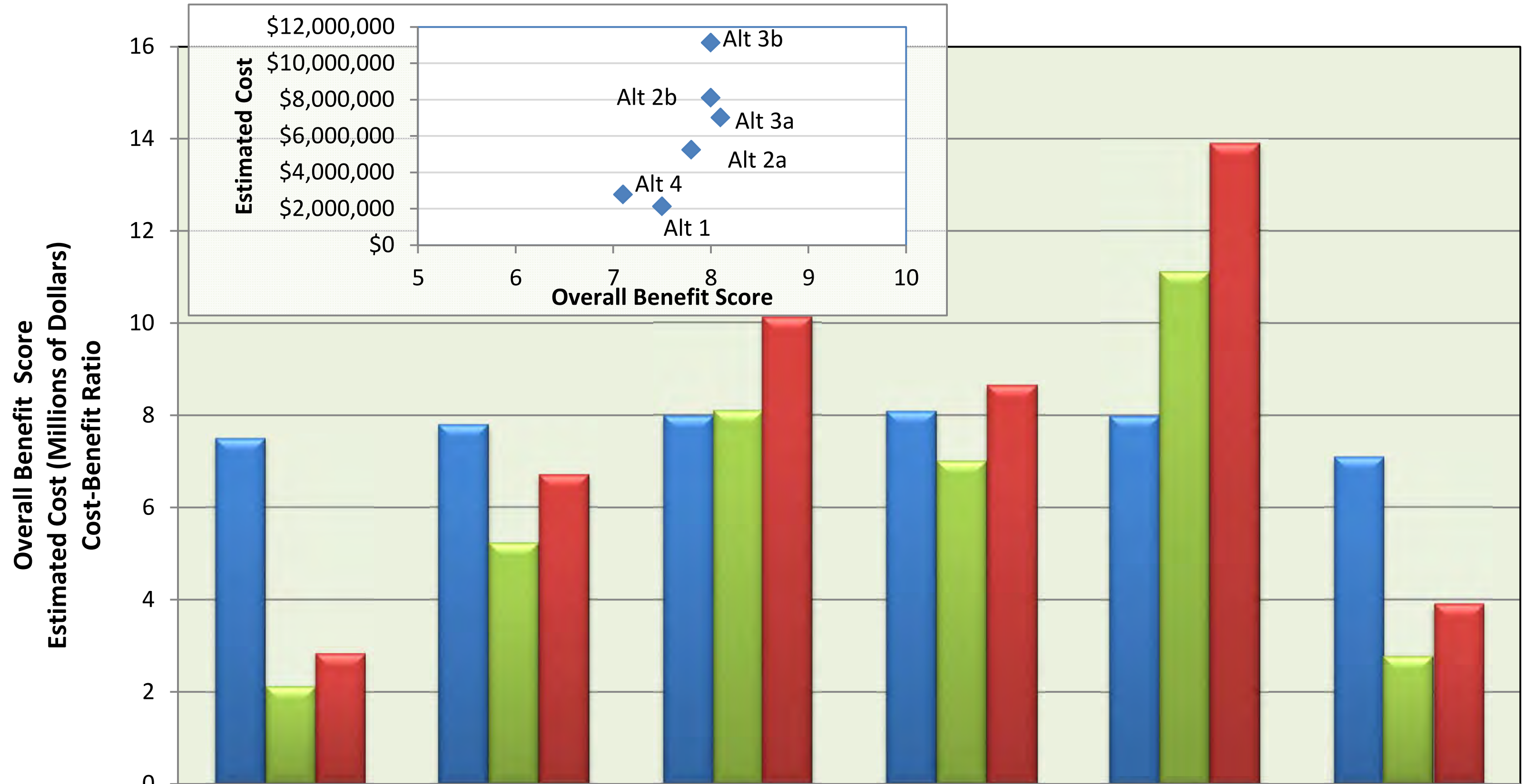

	Alternative 1	Alternative 2a	Alternative 2b	Alternative 3a	Alternative 3b	Alternative 4
Overall Benefit Score	7.5	7.8	8	8.1	8	7.1
Estimated Cost ($ Millions)	$2.1	$5.2	$8.1	$7.0	$11.1	$2.8
Cost-Benefit Ratio	2.8	6.7	10.1	8.7	13.9	3.9

Overall Benefit Score
Estimated Cost ($ Millions)
Cost-Benefit Ratio

Figure 5. MTCA Cost-Benefit Chart
SU2 Feasibility Study

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