Feasibility Study Report

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List of Acronyms

ADP	Anthropogenic Density Plume
ANC	acid-neutralizing capacity
Anchor	Anchor QEA
AOC	Administrative Order on Consent
ARARs	Applicable or Relevant and Appropriate Requirements
ARF	Army Reserve Facility
AWQC	Ambient Water Quality Criteria
bgs	below ground surface
Bluffs	Puget Sound Bluffs
BML	below mud line
CB/NT site	Commencement Bay Nearshore/Tideflats Superfund site
CD	Consent Decree
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
cis-1,2-DCE	cis-1,2-dichloroethene
cm/s	centimeters per second
COC	contaminant of concern or contaminants of concern
CRA	Conestoga-Rovers & Associates (now GHD)
CSM	Conceptual Site Model
CVOC	chlorinated volatile organic compound or chlorinated volatile organic compounds
DCA	Disproportionate Cost Analysis
DNAPL	dense non-aqueous phase liquid
DOC	dissolved oxygen content
Ecology	Washington State Department of Ecology
EHEPA	ecological health exposure pathway assessment
ENVs	environmental heads
ERH	electrical resistance heating
ERT	Evaluation of Remedial Technologies
FEHs	freshwater equivalent heads
FFAs	Federal Facility Agreements
FS	Feasibility Study
ft	feet
ft/d	feet per day
gpm	gallons per minute
GSH	Glenn Springs Holdings, Inc.
GRAs	General Response Actions
GWETS	groundwater extraction and treatment system
HASP	health and safety plan
HCB	hexachlorobenzene
HCBD	hexachlorobutadiene
HHEPA	human health exposure pathway assessment
Hylebos	Hylebos Waterway

List of Acronyms

ICs	Institutional Controls
ISB	in situ bioremediation
ISCO	in situ chemical oxidation
JARPA	Joint Aquatic Resources Permit Application
lbs	pounds
lbs/ft^3	pounds per cubic foot
Meq	megaequivalents
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
MSP	Mass Reduction by Strategic Groundwater Pumping
MTCA	Model Toxics Control Act
MVS/EVS	Mining Visualization System/Environmental Visualization System software package
NaCl	sodium chloride (salt)
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NGVD	National Geodetic Vertical Datum
NPDES	National Pollutant Discharge Elimination System
O&M	operation and maintenance
OCC	Occidental Chemical Corporation
OSHA	United States Occupational Safety and Health Administration
PCBs	polychlorinated biphenyls
PCE	tetrachloroethene or perchloroethylene
PDCE barrier	physical direct contact exposure barrier
POT	Port of Tacoma
PTW	potential principal threat waste
RAGs	Remedial Action Goals (or Remedial Action Objectives)
ROD	Record of Decision
SCR	Site Characterization Report (or Remedial Investigation Report [RI Report])
SEPA	Washington State Environmental Policy Act
SMCL	secondary maximum contaminant level
SMS	MTCA Sediment Management Standards
SOW	Statement of Work for the Administrative Order on Consent
SQAPP	Sampling and Quality Assurance Project Plan
SQOs	Sediment Quality Objectives
SSLs	soil screening levels
s.u.	standard units of pH
SVE	soil vapor extraction
SVOC	semi-volatile organic compound or semi-volatile organic compounds
TCE	trichloroethene or trichloroethylene
TCVOC	total chlorinated volatile organic compound or total chlorinated volatile organic compounds
TDS	total dissolved solids
µg/L	micrograms per liter
Upland Areas	Portions of the Site inland from the Embankment Area as defined in the SOW
US Navy	United States Navy
USEPA	United States Environmental Protection Agency

List of Acronyms

VC	vinyl chloride
VI	vapor intrusion
VOC	volatile organic compound or volatile organic compounds
WAC	Washington Administrative Code
Waterway	Hylebos Waterway
Waterways	Blair Waterway and Hylebos Waterway
WISHA	Washington Industrial Safety and Health Act
WMUs	waste management units
yd^2	square yards
yd^3	cubic yards
yrs	years

1. Introduction

Occidental Chemical Corporation (OCC) has been working with the Washington State Department of Ecology (Ecology) and the United States Environmental Protection Agency (USEPA) (together referred to as the "Agencies") to address remaining environmental issues at the "Occidental" Site associated in part with the former OCC facility located in Tacoma, Washington (Site) under an Administrative Order on Consent (AOC) (USEPA, 2005a). The work activities required under the AOC are outlined in the "Statement of Work for the Administrative Order on Consent" (SOW) (Conestoga-Rovers & Associates [CRA], 2005). Additional work not anticipated in the SOW has been conducted and scheduled consistent with the AOC.

This Feasibility Study (FS) Report presents the evaluation of remedial alternatives to address impacts at the Upland Areas of the Site. The evaluation was conducted in accordance with the Model Toxics Control Act (MTCA) Cleanup Regulation, as amended October 12, 2007 (MTCA Regulations) Chapter 173-340-350, and the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), and builds on the identification and screening of remedial technologies and process options presented in the Draft Evaluation of Remedial Technologies (ERT) Report (CRA, 2014b), the previous Draft Feasibility Study report (CRA, 2015) (2015 Draft FS report), and Agencies' comments on the 2015 Draft FS report (Ecology, 2016a and amendments).

This FS Report is organized as follows:

i) Section 2 — Conceptual Site Model (CSM): provides a summary of the Site characterization including the physical setting, nature and extent of impacts, contaminant fate and transport and exposure pathways assessment.

ii) Section 3 — Identify Remedial Action Goals (RAGs) and Potential Applicable local, State, and Federal Laws: presents medium-specific goals for protecting human health and the environment based on the contaminants of concern (COC), and potential receptors and exposure pathways. It also presents General Response Actions (GRAs) that, alone or in combination, satisfy the RAGs for each medium of concern, and potential applicable local, State, and Federal laws.

iii) Section 4 — Identify Alternatives: identifies and describes a reasonable number and type of remedial alternatives; detailing technologies selected for media and subdivisions of the Upland Areas of the Site.

iv) Section 5 — Containment Alternatives - Initial Screening and Detailed Evaluation: evaluates the identified alternatives to potentially reduce the number for detailed evaluation by eliminating alternatives that do not meet the minimum Washington Administrative Code (WAC) requirements, for which costs are clearly disproportionate, or that are technically not implementable. Evaluates the remaining alternatives with respect to compliance with the minimum requirements in WAC 173-340-360(2), benefits and drawbacks, disproportionate-cost analysis and consistency with the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) (USEPA, 1994).

v)	Section 6	VOC (volatile organic compounds) Mass Removal/Reduction Alternatives - Initial Screening and Detailed Evaluation: evaluates the alternatives with respect to estimated mass removed over time in addition to the same criteria in Section 5.
vi)	Section 7	pH Reduction/Enhanced Containment Alternatives - Initial Screening and Detailed Evaluation: evaluates the alternatives with respect to same criteria in Section 6.
vii)	Section 8	Select Preferred Remedy: presents a recommended remedy based on the detailed evaluation of alternatives, Agency's expectations (WAC 173-340-370), and known public concerns, discussion of proposed performance objectives for the recommended remedy, and documents reasons for the recommendation.
viii)	Section 9	References: lists the documents referenced in this FS Report.

2. Conceptual Site Model

This section presents a summary of the physical and chemical characterization of the Site as it relates to the development and analysis of remedial alternatives. OCC has conducted extensive investigations into the Site's physical characteristics, potential contaminant sources, nature and extent of impacts, and contaminant fate and transport. The primary sources of information presented in this summary are the approved Final Conceptual Site Model Report (CRA, 2014a) (CSM Report), the Site Characterization Report (CRA, 2014c) (SCR; also referred to as Remedial Investigation Report [RI Report] as approved on October 11, 2016 [Ecology, 2016b]) and Data Summary Report (Anchor QEA, 2016) for surface sediment and near-surface porewater in the Hylebos Waterway (Waterway or Hylebos) adjacent to the Site (Anchor Report).

2.1 Site Description

The Site is located on the eastern-most peninsula of the area of ownership and operations of the Port of Tacoma (POT) that extends into Commencement Bay at the mouth of the Puyallup River Valley and is defined in the AOC. A general location map showing the Site, including the formerly OCC-owned properties and that portion of Segment 5 of the Hylebos Waterway contained within the Site, is presented on Figure 2.1.

A plan showing local property ownership is presented on Figure 2.2. The properties formerly owned and/or operated on by OCC or its predecessors include:

- 605 Alexander Avenue property (former OCC Facility currently owned by Mariana Properties, Inc. [Mariana])
- 709 Alexander Avenue property (currently owned by Mariana)

The properties are referred to as the '605 Alexander Ave.' and '709 Alexander Ave.' properties on Figure 2.2. The properties are bounded on the west, north, and south by former Todd Shipyards and/or United States Navy (US Navy) properties (now owned by the POT), and on the east by the Waterway.

The approximate extent of groundwater impacts at the Site is shown on Figure 2.1. The Site is within the roughly 12-square-mile area Commencement Bay Nearshore/Tideflats Superfund site (CB/NT site) which includes several waterway problem areas and adjoining uplands as described by the CB/NT site Record of Decision (ROD) (USEPA, 1989). The Site includes part of Segment 5 of the Mouth of Hylebos Problem Area where impacted sediments were dredged and disposed in 2003-05 (CRA, 2014c), or excavated and capped 2007-08 (Hart Crowser, 2013). This work was performed under the Mouth of Hylebos Consent Decree (USEPA, 2005b).

2.2 Historical Operations

Historical operations at the Site in the past 100 years have included: (a) chemical manufacturing; (b) ship building, maintenance, and dismantling; and (c) petroleum and fuel storage and distribution. Those operations primarily occupied the real properties designated as 401 Alexander Avenue (now the Port of Tacoma's Early Business Center, formerly described as the Port Industrial Yard, the United States Naval Station Tacoma, and Todd Shipyards), 605 Alexander Avenue (the Former OCC Facility), 709 Alexander Avenue (now owned by Mariana Properties and formerly described as the PRI Northwest and Fletcher Oil facilities), and 901 Alexander Avenue (now Port of Tacoma property, a portion formerly designated as 721 Alexander Avenue and formerly described as the Maxwell Petroleum, General Petroleum, and United States Air Force facilities). Those historical operations have been described in previous Site reports, and are generally summarized below. See, e.g., approved CSM Report (CRA, 2014a); Draft ERT Report (CRA, 2014b), and Appendix B of SCR (CRA, 2014c) approved on October 11, 2016 (Ecology, 2016b).

Chemical Manufacturing

OCC's predecessor's chemical manufacturing operations began at the Site in 1929 at 605 Alexander Avenue and were continued by OCC and others until 2002. The operations primarily involved the production of chlorine and caustic soda, but during various time frames also involved the production of sodium hypochlorite, trichloroethene/tetrachloroethene (TCE/PCE), ammonia, muriatic acid, calcium chloride, saturated (hydrogenated) oil, aluminum chloride, and sodium aluminate. Chlorine and caustic soda production occurred throughout the Former OCC Facility history, using electrolysis. TCE/PCE production occurred from 1947 to 1973, primarily on the North 10 Acres of 605 Alexander Avenue. Other production processes occurred for various time periods. Wastes generated during the various manufacturing processes were managed at 605 Alexander Avenue, and included wastewater treatment (settling) ponds, settling barges, landfills, disposal pits, and waste piles. Seventeen waste management units were historically located on the property. Chemical manufacturing ceased in 2002, and nearly all buildings and structures at 605 Alexander Avenue were demolished between 2006 and 2008. The property continues to be the operations center for the groundwater treatment and containment facility installed by OCC and operated since 1996.

Building, Maintenance, and Dismantling of Ships

Shipbuilding began at the Site at least as early as World War One, with the establishment of the Todd Shipyards facility at 401 Alexander Avenue and on a portion of 605 Alexander Avenue (the portion described as the North 10 Acres). Shipbuilding by Todd Shipyards and by the United States occurred in those locations during both World War One and World War Two. The North 10 Acres of 605 Alexander Avenue was used during World War Two for the gathering and incineration of shipyard wastes, among other activities, and in 1945 became the location of the "Navy Todd Dump" on the shoreline of the Hylebos Waterway. The Todd Shipyards facility subsequently became the United States Naval Station Tacoma where ships were stored, maintained, and dismantled until the 401 Alexander Avenue property was acquired by the Port of Tacoma from the United States. Since 1960, numerous tenants' operations have included additional shipbuilding and dismantling. In connection with the historical ship-related activities, waste landfilling, incineration, and disposal (among other activities) occurred along the shoreline and in the uplands.

Petroleum and Fuel Storage Distribution

The petroleum and fuel tank farm facilities located at 709 Alexander Avenue and 901 Alexander Avenue operated from approximately the 1930s to the 1980s. Those historical operations resulted in an area of contaminated soil and groundwater at those and adjacent properties currently being addressed under Ecology oversight and Agreed Order DE 9835 by the Port of Tacoma and Mariana Properties, Inc. The 709 Alexander Avenue property also includes an embankment fill area along the Hylebos Waterway shoreline that was associated with the former chemical manufacturing operations at 605 Alexander Avenue. The 709 Alexander Avenue embankment, as well as the 605 Alexander Avenue embankment, are being addressed as part of the Site.

2.3 Physical Site Setting

Regionally, the Site, Puyallup River Valley, and surrounding area are part of the Puget Sound Lowlands, which are surrounded by the Puget Sound Bluffs (Bluffs). The Bluffs extend along the sides of the Puyallup River Valley, and correspond to the highland areas at the east and west sides of the POT. The Bluffs extend upwards from the eastern shoreline of the Waterway to approximately 350 feet (ft) above the Site peninsula.

The peninsula on which the Site is located is man-made and was created in the early 1900s. The Hylebos and Blair Waterways located on the east and west sides of the Site peninsula, respectively, were dredged and the materials were used to build up the land mass. The Waterways were dredged through the existing tidal mud flats at the mouth of the Puyallup River Valley.

2.3.1 Regional and Site Geology

Regional Geologic Conditions

The geologic framework of the Puyallup River Valley consists of nearly 2,000 ft of unconsolidated sediments overlying bedrock. The area has experienced several glacial advances and retreats. The most recent glacial advance, the Vashon Stade of the Fraser Glaciation, scoured a channel into the pre-Vashon sediments along the Puyallup River Valley. Figure 2.3 shows a conceptual model of the regional geology where the channel scoured into the pre-Vashon sediments is in-filled by post-Vashon sediments, referred to here as deltaic deposits. The deposition of the deltaic material occurred at varying rates and under varying stream flow and sea level conditions, resulting in a series of sand units with interbedded and interfingered silt and clay units with occasional gravelly sand units.

Site Geologic Conditions

Figure 2.4 shows the conceptual geologic conditions for the Puyallup River Valley and Bluffs in the Site vicinity, and is based on the regional geologic conditions described in Appendix A of the approved CSM Report (CRA, 2014a).

Within the Puyallup River Valley, the generalized geologic conditions are based on Site borings and described as follows (from ground surface):

- Fill - variable mixture of sand, silt, and gravel material placed through dredging of the Hylebos and Blair Waterways to develop the Site peninsula. The thickness of the fill across the Site ranges from approximately 10 to 15 ft with hydraulic conductivity values that range from approximately 1.0×10^{-4} to 1.0×10^{-2} centimeters per second (cm/s) (0.3 to 30 feet per day [ft/d]).
- Deltaic deposits - heterogeneous mixture of interbedded sands, silts, and clays. The thickness of the deltaic deposits across the Site ranges from approximately 30 to 200 ft in the eastern and northeastern portion of the Site to greater than approximately 300 ft in the southwestern portion of the Site. Hydraulic conductivity values for the deltaic deposits range from approximately 1.0×10^{-5} to 1.0×10^{-2} cm/s (0.03 to 30 ft/d).
- Glacial deposits - heterogeneous mixture of interbedded gravel, sands, silts, and clays. The thickness of the glacial deposits beneath the Site has not been determined, but based on regional information, is more than 1,000 ft. Hydraulic conductivity values for the glacial deposits range from approximately 5.0×10^{-5} to 5.0×10^{-3} cm/s (0.15 to 15 ft/d). The top surface of the glacially derived deposits slopes downward to the north, west, and south from a mound observed under the central portion of the Site, as shown on Figure 2.4. The glacial deposits are not encountered at borings in the west, southwest, and south portion of the Site peninsula and are inferred to dip downward in this area below the depth of the Site borings.

The extensive Site stratigraphic data indicate that there is an increased frequency of lower permeability lenses, comprised mainly of silt and clay, in the lower deltaic deposits. This is shown schematically on Figure 2.4.

Within the Bluffs, Figure 2.4 shows an alternating sequence of sand/gravel and silt/clay layers based on the regional geologic conditions described in Appendix A of the approved CSM Report (CRA, 2014a).

2.3.2 Regional Hydrogeology/Groundwater Non-Potable Classification

Regional Hydrogeologic Conditions

Regional surface water and groundwater flow through the Puyallup River Valley discharges to Commencement Bay from south to north. Shallow groundwater discharges to rivers, creeks, and waterways as they extend through the Valley. Groundwater within the Puyallup River Valley is replenished by regional upland groundwater inflow into the Valley and by precipitation infiltration. Regional groundwater flow within the Bluffs discharges through seepage faces along the Bluffs and to the waterways/Commencement Bay.

Ecology's letter dated March 30, 2015 (Ecology, 2015) included as Appendix A of this FS Report, determined that the peninsula groundwater meets the MTCA Section 720 non-potable classification. The underlying and surrounding groundwater has salinity levels that exceed USEPA drinking water standards (e.g., total dissolved solids [TDS] >500 milligrams per liter [mg/L], secondary maximum contaminant level [SMCL]).

2.3.3 Site Hydrogeology

Groundwater beneath the Site discharges to the surrounding surface water bodies. Fresh groundwater inflow toward the Site peninsula occurs from the south due to upland regional groundwater flow along the Puyallup River Valley, and from the east due to regional groundwater flow in the Bluffs aquifers discharging to the Valley. Infiltration of precipitation over the Site peninsula contributes a further source of fresh groundwater, and establishes a shallow radial groundwater flow pattern towards the surface water bodies.

The groundwater table at the Site peninsula is located in the fill that was placed on top of the native mud flats. The mud flats historically existed throughout the POT, but the mud flats have not been identified consistently in all Site borings. This might be due to a lack of precision in the stratigraphic logs, or might be due to stream channels that could have incised the fine-grained sediments of the mud flats. For the CSM, a mud flats stratigraphic unit is conceptualized as depicted on Figure 2.4.

In general, the mud flats are assumed to have hydraulic conductivity similar to silts and clays identified within the deltaic deposits. While lower permeability sediments within the mud flats may not be entirely continuous, they clearly create a hydraulic separation between the fill and the underlying deltaic deposits in the southern portion of the Site. Here, groundwater elevations in the fill are approximately 2 ft higher than groundwater elevations in the deltaic deposits immediately beneath the mud flats.

The majority of the Site-related impacts exist within the deltaic deposits. The extensive groundwater quality data indicate that the vertical limit of impacts appears to coincide with the increased frequency of lower permeability lenses in the lower deltaic deposits or the top of the glacial deposits. A discrete continuous layer of low-permeability material is not observed in Site borings in the lower deltaic deposits. However, the groundwater quality, density, and hydraulic evidence supports the concept that the increased frequency of lower permeability lenses inhibits vertical flow creating a zone of apparent confining effect in the lower deltaic deposits. The presence of this zone of apparent confining effect is inferred from:

- Upward vertical hydraulic gradients observed from the upper glacial deposits to the lower deltaic deposits in the east, northeast, and north portion of the Site peninsula where the glacial deposits were encountered.
- Fresh to relatively fresh groundwater observed within the glacial deposits.
- Downward migration of the COC appears to be limited to within the lower deltaic deposits or top of the underlying glacial deposits.

The glacial deposits beneath the deltaic deposits appear to be an aquifer system composed of several glacially-derived aquifers and aquitards separated from the deltaic deposits.

A zone of apparent confining effect in the lower deltaic deposits is consistent with some features of the salt water and fresh groundwater distributions observed at the Site. Relatively fresh groundwater is observed in deeper parts of the deltaic deposits and in the glacial deposits. This fresh water appears to be caused by environmental heads (ENVs) in the deeper deposits that are greater than in the deltaic deposits. The higher pressures in the deeper deposits create upward vertical hydraulic gradients into the deltaic deposits. These upward gradients are supported by fresh groundwater entering the deeper deposits from up-gradient regional groundwater inflow. A zone of apparent confining effect, corresponding to the increased frequency of lower permeability lenses in the lower deltaic deposits, explains these observed conditions.

The observed salt water and fresh groundwater distributions are translated to the approved CSM of hydrogeological conditions in the Site vicinity on Figure 2.5. The salt water distributions and groundwater flow conditions illustrated on Figure 2.5 are generalized representations of pre-contamination conditions. The groundwater flow conditions illustrated on Figure 2.5 are summarized as follows:

- Recharge from precipitation infiltration contributes shallow fresh groundwater in the fill. This recharge migrates laterally through the fill and downward into the underlying deltaic deposits. Lateral flow in the fill and deltaic deposits discharges to the Blair and Hylebos Waterways.
- Fresh groundwater is also introduced to both the deltaic and glacial deposits from the uplands along the Puyallup River Valley and from the east from beneath the Bluffs aquifers that lie below sea level.
- Elevated freshwater equivalent heads (FEHs) in the Bluffs limit the inland extent of the salt water along the east side of the Hylebos.
- Available salinity data from borings completed beneath the Hylebos Waterway show a zone of fresher groundwater from the eastern bluffs extending adjacent to and beneath the Hylebos.
- Available bromide data used as a tracer for identifying naturally-occurring salt water suggest a relatively complex pattern of salt water at intermediate depths underlain by fresher groundwater at depth at some locations.

Releases of high-density liquids from historical Site operations/processes (lime sludge/solvent residue, caustic soda, and salt brine) have a critical influence on groundwater flow and contaminant transport, as described in Subsection 5.6.2.5.1 of the SCR (CRA, 2014c) approved on October 11, 2016 (Ecology, 2016b).

2.4 Nature and Extent of Impacts

Extensive investigations have been conducted at the Site to define the nature and extent of impacts. The chemical characterization of soil, groundwater, porewater, and sediment is based upon the extensive analytical data obtained during the various investigations summarized in the approved SCR (CRA, 2014c) and Anchor Report (Anchor QEA, 2016). This subsection summarizes the potential contaminant sources, media of concern, and contaminant fate and transport. Table 2.1 presents Sitewide COC and media, which are further discussed below.

2.4.1 Potential Contaminant Sources

Past operations at the property generated wastes that were managed on Site. Waste management practices included wastewater treatment (settling) ponds, settling barges, landfills, disposal pits, and waste piles. In total, 17 waste management units (WMUs) were historically located at the Site, in addition to the Navy Todd Dump. Detailed discussions of the WMUs and the chemicals associated with them were presented in the SCR (CRA, 2014c) approved on October 11, 2016 (Ecology, 2016b).

Environmental investigations at the Site began in the 1980s and have shown that the following parameters are the principal COC:

- Chlorinated volatile organic compounds (CVOC)
- Fuel-related volatile organic compounds (fuel-related VOC)
- Caustic (sodium hydroxide)
- Salt (sodium chloride or NaCl)
- Metals (arsenic, chromium, copper, lead, mercury, nickel, thallium, zinc)
- Semi-volatile organic compounds (SVOC) (hexachlorobenzene [HCB] and hexachlorobutadiene [HCBD], which are by-products of solvent production)
- polychlorinated biphenyls (PCBs)
- Dioxins/furans

The principal COC were either used, produced, generated, and/or stored in various locations at the Site. In addition, some wastes generated in the production processes were managed on Site. Key "potential source areas" where the vast majority of releases occurred are listed below and described more fully in the SCR (CRA, 2014c) approved on October 11, 2016 (Ecology, 2016b).

The metals listed above as principal COC were not used in Former OCC Facility operations at the Site, but some of those metals were used in former ship building, maintenance, and dismantling operations at the Site. Geochemical conditions created by the release of caustic and brine (dissolved NaCl), and reducing conditions in groundwater, have resulted in the mobilization of some of these metals in the subsurface. The PCBs listed above as principal COC were used in the shipbuilding, maintenance, and dismantling operations at the Site. PCBs were not used in Former OCC Facility operations at the Site, other than in electrical equipment (such as transformers and capacitors). The dioxins/furans listed above as principal COC were used in and generated by the ship building, maintenance, and dismantling operations at the Site. Dioxins/furans were not used in Former OCC Facility operations other than potentially in spent graphite anodes used at the former chemical production facility, and in overheated electrical equipment (such as transformers and capacitors) containing PCBs.

VOC Potential Sources

Chlorinated solvents (TCE and PCE) were produced at the Site from 1947 to 1973. The former solvent production plant and associated WMUs are shown on Figure 2.6. A single area around the former solvent production plant and WMUs is shown on Figure 2.6 as the "potential CVOC source area". The TCE and PCE impacts in soil and groundwater appear to be primarily associated with the former solvent production plant (S1), former settling ponds (WMU A [S3], WMU G [S4], and WMU H [S5]), former settling barge (WMU F [S2]), and Area 5106. Lime sludge and solvent residue from the chlorinated solvents process were sent to settling ponds and a settling barge over time and in the first year of production were discharged to the Waterway through a direct discharge line.

CVOC and fuel-related VOC groundwater impacts are present on the 709 and 721 Alexander Avenue properties. These properties are being addressed under Agreed Order No. DE 9835, effective October 3, 2013.

Caustic Potential Sources

The elevated pH present in groundwater at the Site is primarily due to the release of sodium hydroxide (caustic soda) produced at the Site. Historical locations of the production and handling of caustic soda are shown on Figure 2.7. The principal potential source area appears to be the Caustic House (S8). A single area around the locations of Caustic House and caustic soda storage/handling is shown on Figure 2.7 as the "potential caustic source area".

Salt Potential Source

Salt was used as a feedstock in the production of chlorine, chlorinated solvents, and caustic soda. Salt was delivered to the Site by ship and stored in open piles on the Salt Pad. Figure 2.8 shows the location of the Salt Pad. Uncovered salt piles were maintained on this pad from the early 1960s until operations ceased. Water was sprayed on the salt piles to make brine. The asphalt pad was diked and sloped to a sump. However, cracks, if they existed, in the asphalt pad or leaks in the sump could have led to salt impacts beneath the Salt Pad.

Metals Potential Sources

Figure 2.9 shows the N Landfill and the Navy Todd Dump located adjacent to the embankment of the Waterway. The N Landfill was used between 1929 and 1971 and investigations have shown that the landfill received wastes containing metals, corrosives, chlorinated organics, and non-burnable debris. The Navy Todd Dump was created in approximately 1945, as a result of World War Two ship construction and waste disposal/incineration activities. Navy Todd Dump investigations have shown that the waste material contains metals (primarily cadmium, chromium, copper, mercury, nickel, and zinc). The N Landfill and Navy Todd Dump are considered potential metals sources.

The approximate boundary of metals impacted embankment fill areas is also shown on Figure 2.9. In addition to the N Landfill and Navy Todd Dump, metals impacted waste material derived from shipbuilding and dismantling activities during and after World War Two as well as chemical production were disposed along the embankment of the Waterway.

The vast majority of metals in the groundwater are present as a result of geochemical conditions (high pH and ionic strength) created by the release of other COC. The geochemical conditions mobilize (dissolve) metals at concentrations above those that would exist naturally in groundwater. This process is described in Subsection 5.4.5.2 of the SCR (CRA, 2014c) approved on October 11, 2016 (Ecology, 2016b).

SVOC Potential Sources

Potential sources of SVOC are shown on Figure 2.10. The two SVOC detected most often at concentrations above their respective criteria are HCB and HCBD. These compounds are by-products of the production of chlorinated solvents, and are found (to some degree) in areas where chlorinated solvents were produced or stored, or where the waste products were handled and disposed.

PCBs and Dioxins/Furans Potential Sources

Potential sources of PCBs and dioxin/furans are shown on Figure 2.11. Significant potential sources of PCBs at the Site would be from the US Navy shipbuilding operations performed at the Site including PCB-containing materials disposed at the Navy Todd Dump, and from ship dismantling and maintenance operations performed at the Site involving PCB-containing materials disposed and handled at the Site. Other potential sources of PCBs in the soil and sediment at the Site would be spills from equipment such as transformers and capacitors containing PCBs.

Dioxins (the common name for polychlorinated dibenzo-para-dioxins) and furans (polychlorinated dibenzofurans) are two closely related groups of chemical byproducts that are found at background levels in most industrial areas. A potential source of dioxins/furans was the incinerator installed and used at the Site for waste disposal by the US Navy and Todd Shipyards during World War Two. The burning of wastes such as PCB-containing materials in the incinerator and along the embankment at the Navy Todd Dump would have been a potential source for dioxins/furans detected at the Site. Various other forms of combustion and smelting processes (e.g., welding), occurred at the World War Two shipyard, which also potentially produced dioxins/furans. Another potential source of dioxins/furans is spent graphite anodes used at the former chemical production facility, and disposed on Site. Other potential sources of dioxins/furans at the Site would have included overheated electrical equipment (such as transformers and capacitors) containing PCBs.

Anthropogenic Density Plume (ADP) Potential Sources

A plume of elevated groundwater density, termed the "Anthropogenic Density Plume" (ADP), exists beneath the Site due to releases of high density materials from historical operations. The potential sources for the ADP consist of:

- Lime was placed in WMU A, WMU F, WMU G, and WMU H, while lime sludge/calcium chloride was placed in WMU C. Lime sludge (calcium chloride) is miscible in water, and a calcium chloride solution with water can have a specific gravity of approximately 1.3 (at 15 degrees Celsius).
- Caustic soda, with a specific gravity of approximately 1.3 to 1.5, is another component of the Site ADP. The "Potential Caustic Source Area" shown on Figure 2.7 represents a potential source location for the ADP.
- Brine (sodium chloride) was created at the Salt Pad and had a specific gravity of approximately 1.2 and is a further component of the ADP. The Salt Pad, shown on Figure 2.8, represents a potential source location for the ADP.

The noted potential contaminant sources have resulted in contamination of environmental media at the Site. A summary of the nature and extent of Site COC in each medium is provided in the following sub-sections.

2.4.2 Soil

The nature and extent of impacts in unsaturated soil is summarized as follows:

- CVOC, primarily as PCE, are present in unsaturated soil at concentrations exceeding the unsaturated soil screening levels (SSLs), primarily in the vicinity of WMU A, the Salt Pad/WMU G, WMU H, and the N Landfill.
- Site SVOC, primarily HCB and HCBD, are present in unsaturated soil at concentrations exceeding the SSLs within the same general areas as CVOC, as well as at several embankment locations.
- PCBs are present in unsaturated soil at concentrations exceeding the SSL primarily near the Navy Todd Dump and the N Landfill.

- Metals, primarily copper, but to a lesser degree arsenic, zinc, and nickel, are present at concentrations exceeding the SSLs in the vicinity of the Salt Pad/WMU G, the former Caustic House, the N Landfill, and Navy Todd Dump.

The nature and extent of impacts in saturated soil is summarized as follows:

- CVOC, primarily as PCE, TCE, and associated degradation products, are present in saturated soil at concentrations exceeding the saturated SSLs. This presence is greatest below the Facility near WMU A, the Salt Pad/WMU G, and WMU R, as well as below the Hylebos. CVOC are present to a lesser degree along the embankment and in the vicinity of the N Landfill.
- Site SVOC, primarily as HCB, are present in saturated soil at concentrations exceeding the SSLs within the same general areas as CVOC.
- Pesticides and PCBs are present in saturated soil at concentrations exceeding the SSLs along the embankment primarily near the Navy Todd Dump and the N Landfill.
- Metals, primarily copper, total chromium, nickel, arsenic, and zinc, are present at concentrations exceeding the SSLs in nearly all samples analyzed across the Site. The highest concentrations occur along the embankment in the vicinity of the N Landfill and Navy Todd Dump.

2.4.3 Dense Non-Aqueous Phase Liquid (DNAPL)

Specific investigations were conducted at the Site to identify the presence of dense non-aqueous phase liquid (DNAPL) following the procedures presented in Kueper and Davies (Kueper, B.H. and K. Davies, 2009). Confirmed DNAPL was identified in the vicinity of the Salt Pad/WMU G and WMU R within the 15-ft and 25-ft zones. Confirmed DNAPL was also detected in the 100-ft, 130-ft, and 160-ft zones. Confirmed DNAPL was not identified in the 50- and 75-ft zones.

2.4.4 Groundwater

The nature and extent of impacts in groundwater is summarized as follows:

- CVOC are present in groundwater at concentrations above the groundwater screening criteria as follows:
    - 25-ft zone – The areas of highest concentrations are located near the Salt Pad and WMU A
    - 50-ft zone – The extent of PCE and TCE is similar to the 25-ft zone, but the extent of vinyl chloride (VC) increases significantly within the 50-ft zone area beyond the limits of PCE and TCE toward the eastern side of the Hylebos
    - 75-ft zone – The highest CVOC concentrations extend eastward under the Hylebos, with lower concentrations extending further north
    - 100-ft zone – The area of highest concentration is somewhat reduced, but has migrated further north
    - 130-ft zone – The area of highest concentration is somewhat reduced, but has migrated north and east when compared to the 100-ft zone
    - 160-ft zone – CVOC concentrations in the 160-ft zone are reduced compared to the 130-ft zone, but the plume continues further northward

- Site SVOC, primarily HCB and HCBD, are present along the embankment and beneath the Hylebos at depths down to 111 ft below ground surface (bgs) upland and 164 ft below mud line (BML) below the Waterway.
- PCBs are present in groundwater primarily along the embankment in the vicinity of the Navy Todd Dump and N Landfill and below the Hylebos.
- Metals, primarily arsenic, copper, and nickel, are present at concentrations exceeding the groundwater screening criteria. The highest concentrations occur in the vicinity of the Salt Pad and Navy Todd Dump, along the embankment, and beneath the Hylebos.
- Elevated pH groundwater is present above the groundwater screening criteria as follows:
  - 25-ft zone – elevated pH was measured across the Site, with the highest values (>13 s.u. [standard units of pH]) detected along the eastern portion of the Site beneath the former plant production areas
  - 50-ft zone – the extent of the highest pH values increases in size relative to the 25-ft zone and is located more to the north toward the Salt Pad
  - 75-ft zone – the extent of the pH plume within the 75-ft zone is reduced relative to the 50-ft zone, but has migrated east with the highest groundwater pH (>12 s.u.) located in the vicinity of the former caustic tanks and the south end of Dock 1
  - 100-ft zone – the pH plume has migrated north and east, with the highest pH near the north end of Dock 1, but is limited to beneath the facility and Hylebos
  - 130-ft zone – the pH plume continues further northeast
  - 160-ft zone – the area of high pH values is much smaller in the 160-ft zone, with the highest readings diminishing
- The seep study performed in the Hylebos confirmed that seepage of impacted groundwater was occurring to some extent into the Hylebos.

2.4.5 Sediment

The August 2016 Anchor QEA investigation of potential CVOC in sediments in the Hylebos included collection of surface sediment samples from the 0- to 10-cm interval at 33 locations in the Hylebos adjacent to the Site and comparison of reported concentrations to the CB/NT site Sediment Quality Objectives (SQOs~~).~~), which were developed in consideration of the MTCA Sediment Management Standards (SMS). The investigation determined that most CVOC were below detection and no reported concentrations exceeded the CB/NT site SQOs.

~~Therefore, developing remedial alternatives for sediments in the Hylebos is not necessary and is not part of this FS Report.~~

Therefore, based on the results presented in the 2016 Anchor QEA Data Summary Report for sediment and porewater, there is no need to develop an FS or remedial alternatives for sediments at this time. It should be noted that it has been over 10 years since dredging was completed and re-contamination of the sediments has not occurred based on the 2016 data. Additionally, there is evidence from data collected in the Hylebos that natural recovery is occurring as predicted for the CB/NT site. Some future monitoring of COC concentrations in sediments may be appropriate to ensure that existing conditions of sediment quality do not change over time, however unlikely this may be.

2.4.6 Porewater

The July/August 2016 Anchor QEA investigation of potential CVOC in porewater beneath the Hylebos included attempted collection of near-bottom surface water samples from 2 to 4 cm above the mudline at 6 locations, and porewater samples from depths of 2 to 4 cm (near-surface), 10 cm, 30 cm, and 90 cm below the mudline at 33 locations in the Hylebos adjacent to the Site. The reported concentrations for near-bottom surface water and near-surface porewater samples collected at 2 to 4 cm above and below the mudline, respectively, were compared to Ambient Water Quality Criteria (AWQC). Only one parameter VC, reported in one sample (adjacent to the northern end of the 605 Alexander Avenue property), had the potential to marginally exceed the associated screening criterion at the applicable point of compliance. Therefore, this migration pathway is not considered significant at this time. Based on the fact that the remedy for the Site will include ~~groundwater~~ containment, it is unlikely that future impacts will occur ~~and this migration pathway is not considered significant~~. Some future monitoring of COC concentrations in porewater may be appropriate to ensure that existing conditions of porewater quality do not change over time, however unlikely this may be.

2.4.7 Indoor Air

The vapor intrusion (VI) investigation included nine buildings in the Site area, including the Army Reserve Facility (ARF), Buildings 326, 407, 532, 592, 595, and 596, and the Guard Shack located on properties owned and/or controlled by the POT, and the OCC Office Building.

The most frequently occurring exceedances of screening levels in indoor air and their potential sources were as follows:

- Indoor sources: 1,2,4-trimethylbenzene, 1,4-dichlorobenzene, naphthalene, m&p-xylenes, styrene, PCE, and TCE
- Outdoor sources: none
- Sub-slab sources: PCE and TCE

The majority of exceedances were concluded to be likely attributable to indoor sources (e.g., vehicle operations, paint operations, miscellaneous power and hand tools, parts washing tubs, chemical storage tanks, flammable material storage lockers, paint cans, cleaning products, miscellaneous building materials, aerosol cans containing chemical cleaners, lubricants, cutting oils, and diesel fuel). Only a few of the exceedances were concluded to be potentially attributable to sub-slab sources, and two of which were sources likely unrelated to the OCC Site. The recommendations for future actions at the nine buildings are as follows:

- Manage occupancy: OCC Office
- Continued monitoring: 595
- No Further Action: ARF, 326, 407, 532, 592, 596, and Guard Shack

2.5 Potential Principal Threat Waste (PTW)

An evaluation of the presence of potential principal threat waste (PTW) at the Site was undertaken and the details and results of this evaluation are presented in Appendix B. The regulatory framework regarding the identification and remediation of hazardous substances and PTW includes

WAC 173-340-350, WAC-173-340-370, CERCLA §121, and the NCP [40 CFR 300.430 (a) (1) (iii)]. A summary of the PTW delineation is presented below.

In general, MTCA, CERCLA, and the NCP consider hazardous substances/PTW to be those source materials that are:

- Highly toxic or
- Highly mobile that generally cannot be reliably contained or
- Would present a significant risk to human health or the environment should exposure occur

MTCA, CERCLA, and the NCP establish an expectation that treatment will be used to address hazardous substances/PTW at a site wherever practicable. This is clearly stated in WAC 173-340-370(1) as follows:

"The department expects that treatment technologies will be emphasized at sites containing liquid wastes, areas contaminated with high concentrations of hazardous substances, highly mobile materials, and/or discrete areas of hazardous substances that lend themselves to treatment."

However, MTCA, CERCLA, and the NCP also acknowledge that hazardous substances/PTW may be contained rather than treated due to difficulties in treating the source material. Ecology's position is stated in Focus No. 94-130 as follows: "***Protecting Human Health and the Environment.*** *The cleanup action selected must either remove or destroy the contamination, restoring the site to cleanup levels, or contain the contamination in such a way that will minimize future exposure of humans and ecological receptors (plants and animals).*" (Ecology, 2013)

As stated in the preamble to the NCP (55 FR at 8703, March 8, 1990), there might be situations where PTW may be contained rather than treated due to difficulties in treating the wastes. Specific situations that might limit the use of treatment are summarized in USEPA (1991) as follows:

- Treatment technologies are not technically feasible or are not available within a reasonable timeframe.
- The extraordinary volume of materials or complexity of the site makes implementation of treatment technologies impracticable.
- Implementation of a treatment-based remedy would result in a greater overall risk to human health and the environment due to risks posed to workers or the surrounding community during implementation.
- Severe effects across environmental media resulting from implementation would occur.

The decision to treat or contain hazardous substances/PTW is made on a site-specific basis through the remedy selection process (USEPA, 1991 and WAC 173-340-360).

The DNAPL and caustic source material that could potentially be considered hazardous substances/PTW were identified following the guidance presented in MTCA, CERCLA, the NCP, and USEPA, 1991. All confirmed DNAPL source zones were considered to be PTW because of their toxic composition and the significant risk that could result should exposure occur. The distribution of potential DNAPL PTW is shown on Figures 3a and 3b in Appendix B. All unsaturated and saturated soil where the soil or groundwater pH was equal to or greater than 12.5 s.u. was considered PTW because they are considered to be characteristically hazardous for corrosivity in accordance with the Code of Federal Regulations (40 CFR 261.22). The areas of caustic-impacted soil that could be considered PTW are shown on Figure 8 in Appendix B.

As presented above, MTCA, CERCLA, and the NCP have an expectation for treatment of hazardous substance/PTW, wherever practicable. At this Site, the complete treatment of hazardous substance/PTW may be considered impracticable for the following reasons:

- Feasible treatment technologies are not available
- Very large volumes of hazardous substances/PTW
- Complex geologic and geochemical conditions
- Potential for increased risks during implementation of treatment

2.6 Contaminant Fate and Transport

Site investigations have confirmed that there are four primary groundwater plumes: the ADP, pH plume, CVOC, and metals. Other COC have not developed large, distinct groundwater plumes. This is likely due to a combination of factors, such as low mobility in groundwater, limited contaminant mass, and attenuation processes.

The primary groundwater plumes have migrated from the potential sources noted in Subsection 2.4.1 via several transport mechanisms that are summarized below.

Table 2.2 Primary Groundwater Plumes and Related Transport Mechanisms

COC Type	Transport Mechanism
ADP	• Density-dependent flow • Migration with groundwater
pH plume	• Density-dependent flow • Migration with groundwater
CVOC	• DNAPL migration • Migration with the ADP • Displacement by the ADP • Migration with groundwater • Volatilization to ambient air and/or indoor air
Metals	• Migration with the ADP • Migration with groundwater
SVOC	• Migration with groundwater
PCBs	• Migration with groundwater

Metals and PCBs have also migrated from potential sources at ground surface via surface water runoff.

2.6.1 Anthropogenic Density Plume (ADP)

Historical Site operations resulted in surface releases of high density fluids from the potential sources described previously (primarily the settling ponds/barge, Potential Caustic Source Area, and Salt Pad). Mixing of lime sludge/solvent residue, caustic soda (sodium hydroxide), and brine (sodium chloride) in groundwater has resulted in a comingled plume of high density that under current conditions consists of specific gravity values ranging to approximately 1.2 (density of 74.9 pounds per cubic foot [lbs/ft^3]). The ADP tends to sink due to its higher density relative to the density of fresh groundwater and salt water. A conceptual figure showing the ADP during the early period of Site operations is shown on Figure 2.12. The early time ADP is envisioned as being within the fill and upper portion of the deltaic deposits below the settling ponds/barge (WMU C, F, G, and H), Salt Pad, and Potential Caustic Source Area. The solvent residue, comprised of PCE and TCE, is the highest density material that was released, and thus the early time ADP is shown to extend somewhat deeper under the settling ponds/barge on Figure 2.12.

Over time, the ADP migrated away from the potential source areas via density-dependent (i.e., gravity-driven) flow. While migrating downwards, the higher density plume displaced the fresh groundwater and salt water initially present beneath the release locations. The fresh groundwater and salt water displacement caused by the downward density plume migration caused lateral groundwater flow that has contributed to the lateral spreading of the density plume, as well as the spreading of impacted groundwater surrounding or comingled with the density plume. This lateral spreading has resulted in a portion of the CVOC plume migrating eastward, beneath the Waterway, opposite the average groundwater flow directions currently observed. The lateral spreading of the CVOC plume caused by the early time ADP is illustrated on Figure 2.13. The primary CVOC found beneath the Waterway currently is VC, which is a biodegradation product of the initially-released PCE and TCE.

The ADP will spread laterally and migrated vertically until encountering lower permeability soil layers or counterbalancing hydraulic pressures, as follows:

- Lateral migration would continue until reaching equilibrium, or counterbalancing hydraulic pressures (i.e., opposing horizontal hydraulic gradients counterbalancing the lateral density-driven gradients), or until encountering a vertical low-permeability barrier, such as the buried valley wall along the Bluffs east of the Waterway. These factors prevented eastward migration of the ADP into the sediments beneath the Bluffs.
- Vertical migration would continue until reaching a combination of the upward vertical hydraulic gradients from the upper glacial deposits to lower deltaic deposits and the increased frequency of lower permeability lenses in the lower deltaic deposits (i.e., the zone of apparent confining effect). Upward vertical hydraulic gradients in the upper glacial deposits counterbalance the tendency of the dense water to sink, and the increased frequency of lower permeability lenses in the lower deltaic deposits limits the vertical rate of migration.

The distribution of the current ADP is shown on Figure 2.14. The ADP is centered beneath the settling ponds/barge and Salt Pad, with the southern portion of the ADP underlying the Potential Caustic Source Area. The ADP has remained relatively consistent since 2006 based on comparison with upland groundwater density data from 2012.

The highest densities of the ADP are well below the groundwater table, reflecting the fact that the major density sources ceased or were removed prior to Site investigations. The ADP has also spread laterally beneath the Waterway and to the north toward Commencement Bay. The vertical migration of the ADP is limited by the zone of apparent confining effect in the lower deltaic deposits and upward vertical hydraulic gradients within the upper glacial deposits. The ADP has migrated northward due to northward-directed hydraulic gradients. The northward ADP migration also appears to be influenced by a northwestward dipping trough in the glacial deposits observed beneath the northeastern portion of the Site peninsula. The zone of apparent confining effect in the lower deltaic deposits appears to follow the trough, and correspondingly the ADP above this. Once the density-driven gradients of the ADP dissipate, diffusion and groundwater advection were the predominant mechanisms for any further migration of the ADP, and COC comingled with the ADP.

2.6.2 pH Plume

Historical Site operations resulted in surface releases of high density/high pH caustic fluids from the Potential Caustic Source Area described in Subsection 2.4.1. The caustic fluids co-mingled with the brine released from the Salt Pad to form the ADP. Thus, the pH plume is largely coincident with the ADP plume. The distribution of the current pH plume is shown on Figure 2.15.

Interaction of historical caustic releases with the aquifer materials has resulted in the formation of hydroxide and silicate ions, primarily within the shallow fill material. These ions react with fresh precipitation infiltration to produce high pH groundwater. Thus, shallow soil that was impacted with caustic is a continuing source of elevated pH to groundwater.

The position and extents of the pH plume has remained relatively consistent since 2006.

2.6.3 Chlorinated Volatile Organic Compounds (CVOC)

The migration of CVOC occurs by several mechanisms:

- DNAPL migration
- Migration of dissolved-phase with the ADP
- Displacement migration at the perimeter of the ADP
- Migration of dissolved-phase with fresh groundwater
- Migration to ambient and indoor (potentially) air

DNAPL Migration

The distribution of DNAPL in the subsurface is shown on Figure 2.16. This figure shows the general distribution of the confirmed and potential DNAPL beneath the Site. DNAPL is observed beneath the former solvent production plant, WMU A, and WMU G. Historical DNAPL release rates and mass likely would have been highly variable, resulting in the separation between confirmed DNAPL at the upper and lower depths within the deltaic deposits shown on Figure 2.16. During vertical migration of the DNAPL, significant lateral migration has occurred, likely due to the DNAPL encountering low-permeability lenses within the deltaic deposits that increase in frequency in the lower portion of the deltaic deposits. DNAPL has also moved northwestward at depth consistent with the zone of apparent confining effect in the lower deltaic deposits following the trough in the glacial deposits. Given the significant timeframe since the initial releases occurred, the tortuous migration of the DNAPL through the heterogeneous deltaic deposits, and increased frequency of lower permeability lenses in the lower deltaic deposits, the current DNAPL distribution is likely stable.

Residual DNAPL will result in a continuing source of dissolved CVOC. Additionally, diffusion into lower permeability (i.e., silt and clay) lenses adjacent to DNAPL will accumulate CVOC mass. The silt and clay then act as secondary sources of aqueous contamination through back-diffusion once groundwater concentrations in higher permeability zones decline. The process of back-diffusion from lower permeability lenses into higher permeability zones, where the bulk of the active groundwater flow occurs, will significantly prolong groundwater remediation timeframes and might result in rebounding of concentrations after certain types of treatment.

Migration with the ADP and Displacement Migration at the Perimeter of the ADP

Figure 2.17 shows the current distribution of CVOC in groundwater at the Site. The CVOC potential sources were in close proximity to the Salt Pad, and as a result, dissolved CVOC have comingled and migrated with the ADP. As the ADP displaced fresh groundwater or salt water in the subsurface, comingled CVOC within the ADP were carried by the ADP as it migrated laterally and downward. In addition, CVOC already dissolved in groundwater at the periphery of the ADP would have been displaced laterally and vertically in advance of the ADP migration. The lateral ADP migration is a primary reason for the presence of CVOC beneath the Hylebos east of the Potential CVOC Source Area even though the average groundwater flow direction observed under current conditions is more north to northwest.

Migration in Groundwater

Dissolved-phase CVOC in groundwater outside the ADP will migrate with groundwater. This will lead to northward migration as the regional groundwater flow direction in the deltaic deposits is generally toward Commencement Bay, with groundwater discharge to the surrounding surface water bodies. This northward flow has resulted in a shallow component of CVOC plume at the northern end of the Site peninsula. This component of the CVOC plume occurs above the salt water/freshwater transition zone, as illustrated on Figure 2.17.

Migration of dissolved-phase CVOC in groundwater is attenuated by the following processes: adsorption; diffusion into low-permeability (i.e., silt and clay) lenses; and degradation.

Adsorption of CVOC onto soil particles depends on the amount of organic matter naturally present in soil and the relative affinity of individual hydrophobic compounds to adhere to organic matter. Adsorption results in the dissolved-phase CVOC plume migrating more slowly than the average groundwater flow velocity.

Diffusion of dissolved-phase CVOC into lower permeability (i.e., silt and clay) lenses also slows the rate of CVOC migration relative to the average groundwater flow velocity in higher permeability zones. The silt and clay then act as secondary sources of dissolved-phase contamination through back-diffusion once groundwater concentrations in higher permeability zones decline.

Degradation of the CVOC is occurring both biologically and abiotically. Biological degradation of PCE and TCE (parent compounds) has produced cis-1,2-dichloroethene (cis-1,2-DCE) and VC (daughter products) at the Site. The distribution of the parent and daughter products in groundwater is shown on figures in the approved CSM Report (CRA, 2014a). In general, the concentrations of PCE and TCE are highest near the surface sources and DNAPL source zones. The concentrations of daughter products are highest in the source zones and beyond the PCE and TCE plume. The presence of cis-1,2-DCE and VC, which are daughter products of the biological degradation of PCE and TCE, confirms that PCE and TCE biodegradation is occurring. Ethene has also been detected in groundwater samples, indicating that complete degradation of VC is occurring at least in some areas of the Site.

The abiotic degradation of PCE and TCE might also be occurring as suggested by the presence of dissolved acetylene in groundwater.

It does not appear that the high ionic strength of the salt water, ADP, and pH plume have a direct effect on CVOC migration because CVOC are non-polar molecules.

The concentrations of CVOC at the base of the Waterway are significantly lower than groundwater concentrations at depth. The shallow concentrations are attenuated because of flushing (dilution) with surface water, which is enhanced via tidal fluctuation. Also, within the salt water zone adjacent to the Waterway mudline, salt water recharges to the aquifer resulting in dilution of the salt water zone. These processes contribute to the presence of low to non-detectable CVOC concentrations near the mudline observed at some Waterway sample locations. In particular, this is expected to occur in areas that are not affected by the ADP where high density groundwater discharge can occur against the salt water equilibrium or in areas that are not affected by high water levels from the eastern Bluffs. Although along the center and eastern shores of the Hylebos, impacted groundwater was detected nearer the mudline. This was confirmed by the findings of the 2016 Anchor QEA porewater investigation, which found no exceedances of AWQC near the mudline in these areas (see Subsection 2.4.6).

Migration to Ambient and Indoor (Potentially) Air

VOC can volatilize from impacted shallow groundwater or from the impacted vadose zone soil. VOC in the vapor phase will then migrate by diffusive and advective mechanisms through the unsaturated soil and be emitted to ambient air and potentially indoor air of enclosed buildings.

Concentrations of PCE and TCE above sub-slab screening levels potentially related to the OCC Site were identified in vapor samples collected from immediately beneath the concrete slabs of the POT Building 595 and OCC Office (TCE only). However, exceedances of indoor air screening levels for PCE and TCE were not identified in POT Building 595 where the sub-slab vapor concentrations are adequately attenuated. Exceedances of an indoor air screening level for TCE were identified in the OCC Office; however, the occupancy of this building is being managed by OCC to mitigate potential exposure.

2.6.4 Metals

The migration of metals occurs by several mechanisms:

- Migration of dissolved metals with the ADP
- Migration of dissolved-phase with fresh groundwater
- Metals transport in surface water runoff

Migration with the ADP

As the ADP displaced fresh groundwater or salt water in the subsurface, comingled dissolved metals within the ADP were carried by the ADP as it migrated laterally and downward. In addition, metals already dissolved in groundwater at the periphery of the ADP would have been forced to migrate laterally and vertically in advance of the ADP migration.

Migration in Groundwater

Infiltrating groundwater that comes into contact with soil containing metals will dissolve some of the metals, carrying them to the water table and into groundwater. Once in groundwater, the metals are transported along with groundwater flow.

The metals concentrations and migration in groundwater are influenced by numerous mechanisms, the most important at the Site are:

- Sorption onto naturally-occurring ferric oxide coatings on aquifer soil particles. This sorption slows the transport of metals in groundwater.
- Suppression of sorption onto the ferric oxide coatings by the high pH of the water in the pH plume mobilizing metals (that would otherwise be adsorbed) and keeping the metals in solution longer.
- Enhancement of the solubility of some metals in soil (both naturally-occurring and anthropogenic) by the high pH of the water in the pH plume.
- Limitation of the sorption of metals due to ion-ion interactions associated with the high ionic strength of the ADP (i.e., competition for sorption sites) keeping the metals in solution.

Migration of metals in groundwater is highly dependent on the pH plume and the ADP. As groundwater pH decreases and the ADP dissipates, natural sorption processes would precipitate metals and reduce the concentrations of metals dissolved in groundwater.

Surface Water Runoff

Precipitation at the Site comes into contact with surficial soil and carries soil particles with the surface water runoff, especially during heavy rainfall events. The surface water at the Site is conveyed by overland flow and the storm sewer system to adjacent surface water bodies.

There has been a storm sewer monitoring program in place at the Site designed to determine if storm water discharge is within regulatory limits. The monitoring program has shown the Site to be in compliance with the Site Storm Water Pollution Plan and has not identified any significant impacts. Based on this fact, it is unlikely that future impacts will occur and this migration pathway is not considered significant. Storm water monitoring data were summarized and presented in the SCR (CRA, 2014c) approved on October 11, 2016 (Ecology, 2016b).

2.6.5 Semi-Volatile Organic Compounds (SVOC)

The migration of SVOC could potentially occur via several mechanisms:

- DNAPL migration
- Migration of dissolved phase with the ADP
- Migration of dissolved phase with fresh groundwater

DNAPL Migration

Because the SVOC were formed as by-products of the solvent manufacturing process, they are inferred to have been present in the DNAPL released to the subsurface at the Site. The SVOC would have then migrated downward along with the DNAPL as described in Subsection 5.6.2.5.1 of the SCR (CRA, 2014c) approved on October 11, 2016 (Ecology, 2016b). The presence of HCB and HCBD in deep soil samples is consistent with this hypothesis.

Migration with the ADP and in Groundwater

The most predominant Site SVOC (HCB and HCBD) tend to sorb strongly to the soil and have limited mobility in groundwater compared to the CVOC. Some dissolution will occur though, as will the sorption to suspended particles (i.e., colloids) in groundwater. However, the migration of the SVOC in the groundwater is, as expected, much more limited than CVOC. Detected concentrations above the Site screening levels tend to be near to the identified potential SVOC source areas described in Subsection 2.4.1.

2.6.6 Polychlorinated Biphenyls (PCBs) and Dioxins/Furans

PCBs and dioxins/furans sorb very strongly to soil particles and therefore migration in the groundwater is limited, although some sorption to colloids might occur, which could result in a limited enhancement of PCBs and dioxins/furans migration. Surface water runoff could also potentially carry suspended soil particles with PCBs or dioxins/furans, if present, into surface water bodies. However, there are very few locations where concentrations are above screening levels on the Site and the mobility of PCBs and dioxins/furans is considered to be very limited. This observation is consistent with the distribution of PCBs and dioxins/furans in groundwater, which indicated the detected concentrations tend to be near the identified potential source areas described in Subsection 2.4.1.

2.7 Exposure Pathway Assessment

An Exposure Pathway Assessment was conducted for the Site in accordance with Ecology and USEPA guidance. The assessment included a human health exposure pathway assessment (HHEPA) and an ecological health exposure pathway assessment (EHEPA). The purpose of the assessment was to identify media and locations that might need corrective action, risk-management measures, or further evaluation. The Exposure Pathway Assessment was presented in the approved SCR Report (CRA, 2014c) and is summarized below.

The transport of COC may lead to the exposure and uptake of COC by human and ecological receptors. Potentially complete human and ecological exposure pathways and receptors are shown schematically on Figure 2.18. These exposure pathways and receptors are summarized below and assume that the future land use of the Site remains industrial/commercial.

Human Receptors and Exposure Pathways

The primary human receptors and exposure pathways at the Site are summarized below.

Table 2.3 Primary Human Receptors and Exposure Pathways

Receptor	Exposure Pathway
Industrial/Commercial Worker	• Inhalation of indoor air impacted by VOC volatilizing from soil and shallow groundwater • Incidental ingestion and dermal contact with impacted surface soil • Incidental ingestion and dermal contact of sediments in the intertidal zone
Construction/Utility Worker	• Incidental ingestion and dermal contact with surface and subsurface soil • Incidental ingestion and dermal contact with impacted groundwater while conducting subsurface excavations that

Table 2.3 Primary Human Receptors and Exposure Pathways

Receptor	Exposure Pathway
	extend to the groundwater table • Inhalation of soil particulates and/or ambient air
Trespasser	• Incidental ingestion and dermal contact with impacted surface soil • Inhalation of soil particulates and/or ambient air • Incidental ingestion and dermal contact of sediments in the intertidal zone
Recreational User	• Incidental ingestion and dermal contact with surface water in the Waterway
Fisher	• Ingestion of fish tissue

The HHEPA identified the following media and exposure pathways that might require corrective action, risk-management measures, or further evaluation.

Table 2.4 Media and Exposure Pathways

Medium	Exposure Pathway
Soil	• Inhalation of indoor air impacted by VOC volatilizing from soil • Inhalation of ambient air impacted by VOC volatilizing from soil • direct contact with impacted surface soil
Groundwater	• Inhalation of indoor air impacted by VOC volatilizing from shallow groundwater • Inhalation of ambient air impacted by VOC volatilizing from shallow groundwater • Direct contact with shallow groundwater
Sediment	• Direct contact with impacted sediment

As noted above in Subsection 2.4.5, the 2016 Anchor QEA investigation surface sediment results determined that most CVOC were below detection and no reported concentrations exceeded the CB/NT site SQOs~~. Therefore, there are no unacceptable risks associated with sediment~~, which were developed in consideration of the MTCA SMS.

Ecological Receptors

Under the industrial/commercial use of the Site, only limited exposure of terrestrial ecological receptors is expected, primarily along the embankment of the Waterway. The primary ecological exposure pathway at the Site is associated with the potential for discharge of impacted groundwater to the biologically active zone of the Waterway and Commencement Bay. The terrestrial and aquatic ecological receptors and exposure pathways at the Site are summarized below.

Table 2.5 Primary Ecological Receptors and Exposure Pathways

Receptor	Exposure Pathway
Soil invertebrates and burrowing animals	• Direct contact and ingestion of soil • Impacted soil gas vapors
Benthic organisms in Sediment of Waterway and Commencement Bay	• Impacted sediment within the biologically active zone • Impacted groundwater discharge into the biologically active zone

Table 2.5 Primary Ecological Receptors and Exposure Pathways

Receptor	Exposure Pathway
Avian carnivore, piscivore, insectivore	• Dietary uptake of prey/food
Aquatic vegetation and invertebrates	• Exposure to impacted groundwater through root uptake and direct contact • Direct contact and ingestion of sediment
Forage and predator fish	• Dietary uptake of plants and small aquatic species

As noted above in Subsection 2.4.5, the 2016 Anchor QEA investigation surface sediment results determined that most CVOC were below detection and no reported concentrations exceeded the CB/NT site SQOs. ~~Therefore, there are no unacceptable risks associated with sediment.~~ As noted above in Subsection 2.4.6, the 2016 Anchor QEA investigation near-bottom surface water and near-surface porewater results showed that only one parameter VC, reported in one sample (adjacent to the northern end of the 605 Alexander Avenue property), had the potential to marginally exceed the associated screening criterion at the applicable point of compliance. ~~Therefore, there are no unacceptable risks associated with the porewater, which represents ecological exposure pathways at the Site related to the potential for discharge of impacted groundwater to the Waterway~~Based on the fact that the remedy for the Site will include containment, it is unlikely that future impacts will occur. Some future monitoring of COC concentrations in sediment and porewater may be appropriate to ensure that existing conditions of sediment and porewater quality do not change over time, however unlikely this may be.

3. Identify Remedial Action Goals (RAGs) and Potential Applicable Local, State, and Federal Laws

This section presents the RAGs and potential applicable local, state, and federal laws and relevant and appropriate requirements identified for the Site.

3.1 Remedial Action Goals (RAGs)

In accordance with MTCA, CERCLA, and the NCP, the development of RAGs is required before the screening of remedial technologies and process options can be completed. The RAGs provide the basis for developing cleanup options that will be protective of human health and the environment. RAGs consist of medium-specific or operable-unit-specific goals expected to be achieved by the cleanup. They are protective of human health and the environment and are based on the COC, and potential receptors and exposure pathways.

Media of concern are defined as those media in which chemicals exceed their respective cleanup or screening levels. The extensive Site characterization data have shown that the media of concern at the Site include soil (unsaturated and saturated), groundwater, sediment, and indoor air. A listing of all chemicals that exceeded screening levels in the media of concern is presented in Table 2.1. Examination of this table shows that types of chemicals that exceed cleanup or screening levels include VOC, SVOC, pesticides, PCBs, dioxins/furans, metals, and pH.

RAGs were previously developed and agreed to among OCC and the Agencies for groundwater, surface water, and sediment. These RAGs were originally presented in the SOW (CRA, 2005). The 2005 RAGs were re-visited based on the current Site characterization and determination that future use of groundwater is non-potable. The media-specific RAGs for the Site developed cooperatively with the Agencies based upon evaluations of site-specific risk accomplished by OCC and by the Agencies working with a contractor (Ridolfi Environmental), and are presented in the table below:

Table 3.1 Remedial Action Goals (RAGs)

Environmental Medium	Remedial Action Goals (RAGs)
Groundwater	1. Prevent discharge of contaminated groundwater to Hylebos Waterway and Commencement Bay resulting in surface water contaminant concentrations exceeding Ambient Water Quality Criteria (AWQC) and applicable health based standards for aquatic life and human consumption of resident fish and shellfish. 2. Prevent discharge of contaminated groundwater to sediments in the Hylebos Waterway and Commencement Bay at concentrations that will re-contaminate the sediments above sediment quality standards for Site contaminants and applicable health based standards for aquatic life and human consumption of resident fish. 3. Prevent use of aquifer groundwater for drinking water, irrigation, or industrial purposes which would result in unacceptable risks to human health. 4. Prevent further migration of the contaminant plume and high pH plume to prevent the spread of contaminated groundwater to the Hylebos Waterway, Commencement Bay, and non-impacted portions of the aquifer.
Surface Water	1. Prevent marine ecological receptors from contacting surface waters that have contaminant concentrations that exceed surface water cleanup levels. 2. Prevent migration of hazardous substances, pollutants, or contaminants to the surface waters at concentrations that exceed surface water cleanup levels. 3. Control bioaccumulation exposures to human receptors associated with releases to surface water from the Site.
Sediment	1. Reduce to protective levels risks to benthic invertebrates and other biota from exposure to contaminated sediments and debris. 2. Reduce risks from direct contact (skin contact and incidental ingestion) to contaminated sediments and debris to protect human health.
Soil	1. Prevent human health risks associated with direct contact, ingestion, or inhalation of shallow soil contaminated above levels for industrial use. 2. Prevent terrestrial ecological receptors from contacting soils

Table 3.1 Remedial Action Goals (RAGs)

Environmental Medium	Remedial Action Goals (RAGs)
	that have contaminant concentrations that exceed industrial soil cleanup levels. 3. Prevent migration of hazardous substances, pollutants, or contaminants from soil to the surface waters at concentrations that exceed surface water cleanup levels.
Indoor air	1. Prevent human exposure to hazardous substances, pollutants, or contaminants from subsurface soil vapor at concentrations in excess of applicable standards and risk-based cleanup levels.

3.2 General Response Actions (GRAs)

GRAs are those actions that, singly or in combination, satisfy the RAGs for each medium of concern. GRAs may include treatment, containment, excavation, extraction, disposal, institutional actions, or a combination of these.

GRAs are applied to the media of concern. As a result, the estimates of the areas or volumes of media to which treatment might be applied were calculated. The areas and volumes are summarized below (not including indoor air, for which an area/volume could not be calculated and sediment, for which the area and volume is zero (0) since reducing risk is not required based on the 2016 Anchor QEA investigation).

Unsaturated Soil

The Exposure Pathway Assessment, presented in the SCR (CRA, 2014c), approved on October 11, 2016 (Ecology, 2016b), and summarized herein and in the approved CSM Report (CRA, 2014a), has shown that potential human exposure to COC in soil may result in unacceptable exposures. The potentially complete pathways that might result in unacceptable exposures were inhalation of indoor air and/or ambient air, and direct contact. The combined total area of the unsaturated impacted soil is approximately 149,000 square yards (yd^2) (CRA, 2014b). Assuming an average depth to water table of 7.5 ft, the estimated volume of impacted unsaturated soil is approximately 372,500 cubic yards (yd^3).

DNAPL

The mass of confirmed DNAPL was estimated using the mass of total chlorinated volatile organic compounds (TCVOC) in soil/porous media. The mass was calculated using the Mining Visualization System/Environmental Visualization System (MVS/EVS) software package, developed by C Tech Development Corporation (C Tech) (C Tech, 2007) model for the Site (as described in the CRA Technical Memorandum – Revised DNAPL Mass Estimates dated November 11, 2014 presented in Appendix C). A threshold soil TCVOC concentration of 100 milligrams per kilogram (mg/kg) was used to define the maximum extent of DNAPL. The ~~mass of~~total TCVOC mass at the Site was determined to be approximately 780,000 ~~pounds~~lbs as presented in Appendix C.

Groundwater

The groundwater plumes with the greatest distribution are the CVOC plume, ADP, and pH plume. The volume of these three plumes (porous media + water volume) was estimated using the MVS/EVS models for these plumes. In the case of the CVOC plume, the volume at a concentration greater than or equal to 2.4 micrograms per liter (μg/L) was estimated. This was based on the SSL for VC. The pH plume volume was determined at pH value greater than or equal to 8.5 s.u., based on the SSL. The ADP volume was estimated at a density greater than or equal to 64 lbs/ft^3 (specific gravity of 1.026). This value was selected because at this density the groundwater is clearly affected by anthropogenic activities.

The total plume volume was then used to estimate the volume of impacted groundwater within each plume by assuming a porosity of 0.43. The estimated plume and impacted water volumes are summarized in the following table.

Table 3.2 Estimated Plume and Impacted Water Volumes

Plume	Total Plume Volume (yd^3)	Impacted Water Volume (yd^3)
CVOC	7,852,223	3,376,456
ADP	2,962,518	1,273,883
pH	13,169,259	5,662,781

Site-specific GRAs were developed for each medium of concern to satisfy the RAGs. The GRAs and corresponding RAGs (from Subsection 3.1) are presented in Table 3.3.

3.3 Identification of Potential Applicable Local, State, and Federal Laws

WAC 173-340-710 discusses requirements for identifying applicable local, state, and federal laws. The requirements in WAC 173-340-710 "*…are similar to the ARAR (applicable, relevant, and appropriate requirements) approach of the federal superfund law. Sites that are cleaned up under an order or decree may be exempt from obtaining a permit under certain laws but they must still meet the substantive requirements of these laws. (See WAC 173-340-710(9).)*" [(WAC 173-340-700(6)(a)].

In accordance with WAC 173-340-710(2), this section identifies potential applicable local, state, and federal laws that may be considered legally applicable or relevant and appropriate requirements for the Site. "*The department shall make the final interpretation on whether these requirements have been correctly identified and are legally applicable or relevant and appropriate.*" [WAC 173-340-710(2)].

"*Legally applicable requirements include those cleanup standards, standards of control, and other environmental protection requirements, criteria, or limitations adopted under state or federal law that specifically address a hazardous substance, cleanup action, location or other circumstances at the site.*" [WAC 173-340-710(3)].

"*Relevant and appropriate requirements include those cleanup standards, standards of control, and other environmental requirements, criteria, or limitations established under state or federal law that, while not legally applicable to the hazardous substance, cleanup action, location, or other* *circumstance at a site, address problems or situations sufficiently similar to those encountered at the site that their use is well suited to the particular site.*" [WAC 173-340-710(4)].

Table 3.4 presents the potential applicable local, state, and federal laws and relevant and appropriate requirements identified for the Site.

4. Identify Alternatives

4.1 Alternatives Development

The Draft ERT Report (CRA, 2014b) presented the identification and screening of remedial technologies and process options to address impacts at the Site. The purpose of that evaluation was to identify appropriate remedial technologies and representative process options that could be used to assemble remedial alternatives for further evaluation in an FS report. The Agencies selected the remedial technologies and representative process options to be retained based on the evaluation presented in the Draft ERT Report (CRA, 2014b) and other sources.

The initial remedial technologies and representative process options that were retained for the development of remedial alternatives were presented in the 2015 Draft FS report. Following Agency review of the 2015 Draft FS report, Ecology provided the Agencies' comments on January 5, 2016. Based on these comments and subsequent discussions among the Agencies and OCC's team, a revised list of remedial technologies and representative process options was developed that included three groups of alternatives. The groups include containment alternatives, VOC mass removal/reduction alternatives, and pH (>12.5 s.u.) reduction/enhanced containment alternatives. Along with the three groups of alternatives, there are Common Elements that will be included in the final selected cleanup action, namely, Institutional Controls (ICs) and monitoring.

The following Subsection 4.2 describes the Common Elements of ICs and monitoring included in all remedial alternatives. Subsection 4.3 describes the Containment Alternatives. Subsection 4.4 describes the VOC Mass Removal/Reduction Alternatives. Subsection 4.5 presents the pH Reduction/Enhanced Containment Alternatives. Consistent with the 2015 Draft FS report, the subsurface was divided into two zones namely: the shallow zone that is defined from ground surface to -60 ft National Geodetic Vertical Datum (NGVD); and the deep zone that is defined as below -60 ft NGVD. The shallow zone corresponds to the approximate base of the Waterway and the deep zone is below the Waterway.

4.2 Common Elements to the Remedial Alternatives

The following elements are common to all remedial alternatives in accordance with WAC 183-340-350(8)(c)(i)(C), except No Action ~~containment alternatives~~alternative:

- Institutional Controls (ICs)
- Groundwater Quality Monitoring
- Soil Vapor Monitoring

4.2.1 Institutional Controls

All remedial alternatives, except No Action ~~containment alternatives~~alternative, will incorporate ICs. ICs are measures undertaken to limit or prohibit activities that interfere with the integrity of a remedy or that might result in exposure to hazardous substances at a site. In most cases, ICs are recorded as part of the property deed to warn future property owners of the condition and to restrict activities or use of the property that could result in exposure to hazardous substances. Tenants must also be notified of the restrictions in any lease agreement.

The circumstances where institutional controls are required as part of a cleanup action include the following (WAC 173-340-440):

- Sites where contamination remains at concentrations that exceed the established cleanup levels.
- Sites where cleanup levels are established representing concentrations that are protective of human health and the environment for specified site uses and conditions.
- Sites where cleanup levels are established based on industrial land use (soil) or a site-specific risk assessment (groundwater).
- Sites where a conditional point of compliance is used.
- Any time an institutional control is required under WAC 173-340-7490 through 173-340-7494 (ecological concerns).
- Where the department determines such controls are required to assure the continued protection of human health and the environment or the integrity of the interim or cleanup action.

Types of ICs include:

- Proprietary controls: easements that restrict use (negative easements) and restrictive covenants.
- Governmental controls: zoning; building codes; state, tribal, or local groundwater use regulations; and commercial fishing bans and sports/recreational fishing limits posed by federal, state, and/or local resources and/or public health agencies.
- Enforcement and permit tools with IC components: administrative orders, permits, Federal Facility Agreements (FFAs), and Consent Decrees (CDs), that limit certain site activities or require the performance of specific activities (e.g., monitor and report on IC effectiveness).
- Informational devices: state registries of contaminated sites, notices in deeds, tracking systems, and fish/shellfish consumption advisories.

ICs for the Site may include:

- Physical barrier to control access to the site (e.g., constructed and routinely maintained fence).
- Use restrictions such as limitations on the use of property or resources.
- Maintenance requirements for engineered controls such as the inspection and repair of perimeter physical barrier, monitoring wells, treatment systems, caps (direct contact barriers), or groundwater barrier systems.
- Educational programs such as signs, postings, public notices, health advisories, mailings, and similar measures that educate the public and/or employees about site contamination and ways to limit exposure.
- Financial assurances.

- Administrative Order used as legal tool that limit certain site activities or require the performance of specific activities (e.g., monitor and report on effectiveness of ICs).
- A Washington Industrial Safety and Health Act and United States Occupational Safety and Health Administration (WISHA/OSHA) compliant worker health, safety and training program to address current and future health and safety issues related to indoor air in the existing OCC Property buildings.
- No future buildings with and without basements or crawlspaces unless engineered to prevent vapor intrusion (e.g., vapor intrusion barriers or other active engineering controls [pressurized buildings or depressurized sub-slab systems] and monitoring).
- Groundwater use restrictions recorded under the deed except when used as part of remedy.
- No excavation or below grade construction without appropriate worker health and safety plans and training as detailed in a Soil and Groundwater Management Plan.
- No excavation or below grade construction without the proper handling, characterization, and disposal of the excavated soil/materials as detailed in a Soil and Groundwater Management Plan.
- Relocation and reuse of soil consistent with the corrective measures and a Soil and Groundwater Management Plan.

Where ICs are required, Agencies will conduct a review of the site every five years to ensure the continued protection of human health and the environment.

4.2.2 Groundwater Quality Monitoring

The purpose of a groundwater quality monitoring program is to verify that plumes are not migrating to non-impacted areas and to verify reduction in overall contaminant concentrations in groundwater over time. WAC 173-340-410(1)(a) states that Protection Monitoring is to "*confirm that human health and the environment are adequately protected during construction and the operation and maintenance period of an interim action or cleanup action as described in the safety and health plan.*" Groundwater quality monitoring will be part of the protection monitoring to ensure the remedy is performing as intended.

A groundwater quality sampling and analysis plan will be developed and submitted to the Agencies with the operation and maintenance plan (WAC 173-340-400) for review and approval during the implementation of the cleanup action. The plan will specify the groundwater samples to be collected, the handling of the samples, and the analysis procedures to be performed per WAC 173-340-820.

4.2.3 Soil Vapor Monitoring

The purpose of a soil vapor monitoring program is to monitor VOC in subsurface soil to determine if concentrations are increasing, decreasing, or remaining constant over time. ~~Increasing concentrations over time might indicate vapor migration from soil and/or groundwater that could affect indoor air concentrations negatively (i.e., higher indoor air concentrations), which might require reassessment of potential mitigation for a building. Decreasing or constant concentrations over time would indicate that reassessment is unnecessary.~~ Soil vapor monitoring will be part of the protection monitoring to ensure the remedy is performing as intended.

A soil vapor sampling and analysis plan will be developed and submitted to the Agencies with the operation and maintenance plan (WAC 173-340-400) for review and approval during the implementation of the cleanup action. The plan will specify the soil vapor samples to be collected, the handling of the samples, and the analysis procedures to be performed per WAC 173-340-820.

4.3 Containment Alternatives

Containment alternatives were determined based on the 2015 Draft FS report and Agencies' review of and comments on that report. More specifically, they are based on the Upland Remedial Alternative#2 (URA#2) presented in the 2015 Draft FS with variations in the proposed groundwater extraction rates. The four containment alternatives include:

1. No Action.
2. C100: Physical direct contact exposure (PDCE) barrier for 605 & 709 Alexander Avenue Properties, sheet pile vertical barrier wall adjacent to Hylebos, hydraulic containment based on URA#2 estimated groundwater pumping rates, and the Common Elements in Subsection 4.2.
3. C150: PDCE barrier for 605 & 709 Alexander Avenue Properties, sheet pile vertical barrier wall adjacent to Hylebos, hydraulic containment based on up to 50 percent greater estimated pumping rates compared to C100, and the Common Elements in Subsection 4.2.
4. C200: PDCE barrier for 605 & 709 Alexander Avenue Properties, sheet pile vertical barrier wall adjacent to Hylebos, hydraulic containment based on up to 100 percent greater estimated pumping rates compared to C100, and the Common Elements in Subsection 4.2.

The following subsections describe the four containment alternatives; designated as No Action, C100, C150, and C200, selected for inclusion in this FS Report, which are listed in Table 4.1 along with other grouped alternatives.

4.3.1 No Action ~~Containment~~ Alternative

Under the No Action alternative, the Site would remain in its present condition with no remedial action performed. This alternative is required by CERCLA and the NCP and is the baseline alternative against which the effectiveness of the other alternatives is compared. This alternative does not include the implementation of any ICs, such as deed restrictions, or future groundwater and soil vapor monitoring. It was also assumed that the current groundwater extraction and treatment system (GWETS) would not be operated.

4.3.2 Containment Alternative C100

Containment Alternative C100 was designed to eliminate, reduce, or otherwise control risks posed through potentially complete exposure pathways and migration routes, and includes the following elements:

- Common Elements (ICs and monitoring) described in Subsection 4.2
- PDCE Barrier for 605 & 709 Alexander Avenue Properties, Navy Todd Dump, N Landfill, and 709 Embankment Fill Area (See Figure 2.9)
- Sheet pile vertical barrier wall adjacent to the Hylebos
- Hydraulic containment through a newly constructed GWETS

The C100 alternative layout is presented on Figure 4.1. Figure 4.1 includes contours for TCVOC concentrations of 0.1 mg/L and 10 mg/L, and pH of 10 s.u. and 12.5 s.u. Figure 4.2a presents north/south and east/west cross-sections showing the TCVOC plume developed from the MVS/EVS that includes the above concentrations and others. Figure 4.2b presents north/south and east/west cross-sections showing the pH plume developed from the MVS/EVS that includes the above pH values and others. The cross-section locations are shown on Figure 4.1. As shown on Figure 4.1, the TCVOC concentrations greater than 10 mg/L are generally at the north end of the 605 Alexander Avenue property and further north and east, and pH greater than 12.5 s.u. are mostly within the east side of the 605 Alexander Avenue property. The cross-sections indicate that there are negligible areas where the TCVOC concentrations greater than 10 mg/L and pH greater than 12.5 s.u. are mixed. This was confirmed with the MVS/EVS used to develop plumes for the Site.

The Upland high pH, elevated VOC and DNAPL (refer to Appendices B, C, and D), and SVOC and metals (see Subsection 2.4) in shallow soil (down to -21 ft NGVD) are covered with a physical direct contact exposure (PDCE) barrier. The elevation -21 ft NGVD represents the depth in the shallow zone corresponding to highest TCVOC concentrations in soil (See Appendix D). The PDCE barrier would be placed over the area shown on Figure 4.1 to cover the contaminants. The primary purpose of the PDCE barrier is to isolate the contaminated soil from potential direct contact with human and ecological receptors and prevent the transport of contaminated soil to other portions of the Site. PDCE barriers can consist of a membrane liner, reinforced concrete, asphalt, clay soil, or a combination of these materials and are often used in combination with physical or hydraulic containment of groundwater. For estimating cost, it was assumed that the PDCE barrier would consist of asphalt and would cover approximately 34.5 acres.

The C100 alternative also includes a sheet pile vertical barrier wall placed along the eastern boundary of the Site as shown on Figure 4.1. Sheet pile technology was selected for the vertical barrier wall due to the greater implementability within a waterway, which will allow the vertical barrier to separate the upland portions of the Site from the Hylebos. Sheet pile technology has a long life expectancy in the order of 50 to 75 years, and could be repaired if necessary. The primary purpose of the vertical barrier wall is to eliminate the horizontal discharge from seeps and shallow groundwater with high pH to the Waterway. In addition, the vertical barrier wall would limit transient tidal effects on shallow groundwater levels, thereby resulting in less contaminant "flushing" in the vicinity of the embankment and more consistent performance of the groundwater extraction system in this area. The vertical barrier wall would also contain the contaminated embankment area, Navy Todd Dump, the N Landfill and the 709 Embankment Fill areas (See Figure 2.9). Additionally, approximately 25-30 percent of Area 5106 (see Figure 2.6) would be contained within (i.e., west of) the vertical barrier wall. The former intertidal zone on the upland side of the vertical barrier wall would be backfilled and covered by the PDCE barrier. The loss of intertidal zone would likely be offset by mitigation to comply with the Clean Water Act.

The proposed sheet pile vertical barrier wall alignment is shown on Figure 4.1. The vertical barrier wall would be approximately 2,200 ft long and approximately 70-75 ft deep. The vertical barrier wall would be installed with a top elevation of approximately 12 ft NGVD and a base elevation of approximately -61.25 ft NGVD, a few feet below the base of the Hylebos. The bottom elevation was selected to prevent potential direct horizontal discharge of shallow impacted groundwater to the Hylebos. A schematic cross-section along the embankment within the Area 5106 removal area is shown on Figure 4.3.

Impacts from ~~DNAPL,~~ shallow and deep DNAPL, TCVOC, and high pH ~~impacts,~~ would be contained through a GWETS in conjunction with the sheet pile vertical barrier wall. Extraction wells would be located to minimize mass discharge outside the containment area by controlling groundwater flow and contaminant migration, and to avoid pumping directly from areas of high pH (i.e., pH ≥10 s.u.). All extraction wells were modeled in upland areas where the groundwater pH was less than 10 s.u. Direct pumping from areas of high pH would be avoided in order to minimize/prevent: potential fouling of the GWETS; the need for treatment of high pH water; and disposal of additional solids associated with this high pH groundwater. Difficulties with GWETS fouling due to pumping high pH water at the Site have been well document during 22 years of operating the existing GWETS. Additionally, the numerous treatability studies that have been conducted for the Site have not determined a practical solution for overcoming the difficulties of direct pumping of groundwater from areas of high pH.

The extracted groundwater would be conveyed to an ex situ treatment system. The treatment plant would need to address groundwater with elevated VOC, as well as other chemistry. This alternative includes a network of ten new extraction wells and one existing inactive extraction well (EXT-9). The locations and depths of the proposed extraction wells were developed through a groundwater flow modeling optimization evaluation presented in Appendix E. The proposed extraction well layout and groundwater pumping rates are shown on Figure 4.1. Although some wells appear in plan view on the figure to be within higher pH, they are not because their depths (screen intervals) do not coincide with the groundwater with the high pH.

The ex situ treatment system would potentially include components such as building, controls, equalization tank, clarifier, filter press, filters, air stripper, thermal oxidizer, scrubber, pumps, and meters. A contingency for pH treatment has been included as per Agencies' request in the event that some high pH water is drawn into the system at some time in the future. The contingency is based on diluting up to 50 percent of the extracted groundwater with City of Tacoma potable water at a ratio of 1:1 prior to pH adjustment within the treatment system. The 50 percent value was selected because approximately half of the groundwater extraction would be from wells closer to the high pH areas. It is reasonable to assume that if the pH increased in a well, it would do so at a gradual rate since the pH would need to be drawn from areas of high pH through areas of lower pH towards the wells. Therefore, the quantity of dilution water required would increase gradually as well. The 1:1 ratio of groundwater to dilution water was selected as a reasonable estimate of the amount of dilution water that might be needed to minimize solids/silica gel formation based on the above and the pH pilot studies completed for the Site. Based on the pH pilot studies (CRA, 2011), dilution of the groundwater using potable water would limit the amount of solids/silica gel that might form if the pH is lowered rapidly by chemical treatment within the treatment plant. The groundwater with high pH is analogous to a super saturated solution of silica and the potable water adds some additional solute volume to keep the silica dissolved during treatment to reduce the pH. Salt water or groundwater with lower pH generally has higher dissolved solids and therefore would not likely provide the same solute volume as potable water.

GHD has confirmed with the City of Tacoma (email received on May 24, 2016 from Tacoma Water) that sufficient quantities of water are available at the Site (potentially up to approximately 150 gallons per minute [gpm]) for use as dilution water; however, the need for and best source of dilution water will be subject to examination and optimization during the design phase.

4.3.3 Containment Alternative C150

Containment Alternative C150 was designed to eliminate, reduce, or otherwise control risks posed through potentially complete exposure pathways and migration routes, and includes the same elements as Containment Alternative C100, but with a higher overall groundwater pumping rate. The purpose of a higher pumping rate is to evaluate the potential benefits of increasing overall drawdown on the degree and demonstrability of groundwater capture. The evaluation of the potential benefits is discussed in Section 5. The proposed extraction well layout is the same as the C100 alternative and is shown on Figure 4.4, along with the extraction well pumping rates for Alternative C150.

The target groundwater pumping rates for the Containment Alternative C150 extraction wells were 50 percent higher than the pumping rates for Containment Alternative C100. If the groundwater flow model predicted that a 50 percent increased pumping rate could not be sustained in an individual extraction well, then the pumping rate in the affected extraction well was reduced until a sustainable rate was achieved in the groundwater flow model. The groundwater flow modeling presented in Appendix E showed that a combined groundwater pumping rate of approximately 226.25 gpm is achievable with the well network. This represents an overall pumping rate increase of approximately 44 percent compared to Containment Alternative C100. The ex situ treatment system would be similar to that described in Subsection 4.3.2, but sized for the combined modeled flow rate and dilution water for contingency pH treatment.

4.3.4 Containment Alternative C200

Containment Alternative C200 was designed to eliminate, reduce, or otherwise control risks posed through potentially complete exposure pathways and migration routes, and includes the same elements as Containment Alternatives C100 and C150, but with an even higher overall groundwater pumping rate. The purpose of a higher pumping rate is to evaluate the potential benefits of increasing overall drawdown on the degree and demonstrability of groundwater capture. The evaluation of the potential benefits is discussed in Section 5. The proposed extraction well layout is the same as the C100 alternative and is shown on Figure 4.5, along with the extraction well pumping rates for Alternative C200.

The target groundwater pumping rates for the Containment Alternative C200 extraction wells were 100 percent higher than the pumping rates presented for Containment Alternative C100. If the groundwater flow model predicted that a 100 percent increased pumping rate could not be sustained in an individual extraction well, then the pumping rate in the affected extraction well was reduced until a sustainable rate was achieved in the groundwater flow model. The groundwater flow modeling presented in Appendix E showed that a combined groundwater pumping rate of approximately 281.5 gpm is achievable with the well network. This represents an overall pumping rate increase of approximately 79 percent compared to Containment Alternative C100. The ex situ treatment system would be similar to that described in Subsection 4.3.2, but sized for the combined modeled flow rate and dilution water for contingency pH treatment.

4.4 VOC Mass Removal/Reduction Alternatives

VOC Mass Removal/Reduction Alternatives were determined based on the 2015 Draft FS report and Agencies' review of and comments on that report and subsequent discussions among the Agencies and OCC’s team. The alternatives are focused on evaluating selected potential technologies and process options for more immediately removing or reducing VOC concentrations in soil and/or groundwater. The ten VOC mass removal/reduction alternatives include:

~~1. No Action.~~

1. No Additional Action (i.e., only a containment alternative from Subsection 4.3 is implemented).
2. VOC source area mass reduction by groundwater extraction, which includes three variations of groundwater pumping rates referred to as M100, M150, and M200, and ex situ treatment.
3. VOC source area mass reduction by strategic groundwater pumping, which is referred to as mass reduction by strategic groundwater pumping (MSP), and ex situ treatment.
4. M3: VOC source area mass removal by shallow soil excavation and on-Site ex situ treatment and backfilling.
5. M4: VOC source area mass removal by shallow soil excavation and off-Site transport, ex situ treatment, and disposal.
6. M5: VOC source area mass reduction by shallow soil in situ treatment.
7. M6: VOC source area mass removal by shallow soil excavation and on-Site ex situ treatment and backfilling, and VOC source area mass reduction by shallow soil in situ treatment.
8. M7: VOC source area mass removal by shallow soil excavation and off-Site transport, ex situ treatment, and disposal, and VOC source area mass reduction by shallow soil in situ treatment.
9. M8: VOC mass reduction by shallow groundwater in-situ treatment and VOC source area mass reduction by shallow soil in situ treatment.
10. M9: VOC mass reduction by shallow and deep groundwater in-situ treatment and VOC source area mass reduction by shallow and deep soil in situ treatment.

The VOC targeted by the above alternatives include TCVOC mass in shallow (ground surface to -60 ft NGVD) and/or deep (-60 ft NGVD to the bottom of the impacted aquifer) zones within portions of the upland areas. The estimated total soil volumes and quantity of TCVOC mass in the shallow and deep target zones based on the estimated total DNAPL mass of 780,000 ~~pounds (~~lbs~~)~~ presented in Appendix C are shown on Figure 4.6 and summarized in the table below.

Table 4.2 Summary of Estimated Soil Volumes and Quantity of TCVOC Mass within Target Zones

Targeted Zone	Estimated Impacted Soil Volume (yd^3)	Estimated Quantity of TCVOC Mass (lbs)
Shallow	98,229	107,260
Deep	472,590	669,430
Not Targeted	16,230	3,310

Table 4.2 and Figure 4.6 also include the small portion that is not targeted.

The following subsections describe the ten VOC mass removal/reduction alternatives, including: No Additional Action; three sub-alternatives for groundwater extraction, designated as M100, M150, and M200; MSP; and M3 through M9 selected for inclusion in this FS Report, which are listed in Table 4.1 along with other grouped alternatives.

4.4.1 No Additional Action VOC Mass Removal/Reduction Alternative

Under the No Additional Action alternative, only a containment alternative (see Subsection 4.3) would be implemented with no additional remedial action performed. This VOC mass removal/reduction alternative ~~is required by CERCLA and the NCP and~~ is the baseline alternative against which the effectiveness of the other VOC mass removal/reduction alternatives is compared.

4.4.2 VOC Mass Reduction Alternatives M100, M150, and M200

4.4.2.1 VOC Mass Reduction Alternative M100

Mass Reduction Alternative M100 was designed to extract shallow and deep groundwater with high concentrations of VOC outside the areas of high pH (i.e., less than 10 s.u. as noted in Subsection 4.3.2). Direct pumping from areas of high pH would be avoided in order to minimize/prevent: potential fouling of the extraction and treatment system; the need for treatment of high pH water; and disposal of additional solids associated with this groundwater. The locations and depths of two proposed extraction wells, one shallow and one deep, were developed through a groundwater flow modeling optimization evaluation presented in Appendix E. The proposed extraction well layout and pumping rates for the M100 alternative are presented on Figure 4.7. The locations are the same that were proposed for the Upland Remedial Alternative#3 (URA#3) presented in the 2015 Draft FS report. The extracted groundwater would be conveyed to an ex situ treatment system. This would be the same system constructed for one of the containment alternatives described in Subsection 4.3.

Figure 4.7 depicts the layout of the Site and includes contours for TCVOC concentrations of 0.1 mg/L and 10 mg/L. Figure 4.7 also shows the target areas for all of the VOC ~~Mass~~mass removal/reduction alternatives that are further discussed in the following Subsections. Figure 4.8 presents north/south and east/west cross-sections showing the TCVOC plume developed from the MVS/EVS that includes the these concentrations and others, and identifies the approximate locations of the shallow and deep groundwater with high TCVOC dissolved concentrations targeted for extraction by the two proposed wells. The cross-section locations are shown on Figure 4.7. As shown on Figure 4.7 the TCVOC greater than 10 mg/L are generally at the north end of the 605 Alexander Avenue property and further north and east.

The groundwater flow modeling presented in Appendix E showed that the combined groundwater pumping rate of 35 gpm could be maintained by the two extraction wells. The rationale for this pumping rate is discussed in Appendix E. The evaluation of groundwater pumping for mass reduction is discussed in Section 6. The total mass ~~captured~~outside pH >10 s.u. removed over ~~100~~20 years was estimated by the model to be ~~99,037 lbs (dissolved) or 663,127~~275,132 lbs (dissolved, sorbed, and DNAPL phases), which represent ~~12.7 or 85~~35.3 percent~~, respectively,~~ of the estimated total DNAPL mass of 780,000 lbs presented in Appendix C**. Note that estimated mass removal rates were determined using the three-dimensional (3D) groundwater flow model that was specifically constructed and calibrated for the Site. The Site groundwater flow model provides a useful tool to evaluate the potential effectiveness of the groundwater mass reduction remedial alternatives that incorporate groundwater extraction.** It is noted that the model assumes idealized mass transport controlled by advection and equilibrium sorption and all mass is assumed to be either dissolved in the groundwater or sorbed onto the aquifer matrix.

Potential effects of non-aqueous phase liquids are not included. The potential effects of diffusion into low-permeability units or areas are not included. Additionally, the estimates do not include potential effects of high pH potentially reaching extraction wells, all contributing to the uncertainty of the mass estimates. However, the evaluation approach was applied consistently for all alternatives.

4.4.2.2 VOC Mass Reduction Alternative M150

Mass Reduction Alternative M150 includes the same elements as Mass Reduction Alternative M100, but with a higher overall groundwater pumping rate. The purpose this alternative is to evaluate the potential benefits of increasing the rate of VOC mass reduction and potentially total VOC mass reduction, noting that generally a higher overall pumping rate would result in higher overall costs. The evaluation of the potential benefits is discussed in Section 6. The proposed extraction well layout (same as M100) and extraction well pumping rates (higher than M100) are shown on Figure 4.9.

The target groundwater pumping rates for the Mass Reduction Alternative M150 extraction wells were 50 percent higher than the pumping rates presented for Mass Reduction Alternative M100. The groundwater flow modeling presented in Appendix E predicted that a 50 percent increased pumping rate could be sustained for both wells. The combined groundwater pumping rate for this alternative is approximately 52.5 gpm. The total mass ~~captured~~outside pH >10 s.u. removed over ~~100~~20 years was estimated by the model to be ~~116,755 lbs (dissolved) or 698,995~~285,394 lbs (dissolved, sorbed, and DNAPL phases), which represents ~~15 or 90~~36.6 percent~~, respectively,~~ of the estimated total DNAPL mass of 780,000 lbs presented in Appendix C.

4.4.2.3 VOC Mass Reduction Alternative M200

Mass Reduction Alternative M200 includes the same elements as Mass Reduction Alternatives M100 and M150, but with an even higher overall groundwater pumping rate to aid in evaluating the potential benefits of increasing the rate of VOC mass reduction and potentially total VOC mass reduction. The evaluation of the potential benefits is discussed in Section 6. The proposed extraction well layout (same as M100 and M150) and extraction well pumping rates (higher than M100 and M150) are shown on Figure 4.10.

The target groundwater pumping rates for the Mass Reduction Alternative M200 extraction wells were 100 percent higher than the pumping rates presented for Mass Reduction Alternative M100. The groundwater flow modeling presented in Appendix E predicted that a 100 percent increased pumping rate could be sustained for both wells. The combined groundwater pumping rate for this alternative is approximately 70 gpm. The total mass ~~captured~~outside pH >10 s.u. removed over ~~100~~20 years was estimated by the model to be ~~127,786 lbs (dissolved) or 719,904~~291,648 lbs (dissolved, sorbed, and DNAPL phases), which represents ~~16~~37.4~~ or 92~~ percent~~, respectively,~~ of the estimated total DNAPL mass of 780,000 lbs presented in Appendix C.

4.4.3 VOC Mass Reduction Alternative MSP (Mass Reduction by Strategic Groundwater Pumping)

Mass Reduction Alternative MSP was designed to extract shallow and deep groundwater within areas of high concentrations of VOC outside the areas of high pH (i.e., less than 10 s.u. as noted in Subsection 4.3.2) to achieve a higher initial rate of mass reduction than the Mass Reduction Alternatives M100, M150, and M200. For this alternative, a greater number of wells were strategically placed in areas of high VOC concentrations in both saturated soil and groundwater (i.e., near DNAPL source zones). The location of extraction wells near CVOC source zones can accelerate mass dissolution from DNAPL and thus expedite source area depletion. Strategic pumping can increase mass removal efficiency and decrease mass loading to groundwater (i.e., reduces dissolved phase contamination).

Similar to Mass Reduction Alternatives M100, M150, and M200, direct pumping from areas of high pH would be avoided in order to minimize/prevent: potential fouling of the extraction and treatment system; the need for treatment of high pH water; and disposal of additional solids associated with this groundwater. The locations and depths of the proposed extraction wells were developed through a groundwater flow modeling optimization evaluation presented in Appendix E. The proposed extraction well layout and pumping rates for the MSP alternative are presented on Figure 4.11. The extracted groundwater would be conveyed to an ex situ treatment system. The treatment system would be similar to the system constructed for the M150 or M200 containment alternatives described in Subsection 4.3.

Figure 11 depicts the layout of the Site and includes contours for TCVOC groundwater concentrations of 0.1 mg/L and 10 mg/L. Figure 11 also shows the target areas for all of the VOC ~~Mass~~mass removal/reduction alternatives that are discussed in the following Subsections. Figure 12 presents north/south and east/west cross-sections showing the TCVOC groundwater plume developed from the MVS/EVS, and identifies the approximate locations of the shallow and deep high TCVOC concentration areas. The cross-section locations are shown on Figure 11. As shown on Figure 11 the TCVOC concentrations greater than 10 mg/L in groundwater are generally at the north end of the 605 Alexander Avenue property and further north and east.

The groundwater flow modeling presented in Appendix E showed that the combined groundwater pumping rate of 210 gpm could be maintained by the extraction wells. The rationale for this pumping rate is discussed in Appendix E. The evaluation of groundwater pumping for mass reduction is discussed in Section 6. The total mass ~~captured~~outside pH >10 s.u. removed over ~~the initial 10~~20 years was estimated by the model to be ~~656,140~~323,883 lbs, which represents ~~84~~41.5 percent of the estimated total DNAPL mass of 780,000 lbs presented in Appendix C~~. This is greater than 30 percent more than the M100, M150, and M200 alternatives for which the model estimates percentages of 42, 48, and 52, respectively. The total mass captured over 100 years was estimated by the model to be 766,835 lbs, which represents 98 percent of the estimated total DNAPL mass and is greater than the M100 (85%), M150 (90%), and M200 (92%) alternatives~~.

4.4.4 VOC Mass Removal Alternative M3

Mass Removal Alternative M3 was designed to remove near-surface soil potentially containing DNAPL (PTW) that could be a future source of contamination in soil and groundwater. The M3 alternative includes the following elements:

- Excavation of shallow soil above -4 ft NGVD containing TCVOC concentrations greater than 100 mg/kg
- Removal of VOC from the excavated soil by on-Site treatment
- Backfill on Site of treated excavated soil

The TCVOC concentration of 100 mg/kg is representative of areas with confirmed or potential DNAPL as presented in Appendix C and is considered PTW as presented in Appendix B.

The M3 alternative layout is presented on Figure 4.13. Figure 4.13 shows the areas above -4 ft NGVD that have TCVOC concentrations greater than 100 mg/kg. Figure 4.14 presents north/south and east/west cross-sections showing the TCVOC plume developed from the MVS/EVS through some of these areas. The cross-section locations are shown on Figure 4.13. The mass of TCVOC within the volume of soil defined by the parameters above is approximately 23,200 lbs, which represents 3.0 percent of the estimated total DNAPL mass of 780,000 lbs presented in Appendix C. The vertical extent of the target zone is shown on Figure 4.14.

Soil above -4 ft NGVD that has TCVOC concentrations greater than 100 mg/kg would be excavated and consolidated into piles set up for treatment to reduce VOC concentrations. Excavated soil that is saturated would require dewatering/drying before treatment. The excess water from the piles would drain back into the excavations. Soil that has TCVOC concentrations less than 100 mg/kg overlying the soil targeted for on-Site treatment would be temporarily stockpiled separately for reuse. The on-Site treatment would involve ex situ soil vapor extraction (SVE) to remove VOC from the soil followed by treatment of the extracted vapors by a portable thermal oxidizer system and/or activated carbon. SVE is typically an in situ remedial technology that may be applied to stockpiles of excavated soil. There are various types of vapor extraction methods including vertical and horizontal pipes, gravel beds, and trenches. Synthetic membranes are often placed over the soil surface to prevent short-circuiting and to increase the radius of influence of the extraction pipes. Thermal oxidation would involve transferring extracted soil vapors through a vessel that uses thermal processes (e.g., exposure to flame) to oxidize VOC into innocuous compounds before being released to the atmosphere. Activated carbon treatment would involve transferring extracted soil vapors through filtrate vessels, which promote adsorption of VOC via contact with filter material.

Following completion of the SVE, the treated soil and soil suitable for reuse would be backfilled on the 605 Alexander Avenue property within and around the excavations and ultimately would be under a PDCE barrier (see Subsection 4.3.2). Excavations beyond the 605 Alexander Avenue property would be backfilled with soil suitable for reuse and/or imported clean material. The surfaces would be returned to the same or better conditions that were present prior to the excavation.

4.4.5 VOC Mass Removal Alternative M4

Mass Removal Alternative M4 includes the same excavation element as Mass Removal Alternative M3, but with off-Site transportation, treatment, and disposal of the excavated material containing TCVOC concentrations greater than 100 mg/kg. Figure 4.13 presents the layout and Figure 4.14 presents cross-sections related to the M4 alternative. The mass of TCVOC targeted for this alternative is the same as the M3 alternative described above in Subsection 4.4.4.

Soil above -4 ft NGVD that has TCVOC concentrations greater than 100 mg/kg would be excavated. Unsaturated soil would be consolidated directly into licensed trucks that would transport the material to an appropriate facility licensed to accept, treat, and dispose of the material. Saturated soil would be consolidated into temporary piles adjacent to the excavations to allow for some drying. The excess water from the piles would be permitted to drain back into the excavations. Once appropriate moisture content levels were achieved to allow proper transport, this soil would be consolidated into licensed trucks that would transport the material to an appropriate facility licensed to accept, treat, and dispose of the material. Soil that has TCVOC concentrations less than 100 mg/kg overlying the soil targeted for off-Site disposal would be temporarily stockpiled separately for reuse. Excavations would be backfilled with the soil suitable for reuse and imported clean material to replace the soil that was removed and transported off Site for treatment and disposal. The surfaces would be returned to the same or better conditions that were present prior to the excavation.

4.4.6 VOC Mass Reduction Alternative M5

Mass Reduction Alternative M5 was designed to further reduce, compared to the M3 and M4 alternatives, TCVOC concentrations in shallow soil potentially containing DNAPL (PTW) that could be a future source of contamination in soil and groundwater. The M5 alternative includes in situ treatment with the following elements:

- Treatment using in situ electrical resistance heating (ERH) of shallow saturated soil below 2.5 ft NGVD and above -21 ft NGVD containing TCVOC concentrations greater than 500 mg/kg.
- Treatment using in situ SVE of shallow unsaturated (vadose zone) soil above 2.5 ft NGVD containing TCVOC concentrations greater than 500 mg/kg.

The TCVOC concentration of 500 mg/kg represents the lower limit to identify areas with potential DNAPL for potential remediation based on a significantly declining benefit (i.e., diminishing returns) analysis presented in Appendix D. As shown in Appendix D, shallow soil down to -21 ft NGVD contains this potential DNAPL mass in the shallow zone. It is also considered PTW as presented in Appendix B.

The M5 alternative layout is presented on Figure 4.15. Figure 4.15 shows the areas above 2.5 ft NGVD and between 2.5 ft NGVD and above -21 ft NGVD that have TCVOC concentrations greater than 500 mg/kg. Figure 4.16 presents north/south and east/west cross-sections showing the TCVOC plume developed from the MVS/EVS through some of these areas. The cross-section locations are shown on Figure 4.15. The mass of TCVOC within the volume of soil defined by the parameters above is approximately 62,200 lbs, which represents 8.0 percent of the estimated total mass of DNAPL of 780,000 lbs presented in Appendix C. The vertical extent of the target zones are shown on Figure 4.16.

ERH is a thermal treatment technology that increases the temperature of the saturated zone and allows contaminants to be more easily volatilized, mobilized, and extracted from the subsurface. ERH involves the installation of electrodes in the ground and passing an alternating current through the electrodes, thereby heating the soil. Steam is generated when the subsurface temperature is raised to the boiling point of the saturated media. The steam strips the contaminants from the subsurface and enables extraction through liquid or vapor recovery wells.

SVE is an in situ remedial technology where a vacuum is applied through extraction wells located near the source of elevated chemical concentrations in the unsaturated soil zone. Volatile constituents of the chemical mass volatilize and the vapors are drawn toward the extraction wells thus reducing the concentrations of VOC sorbed to the soil in the vadose zone. The extracted vapors are then typically treated as necessary using thermal oxidation or activated carbon before being released to the atmosphere. Synthetic membranes are often placed over the soil surface to prevent short-circuiting and to increase the radius of influence of the extraction wells.

As shown on Figure 4.15, the area designated for treatment by SVE is within the area designated for treatment by ERH. Since SVE is necessary over the ERH treatment area to collect VOC migrating to the surface during the ERH process, the in situ ERH treatment (with in situ SVE) will cover the smaller area shown on Figure 4.15 designated for SVE treatment alone.

4.4.7 VOC Mass Removal/Reduction Alternative M6

Mass Removal/Reduction Alternative M6 was designed to remove near-surface impacted soil and to further reduce TCVOC concentrations in shallow soil potentially containing DNAPL (PTW) that could be a future source of contamination in soil and groundwater. The M6 alternative is a combination of the excavation and in situ ERH treatment elements from the M3 and M5 alternatives, respectively, and includes the following elements:

- Excavation of shallow soil above -4 ft NGVD containing TCVOC concentrations greater than 100 mg/kg.
- Removal of VOC from the excavated soil by on-Site treatment.
- Backfill on Site of treated excavated soil.
- Treatment using in situ ERH (with SVE) of shallow soil below -4 ft NGVD and above -21 ft NGVD containing TCVOC concentrations greater than 500 mg/kg.

The M6 alternative layout is presented on Figure 4.17, which shows the areas above -4 ft NGVD that have TCVOC concentrations greater than 100 mg/kg and between -4 ft NGVD and above -21 ft NGVD that have TCVOC concentrations greater than 500 mg/kg. Figure 4.18 presents north/south and east/west cross-sections showing the TCVOC plume developed from the MVS/EVS through some of these areas. The cross-section locations are shown on Figure 4.17. The mass of TCVOC within the volume of soil defined by the parameters above is approximately 66,200 lbs, which represents 8.5 percent of the estimated total mass of DNAPL of 780,000 lbs presented in Appendix C. The vertical extent of the target zones are shown on Figure 4.17.

Descriptions of excavation, on-Site treatment, and backfilling are provided in Subsection 4.4.4. Descriptions of ERH and SVE technologies are provided in Subsection 4.4.6 above.

4.4.8 VOC Mass Removal/Reduction Alternative M7

Mass Removal/Reduction Alternative M7 includes the same elements as Mass Removal/Reduction Alternative M6, but with off-Site transportation, treatment, and disposal of the excavated material containing TCVOC concentrations greater than 100 mg/kg. It is a combination of the excavation and in situ ERH treatment elements from the M4 and M5 alternatives, respectively. Figure 4.17 presents the layout and Figure 4.18 presents cross-sections related to the M7 alternative. The mass of TCVOC targeted for this alternative is the same as the M6 alternative described above in Subsection 4.4.7.

4.4.9 VOC Mass Removal/Reduction Alternative M8

Mass Reduction Alternative M8 was designed to further reduce TCVOC concentrations in shallow groundwater and in shallow soil potentially containing DNAPL (PTW) that could be a future source of contamination in soil and groundwater. The M8 alternative includes elements from the M5 alternative (ERH and SVE) plus elements for in situ treatment of shallow groundwater as follows:

- Treatment using in situ chemical oxidation (ISCO) of shallow groundwater above -60 ft NGVD containing TCVOC concentrations greater than 10 mg/L within the zone where pH is between 10 s.u. and 12.5 s.u.

- Treatment using enhanced in situ bioremediation (ISB) of shallow groundwater above -60 ft NGVD containing TCVOC concentrations greater than 10 mg/L within the zone where pH is less than 10 s.u.

The TCVOC concentration of 10 mg/L was selected because in situ groundwater treatment is usually applied to concentrated source areas and not to widely-dispersed, low-concentration plumes.

The M8 alternative layout is presented on Figure 4.19. Figure 4.19 shows the areas above 2.5 ft NGVD and between 2.5 ft NGVD and above -21 ft NGVD that have TCVOC concentrations greater than 500 mg/kg. It also shows areas above -60 ft NGVD that have TCVOC concentrations greater than 10 mg/L within the zones where pH is between 10 s.u. and 12.5 s.u. and less than 10 s.u. Figure 4.20 presents north/south and east/west cross-sections showing the TCVOC plume developed from the MVS/EVS through some of these areas. The cross-section locations are shown on Figure 4.19.

The mass of TCVOC within the volume of soil defined by the parameters above is the same as the M5 alternative (approximately 62,200 lbs, which represents 8.0 percent of the estimated total mass of DNAPL of 780,000 lbs presented in Appendix C). The vertical extent of the target zone is shown on Figure 4.20. Descriptions of ERH and SVE technologies are provided in Subsection 4.4.6 above.

The mass of TCVOC within the volume of shallow groundwater defined by the parameters above is approximately 19,400 lbs, which represents 12.4 percent of the estimated total mass of TCVOC in groundwater of 156,960 lbs.

The total mass of TCVOC within the volume of soil and groundwater defined above represents 10.5 percent of the estimated total DNAPL mass of 780,000 lbs presented in Appendix C.

ISCO by injection would be used to introduce chemical oxidant into groundwater to react with and destroy organic contaminants. Multiple injections of the oxidant are usually required and for this site would be completed using installed wells because of the depth of the target zone. Alkaline persulfate would be used as the oxidant because it would take advantage of the synergistic effects of the elevated pH in groundwater between 10 s.u. and 12.5 s.u. to activate the alkaline persulfate. This technology is non-selective meaning that other organic material present in the target zone would be oxidized along with the targeted organic material. Therefore, overdosing would be required to effectively treat the groundwater. ISCO was successfully demonstrated to reduce contaminants to carbon dioxide (CO_2) and water at small sites in permeable material (McGuire et al., 2013, 2014).

ISB by injection in wells would be used to establish vertical "curtains" of biological activity where impacted groundwater would flow through treating (degrading) VOC. Multiple injections of the substrate (emulsified vegetable oil), *Dehalococoides* spp. (DHC) and enhancements are usually required to maintain suitable conditions for biological activity. Additionally, an electron donor would be released into groundwater and would be transported downgradient of each "curtain." The electron donor would promote further contaminant biodegradation in the aquifer. The target zone for this technology would be within areas of pH that are less than 10 s.u., since it is not effective in higher pH.

4.4.10 VOC Mass Removal/Reduction Alternative M9

Mass Reduction Alternative M9 was designed to further reduce TCVOC concentrations in shallow and deep groundwater and in shallow and deep soil potentially containing DNAPL (PTW) that could be a future source of contamination in soil and groundwater. The M9 alternative includes elements from the M8 alternative plus elements for in situ treatment of deep groundwater and soil as follows:

- Treatment using ISCO of deep soil below -60 ft NGVD containing TCVOC concentrations greater than 500 mg/kg within the zone where pH is between 10 s.u. and 12.5 s.u.
- Treatment using ISB of deep soil below -60 ft NGVD containing TCVOC concentrations greater than 500 mg/kg within the zone where pH is less than 10 s.u.
- Treatment using ISCO of deep groundwater below -60 ft NGVD containing TCVOC concentrations greater than 10 mg/L within the zone where pH is between 10 s.u. and 12.5 s.u.
- Treatment using ISB of deep groundwater below -60 ft NGVD containing TCVOC concentrations greater than 10 mg/L within the zone where pH is less than 10 s.u.

The M9 alternative layout is presented on Figure 4.21. Figure 4.21 shows the areas above 2.5 ft NGVD, between 2.5 ft NGVD and above -21 ft NGVD, and below -60 ft NGVD that have TCVOC concentrations greater than 500 mg/kg. It also shows areas that have TCVOC concentrations greater than 10 mg/L within the zones where pH is between 10 s.u. and 12.5 s.u. and less than 10 s.u through the full depth of the Site. Figure 4.22 presents north/south and east/west cross-sections showing the TCVOC plume developed from the MVS/EVS through some of these areas. The cross-section locations are shown on Figure 4.21.

The mass of TCVOC within the volume of soil defined by the parameters above is approximately 525,800 lbs, which represents 67.4 percent of the estimated total mass of DNAPL of 780,000 lbs presented in Appendix C. The vertical extent of the target zones are shown on Figure 4.22.

The mass of TCVOC within the volume of ~~shallow~~ groundwater defined by the parameters above is approximately 87,500 lbs, which represents 55.7 percent of the estimated total mass of TCVOC in groundwater of 156,960 lbs.

The total mass of TCVOC within the volume of soil and groundwater defined above represents 78.6 percent of the estimated total DNAPL mass of 780,000 lbs presented in Appendix C

Descriptions of the technologies are provided in Subsections 4.4.6 and 4.4.9.

4.5 pH Reduction/Enhanced Containment Alternatives

The pH Reduction/Enhanced Containment Alternatives were determined based on the 2015 Draft FS report and Agencies' review of and comments on that report. The alternatives are focused on evaluating selected potential technologies and process options for reducing or enhancing containment of pH in soil and groundwater. The seven reduction/enhanced containment alternatives include:

~~1. No Action~~

1. No Additional Action (i.e., only a containment alternative from Subsection 4.3 is implemented).
2. pH2: pH >12.5 s.u. reduction by shallow soil and groundwater in situ treatment.

3. pH3: pH >12.5 s.u. enhanced containment by shallow soil and groundwater in situ treatment.
4. pH4: pH >12.5 s.u. enhanced containment of shallow soil and groundwater by vertical barrier.
5. pH5: pH >12.5 s.u. reduction by shallow and deep soil and groundwater in situ treatment.
6. pH6: pH >12.5 s.u. enhanced containment by shallow and deep soil and groundwater in situ treatment.
7. pH7: pH >12.5 s.u. enhanced containment of shallow and deep soil and groundwater by vertical barrier.

The pH targeted by the above alternatives includes pH in shallow (ground surface to -60 ft NGVD) and/or deep (-60 ft NGVD to the bottom of the impacted aquifer) zones within portions of the upland areas. The estimated total soil volumes and quantity of pH >12.5 s.u. (quantified as acid-neutralizing capacity [ANC] as presented in Appendix F) in the shallow and deep target zones based on the estimated total ANC of 200 Megaequivalents (Meq) acid presented in Appendix F are shown on Figure 4.23 and summarized in the table below.

Table 4.3 Summary of Estimated Soil Volumes and Quantity of pH within Target Zones

Targeted Zone	Estimated Impacted Soil Volume (yd^3)	Estimated Quantity of pH (ANC) (Meq acid)
Shallow	78,068	91
Deep	85,690	97
Not Targeted	10,560	12

Table 4.3 and Figure 4.23 also include the small portion that is not targeted.

The following subsections describe the seven reduction/enhanced containment pH alternatives designated as No Additional Action and pH2 through pH7 selected for inclusion in this FS Report, which are listed in Table 4.1 along with other grouped alternatives.

4.5.1 No Additional Action pH Reduction/Enhanced Containment Alternative

Under the No Additional Action alternative, only a containment alternative (see Subsection 4.3) would be implemented with no additional remedial action performed. This pH reduction/enhanced containment alternative ~~is required by CERCLA and the NCP and~~ is the baseline alternative against which the effectiveness of the other pH reduction/enhanced containment alternatives is compared.

4.5.2 pH Reduction Alternative pH2

The pH Reduction Alternative pH2 was designed to reduce, by in situ treatment, pH >12.5 s.u. (i.e., PTW) in shallow soil and groundwater that could be a future source of contamination in soil and groundwater. The pH2 alternative includes the following elements:

- Treatment using in situ mixing of sodium persulfate with shallow soil and groundwater above -60 ft NGVD containing pH greater than 12.5 s.u.

The 12.5 s.u. target treatment level was selected because material with pH greater than 12.5 s.u. would be characteristically hazardous for corrosivity in accordance with the Code of Federal Regulations (40 CFR 261.22) and is considered PTW as presented in Appendix B.

The pH2 alternative layout is presented on Figure 4.24 and includes contours for pH of 10 s.u. and 12.5 s.u. As shown on Figure 4.24, pH greater than 12.5 s.u. is mostly within the east side of the 605 Alexander Avenue property. Figure 4.24 also shows the areas above -60 ft NGVD that have pH greater than 12.5 s.u. Figure 4.25 presents north/south and east/west cross-sections showing the pH developed from the MVS/EVS through some of these areas. The cross-section locations are shown on Figure 4.24. The volume of aquifer defined by the parameters above have an ANC that is approximately 11.2 percent of the estimated ANC in the aquifer with pH greater than 7 s.u. (pH neutral) as presented in Appendix F. The vertical extent of the target zone is shown on Figure 4.25.

In situ reagent mixing would involve mixing a chemical reagent vertically into the unsaturated and saturated subsurface using either a single auger or multiple augers equipped with mixing paddles. The augers would penetrate the ground and mix the soil and groundwater as they rotate. The reagent would be simultaneously injected through the hollow drill stem as the augers retreat back to the surface. Each treated soil column would be typically 3 to 5 ft in diameter after mixing. The treatment process would be repeated over the treatment area, overlapping each soil column to ensure complete mixing. Sodium persulfate would be used. The pH pilot studies (CRA, 2011) conducted for the Site, indicate that it would be expected that pH values would rebound after treatment and therefore would require over treatment to initially reduce the pH below the target treatment level of 12.5 s.u. (e.g., 10-11 s.u.).

4.5.3 pH Enhanced Containment Alternative pH3

The pH Enhanced Containment Alternative pH3 was designed to contain, by in situ treatment, pH >12.5 s.u. (i.e., PTW) in shallow soil and groundwater that could be a future source of contamination in soil and groundwater. The pH3 alternative includes the following elements:

- Treatment using in situ mixing of cement with shallow soil and groundwater above -60 ft NGVD containing pH greater than 12.5 s.u.

The pH3 alternative layout is the same as the pH2 alternative and is presented on Figure 4.24. Figure 4.24 shows the areas above -60 ft NGVD that have pH greater than 12.5 s.u. Figure 4.25 presents north/south and east/west cross-sections showing the pH developed from the MVS/EVS through some of these areas. The cross-section locations are shown on Figure 4.24. The ANC within the volume of aquifer defined by the parameters above is the same as the pH2 alternative, approximately 11.2 percent.

A description of the mixing technology is provided in Subsection 4.5.2. Cement would be used to contain the pH greater than 12.5 s.u by stabilization. The technology would involve the mixing of a binding agent (cement) into soil to greatly reduce the potential ability of contaminants to migrate with groundwater. It will also reduce the permeability of the soil, which reduces groundwater flow through the area.

4.5.4 pH Enhanced Containment Alternative pH4

The pH Enhanced Containment Alternative pH4 was designed to contain, by in situ vertical barrier, pH >12.5 s.u. (i.e., PTW) in shallow soil and groundwater that could be a future source of contamination in soil and groundwater. The pH3 alternative includes the following elements:

- Construction of a vertical slurry barrier wall around shallow soil and groundwater above -60 ft NGVD containing pH greater than 12.5 s.u.

The pH4 alternative layout is presented on Figure 4.26 that includes the conceptual potential location of a vertical slurry barrier wall around the areas above -60 ft NGVD that have pH greater than 12.5 s.u. Figure 4.25 presents north/south and east/west cross-sections showing the pH developed from the MVS/EVS through some of these areas. The cross-section locations are shown on Figure 4.24. The ANC within the volume of aquifer defined by the parameters above is the same as the pH2 and pH3 alternatives, approximately 11.2 percent.

A vertical slurry barrier wall would be used to enhance the containment of groundwater with high pH and prevent it from reaching environmental receptors and potential extraction wells related to the containment alternatives. (See Subsection 4.3). The vertical slurry barrier wall would also contain other contaminants preventing horizontal migration but also limiting contaminant extraction by pumping groundwater related to the containment alternatives and the Mass Reduction Alternatives, M100, M150, M200, and ~~M200~~MSP. (See Subsection 4.4.2). Extraction of contaminants would be limited to groundwater movement under the vertical slurry barrier wall due to pumping.

The alignment shown on Figure 4.26 would result in a vertical slurry barrier wall approximately 1,650 ft long and approximately 70 to 75 ft bgs. The vertical slurry barrier wall would be installed to ground surface, at a top elevation of approximately 12 ft NGVD and base elevation of approximately -60 ft NGVD. The spoils would be placed within the contained area and under the proposed PDCE barrier. (See Subsection 4.3).

4.5.5 pH Reduction Alternative pH5

The pH Reduction Alternative pH5 was designed to reduce, by in situ treatment, pH >12.5 s.u (i.e., PTW) in shallow and deep soil and groundwater that could be a future source of contamination in soil and groundwater. The pH5 alternative includes the following elements:

- Treatment using in situ mixing of sodium persulfate with shallow and deep soil and groundwater containing pH greater than 12.5 s.u.

The pH5 alternative layout is presented on Figure 4.27. Figure 4.27 shows the areas that have pH greater than 12.5 s.u. Figure 4.28 presents north/south and east/west cross-sections showing the pH developed from the MVS/EVS through some of these areas. The cross-section locations are shown on Figure 4.24. The volume of aquifer defined by the parameters above have an ANC that is approximately 23.3 percent of the estimated ANC in the aquifer with pH greater than 7 s.u. (pH neutral) as presented in Appendix F. The vertical extent of the target zones are shown on Figure 4.28.

A description of the technology is provided in Subsection 4.5.2.

4.5.6 pH Enhanced Containment Alternative pH6

The pH Enhanced Containment Alternative pH6 was designed to contain, by in situ treatment, pH >12.5 s.u (i.e., PTW) in shallow and deep soil and groundwater that could be a future source of contamination in soil and groundwater. The pH6 alternative includes the following elements:

- Treatment using in situ mixing of cement with shallow and deep soil and groundwater containing pH greater than 12.5 s.u.

The pH6 alternative layout is the same as the pH6 alternative and is presented on Figure 4.27. Figure 4.27 shows the areas that have pH greater than 12.5 s.u. Figure 4.28 presents north/south and east/west cross-sections showing the pH developed from the MVS/EVS through some of these areas. The cross-section locations are shown on Figure 4.24. The ANC within the volume of aquifer defined by the parameters above is the same as the pH5 alternative, approximately 23.3 percent.

A description of the technology is provided in Subsection 4.5.3.

4.5.7 pH Enhanced Containment Alternative pH7

The pH Enhanced Containment Alternative pH7 was designed to contain, by in situ vertical barrier, pH >12.5 s.u (i.e., PTW) in shallow and deep soil and groundwater that could be a future source of contamination in soil and groundwater. The pH7 alternative includes the following elements:

- Construction of a vertical slurry barrier wall around shallow and deep soil and groundwater containing pH greater than 12.5 s.u.

The pH7 alternative layout is presented on Figure 4.29 that includes the conceptual potential location of vertical slurry barrier walls around the areas that have pH greater than 12.5 s.u. Figure 4.28 presents north/south and east/west cross-sections showing the pH developed from the MVS/EVS through some of these areas. The cross-section locations are shown on Figure 4.24. The ANC within the volume of aquifer defined by the parameters above is the same as the pH5 and pH6 alternatives, approximately 23.3 percent.

A description of the technology is provided in Subsection 4.5.4. The alignment shown on Figure 4.29 would result in vertical slurry barrier walls including: approximately 970 ft long and approximately 70 to 75 ft bgs for shallow pH enhanced containment (see Subsection 4.5.4); approximately 2,235 ft long and approximately 110 to 115 ft bgs for deep pH enhanced containment within the 605 Alexander Avenue property; and approximately 625 ft long and approximately 150 to 155 ft bgs for deep pH enhanced containment outside of the 605 Alexander Avenue property. The vertical slurry barrier walls would be installed to ground surface, at a top elevation of approximately 12 ft NGVD and base elevations of approximately -60 ft NGVD, -100 ft NGVD, and -140 ft NGVD. The spoils would be placed within the contained area and under the proposed PDCE barrier. (See Subsection 4.3).

5. Containment Alternatives - Initial Screening and Detailed Evaluation

5.1 Initial Screening

The purpose of an initial screening of alternatives is to potentially reduce the number of alternatives for the detailed evaluation, if appropriate. Cleanup action alternatives or components may be eliminated from further consideration if:

(i) it is determined (by the Agencies) based on a preliminary analysis that an alternative or a component so clearly does not meet the minimum requirements specified in WAC 173-340-360. This includes an alternative or a component for which costs are clearly disproportionate under WAC 173-340-360(3)(e).

(ii) the alternative or component is not technically possible at the site.

The minimum requirements in WAC 173-340-360 include threshold requirements as follows:

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

The threshold criteria in CERCLA and the NCP include overall protection of human health and the environment and compliance with Applicable or Relevant and Appropriate Requirements (ARARs). These are included in the WAC threshold requirements. Determining if an alternative is administratively and technically possible is analogous to the NCP criterion of implementability (administrative and technical).

The containment alternatives are described in Subsection 4.3. Except for the No Action alternative, it has been determined that the containment alternatives would meet the minimum requirements and are administratively and technically possible. The No Action alternative is retained for comparison with the other alternatives consistent with CERCLA and the NCP even though it does not meet the minimum/threshold requirements.

It is recognized for this Site that a reasonable restoration time frame, which is meaningful and a reliable estimate, cannot be reasonably established because of inherent uncertainties in existing conditions and in the future response of those conditions to site remediation activities. This is a fundamental reason for including containment in all the alternatives described in Section 4., except the No Action Alternative. It is further recognized that a restoration time frame for this Site will likely exceed 100 years for all feasible remediation alternatives. Therefore, for the purpose of evaluating and comparing alternatives, a 100-year period of time is used for comparing the potential effectiveness over the long term in the disproportionate cost analyses.

The following Subsections present the initial screening of the containment alternatives C100, C150, and C200 with respect to relative costs for alternatives that have similar technical implementability and potential effectiveness.

5.1.1 Containment Alternative C100

Alternative C100 is fully implementable and would be effective to protect human health and the environment by eliminating and managing potential exposure pathways. Proper maintenance and monitoring would ensure permanence and effectiveness of the containment alternative.

The relative cost of this alternative would be lowest of the containment alternatives based on a lower groundwater extraction rate that would require, for example, smaller equipment, less consumables (e.g., less power and chemicals for ex situ treatment), and less solids disposal. The contingency pH treatment (see Subsection 4.3.2) would increase cost for pH treatment equipment and the operation and maintenance (O&M) costs for power consumption, chemical usage, and solids disposal, but would not increase the size of the treatment plant and other equipment that would be sufficiently sized to accommodate up to 50 percent more flow from adding dilution water.

5.1.2 Containment Alternative C150

Alternative C150 is fully implementable and would be effective to protect human health and the environment by eliminating and managing potential exposure pathways. Proper maintenance and monitoring would ensure permanence and effectiveness of the containment alternative.

The relative cost of this alternative would be slightly higher than the containment alternative C100 based on a higher groundwater extraction rate that would require increased O&M, for example, more consumables (e.g., more power and chemicals for ex situ treatment) and more solids disposal. The treatment plant/equipment size would be relatively the same. However, when factoring in the contingency pH treatment (see Subsection 4.3.2), the treatment plant/equipment would need to be larger to accommodate up to 50 percent more flow from adding dilution water and therefore the capital costs would be slightly higher as well. Additionally, the O&M costs for consumables and solids disposal would further increase commensurate with the additional flow.

5.1.3 Containment Alternative C200

Alternative C200 is fully implementable and would be effective to protect human health and the environment by eliminating and managing potential exposure pathways. Proper maintenance and monitoring would ensure permanence and effectiveness of the containment alternative.

The relative cost of this alternative would be higher than the containment alternatives C100 and C150 based on a higher groundwater extraction rate that would require larger treatment plant equipment and more consumables (e.g., more power and chemicals for ex situ treatment) and more solids disposal. When factoring in the contingency pH treatment (see Subsection 4.3.2), the larger treatment plant equipment associated with the C150 alternative would be adequate to accommodate the up to 50 percent more flow from adding dilution water. The O&M costs for consumables and solids disposal would further increase commensurate with the additional flow. The relative O&M cost of the C200 alternative with the contingency pH treatment would be higher than the C150 alternative with the contingency pH treatment, but the treatment plant equipment would be the same as noted above. The higher O&M costs would be based on a higher groundwater extraction rate that would require, for example, more consumables (e.g., more power and chemicals for ex situ treatment) and more solids disposal. The relative cost of the C200 alternative with the contingency pH treatment would be greater than the C100 alternative with the contingency pH treatment since the treatment plant equipment would be larger and O&M costs would be greater.

5.1.4 Summary

All three containment alternatives (C100, C150, and C200) are fully implementable and similar in O&M required. The effectiveness of the drawdown (a measure of containment; see Subsection 5.2) increases with increases in pumping rate, which in turn increases the costs to construct, operate, and maintain to some degree. The potential benefits of increasing the pumping rate do not appear to clearly add disproportionate costs (i.e., no large increase in costs). Therefore, the initial screening did not eliminate any of the alternatives based on the requirements presented above.

5.2 Detailed Evaluation

Purpose and Evaluation Criteria

The detailed evaluation of the Containment Alternatives involved using the calibrated groundwater flow model developed for the Site, as presented in Appendix E, to determine if the alternatives meet the model-based objectives provided by the Agencies. In general, the purpose and objectives of the modeling evaluation include:

- Evaluate potential discharge of TCVOC mass to the surface water bodies that surround the Site peninsula.
- Evaluate the degree of hydraulic containment achieved by groundwater extraction.

The specific Model-Based Performance Objectives for the Containment Alternatives consist of:

1) Within the hydraulic control boundaries provided by the Agencies on March 30, 2016, there must be inward gradients and a target drawdown of at least 1 foot (See Appendix E).

~~1)~~2) The Site groundwater flow model must be used to estimate the future mass discharge to Commencement Bay and the Hylebos Waterway with the containment system in place. In addition to needing to meet RAGs presented in Subsection 3.1, as a minimum, the containment system must result in an estimated TCVOC mass discharge of less than 0.2 percent of the current estimated total TCVOC mass in the aquifer~~ (i.e., 0.2 percent of 780,000 lbs).~~.

~~2)~~3) ~~The Site groundwater~~Groundwater flow ~~model must be used to show that the simulated drawdown within the Site peninsula along the 1,000 μg/L TCVOC contour in groundwater is at least 1 foot and show that groundwater flow under~~beneath the Waterway ~~is~~must be directed to the plant~~-~~-west toward the containment system.

Per MTCA and CERCLA, other factors to consider include:

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

5.2.1 Containment Alternative C100

Evaluation of Model-Based Performance Objectives

Containment Alternative C100 includes a physical hydraulic barrier wall along the Site peninsula adjacent to the Waterway and upland groundwater extraction wells on the Site peninsula. The location and number of upland extraction wells were optimized using the groundwater flow model. The objective of optimization was to maximize TCVOC groundwater plume containment while not placing extraction wells where the pH was greater than 10 s.u. (to minimize fouling of extraction wells). For Containment Alternative C100, the optimization resulted in eleven extraction wells (including existing inactive extraction well EXT-9) at a total groundwater pumping rate of 157.5 gpm. The detailed modeling evaluation of Containment Alternative C100 is presented in Appendix E, and the results of the modeling evaluation are summarized below relative to meeting Model-Based Performance Objectives 1 and 2.

Containment Alternative C100 achieves inward gradients and simulated drawdown of at least 1 foot where TCVOC concentrations are above 1,000 µg/L in the 15-ft zone (see Figure 1 of Appendix E). Containment Alternative C100 achieves inward gradients and simulated drawdown of at least 1 foot within the majority of the hydraulic control boundaries for the 25-ft to 75-ft zones (see Figures 2 to 4 in Appendix E), which essentially meets Model-Based Performance Objective 1). However, the simulated drawdown is less than 1 foot within a significant portion of the hydraulic control boundaries for the 100-ft and 130-ft zones (see Figures 5 and 6 in Appendix E), and this does not meet Model-Based Performance Objective 1), although inward gradients are simulated for these zones.

Containment Alternative C100 results in an estimated TCVOC mass discharge of less than 0.2 percent of the total TCVOC mass in the aquifer, which meets Model-Based Performance Objective 12) (see Table 2 of Appendix E). The TCVOC mass discharge to the surface water bodies surrounding the Site peninsula is approximately 0.02 percent of the total TCVOC mass in the aquifer (188 lbs) after the 1,000-year simulation duration.

Containment Alternative C100 essentially achieves simulated drawdown of 1 ft or greater where TCVOC concentrations are above 1,000 µg/L in the 15-ft to 50-ft zones on the Site peninsula (see Figures 1 to 3 of Appendix E). However, the simulated drawdown is less than 1 ft in significant areas where TCVOC concentrations are above 1,000 µg/L in the 75-ft to 130-ft zones (see Figures 4 to 6 of Appendix E), which does not meet the required drawdown component of Model-Based Performance Objective 2.

Figures 4, 5, and 6 of Appendix E show that simulated groundwater flow directions under the Waterway in the 75-ft, 100-ft, and 130-ft zones, respectively, are directed toward the Site peninsula and the groundwater extraction system, which meets the groundwater flow direction component of Model-Based Performance Objective 2.3).

Since Containment Alternative C100 does not meet the required drawdown component of Model-Based Performance Objective 2,1), it is not evaluated further in the FS.

5.2.2 Containment Alternative C150

Evaluation of Model-Based Performance Objectives

Containment Alternative C150 is based on Containment Alternative C100 but with increased extraction rates. Containment Alternative C150 applies the same extraction wells as Containment Alternative C100, but with pumping rates increased by up to 50 percent from that applied in Containment Alternative C100. The total groundwater pumping rate applied for Containment Alternative C150 corresponds to 226.25 gpm, which is approximately 44 percent higher than Alternative C100. The detailed modeling evaluation of Containment Alternative C150 is presented in Appendix E, and the results of the modeling evaluation are summarized below relative to meeting Model-Based Performance Objectives 1 and 2.

Containment Alternative C150 achieves Model-Based Performance Objective 1inward gradients and simulated drawdown of at least 1 foot where TCVOC concentrations are above 1,000 µg/L in the 15-ft zone (see Table 2 ofFigure 8 in Appendix E). The TCVOC mass discharge to the surface water bodies surrounding the Site peninsula is approximately 0.004 percent of the total TCVOC mass in the aquifer (35 lbs) after the 1,000-year simulation duration, which is 0.016 percent less than Alternative C100.

Containment Alternative C150 achieves simulated drawdown of 1 ft or greaterinward gradients and simulated drawdown of at least 1 foot within the hydraulic control boundaries for the 25-ft and 50-ft zones (see Figures 9 and 10 in Appendix E), which meets Model-Based Performance Objective 1). Containment Alternative C150 achieves inward gradients and simulated drawdown of at least 1 foot within the vast majority of the hydraulic control boundaries for the 75-ft to 130-ft zones (see Figures 11 to 13 in Appendix E), The 1-foot simulated drawdown encompasses where TCVOC concentrations are above 1,000 µg/L in the 1575-ft to 130-ft zones on the Site peninsula (see Figures 8 to 13 of Appendix E), which meets the required drawdown component. The above in combination with simulating inward gradients for the 75-ft to 130-ft zone hydraulic control boundaries, satisfies the intent of Model-Based Performance Objective 2.1). Simulating significant drawdown (i.e., 1 ft or more) in the 160-ft zone is not expected since much of this zone lies below the zone of apparent confining effect where lower permeability is represented in the groundwater flow model (see Figure 14 of Appendix E).

Containment Alternative C150 achieves Model-Based Performance Objective 2) (see Table 2 of Appendix E). The TCVOC mass discharge to the surface water bodies surrounding the Site peninsula is approximately 0.004 percent of the total TCVOC mass in the aquifer (35 lbs) after the 1,000-year simulation duration, which is 0.016 percent less than Alternative C100.

Containment Alternative C150 achieves simulated groundwater flow directions under the Waterway in the 75-ft, 100-ft, and 130-ft zones that are directed toward the Site peninsula and the groundwater extraction system, which meets the groundwater flow direction component of Model-Based Performance Objective 23) (see Figures 11, 12, and 13 of Appendix E).

Other Factors to Consider

Containment Alternative C150 is designed to eliminate, reduce, or otherwise control risks posed through potentially complete exposure pathways and migration routes. Therefore, a properly operated, maintained, and monitored C150 containment alternative would protect human health and the environment, including potential ecological receptors, by containing and preventing exposure to media with concentrations of COC above SSLs and by meeting the Site RAGs (see Subsection 3.1).

The technologies proposed are common and practical for containing a large complex site such as this and could be effectively operated, maintained, and monitored. The C150 alternative components presented herein are administratively and technically possible at the Site. The applicable state and federal laws (see Subsection 3.3) would be complied with during the design and implementation phases by meeting the substantive requirements. Administratively, substantive requirements of permitting would be met in terms of the following:

1. Construction - storm water, potential air monitoring, and building.
2. Post Construction and Long-term operations - National Pollutant Discharge Elimination System (NPDES) (to include wastewater sampling, storm water sampling, air monitoring).

Pre-Construction and Construction (including demolition and construction) - might include Washington State Environmental Policy Act (SEPA), Ecology construction storm water permitting requirements, Port of Tacoma tenant improvement requirements for off-property work, City of Tacoma construction permitting requirements, and Joint Aquatic Resources Permit Application (JARPA) working in water ways (US Army Corps Of Engineers - requirements for general permit, nationwide permit, standard individual permits, and letter of permission - as authorized under Section 10 and/or Section 404). It is most likely that a sheet pile vertical barrier wall would require the most effort and would take the longest time to meet the substantive requirements. Port of Tacoma officials report that recently observed permitting time frames in the Tacoma Tideflats area has taken up to 1.5 years to complete. Air monitoring might be required during construction if emissions are expected during construction.

Post-construction, an impermeable barrier (PDCE barrier) over an area of approximately 34.5 acres would result in large quantities of runoff during storm events and would need to meet NPDES substantive requirements. Discharge from the GWETS would need to meet NPDES substantive requirements as well. Air discharge from the GWETS would need to meet the substantive requirements of applicable State and Federal air emissions regulations.

ICs and compliance monitoring along with O&M are very reliable and effective means to ensure control of potential future migration of hazardous substances. Compliance monitoring would include performance monitoring, confirmation monitoring, and protection monitoring. The C150 containment alternative would include compliance monitoring in the forms of the Common Elements of ICs and monitoring (see Subsection 4.2), substantive requirements of permitting, five-year reviews, and field-based performance objectives. The existing network of monitoring wells is likely more than adequate to monitor the effectiveness and field-based performance objectives. The compliance monitoring would ensure that potential exposure to residual threats are eliminated or managed.

The C150 alternative would be compatible with the current and anticipated future uses of the Site and surrounding areas, which are industrial with generally paved surfaces.

This alternative would prevent future potential discharges into surface water that could potentially adversely impact ecological populations. The area is serviced by a municipal water supply and the groundwater beneath the Site has been determined to be non-potable (see Appendix A).

Since the containment system would not significantly alter the geochemical conditions in the subsurface, natural processes (e.g., biodegradation) documented to occur at the Site would also continue to reduce concentrations of hazardous substances.

5.2.3 Containment Alternative C200

Evaluation of Model-Based Performance Objectives

Containment Alternative C200 is based on Containment Alternative C100 but with increased extraction rates, which are higher than the C150 alternative extraction rates as well. Containment Alternative C200 applies the same extraction wells as Containment Alternative C100, but with pumping rates increased by up to 100 percent from that applied in Containment Alternative C100. The total groundwater pumping rate applied for Containment Alternative C200 corresponds to 281.5 gpm, which is approximately 79 percent higher than Alternative C100 and 24 percent higher than Alternative C150. The detailed modeling evaluation of Containment Alternative C200 is presented in Appendix E, and the results of the modeling evaluation are summarized below relative to meeting Model-Based Performance Objectives 1 and 2.

Containment Alternative C200 achieves Model-Based Performance Objective 1 (see Table 2 of Appendix E).Containment Alternative C200 achieves inward gradients and simulated drawdown of at least 1 foot where TCVOC concentrations are above 1,000 µg/L in the 15-ft zone (see Figure 15 in Appendix E). Containment Alternative C200 achieves inward gradients and simulated drawdown of at least 1 foot within the hydraulic control boundaries for the 25-ft and 50-ft zones (see Figures 16 and 17 in Appendix E), which meets Model-Based Performance Objective 1). Similar to Containment Alternative C150, Containment Alternative C200 achieves inward gradients and simulated drawdown of at least 1 foot within the vast majority of the hydraulic control boundaries for the 75-ft to 130-ft zones (see Figures 18 to 20 in Appendix E). The 1-foot simulated drawdown encompasses where TCVOC concentrations are above 1,000 µg/L in the 75-ft to 130-ft zones on the Site peninsula. The above in combination with simulating inward gradients for the 75-ft to 130-ft zone hydraulic control boundaries, satisfies the intent of Model-Based Performance Objective 1). Simulating significant drawdown (i.e., 1 ft or more) in the 160-ft zone is not expected since much of this zone lies below the zone of apparent confining effect where lower permeability is represented in the groundwater flow model (see Figure 21 of Appendix E).

Containment Alternative C200 achieves Model-Based Performance Objective 2) (see Table 2 of Appendix E). The TCVOC mass discharge to the surface water bodies surrounding the Site peninsula is approximately 0.004 percent of the total TCVOC mass in the aquifer (30 lbs) after the 1,000-year simulation duration, which is 0.016 percent less than Alternative C100 and essentially the same as Alternative C150.

Containment Alternative C200 achieves simulated drawdown of 1 ft or greater where TCVOC concentrations are above 1,000 µg/L in the 15-ft to 130-ft zones on the Site peninsula (see Figures 15 to 20 of Appendix E), which meets the required drawdown component of Model-Based Performance Objective 2. Simulating significant drawdown (i.e., 1 ft or more) in the 160-ft zone is not expected since much of this zone lies below the zone of apparent confining effect where lower permeability is represented in the groundwater flow model (see Figure 21 of Appendix E).

Containment Alternative C200 achieves simulated groundwater flow directions under the Waterway in the 75-ft, 100-ft, and 130-ft zones that are directed toward the Site peninsula and the groundwater extraction system, which meets ~~the groundwater flow direction component of~~ Model-Based Performance Objective ~~2~~3) (see Figures 18, 19, and 20 of Appendix E).

Other Factors to Consider

The consideration of other factors for Containment Alternative C200 is consistent with the evaluation for Containment Alternative C150. The Containment Alternative C200 meets the Model-Based Performance Objectives similar to Containment Alternative C150.

5.2.4 Disproportionate Cost Analysis

A disproportionate cost analysis (DCA) is designed to evaluate if the incremental costs of an alternative over that of a lower cost alternative exceed the incremental degree of benefits potentially achieved by the more costly alternative. As presented in WAC 173-340-360(3)(f), the evaluation criteria are as follows:

(i) Protectiveness

(ii) Permanence

(iii) Effectiveness over the long term

(iv) Management of short-term risks

(v) Technical and administrative implementability

(vi) Consideration of public concerns

(vii) Cost

These MTCA evaluation criteria are analogous to the NCP evaluation criteria under CERCLA.

In the DCA process, each alternative is assigned a rank (score) for each criterion using a scale of 1 to 10 (10 being the best) that represent a judgement of how well an alternative satisfies a criterion. Since each criterion is not considered equal by the Agencies, each rank is multiplied by a weighting factor or percentage representative of the criterion before the ranks are added up to produce a total that is referred to as an 'overall benefit score.' The overall benefit score is divided by the relative cost (normalized by dividing the actual costs by the order of magnitude of the lowest cost alternative [e.g., 10,000,000]) to come up with a relative benefit score to cost ratio. These ratios are compared and the higher the ratio the more beneficial the alternative is.

Table 5.1 presents the weighting percentages developed for this Site and the rationale for each, which are summarized below:

(i) Protectiveness - 30%

(ii) Permanence - 20%

(iii) Effectiveness over the long term - 20%

(iv) Management of short term risks - 10%

(v) Technical and administrative implementability - 10%

(vi) Consideration of public concerns - 10%

The following presents an evaluation of Containment Alternatives C150 and C200 with respect to the above DCA process.

Protectiveness

Both Containment Alternatives C150 and C200 would provide similar protectiveness.

The required protection for human health and the environment would be met through access restrictions, ICs, and engineered barriers (i.e., PDCE and sheet pile vertical barrier wall). The PDCE would protect against incidental ingestion, inhalation, and dermal contact with impacted soil and shallow DNAPL. It would prevent runoff of potentially impacted surface water. Additionally, the PDCE might reduce infiltration/percolation through impacted soil in the vadose zone, potentially reducing migration. The sheet pile vertical barrier wall along the Waterway would isolate the impacted embankment material preventing direct contact by human and ecological receptors. The sheet pile vertical barrier wall would also prevent flushing of shallow soil by tidal fluctuations and prevent shallow groundwater discharge to surface water and aquatic receptors. The treatment of impacted groundwater would prevent discharge of impacted water to surface water bodies.

Potential risks associated with the Site would be reduced within the construction time frame and would continue to be reduced over time as contaminated groundwater is extracted and treated. Overall environmental quality would improve by preventing direct contact with, incidental ingestion of and inhalation of hazardous substances, and potential discharge of groundwater with concentrations above SSLs to surface water.

Permanence

Both Containment Alternatives C150 and C200 would offer essentially the same practical solution and equal permanence.

Groundwater extraction under this alternative would contain the impacted groundwater plumes, thus reducing contaminant mobility. The treatment of the extracted groundwater would destroy contaminants, resulting in a reduction of their toxicity and volume. Migration and potential release of hazardous substances would be mitigated by maintaining inward hydraulic gradients and demonstrating containment using existing monitoring wells to achieve field-based performance objectives that would be determined during the design phase. The treatment process would result in the generation of solids that would require off-Site transportation and disposal.

Effectiveness Over the Long Term

Containment Alternatives C150 and C200 would be equally effective over the long term since they equally meet the ~~model-based performance objectives~~Model-Based Performance Objectives and are anticipated to equally meet the field-based performance objective. Containment Alternative C200 has an increased risk of drawing in groundwater with higher pH since the pumping rates are higher. As discussed in Subsection 4.3.2, pumping groundwater with high pH should be avoided in order to minimize/prevent: potential fouling of the treatment system; the need for treatment of high pH water; and disposal of additional solids associated with this high pH groundwater. Therefore, a lower groundwater pumping rate would be preferred to minimize this potential risk.

Both Containment Alternatives C150 and C200 would include technologies that are common and practical for containing a large complex site, could be effectively operated, maintained, and monitored, and are proven to be successful and reliable over time. Both alternatives reduce risk by eliminating or managing potential exposure pathways and containing hazardous substances remaining at the Site. Long-term effectiveness would require ongoing operation and/or maintenance of the components, monitoring, and maintenance of ICs.

The installation of the PDCE barrier would be an effective and reliable solution to eliminate exposure to the impacted soil, impacted embankment material, and shallow DNAPL. The asphalt cover would need to be maintained and periodically repaired or replaced. The long-term integrity and effectiveness of well-designed and constructed PDCE barriers is well documented. PDCE barrier technology must be used in combination with ICs to protect the integrity of the barrier material, and other technologies to address potential migration of subsurface impacts under the PDCE barrier.

The installation of the sheet pile vertical barrier wall is an effective and reliable solution to provide isolation of the impacted embankment material and to prevent discharge of impacted shallow groundwater to the Hylebos. The installation of sheet pile vertical barrier wall to the depths anticipated is commonly done in both upland and marine settings.

The GWETS would be effective in maintaining containment and would reduce mass over time through extraction and treatment of contaminated groundwater.

Management of Short-term Risks

The short-term risks during construction and implementation of both alternatives would be the same and would be managed through standard safety and health procedures that would be documented in a Site-specific health and safety plan (HASP). The types of procedures that would be required are those regularly practiced for the types of construction anticipated.

In addition to the HASP, other plans for activities such as soil management, traffic control, and air monitoring would be developed to protect human health and the environment during construction and implementation.

Technical and Administrative Implementability

As discussed in Subsection 5.1, both alternatives are equally implementable.

The technical implementability of a PDCE barrier is high as PDCE barrier is a proven technology that was used successfully at many sites and PDCE barrier materials (e.g., asphalt and granular bedding materials) are readily available. The technical implementability of sheet pile vertical barrier wall technology is high as well as this technology is widely used for containment in upland and marine applications, and materials and equipment to install sheet pile vertical barrier walls are widely available. A barrier wall could be easily installed to the depths anticipated. Groundwater extraction wells are commonly used, and are generally simple to maintain. Experience at the Site has shown that extraction wells could be operated for long periods of time outside of the zone where groundwater pH is greater than 10 s.u. Wells could be maintained and rehabilitated using standard techniques. Well construction contractors and materials are readily available.

Since the engineered barriers and groundwater extraction technology are proven technologies and typically applied at many sites; services, capabilities, equipment, specialists, and materials should be readily available for implementation of these remedial technologies. Permitting of these remedial technologies is also expected to be obtained without significant difficulties.

Consideration of Public Concerns

Ecology held a public comment period from October 23, 2015 through February 1, 2016 for the approved SCR (CRA, 2014c), during which, Ecology received a total of 14 letters and emails. The following four common significant themes were apparent in the public comments:

1) Several comments were largely unrelated to the Site, and focused more on the CB/NT site, sediment cleanup standards, and uses of the Hylebos.
2) Some comments believed that the Exposure Pathway Assessment (sediment and shallow groundwater discharge assessment) is incomplete.
3) A few comments believed that the full extent of the biological receptors has not been assessed.
4) A couple of comments believed that the northern boundary of the plume extent has not been fully defined.

As the comments in Item 1 above were largely unrelated to the Site, they are outside the scope of this FS. The comments in Items 2, 3, and 4 above were addressed through the 2016 Anchor QEA investigation sediment and porewater sampling in the Hylebos as discussed in Subsection 2.4.5 and 2.4.6. To the extent that the comments were related to Upland Areas of the Site, they would be addressed by a containment system.

Public notice and participation is an integral part of the remedy selection process. The public notice and participation requirements for cleanups conducted are set forth in MTCA (WAC 173-340-600), NCP 40 CFR 300.430(f)(3)(i), and CERCLA §117. The public will have an opportunity to voice any concerns regarding the FS during a public comment period.

It is expected that the public will be supportive of a reliable containment system that protects human health and the environment by eliminating all potential exposure pathways. Containment systems, which could be effectively operated, maintained, and monitored, are common and have proven to be reliable and effective solutions for large complex sites like this one. Mobility of mass within the containment system would be of minimal concern as long as there is hydraulic control of the target zones. A containment alternative is the foundation of any other measures that are deemed appropriate to address Site conditions.

Cost

The estimated costs for Containment Alternatives C150 and C200 are presented in Appendix G and were developed in accordance with guidance (USEPA, 2000) specified by the Agencies. The costs include a placeholder for potential mitigation for the loss of intertidal zone along the embankment to comply with the Clean Water Act. The cost estimates include periods of 30 years (yrs), in accordance with the guidance (USEPA, 2000), and 100 years, at the request of the Agencies. Discount factors for O&M and periodic costs include 7 percent, in accordance with the guidance (USEPA, 2000), and 1.5 percent (2016 Discount Rate for OMB Circular No. A-94 for the 30-Year Real Interest Rate on Treasury Notes and Bonds of Specific Maturities), at the request of the Agencies. A summary of the capital, O&M, and periodic costs is as follows:

Table 5.2 Summary of Containment Alternatives Estimated Costs

Cost Type	Alternative C150	Alternative C200
Capital	$38,700,240	$38,700,240
O&M/Periodic (30yrs;7%)	$15,656,240	$16,490,000
O&M/Periodic (30yrs;1.5%)	$30,652,600	$32,266,220
O&M/Periodic (100yrs;7%)	$18,469,760	$19,429,760
O&M/Periodic (100yrs;1.5%)	$70,539,760	$74,009,760

As shown in the above table, the estimated capital costs are the same since the same plant would be constructed for either extraction system. The O&M/Periodic costs for the C200 alternative are higher than the C150 alterative due to requirements for treating the additional flow such as increased power consumption, chemical usage for solids removal and pH adjustment, and production of solids requiring off-Site disposal.

Disproportionate Cost Analysis Summary

Table 5.3 presents a DCA summary table that provides relative benefit score to cost ratios for the Containment Alternatives C150 and C200 using weighting percentages from Table 5.1 and the scoring from Table 5.3. As shown in Table 5.3, the C150 alternative has a benefit score to cost ratio of 1.36 that is slightly greater than the benefit score to cost ratio for the C200 alternative of 1.34.

The following provides additional discussion regarding the common elements costs, cash flow projections, and alternative durations.

Figure 5.1 presents the common elements capital cost distribution for Containment Alternatives C150 and C200. As shown on this figure, the costs are the same. Figure 5.2 presents the alternatives anticipated 30-year cash flow projections. As shown on this figure, the costs are similar; however, they are higher for C200 alternative. Figure 5.3 shows the anticipated durations for the different components of the alternatives, which are the same.

Since Containment Alternatives C150 and C200 are essentially equivalent based on the evaluation criteria other than cost, there is no tangible degree of incremental benefit of the higher cost alternative. This is substantiated by C150 alternative having a higher benefit score to cost ratio than C200 alternative in Table 5.3.

5.2.5 Summary

Containment Alternatives C150 and C200 both meet the Model-Based Performance Objectives and Containment Alternative C100 does not. Containment Alternatives C150 and C200 would be equally implementable, effective, and permanent. Since Containment Alternatives C150 and C200 are essentially equivalent based on the evaluation criteria and the C150 alternative has a higher benefit score to cost ratio, there is no tangible degree of incremental benefit to justify selecting the higher cost alternative. Therefore, the identified preferred alternative is Containment Alternative C150.

6. VOC Mass Removal/Reduction Alternatives - Initial Screening and Detailed Evaluation

6.1 Initial Screening

The VOC mass removal/reduction alternatives are described in Subsection 4.4. The initial screening criteria are described in Subsection 5.1.

The VOC mass removal/reduction alternatives are designed to remove or reduce concentrations of contaminants, primarily TCVOC, in groundwater and soil. The VOC mass removal/reduction alternatives would not protect human health and the environment, including potential ecological receptors, at the Site by themselves. Therefore, they would not meet all the minimum/threshold requirements. However, in combination with containment technologies they would meet the minimum/threshold requirements (see Subsection 5.1). Accordingly, the VOC mass removal/reduction alternatives all assume that appropriate containment technologies are implemented at the Site. Therefore, none of the VOC mass removal/reduction alternatives were removed from further evaluation based on this initial screening.

The VOC mass removal alternatives M3 and M4 (see Subsection 4.4 for descriptions) would include excavation of the same quantity of shallow soil containing concentrations of TCVOC greater than 100 mg/kg. Therefore, these two alternatives would be equally effective in removing VOC mass from the Site. The difference between these alternatives would be the method of treatment/disposal after the soil is excavated. The M3 alternative includes on-Site treatment and backfilling whereas the M4 alternative includes off-Site transportation, treatment, and disposal. Based on discussions with vendors the cost would be approximately $720 per ton of soil for transportation, treatment, and disposal at an off-Site hazardous waste facility. On-Site treatment via ex situ SVE and backfilling is expected to be significantly less, on the order of $150 per ton, since there would not be any transportation or disposal costs. There would be some additional cost for backfilling under the M3 alternative but this would not be a significant cost and would be less than the cost to import clean backfill for excavated areas under the M4 alternative. Therefore, the costs for the M4 alternative would be clearly disproportionate compared to the M3 alternative, which would be equally as effective in removing concentrations of TCVOC greater than 100 mg/kg in shallow soil.

Similarly, the M6 and M7 alternatives (see Subsection 4.4 for descriptions) would be equally as effective because they would include the same technologies for treating and removing soils and the only difference would be the method of treatment/disposal for excavated soil, which is the same as the M3 and M4 alternatives. Therefore, the costs for the M7 alternative would be clearly disproportionate compared to the M6 alternative, which would be equally as effective.

The remaining VOC mass removal/reduction alternatives would be sufficiently different because of the technologies used and/or areas targeted that determining which alternatives' costs would be clearly disproportionate under WAC 173-340-360(3)(e) and/or have the ~~greatest~~lowest relative benefit score to cost ratio in the initial screening is not evident. Therefore, no additional VOC mass removal/reduction alternatives were removed from further evaluation based on this initial screening criterion.

The VOC mass removal/reduction alternatives and components presented herein are administratively and technically possible at the Site and therefore none of the VOC mass removal/reduction alternatives were removed from further evaluation based on this initial screening criterion. However, the M8 and M9 alternatives effective implementation might not be feasible because of the depth and size of the targeted zones and other activities on the peninsula. These alternatives include in situ treatment of VOC in deep soil and groundwater north of the 605 Alexander Avenue property. This is discussed further in the following detailed evaluation subsection.

Based on the above, the initial screening eliminated the M4 and M7 alternatives from further evaluation.

6.2 Detailed Evaluation

Purpose and Evaluation Criteria

The purpose of the detailed evaluation is to select an alternative, retained following the initial screening, which does not have an incremental cost that exceeds the incremental degree of benefits potentially achieved. The detailed evaluation of the VOC ~~Mass Removal/Reduction Alternatives~~mass removal/reduction alternatives involved assessing MTCA and CERCLA factors to be considered (see Subsection 5.2) and conducting a disproportionate cost analysis per WAC 173-340-360(3)(f). The detailed evaluation assumes that containment is part of the selected remedy for the Site, which is consistent with the initial screening of the VOC mass removal/reduction alternatives.

6.2.1 No Additional Action VOC Mass Removal/Reduction Alternative

The No Additional Action VOC Mass Removal/Reduction Alternative would not enhance a containment alternative with respect to minimizing potential risks to human health and the environment. It would not alter or undermine the practicality and effectiveness of a containment alternative and therefore would be compatible with the use at the Site. This alternative would not reduce/remove or enhance containment of VOC mass in media at the Site and thus would not increase permanence or long-term effectiveness. However, VOC mass would be reliably contained by containment technologies. There are no short-term risks and it is fully implementable. Since this alternative would not alter the geochemical conditions in the subsurface, natural processes (e.g., biodegradation) documented to occur at the Site would also continue to reduce concentrations of hazardous substances.

6.2.2 VOC Mass Reduction Alternatives M100, M150, and M200

The detailed evaluation of the VOC Mass Reduction Alternatives M100, M150, and M200 involved using the calibrated groundwater flow model developed for the Site, as presented in Appendix E, to determine TCVOC mass reduction that might be achieved by groundwater extraction.

The simulated TCVOC mass removal by groundwater extraction is evaluated relative to the total TCVOC mass in the aquifer beneath the Site calculated from TCVOC concentrations in soil (above a threshold soil concentration of 100 mg/kg) equal to approximately 780,000 lbs presented in Appendix C. Soil concentrations represent mass in the dissolved, sorbed, and DNAPL phases.

6.2.2.1 VOC Mass Reduction Alternative M100

VOC Mass Reduction Alternative M100 includes a physical hydraulic barrier wall along the Site peninsula adjacent to the Waterway and two upland mass removal groundwater extraction wells on the Site peninsula. Groundwater extraction was represented in the model only from areas of elevated concentrations in the shallow and deep TCVOC groundwater plume to yield reduction in TCVOC mass. Two extraction wells were simulated to pump from shallow and deep groundwater with high dissolved concentrations of TCVOC outside the areas of elevated pH (i.e., ~~less~~greater than [>]10 s.u.). Figure 22 of Appendix E shows the locations and depths of two proposed mass reduction extraction wells, one shallow and one deep. A total groundwater pumping rate of 35 gpm was applied for VOC Mass Reduction Alternative M100. The rationale for this pumping rate is discussed in Appendix E. Simulated mass-weighted particle capture for VOC Mass Reduction Alternative M100 was completed for 30 years and 100 years, as requested by the Agencies.

VOC Mass Reduction Alternative M100 would not enhance a containment alternative with respect to minimizing potential risks to human health and the environment because the uplands VOC would already be reliably contained. However, it would increase the rate of VOC removal from the subsurface in the ~~near~~short term and the total quantity of VOC removed in the long term in combination with a containment alternative, and thus would significantly increase permanence and long-term effectiveness. The technology proposed is common and practical for extracting contaminated groundwater from a large complex site such as this and could be effectively operated, maintained, and monitored. There are some manageable short-term risks related to construction and it is implementable. The M100 alternative is not expected to alter or undermine the practicality of a containment alternative and could be easily incorporated into the design of the GWETS. It would enhance the drawdown and gradients within the containment system, which would require optimization if the M100 alternative was selected to be combined with a containment alternative. The alternative would be compatible with the current and anticipated future uses of the Site and surrounding areas, which are industrial with generally paved surfaces. Since the M100 alternative would not significantly alter the geochemical conditions in the subsurface, natural processes (e.g., biodegradation) documented to occur at the Site would also continue to reduce concentrations of hazardous substances.

6.2.2.2 VOC Mass Reduction Alternative M150

VOC Mass Reduction Alternative M150 is based on VOC Mass Reduction Alternative M100. VOC Mass Reduction Alternative M150 applies the same extraction wells as VOC Mass Reduction Alternative M100, but with pumping rates increased by 50 percent from that applied in VOC Mass Reduction Alternative M100. A total groundwater pumping rate of 52.5 gpm was applied for VOC Mass Reduction Alternative M150.

VOC Mass Reduction Alternative M150 would not enhance a containment alternative with respect to minimizing potential risks to human health and the environment because the uplands VOC would already be reliably contained. However, it would increase the rate of VOC removal from the subsurface in the ~~near~~short term and the total quantity of VOC removed in the long term in combination with a containment alternative, and thus would significantly increase permanence and long-term effectiveness. The rate of removal and quantity of VOC removed would be greater than the M100 alternative as shown on Figures 30 and 31 in Appendix E. The technology proposed is common and practical for extracting contaminated groundwater from a large complex site such as this and could be effectively operated, maintained, and monitored. There are some manageable short-term risks related to construction and it is implementable. The M150 alternative is not expected to alter or undermine the practicality of a containment alternative and could be easily incorporated into the design of the GWETS. It would enhance the drawdown and gradients within the containment system, which would require optimization if the M150 alternative was selected to be combined with a containment alternative. The alternative would be compatible with the current and anticipated future uses of the Site and surrounding areas, which are industrial with generally paved surfaces. Since the M150 alternative would not significantly alter the geochemical conditions in the subsurface, natural processes (e.g., biodegradation) documented to occur at the Site would also continue to reduce concentrations of hazardous substances.

6.2.2.3 VOC Mass Reduction Alternative M200

VOC Mass Reduction Alternative M200 is based on VOC Mass Reduction Alternative M100. VOC Mass Reduction Alternative M200 applies the same extraction wells as VOC Mass Reduction Alternative M100, but with pumping rates increased by 100 percent from that applied in VOC Mass Reduction Alternative M100. A total groundwater pumping rate of 70 gpm was applied for VOC Mass Reduction Alternative M200.

VOC Mass Reduction Alternative M200 would not enhance a containment alternative with respect to minimizing potential risks to human health and the environment because the uplands VOC would already be reliably contained. However, it would increase the rate of VOC removal from the subsurface in the ~~near~~short term and the total quantity of VOC removed in the long term in combination with a containment alternative, and thus would significantly increase permanence and long-term effectiveness. The rate of removal and quantity of VOC removed would be greater than the M100 and M150 alternatives as shown on Figures 30 and 31 in Appendix E. The technology proposed is common and practical for extracting contaminated groundwater from a large complex site such as this and could be effectively operated, maintained, and monitored. There are some manageable short-term risks related to construction and it is implementable. The M200 alternative is not expected to alter or undermine the practicality of a containment alternative and could be easily incorporated into the design of the GWETS. It would enhance the drawdown and gradients within the containment system, which would require optimization if the M200 alternative was selected to be combined with a containment alternative. The alternative would be compatible with the current and anticipated future uses of the Site and surrounding areas, which are industrial with generally paved surfaces. Since the M200 alternative would not significantly alter the geochemical conditions in the subsurface, natural processes (e.g., biodegradation) documented to occur at the Site would also continue to reduce concentrations of hazardous substances.

6.2.3 VOC Mass Reduction Alternative MSP

The detailed evaluation of the VOC Mass Reduction Alternatives MSP involved using the calibrated groundwater flow model developed for the Site, as presented in Appendix E, to determine TCVOC mass reduction that might be achieved by groundwater extraction in areas of higher mass in soil below the water table and outside areas of high pH (~~e.g., greater than~~ i.e., >10 s.u.).

The simulated TCVOC mass removal by groundwater extraction is evaluated relative to the total TCVOC mass in the aquifer beneath the Site calculated from TCVOC concentrations in soil (above a threshold soil concentration of 100 mg/kg) equal to approximately 780,000 lbs presented in Appendix C. The soil concentrations represent mass in the dissolved, sorbed, and DNAPL phases.

VOC Mass Reduction Alternative MSP includes a physical hydraulic barrier wall along the Site peninsula adjacent to the Waterway and eleven upland groundwater mass removal and containment extraction wells strategically positioned on the Site peninsula. Groundwater extraction was represented in the model from areas of elevated concentrations of TCVOC in the shallow and deep soil below the water table to reduce TCVOC mass (i.e., strategic pumping). Nine extraction wells were simulated to pump from shallow and deep groundwater with high concentrations of

TCVOC outside the areas of elevated pH (i.e., pump in areas where pH is less than [<]10 s.u.). Additionally, two extraction wells were simulated to pump from shallow groundwater to supplement the groundwater containment achieved by pumping in zones of high TCVOC concentrations. Figure 23 of Appendix E shows the strategic locations of the eleven proposed groundwater mass reduction and containment extraction wells, four shallow and seven deep. A total groundwater pumping rate of 210 gpm was applied for VOC Mass Reduction Alternative MSP. The rationale for this pumping rate is discussed in Appendix E. Simulated mass-weighted particle capture for VOC Mass Reduction Alternative MSP was completed for 30 years and 100 years, as requested by the Agencies.

VOC Mass Reduction Alternative MSP would replace the components related to groundwater pumping of a containment alternative because it satisfies the model-based containment objectives for the Site (see Appendix E). It would minimize potential risks to human health and the environment because the uplands VOC would be reliably contained. It would increase the rate of VOC removal from the subsurface in the ~~near~~short term and the total quantity of VOC removed in the long term by strategic pumping, and thus would significantly increase permanence and long-term effectiveness. The technology proposed is common and practical for extracting contaminated groundwater from a large complex site such as this and could be effectively operated, maintained, and monitored. There are some manageable short-term risks related to construction and it is implementable. The MSP alternative could be easily incorporated into the design of a treatment system presented for the containment alternatives. The parts other than the extraction wells of a containment alternative would need to be included with the MSP alternative to protect human health and environment as discussed above. The alternative would be compatible with the current and anticipated future uses of the Site and surrounding areas, which are industrial with generally paved surfaces. Since the MSP alternative would not significantly alter the geochemical conditions in the subsurface, natural processes (e.g., biodegradation) documented to occur at the Site would also continue to reduce concentrations of hazardous substances.

6.2.4 VOC Mass Removal Alternative M3

The VOC Mass Removal Alternative M3 includes removing elevated concentrations of TCVOC in shallow (-4 ft NGVD) soil by excavation, on-Site treatment of the soil, and on-Site backfilling of the treated soil. It would not enhance a containment alternative with respect to minimizing potential risks to human health and the environment because the uplands TCVOC mass would already be reliably contained. It would reduce very little potential for migration of TCVOC via leaching to groundwater and volatilization, adding ~~little~~a small degree of permanence and long-term effectiveness. Excavation of shallow soil would be practical and implementable with some short-term risks for construction and added effort to manage saturated soil and potential release of VOC to ambient air during material handling. The M3 alternative is not expected to alter or undermine the practicality of a containment alternative or its effectiveness. The alternative would be compatible with the current and anticipated future uses of the Site and surrounding areas, which are industrial with generally paved surfaces. Since the M3 alternative would not significantly alter the geochemical conditions in the subsurface, natural processes (e.g., biodegradation) documented to occur at the Site would also continue to reduce concentrations of hazardous substances.

6.2.5 VOC Mass Reduction Alternative M5

The VOC Mass Reduction Alternative M5 includes treating elevated concentrations of TCVOC in shallow (-21 ft NGVD) soil by in situ ERH and in situ SVE. It would not enhance a containment alternative with respect to minimizing potential risks to human health and the environment because the uplands TCVOC mass would already be reliably contained. It would reduce some potential for migration of TCVOC via leaching to groundwater and volatilization compared to the M3 alternative, but still adding a very littlesmall degree of permanence and long-term effectiveness. In situ treatment of shallow soils by ERH and SVE would be practical and implementable as these technologies have proven to be successful at reducing VOC concentrations in unsaturated (SVE) and saturated (ERH) soils at other sites. There would be some short-term risks for construction and operation of the technologies. The M5 alternative is not expected to alter or undermine the practicality of a containment alternative or its effectiveness. The alternative would be compatible with the current and anticipated future uses of the Site and surrounding areas, which are industrial with generally paved surfaces. Since the M5 alternative would not significantly alter the geochemical conditions in the subsurface outside the immediate target zone, natural processes (e.g., biodegradation) documented to occur at the Site would also continue to reduce concentrations of hazardous substances.

6.2.6 VOC Mass Removal/Reduction Alternative M6

The M6 alternative is a combination of the excavation and in situ ERH treatment elements from the M3 and M5 alternatives, respectively. It would not enhance a containment alternative with respect to minimizing potential risks to human health and the environment because the uplands TCVOC mass would already be reliably contained. It would further reduce some potential for migration of TCVOC via leaching to groundwater and volatilization compared to the M3 and M5 alternatives, but still adding a very littlesmall degree of permanence and long-term effectiveness. As noted previously the technologies would be practical and implementable at the Site. There would be some short-term risks for construction, operation of the technologies, and added effort to manage saturated soil and potential release of VOC to ambient air during material handling. The M6 alternative is not expected to alter or undermine the practicality of a containment alternative or its effectiveness. The alternative would be compatible with the current and anticipated future uses of the Site and surrounding areas, which are industrial with generally paved surfaces. Since the M6 alternative would not significantly alter the geochemical conditions in the subsurface outside the immediate target zone, natural processes (e.g., biodegradation) documented to occur at the Site would also continue to reduce concentrations of hazardous substances.

6.2.7 VOC Mass Removal/Reduction Alternative M8

The M8 alternative includes the shallow soil treatment from the M5 alternative (ERH and SVE) and treatment of elevated concentrations of TCVOC in shallow (-60 ft NGVD) groundwater (and soil) by ISCO and ISB. It would not enhance a containment alternative with respect to minimizing potential risks to human health and the environment because the uplands TCVOC mass would already be reliably contained. It would further reduce some potential for migration of TCVOC via leaching to groundwater, groundwater flow, and volatilization compared to the M3, M5, and M6 alternatives, but adding a very littlesmall degree of permanence and long-term effectiveness. As noted previously the technologies from the M5 alternative would be practical and implementable at the Site. The ISCO technology would be practical and implementable, as this technology has proven to be successful at reducing VOC concentrations in saturated soils at other sites. The ISB technology would also be practical and implementable for similar reasons; however, the treatment relies on maintaining optimal conditions for biological activity and contaminated groundwater passing through/near the treatment curtains. Therefore the effectiveness might be limited if the optimal conditions cannot be maintained because of Site-specific subsurface conditions (e.g., pH above

10 s.u., low dissolved oxygen content [DOC], high salt content) and/or if impacted groundwater does not pass through/near the treatment curtains under natural flow or groundwater pumping conditions. There would be some short-term risks for construction, operation of the technologies, and protection of the injection wells from traffic on the Port of Tacoma properties. The M8 alternative is not expected to alter or undermine the practicality of a containment alternative, but it might alter the effectiveness by altering the groundwater flow patterns in the target zone. For example, ISCO might alter the hydraulic conductivity if significant quantities of solids are precipitated out of solution. This could potentially impact drawdown and gradients within the containment system and might reduce the quantity of TCVOC mass that would be extracted from the subsurface over time. However, the M8 alternative would reduce concentrations of TCVOC in the target zones in ~~the short term~~a shorter time frame, which otherwise would be extracted by the containment system. Despite the concern of impacting the containment alternative, it would still be compatible with the use at the Site since the target zone would still be reliably contained. It would alter the geochemical conditions in the subsurface and therefore natural processes (e.g., biodegradation) documented to occur at the Site that reduce concentrations of hazardous substances might be affected.

6.2.8 VOC Mass Removal/Reduction Alternative M9

The M9 alternative includes the shallow soil and groundwater treatment from the M8 alternative and treatment of elevated concentrations of TCVOC in deep (below -60 ft NGVD) groundwater and soil by ISCO and ISB. It would not enhance a containment alternative with respect to minimizing potential risks to human health and the environment because the uplands TCVOC mass would already be reliably contained. It would significantly reduce the potential for migration of TCVOC via leaching to groundwater, groundwater flow, and volatilization compared to the M3, M5, M6, and M8 alternatives, adding significant additional permanence and long-term effectiveness. As noted previously the technologies from the M8 alternative would be practical and implementable at the Site. The ISCO technology would be practical and implementable in the deeper target zones, as this technology has proven to be successful at reducing VOC concentrations in deep saturated soils at other sites. The ISB technology would also be practical and implementable for similar reasons; however, the treatment relies on maintaining optimal conditions for biological activity and contaminated groundwater passing through/near the treatment curtains. Therefore, the effectiveness might be limited. Another potential difficulty is with potential overlapping of technologies that might impact the effectiveness. For example, applying ISCO near ISB might cause loss of optimal conditions for biological activity in the short-term and inhibit native microbial populations in the long-term. This might delay implementation of a technology that is not compatible with another. There would be some short-term risks for construction and operation of the technologies. There would be significant short-term risks for protection of the injection wells from traffic on the Port of Tacoma properties because of the large area required to implement the technologies. The M9 alternative is not expected to alter or undermine the practicality of a containment alternative, but it might alter the effectiveness by changing the groundwater flow (i.e., hydraulic conductivity) in the target zone. This could potentially impact drawdown and gradients within the containment system and might reduce the quantity of TCVOC mass that would be extracted from the subsurface over time. However, the M9 alternative would reduce concentrations of TCVOC in the target zones in ~~the short term~~a shorter time frame, which otherwise would be extracted by the containment system. Despite the concern of impacting the containment alternative, it would still be compatible with the use at the Site since the target zones would still be reliably contained. It would alter the geochemical conditions in the subsurface and therefore natural processes (e.g., biodegradation) documented to occur at the Site that reduce concentrations of hazardous substances might be affected.

6.2.9 Disproportionate Cost Analysis

A DCA of the VOC ~~Mass Removal/Reduction Alternatives~~mass removal/reduction alternatives was conducted using the same process described in Subsection 5.2.4. The following presents an evaluation of VOC Mass Removal/Reduction Alternatives M100, M150, M200, MSP, M3, M5, M6, M8, and M9, and the No Additional Action alternative with respect to the DCA process.

Protectiveness

The VOC ~~Mass Removal/Reduction Alternatives~~mass removal/reduction alternatives would not protect human health and the environment, including potential ecological receptors, at the Site by themselves. Therefore, they would not meet all the minimum/threshold requirements. However, they would in combination with a containment alternative, each of which meet the minimum/threshold requirements (see Subsection 5.1) or parts of a containment alternative in the case of the MSP alternative. Accordingly, the VOC mass removal/reduction alternatives assume that all or part of a containment alternative is implemented at the Site to meet the minimum/threshold requirements.

Permanence

The No Additional Action alternative would not add any permanence to a Site remedy.

Alternatives M100, M150, and M200 would each add a significant degree of permanence since concentrations of TCVOC in the subsurface would be reduced over time via extraction of impacted groundwater that would remove TCVOC mass. ~~In comparison to the potential removal of TCVOC mass for the C150 containment alternative presented in Section 5 (i.e., quantities of approximately 120~~The added degree of permanence would be significant because between approximately 305 and 326 thousand lbs of TCVOC ~~[dissolved phase] or 513 thousand pounds of TCVOC [~~(dissolved, sorbed, and DNAPL phases~~]~~) outside areas of pH >10 s.u. would be extracted over 100 years~~), the added degree of permanence would be significant (i.e., added quantities between approximately 99 and 128 thousand lbs of TCVOC [dissolved phase] or total quantities between 663 and 720 thousand pounds of TCVOC [dissolved, sorbed, and DNAPL phases] extracted over 100 years)~~ as shown in ~~Tables 2 and 3~~Table 4 in Appendix E. The M200 alternative would add the highest degree of permanence since it would remove a greater quantity of TCVOC mass over time compared to the M100 and M150 mass removal/reduction alternatives ~~and the C150 containment alternative~~ as shown in ~~Tables 2 and 3~~Table 4 in Appendix E.

Alternative MSP would add a significant degree of permanence since concentrations of TCVOC in the subsurface would be reduced over time via targeted extraction of impacted groundwater (i.e., strategic pumping) that would remove TCVOC mass. In comparison to the M100, M150, and M200 alternatives, the added degree of permanence would be significant in the short term (i.e., ~~84~~324 thousand ~~lbs [dissolved phase] or 656 thousand~~ lbs [dissolved, sorbed, and DNAPL phases] compared to less than ~~44~~292 thousand ~~lbs [dissolved phase] or less than 402 thousand~~ lbs [dissolved, sorbed, and DNAPL phases] ~~in~~ extracted outside areas of pH >10 s.u. in 20 years). The added degree of permanence would be greater in the long term (i.e., ~~147~~329 thousand ~~lbs [dissolved phase] or 766 thousand~~ lbs [dissolved, sorbed, and DNAPL phases]) as shown in ~~Tables 2 and 3~~Table 4 in Appendix E.

Alternative M3 would add a very ~~little~~small degree of permanence since up to 23 thousand lbs of TCVOC mass (dissolved, sorbed, and DNAPL phases) would be excavated, treated on Site, and backfilled on Site. The added degree of permanence would be very ~~little~~small in comparison to the M100, M150, M200, and MSP alternatives.

Alternative M5 would add a very ~~little~~small degree of permanence since up to 62 thousand lbs of TCVOC mass (dissolved, sorbed, and DNAPL phases) would be removed from the subsurface by in situ treatment. The added degree of permanence would be much less than the M100, M150, M200, and MSP alternatives, but more than the M3 alternative.

Alternative M6 would add a very ~~little~~small degree of permanence similar to the M5 alternative since up to 66 thousand lbs of TCVOC mass (dissolved, sorbed, and DNAPL phases) would be removed from the subsurface by a combination of excavation, treatment on Site and backfilling on Site, and in situ treatment. The added degree of permanence would be much less than the M100, M150, M200, and MSP alternatives, but more than the M3 alternative and slightly more than the M5 alternative.

Alternative M8 would add a very ~~little~~small degree of permanence since up to 82 thousand lbs of TCVOC mass (dissolved, sorbed, and DNAPL phases) would be removed from the subsurface by in situ treatment. The added degree of permanence would be less than the M100, M150, M200, and MSP alternatives, but more than the M3, M5, and M6 alternatives.

Alternative M9 would add a significant degree of permanence since up to 613 thousand lbs of TCVOC mass (dissolved, sorbed, and DNAPL phases) would be removed from the subsurface by in situ treatment. The added degree of permanence ~~in the short-term (i.e., 20 years to implement the M9 alternative)~~ would be ~~less than the MSP alternative (719 thousand lbs [dissolved, sorbed, and DNAPL phases]) and~~ greater than ~~all~~the other mass reduction/removal alternatives~~ (23 to 506 thousand lbs [dissolved, sorbed, and DNAPL phases]). In the long term (i.e., 100 years), the added degree of permanence would be less than the MSP, M100, M150, and M200 alternatives and much greater than the rest~~.

It is noted that for all mass removal/reduction alternatives, the ~~targeted zones and~~ areas outside the target zones would still contain elevated TCVOC concentrations that would require containment to maintain long-term permanence.

Effectiveness Over the Long Term

The No Additional Action alternative would not have any effectiveness over the long term.

Alternatives M100, M150, and M200 would have effectiveness over the long term since outside the areas of pH >10 s.u. they would remove approximately ~~85~~ 39.1 to ~~92~~41.7 percent of the total TCVOC mass (dissolved, sorbed, and DNAPL phases) and enhance a containment system. These alternatives might shorten the length of time of O&M for some parts of the Site since they remove a significant amount of mass. However, there may still be areas that would require long-term containment.

Alternative MSP would have the greatest effectiveness over the long term with the exception of Alternative M9 since outside the areas of pH >10 s.u. it would remove the most mass (approximately ~~84~~42.1 percent of dissolved, sorbed, and DNAPL phases) and meet the model-based containment objectives. It might shorten the length of time of O&M for some parts of the Site since it removes the second most mass of all the alternatives. However, there may still be areas that would require long-term containment.

Alternatives M3, M5, M6, and M8 would have less effectiveness over the long term compared to the M100, M150, M200, and MSP alternatives since they would remove much less mass. These alternatives would not affect the length of time for O&M of a containment alternative that was modeled for 100 years and would be required to contain the remaining mass outside the targeted areas. Additionally for the M8 alternative, the effectiveness of ISB might be limited as discussed in Subsection 6.2.~~6~~7.

Alternative M9 would have ~~less~~the most effectiveness over the long term compared to the ~~MSP alternative~~other alternatives since it would remove ~~less of~~ the most VOC mass. Similar to MSP alternative, it might affect the length of time for O&M of a containment alternative for some parts of the Site. However, there may still be areas that would require long-term containment. Additionally, the effectiveness of ISB might be limited as discussed in Subsection 6.2.~~7~~8.

Management of Short-Term Risks

The short-term risks during construction and implementation of the alternatives would be managed through standard safety and health procedures that would be documented in a Site-specific HASP. The types of procedures that would be required are those regularly practiced for the types of construction anticipated. The M9 alternative would present more short-term risks because the scope extends to greater depths, covers a greater area outside of the 605 Alexander Avenue property, and would require up to 20 years to maintain/protect injection points in areas of active business and traffic. The M100, M150, M200, and MSP alternatives would present the lowest short-term risks, excluding the No Additional Action alternative, because they could be implemented relatively quickly, would involve the least amount of equipment and smallest areal footprint (e.g., less noise impact, construction-related risks, and potential for fugitive emissions), the infrastructure would be underground, and would have the lowest potential for human/ecological exposure. Soil excavation with on-Site treatment would include additional short-term risks such as exposure to high concentration of VOC in soil, water, and air (from vitalization), managing access to large open holes, managing stockpiles hazardous materials including saturated soils, and managing potential water run-off from stockpiled materials. ERH and SVE would include additional short-term risks such as hazards related to high temperatures, high-voltage electricity, controlling and treating VOC, and vapor migration through existing utilities. ISCO and ISB would include additional short-term risks such as chemical transport, mixing, and handling, chemical daylighting (i.e., chemicals flowing to and over ground surface), and managing soils (drill cuttings) and equipment over a large footprint. Additionally, ERH, ISCO, and ISB might delay startup of parts of the containment system to permit implementation of these technologies.

In addition to the HASP, other plans for activities such as soil management, traffic control, and air monitoring would be developed to protect human health and the environment during construction and implementation.

Technical and Administrative Implementability

As discussed in Subsection 6.1, all of the VOC mass removal/reduction alternatives are implementable.

The technical implementability of the M100, M150, M200, MSP, M3, M5, and M6 alternatives are considered good since these technologies have been successful at similar depths at other sites. Additionally, the target zones are within the 605 Alexander Avenue property or in areas outside building envelopes and therefore access to the target zones would be relatively easy since the area would be either void of any operations or in manageable areas.

The technical implementability of the M8 alternative is considered fair to good since these technologies have been successful at similar depths at other sites; however, some of the target zones would be below building envelopes and in roadways. This would make access to these target zones more difficult. The remainder of the target zones would be within the 605 Alexander Avenue property or in areas outside building envelopes and roadways where access would be relatively easy.

The technical implementability of the M9 alternative is considered fair since the additional depth of target zones in some areas might present difficulties, some of the target zones would be below building envelopes and roadways making access more difficult, and overlapping target zones require different technologies that might affect each other or delay implementation.

Since the technologies selected are proven and typically applied at many sites; services, capabilities, equipment, specialists, and materials should be available for implementation of these remedial alternatives. Permitting of these remedial alternatives is also expected to be obtained without significant difficulties.

Consideration of Public Concerns

As noted in Subsection 5.2.4, under *Consideration of Public Concerns*, a containment system alone would be protective of human health and the environment by eliminating all potential exposure pathways and is a common, reliable, and effective solution for large complex sites like this one, which could be effectively operated, maintained, and monitored. Additionally, public concerns regarding the Hylebos documented during a public comment period from October 23, 2015 through February 1, 2016 for the approved SCR (CRA, 2014c) are addressed through the 2016 Anchor QEA investigation sediment and porewater sampling in the Hylebos. (See Subsection 2.4.5 and 2.4.6). ~~The public made no comments related to VOC mass removal/reduction in these correspondences.~~

Mobility of mass within the containment system would be of minimal concern as long as there is hydraulic control of the target zones. Therefore, the mass removal/reduction alternatives do not materially enhance protectiveness, would add minimal long-term effectiveness and permanence in terms of containment, and none would provide any incremental benefit to mitigating potential impacts from the Site and overall potential impacts from other sites adjacent to the Waterways and Commencement Bay. Short-term risks for some of the alternatives might be of concern, but could be managed. Any other potential measures in addition to a containment alternative to address Site conditions are not necessary but rather augmentations to a system that reliably contains contaminants at the Site. For these reasons, it is expected that the public would be supportive of any overall remedy for the Site that includes containment.

Public notice and participation is an integral part of the remedy selection process. The public notice and participation requirements for cleanups conducted are set forth in MTCA (WAC 173-340-600), NCP 40 CFR 300.430(f)(3)(i), and CERCLA §117. The public will have an opportunity to voice any concerns regarding the FS during a public comment period.

Cost

The estimated costs for VOC Mass Removal/Reduction Alternatives M100, M150, M200, MSP, M3, M5, M6, M8, and M9, and the No <u>Additional</u> Action alternative are presented in Appendix G and were developed in accordance with guidance (USEPA, 2000) specified by the Agencies. The cost estimates include periods of 30 years, in accordance with the guidance (USEPA, 2000), and 100 years, at the request of the Agencies. Discount factors for O&M and periodic costs include 7 percent, in accordance with the guidance (USEPA, 2000), and 1.5 percent (2016 Discount Rate for OMB Circular No. A-94 for the 30-Year Real Interest Rate on Treasury Notes and Bonds of Specific Maturities), at the request of the Agencies. A summary of the capital, O&M, and periodic costs, which include costs for containment required to meet the threshold criteria discussed previously, is provided in Table 6.1 below. The alternatives are listed/ranked from most to least added degree of permanence (i.e., most to least lbs of TCVOC mass removed/reduced [see Table 6.3]) in accordance with WAC 173-340-360(3)(e)(ii)(A).

Table 6.1 Summary of VOC Mass Removal/Reduction Alternatives Estimated Costs

Alternative	Capital	Capital plus O&M/Periodic (30yrs;7%)	Capital plus O&M/Periodic (30yrs;1.5%)	Capital plus O&M/Periodic (100yrs;7%)	Capital plus O&M/Periodic (100yrs;1.5%)
<u>M9</u>	<u>$35,480,940</u>	<u>$401,254,360</u>	<u>$442,991,030</u>	<u>$405,747,880</u>	<u>$488,428,190</u>
MSP	$38,854,780	$54,877,530	$70,216,710	$57,750,000	$110,920,000
M200	$38,903,190	$56,232,640	$72,794,730	$59,300,000	$116,430,000
M150	$38,903,190	$55,838,770	$72,032,470	$58,850,000	$114,790,000
M100	$38,903,190	$55,442,430	$71,265,400	$58,390,000	$113,140,000
~~M9~~	~~$35,4880,940~~	~~$401,254,360~~	~~$442,991,030~~	~~$405,747,880~~	~~$488,428,190~~
M8	$114,264,240	$142,006,010	$167,471,640	$146,499,530	$212,908,800
M6	$52,488,140	$68,144,380	$83,140,740	$72,637,900	$128,577,900
M5	$50,712,040	$66,368,280	$81,364,640	$70,861,800	$126,801,800
M3	$41,366,240	$57,022,480	$72,018,840	$61,516,000	$117,456,000
No <u>Additional</u> Action<u>*</u>	$38,700,240	$54,356,480	$69,352,840	$57,170,000	$109,240,000

~~Note~~<u>Notes</u>:
Costs for compliance monitoring are assumed to be included in a selected containment alternative.
<u>* meaning no additional action will be conducted beyond implementing a containment alternative.</u>

As shown in Table 6.1 the MSP alternative ranked <u>the second</u> highest for added degree of permanence would have a cost that is similar to or less than alternatives with lesser degrees of permanence. The M9 alternative ranked ~~second~~ highest for added degree of permanence would have the highest cost, which is much higher than the other VOC mass removal/reduction alternatives. The M200 alternative ranked third for added degree of permanence has a cost that is slightly higher compared to the MSP, M150 and M100 alternatives over 30 years using a discount rate of 7 percent and lower in costs compared to the M8, M6, M5, and M3 alternatives that are ranked lower for added degree of permanence.

Disproportionate Cost Analysis Summary

Table 6.2 presents a DCA summary table that provides relative benefit score to cost ratios for the VOC ~~Mass Reduction/Removal Alternatives~~<u>mass reduction/removal alternatives</u> using weighting percentages from Table 5.1. As shown in Table 6.2, the MSP alternative has a benefit score to cost ratio of 1.~~51~~37 that is greater than the benefit score to cost ratios for the other alternatives. The next highest ratios are 1.~~42~~32, 1.~~41~~31, and 1.~~40~~30 for the M100, M150, and M200 alternatives, respectively. The M3 alternative had the next highest ratio of 1.17 followed by 1.03 for the No Additional Action alternative. The benefit score to cost ratios for the remaining alternatives are less than No Additional Action alternative, which indicate that the costs exceed the benefits of these alternatives. The benefit score to cost ratios for M9 of 0.18 and M8 of 0.46 are the lowest and are clearly disproportionate in cost compared to the other alternative ratios.

The following provides additional discussion regarding the relationship between costs and TCVOC mass potentially addressed, cash flow projections, and alternative durations.

The table below summarizes the quantity of TCVOC mass (dissolved, sorbed, and DNAPL phases) potentially addressed by each alternative in ~~100~~ 20 years as presented in Subsection 4.4 and Appendix E. Figure 6.1 presents the information graphically. A 20-year time frame was selected because all the non-pumping mass removal alternatives (M3, M5, M6, M8, and M9) are estimated to be completed after 20 years. An estimated quantity of TCVOC mass potentially addressed by Containment Alternative C150 to represent the No Additional Action VOC Mass Removal/Reduction Alternative is included in the table for comparison purposes.

Table 6.3 Summary of Estimated Quantity of VOC Mass Potentially Addressed by each VOC Mass Removal/Reduction Alternative

Alternative	Estimated Quantity of TCVOC Mass Potentially Addressed (lbs)	Estimated Percent of Total Estimated TCVOC Mass (%)	Estimated Cost (~~100yrs~~30yrs;7%) per Pound of TCVOC Potentially Addressed ($/lb)
M9	613,300	78.6	654
MSP	~~766,835~~323,883*	~~98.3~~41.5	~~75~~169
M200	291,648*	37.4	193
M150	285,394*	36.6	196
M100	275,132*	35.3	202
~~M9~~	~~613,300~~	~~78.6~~	~~662~~
M8	81,600	10.5	1,740
M6	66,200	8.5	1,029
M5	62,200	8.0	1,067
M3	23,200	3.0	2,458
No Additional Action	151,735*	19.5	358

Note: *Represents mass outside areas of pH >10 s.u. only.

Note that estimated quantity of TCVOC mass potentially addressed for the alternatives that incorporate groundwater extraction (i.e., MSP, M200, M150, M100, and No Additional Action [equivalent to C150]) were determined using the three-dimensional (3D) groundwater flow model that was specifically constructed and calibrated for the Site. The Site groundwater flow model provides a useful tool to evaluate the potential effectiveness of the groundwater mass reduction remedial alternatives that incorporate groundwater extraction. It is noted that the model assumes idealized mass transport controlled by advection and equilibrium sorption and all mass is assumed to be either dissolved in the groundwater or sorbed onto the aquifer matrix. Potential effects of non-aqueous phase liquids are not included. The potential effects of diffusion into low-permeability units or areas are not included. Additionally, the estimates do not include potential effects of high pH potentially reaching extraction wells, all contributing to the uncertainty of the mass estimates. However, the evaluation approach was applied consistently for all alternatives.

The MSP alternative adds the second greatest degree of permanence over the other alternatives and has the highest benefit score to cost ratio, addresses up to ~~98.3~~41.5 percent of the estimated total TCVOC mass for a cost of approximately $~~57.8M.~~54.9M (capital plus 30 years O&M at a discount rate of 7 percent). This is equivalent to approximately $~~75~~169/lb. Additionally, the MSP alternative is predicted to remove a significant quantity of TCVOC mass (dissolved, sorbed, and DNAPL phases) in the short term (i.e., ~~656~~324 thousand lbs in ~~ten~~ 20 years)

The M200 alternative, which is ranked ~~second~~third in adding degree of permanence and has the fourth highest benefit score to cost ratio, addresses less than the MSP alternative achieves (~~92.3~~37.4 percent) for a similar cost of approximately $~~59.3M (capital plus 100 years O&M at a discount rate of 7 percent),~~56.2M, which is equivalent to approximately $~~82~~193/lb.

The M150 and M100 alternatives are ranked lower in adding degree of permanence since they remove less mass and cost more per pound of TCVOC mass addressed. However, their benefit score to cost ratios are slightly greater than the M200 alternative.

The M9 alternative adds the ~~fifth~~ greatest degree of permanence, but has a very low benefit score to cost ratio (i.e., disproportionate cost) that is less than the ratio for the No Additional Action alternative. It addresses up to 78.6 percent of the estimated total TCVOC mass for a cost of approximately $~~406M~~401M. This is equivalent to approximately $~~662~~654/lb. assuming all the targeted mass is removed. As noted above, the effectiveness of the M9 alternative is less certain than the other alternatives and is expected to be more difficult to implement. It would also present more short-term risks than any other alternative.

The remaining alternatives ~~(excluding~~including No Additional Action~~)~~ remove less mass for significantly greater cost per pound. The benefit score to cost ratios for the M3 alternative is above the ratio for the No Additional Action alternative and the remaining ratios are below.

Figure 6.2 presents the relationship between estimated cost and estimated quantity of TCVOC mass potentially addressed by the alternatives. As shown on the figure the MSP, M100, M150, and M200 alternatives remove the largest quantity of TCVOC mass for the lowest costs. The figure also shows that the M9 alternative, which ~~also~~ addresses ~~a significant amount of~~the most mass, is disproportionate in cost since it is approximately ~~8~~seven times greater in cost than the above noted alternatives. Figure 6.3 presents the alternatives anticipated 30-year cash flow projections. As shown on this figure, the costs are lowest for the MSP alternative~~, except for the No Action alternative.~~. The M8 and M9 alternatives costs are much greater in comparison to the other alternatives. Figure 6.4 shows the anticipated durations for the different components of the alternatives. The MSP, M100, M150, and M200 alternatives require a short time (~~less than~~ 6 months to 1 year) to construct and include operation and maintenance over the entire time frame of 100 years. The duration for ISB for Alternatives M8 and M9 including construction is approximately ~~17~~19 years. The remaining alternatives are shown to be completed within 2 years. Figure 6.5 presents the relationship between estimated time and estimated quantity of TCVOC mass potentially addressed by the alternatives. As shown on the figure, after approximately ~~20~~2 years of operation the quantity of TCVOC mass removed for the MSP alternative is the greatest. After approximately 20 years, only the M9 alternative potentially addresses more mass than the MSP alternative. After 100 years, the MSP alternative still removes the most mass of all the alternatives that include groundwater extraction (i.e., MSP, M100, M150, and M200).

6.2.10 Summary

Each of the alternatives, except the No Additional Action alternative, would simply augment a containment system that is reliably operated and maintained. The Mass Reduction/Removal Alternatives in addition to a containment alternative to address Site conditions are not necessary to protect human health and the environment and would provide minimal additional protectiveness. However, it is recognized that there might be a desire to achieve some additional mass removal to augment the mass reduction expected from a containment system. The disproportionate cost analysis indicates that a point of diminishing returns is quickly reached after the mass reduction alternatives that include groundwater extraction (i.e., less or similar benefit for more cost).

The MSP alternative has the lowest cost, the highest benefit score to cost ratio, and includes the hydraulic component of a containment alternative since it meets the model-based containment objectives. The MSP alternative potentially addresses the most mass in the short term and the second most mass in the long term. The M9 alternative potentially addresses the most mass in the long term, but was shown to be disproportionate in cost. The M100, M150, and M200 alternatives have the next highest benefit score to cost ratios, but remove less mass than the MSP ~~and M9 alternatives.~~alternative. The M100, M150, and M200 alternatives would require higher sustainable individual and collective groundwater pumping rates when combined with a containment alternative as would be required to meet all the minimum/threshold requirements. The ~~M9~~M8 alternative was shown to be disproportionate in cost~~ along with the M8 alternative~~. The remaining VOC Mass Reduction/Removal Alternatives (M3, M5, and M6) remove less mass and have lower benefit score to cost ratios. The No Additional Action alternative does not remove any additional mass.

Based on the above evaluation, the identified preferred alternative is VOC Mass Reduction Alternative MSP since it has the highest benefit score to cost ratio, removes the highest quantity of mass in the short term~~ and long term~~, and has the lowest per pound cost. The MSP alternative is a cost-effective means to remove additional mass from the subsurface and meet the model-based containment objectives and can be reliably operated and maintained.

7. pH Reduction/Enhanced Containment Alternatives - Initial Screening and Detailed Evaluation

7.1 Initial Screening

The pH reduction/enhanced containment alternatives are described in Subsection 4.5. The initial screening criteria are described in Subsection 5.1.

The pH reduction/enhanced containment alternatives are designed to reduce or otherwise enhance containment of high pH in groundwater and soil. The pH reduction/enhanced containment alternatives would not protect human health and the environment, including potential ecological receptors, at the Site by themselves. Therefore, they would not meet all the minimum/threshold requirements. However, in combination with containment technologies they would meet the minimum/threshold requirements (see Subsection 5.1). Accordingly, the pH alternatives all assume that appropriate containment technologies are implemented at the Site. Therefore, none of the pH alternatives were removed from further evaluation based on this initial screening.

The pH alternatives are sufficiently different because of the technologies used and/or areas targeted that determining which alternatives' costs would be clearly disproportionate under WAC 173-340-360(3)(e) in the initial screening is not evident. Therefore, none of the pH alternatives were removed from further evaluation based on this initial screening criterion.

The pH alternatives and components presented herein are administratively and technically possible at the Site and therefore none of the pH alternatives were removed from further evaluation based on this initial screening criterion.

Based on the above, the initial screening did not eliminate any of the pH alternatives.

7.2 Detailed Evaluation

Purpose and Evaluation Criteria

The purpose of the detailed evaluation is to select an alternative, retained following the initial screening, which does not have an incremental cost that exceeds the incremental degree of benefits potentially achieved. The detailed evaluation of the pH Reduction/Enhanced Containment Alternatives involved assessing MTCA and CERCLA factors to be considered (see Subsection 5.2) and conducting a disproportionate cost analysis per WAC 173-340-360(3)(f). The detailed evaluation assumes that containment is part of the selected remedy for the Site, which is consistent with the initial screening of the pH alternatives.

7.2.1 No Additional Action pH Reduction/Enhanced Containment Alternative

The No Additional Action pH Reduction/Enhanced Containment Alternative would not enhance a containment alternative with respect to minimizing potential risks to human health and the environment. It would not alter or undermine the practicality and effectiveness of a containment alternative and therefore would be compatible with the use at the Site. This alternative would not reduce or enhance containment of high pH in media at the Site and thus would not increase permanence or long-term effectiveness. However, the high pH would be reliably contained by containment technologies. There are no short-term risks and it is fully implementable. Since this alternative would not alter the geochemical conditions in the subsurface, natural processes (e.g., biodegradation) documented to occur at the Site would also continue to reduce concentrations of hazardous substances.

7.2.2 pH Reduction Alternative pH2

The pH Reduction Alternative pH2 includes reducing high pH in shallow groundwater and soil by in situ mixing of sodium persulfate. It would not enhance a containment alternative with respect to minimizing potential risks to human health and the environment because the uplands high pH would already be reliably contained. It would reduce a little pH. Therefore, the pH2 alternative would add a very ~~little~~small degree of permanence and limited long-term effectiveness. It would prevent the potential for migration of a little high pH water to extraction wells; however, the extraction wells would be positioned to minimize this potential already. Additionally, the containment alternatives include a contingency for pH treatment. The pH2 alternative would not reduce the time for O&M of a containment alternative.

Based on discussions with an experienced contractor, in situ mixing to a depth of -60 ft NGVD (approximately 75 ft below grade) would be practical and implementable with some difficulty if the subsurface contains deleterious material and/or non-cohesive soil that could bind the mixing equipment. There would be short-term risks for construction and managing the sodium persulfate. The pH2 alternative is not expected to alter or undermine the practicality of a containment alternative, but it might alter the effectiveness by changing the groundwater flow (i.e., hydraulic conductivity) in the target zone. This could potentially impact drawdown and gradients within the containment system and might reduce the quantity of TCVOC mass that would be extracted from the subsurface over time. Despite this concern, it would still be compatible with the use at the Site since the target zone would still be reliably contained. It would alter the geochemical conditions in the subsurface and therefore natural processes (e.g., biodegradation) documented to occur at the Site that reduce concentrations of hazardous substances might be affected. However, since sodium persulfate is an oxidant and would be introduced into zones of TCVOC mass and high pH, it would be expected that concentrations of TCVOC within the target zone would decrease since the high pH is likely to activate the sodium persulfate, which in theory will oxidize ~~TCVOC~~CVOC. It should be noted that only a small percentage (i.e., less than one percent) of the TCVOC mass is present within the zones of pH greater than or equal to 12.5 s.u. Therefore, this added benefit is not expected to be significant with respect to reducing the quantity of TCVOC mass. There are safety concerns while handling sodium persulfate since the dust can be hazardous primarily if inhaled; however, these concerns would be minimized with handling and storage in accordance with the manufacturer's guidelines and a health and safety program.

7.2.3 pH Enhanced Containment Alternative pH3

The pH Enhanced Containment Alternative pH3 includes containment of high pH in shallow groundwater and soil by in situ mixing of cement. It would not enhance a containment alternative with respect to minimizing potential risks to human health and the environment because the uplands high pH would already be reliably contained. It would not reduce pH. Therefore, the pH3 alternative would not add any permanence and long-term effectiveness. It would prevent the potential for migration of a little high pH water to extraction wells; however, the extraction wells would be positioned to minimize this potential already. Additionally, the containment alternatives include a contingency for pH treatment. The pH3 alternative would not reduce the time for O&M of a containment alternative.

Based on discussions with an experienced contractor, in situ mixing to a depth of -60 ft NGVD (approximately 75 ft below grade) would be practical and implementable with some difficulty if the subsurface contains deleterious material and/or low permeability soil that could bind the mixing equipment. There would be short-term risks for construction and managing the cement. The pH3 alternative is not expected to alter or undermine the practicality of a containment alternative, but it might alter the effectiveness by changing the groundwater flow (i.e., hydraulic conductivity) in the target zone. This could potentially impact drawdown and gradients within the containment system and might reduce the quantity of TCVOC mass that would be extracted from the subsurface over time. Despite this concern, it would still be compatible with the use at the Site since the target zone would still be reliably contained. It would alter the geochemical conditions in the subsurface and therefore natural processes (e.g., biodegradation) documented to occur at the Site that reduce concentrations of hazardous substances might be affected. The introduction of cement would not decrease concentrations of TCVOC within the target zone. It should be noted that only a small percentage (i.e., less than one percent) of the TCVOC mass is present within the zones of pH greater than or equal to 12.5 s.u. There are safety concerns while handling cement since it is caustic (high pH); however, these concerns would be minimized with handling and storage in accordance with the manufacturer's guidelines and a health and safety program. Another concern would be due to the exothermic cementitious reactions that produce heat that could increase vitalization of VOC near the ground surface. Air collection and treatment devices might be needed to capture VOC that volatilize during the mixing process. This might also slow the mixing process in order to control the reaction.

7.2.4 pH Enhanced Containment Alternative pH4

The pH Enhanced Containment Alternative pH4 includes containment of high pH in shallow groundwater and soil by construction of a vertical slurry wall north, south, and west of the high pH. The eastern extent of the high pH would be contained by a sheet pile vertical barrier wall that is part of the containment alternatives. It would not enhance a containment alternative with respect to minimizing potential risks to human health and the environment because the uplands high pH would already be reliably contained. It would not reduce pH. Therefore, the pH4 alternative would not add any permanence and long-term effectiveness. It would prevent the potential for migration of a little high pH water to shallow extraction wells; however, the extraction wells would be positioned to minimize this potential already. Additionally, the containment alternatives include a contingency for pH treatment. The pH4 alternative would not reduce the time for O&M of a containment alternative.

Based on discussions with an experienced contractor, construction of the slurry wall to a depth of -60 ft NGVD (approximately 75 ft below grade) would be practical and implementable with some difficulty if the subsurface contains deleterious material. There would be short-term risks for construction and managing the slurry. The pH4 alternative is not expected to alter or undermine the practicality of a containment alternative, but it might alter the effectiveness by changing the groundwater flow (i.e., hydraulic conductivity) in the target zone. This could potentially impact drawdown and gradients within the containment system and might reduce the quantity of TCVOC mass that would be extracted from the subsurface over time. Despite this concern, it would still be compatible with the use at the Site since the target zone would still be reliably contained. Additionally, it should be noted that only a small percentage (i.e., less than one percent) of the TCVOC mass is present within the zones of pH greater than or equal to 12.5 s.u. It would not alter the geochemical conditions in the subsurface except in the immediate vicinity of the wall and therefore natural processes (e.g., biodegradation) documented to occur at the Site would also continue to reduce concentrations of hazardous substances.

7.2.5 pH Reduction Alternative pH5

The pH Reduction Alternative pH5 includes reducing high pH in shallow and deep groundwater and soil by in situ mixing of sodium persulfate. This alternative would involve the same processes as the pH2 alternative, but the mixing would extend to greater depths. It would not enhance a containment alternative with respect to minimizing potential risks to human health and the environment because the uplands high pH would already be reliably contained. It would further reduce pH compared to the pH2 alternative. Therefore, the pH5 alternative would add a ~~little more~~small degree of permanence and long-term effectiveness compared to the pH2 alternative. It would prevent the potential for migration of some high pH water to extraction wells; however, the extraction wells would be positioned to minimize this potential already. Additionally, the containment alternatives include a contingency for pH treatment. The pH5 alternative would not reduce the time for O&M of a containment alternative.

Based on discussions with an experienced contractor, in situ mixing to depths below -60 ft NGVD (approximately 75 ft below grade) would be implementable but not with conventional equipment resulting in increased costs. There would be additional difficulties if the subsurface contains deleterious material and/or non-cohesive soil that could bind the mixing equipment, which would increase with depth. There would be short-term risks for construction and managing the sodium persulfate. The pH5 alternative is not expected to alter or undermine the practicality of a containment alternative, but it might further alter the effectiveness by changing the groundwater flow (i.e., hydraulic conductivity) in the target zone. This could potentially impact drawdown and gradients within the containment system and might further reduce the quantity of TCVOC mass that would be extracted from the subsurface over time. Despite this concern, it would still be compatible with the use at the Site since the target zone would still be reliably contained. It would further alter the geochemical conditions in the subsurface and therefore natural processes (e.g., biodegradation) documented to occur at the Site that reduce concentrations of hazardous substances might be further affected. However, since sodium persulfate is an oxidant and would be introduced into zones of TCVOC mass and high pH, it is expected that concentrations of TCVOC within the target zone would decrease since the high pH is likely to activate the sodium persulfate, which in theory will oxidize ~~TCVOC~~CVOC. It should be noted that only a small percentage (i.e., less than one percent) of the TCVOC mass is present within the zones of pH greater than or equal to 12.5 s.u. Therefore, this added benefit is not expected to be significant with respect to reducing the quantity of TCVOC mass. There are safety concerns while handling sodium persulfate since the dust can be hazardous primarily if inhaled; however, these concerns would be minimized with handling and storage in accordance with the manufacturer's guidelines and a health and safety program.

7.2.6 pH Enhanced Containment Alternative pH6

The pH Enhanced Containment Alternative pH6 includes containment of high pH in shallow and deep groundwater and soil by in situ mixing of cement. This alternative would involve the same processes as the pH3 alternative, but the mixing would extend to greater depths. It would not enhance a containment alternative with respect to minimizing potential risks to human health and the environment because the uplands high pH would already be reliably contained. It would not reduce pH. Therefore, the pH6 alternative would not add any permanence and long-term effectiveness. It would prevent the potential for migration of some high pH water to extraction wells; however, the extraction wells would be positioned to minimize this potential already. Additionally, the containment alternatives include a contingency for pH treatment. The pH6 alternative would not reduce the time for O&M of a containment alternative.

The pH6 alternative would have the same difficulties with mixing at depth as the pH5 alternative. There would be short-term risks for construction and managing the cement. The pH6 alternative is not expected to alter or undermine the practicality of a containment alternative, but it might further alter the effectiveness by changing the groundwater flow (i.e., hydraulic conductivity) in the target zone. This could potentially impact drawdown and gradients within the containment system and might reduce the quantity of TCVOC mass that would be extracted from the subsurface over time. Despite this concern, it would still be compatible with the use at the Site since the target zone would still be reliably contained. It would further alter the geochemical conditions in the subsurface and therefore natural processes (e.g., biodegradation) documented to occur at the Site that reduce concentrations of hazardous substances might be further affected. The introduction of cement would not decrease concentrations of TCVOC within the target zone. It should be noted that only a small percentage (i.e., less than one percent) of the TCVOC mass is present within the zones of pH greater than or equal to 12.5 s.u. There are safety concerns while handling cement since it is caustic (high pH); however, these concerns would be minimized with handling and storage in accordance with the manufacturer's guidelines and a health and safety program. Another concern would be due to the exothermic cementitious reactions that produce heat and would vaporize the VOC in the subsurface. Air collection and treatment devices might be needed to capture VOC that volatilize during the mixing process. This might also slow the mixing process in order to control the reaction.

7.2.7 pH Enhanced Containment Alternative pH7

The pH Enhanced Containment Alternative pH7 includes containment of high pH in shallow and deep groundwater and soil by construction of vertical slurry walls north, south, and west of the shallow high pH and in all directions around the deep high pH. The eastern extent of the shallow high pH would be contained by a sheet pile vertical barrier wall that is part of the containment alternatives. It would not enhance a containment alternative with respect to minimizing potential risks to human health and the environment because the uplands high pH would already be reliably contained. It would not reduce pH. Therefore, the pH7 alternative would not add any permanence and long-term effectiveness. It would prevent the potential for migration of some high pH water to extraction wells; however, the extraction wells would be positioned to minimize this potential already. Additionally, the containment alternatives include a contingency for pH treatment. The pH7 alternative would not reduce the time for O&M of a containment alternative.

Based on discussions with an experienced contractor, construction of slurry walls to depths greater than -60 ft NGVD (approximately 75 ft below grade) would be practical and implementable with some difficulty if the subsurface contains deleterious material and depending on the subsurface soil types at depth. The contractor indicated that the slurry walls would be constructed to ground surface because the construction technique relies on an established slope to prevent segregation and permit the backfill material to slide down through the slurry. There would be short-term risks for construction and managing the slurry. The pH7 alternative is not expected to alter or undermine the practicality of a containment alternative, but it might further alter the effectiveness by changing the groundwater flow (i.e., hydraulic conductivity) in the target zone. This could potentially impact drawdown and gradients within the containment system and might reduce the quantity of TCVOC mass that would be extracted from the subsurface over time. This would be most significant in the shallow zone above the deeper high pH target zone, where high concentrations of TCVOC exist. The deeper slurry wall would effectively prevent groundwater flow in this area and therefore prevent extraction of higher concentrations of TCVOC within parts of the shallow zone. Despite this concern, it would still be compatible with the use at the Site since the target zone would still be reliably contained. It would not alter the geochemical conditions in the subsurface except in the immediate vicinity of the wall and therefore natural processes (e.g., biodegradation) documented to occur at the Site would also continue to reduce concentrations of hazardous substances.

7.2.8 Disproportionate Cost Analysis

A DCA of the pH Reduction/Enhanced Containment Alternatives was conducted using the same process described in Subsection 5.2.4. The following presents an evaluation of pH Reduction/Enhanced Containment Alternatives pH2 through pH7 and the No Additional Action alternative with respect to the DCA process.

Protectiveness

The pH Reduction/Enhanced Containment Alternatives would not protect human health and the environment, including potential ecological receptors, at the Site by themselves. Therefore, they would not meet all the minimum/threshold requirements. However, they would in combination with a containment alternative, each of which meet the minimum/threshold requirements (see Subsection 5.1). Accordingly, the pH alternatives all assume that one of the containment alternatives is implemented at the Site to meet the minimum/threshold requirements.

Permanence

The No Additional Action alternative would not add any permanence to a Site remedy.

Alternative pH2 would add a very ~~little~~small degree of permanence since the high pH in the shallow zone would be reduced to less than 12.5 s.u. However, the targeted zone and areas outside the target zone would still contain elevated pH, including pH greater than 12.5 s.u. in the deep zone. This residual high pH would require O&M of a containment alternative for long-term permanence.

Alternatives pH3 and pH4 would not add any degree of permanence since enhanced containment of the high pH within the cemented aquifer or within slurry walls in the shallow zone would not affect the length of time for O&M of a containment alternative.

Alternative pH5 would add a ~~little~~small degree of permanence greater than the pH2 alternative since the high pH in the shallow and deep zones would be reduced to less than 12.5 s.u. However, the targeted zones and areas outside the target zones would still contain elevated pH that would require O&M of a containment alternative for long-term permanence.

Alternatives pH6 and pH7 would not add any degree of permanence since enhanced containment of the high pH within the cemented aquifer or within slurry walls in the shallow zone would not affect the length of time for O&M of a containment alternative. Alternative pH7 might decrease the degree of permanence of a containment alternative since the deeper slurry wall would effectively prevent groundwater flow in the parts of the shallow zone where higher concentrations of TCVOC are and therefore prevent extraction of groundwater with these higher concentrations of TCVOC.

Effectiveness Over the Long Term

The No Additional Action alternative would not have any effectiveness over the long term.

Alternative pH2 would have very little effectiveness over the long term since it does not treat all groundwater and soil with elevated pH, including groundwater and soil at depth with pH greater than 12.5 s.u. Additionally, there is a possibility that pH values could rebound in the targeted zone based on the results of the extensive pH studies conducted for the Site. This alternative would not affect the length of time for O&M of a containment alternative.

Alternatives pH3 and pH4 would have limited overall effectiveness over the long term since they do not enhance containment of all groundwater and soil with elevated pH, including groundwater and soil at depth with pH greater than 12.5 s.u. The limited effectiveness in the target zone would be in terms of preventing migration of high pH to a containment alternative extraction wells. However, this is considered a low risk since the extraction wells would be located away from the high pH. Additionally, the containment alternatives include a contingency for pH treatment. These two alternatives would not affect the length of time for O&M of a containment alternative. Additionally for the pH4 alternative, groundwater with elevated pH might migrate below the vertical slurry wall and/or the sheet pile vertical barrier wall since hydraulic containment within the target zone is not expected because none of the wells from a containment alternative would be within the area surrounded by the walls.

Alternative pH5 would have a little effectiveness over the long term since it treats all of the groundwater and soil with pH greater than 12.5 s.u. However, it does not treat all groundwater and soil with elevated pH and there is a possibility that pH values could rebound in the targeted zone based on the results of the extensive pH studies conducted for the Site. This alternative would not affect the length of time for O&M of a containment alternative.

Alternatives pH6 and pH7 would have limited overall effectiveness over the long term since they do not enhance containment of all groundwater and soil with elevated pH. The limited effectiveness in the target zone would be in terms of preventing migration of high pH to a containment alternative extraction wells. However, this is considered a low risk since the extraction wells would be located away from the high pH. Additionally, the containment alternatives include a contingency for pH treatment. These two alternatives would not affect the length of time for O&M of a containment alternative. Additionally for the pH7 alternative, groundwater with elevated pH might migrate below the shallower vertical slurry wall and/or the sheet pile vertical barrier wall since hydraulic containment within the target zone is not expected because none of the wells from a containment alternative would be within the area surrounded by the walls. For the pH in the deeper zone, the deeper vertical slurry walls surround the pH greater than 12.5 s.u.

Management of Short-term Risks

The short-term risks during construction and implementation of the alternatives would be managed through standard safety and health procedures that would be documented in a Site-specific HASP. The types of procedures that would be required are those regularly practiced for the types of construction anticipated. The pH6 and pH7 alternatives might present more short-term risks because their scopes extend to greater depths compared to the pH3 and pH4 alternatives. The pH4 and pH7 alternatives that include a slurry wall would present the lowest short-term risks, excluding the No Additional Action alternative, because they involve the smallest areal footprint (e.g., less noise impact, construction-related risks, and potential for fugitive emissions), and less sub-surface disturbance for potential exposure to hazardous materials. The pH2, pH3, pH5, and pH6 alternatives that involve mixing of subsurface soils would include additional short-term risks such as chemical transport, mixing, and handling, managing soil stability and chemical daylighting (i.e., chemicals flowing to and over ground surface), and managing equipment over a large footprint.

In addition to the HASP, other plans for activities such as soil management, traffic control, and air monitoring would be developed to protect human health and the environment during construction and implementation.

Technical and Administrative Implementability

As discussed in Subsection 7.1, all of the pH alternatives are implementable.

The technical implementability of the pH2 and pH3 alternatives involving in situ mixing and pH4 alternative involving construction of vertical slurry walls is considered good since these technologies have been successful at similar depths at other sites. Additionally, the target zone is within the 605 Alexander Avenue property and therefore access to the target zone would be relatively easy since the area would be void of any operations. The pH2 and pH3 alternatives would be less implementable because they involve disturbance of large areas and depths of soil, which might affect surface stability.

The technical implementability of the pH5 and pH6 alternatives involving in situ mixing and pH7 alternative involving construction of vertical slurry walls is considered fair to good since the additional depth of target zones in some areas might present difficulties and require more specialized equipment as discussed previously in Subsection 7.2.5. Additionally, the targeted area on the Port of Tacoma property is under an existing building that further complicates implementation. The pH5 and pH6 alternatives would be the least implementable because they involve disturbance of even large areas and greater depths of soil, which might affect surface stability.

Since the in situ mixing and vertical slurry walls are proven technologies and typically applied at many sites; services, capabilities, equipment, specialists, and materials should be available for implementation of these remedial alternatives. Permitting of these remedial alternatives is also expected to be obtained without significant difficulties.

Consideration of Public Concerns

As noted in Subsection 5.2.4, under *Consideration of Public Concerns*, a containment system alone would be protective of human health and the environment by eliminating all potential exposure pathways and is a common, reliable, and effective solution for large complex sites like this one, which could be effectively operated, maintained, and monitored. Additionally, public concerns regarding the Hylebos documented during a public comment period from October 23, 2015 through February 1, 2016 for the approved SCR (CRA, 2014c) are addressed through the 2016 Anchor QEA investigation sediment and porewater sampling in the Hylebos. (See Subsection 2.4.5 and 2.4.6). ~~The public made no comments related to pH reduction/enhanced containment in these correspondences.~~

Mobility of pH within the containment system would be of minimal concern as long as there is hydraulic control of the target zones. Therefore, the pH reduction/enhanced containment alternatives do not materially enhance protectiveness, would add minimal or no long-term effectiveness and permanence in terms of containment, might negatively impact a containment system that would reliably contain all high pH, and none would provide any incremental benefit to mitigating potential impacts from the Site and overall potential impacts from other sites adjacent to the Waterways and Commencement Bay. Short-term risks for some of the alternatives might be of concern, but could be managed. Any other potential measures in addition to a containment alternative to address Site conditions are not necessary but rather augmentations to a system that reliably contains contaminants at the Site. For these reasons, it is expected that the public will be supportive of any overall remedy for the Site that includes containment.

Public notice and participation is an integral part of the remedy selection process. The public notice and participation requirements for cleanups conducted are set forth in MTCA (WAC 173-340-600), NCP 40 CFR 300.430(f)(3)(i), and CERCLA §117. The public will have an opportunity to voice any concerns regarding the FS during a public comment period.

Cost

The estimated costs for pH Reduction/Enhanced Containment Alternatives pH2 through pH7 and the No Additional Action alternative are presented in Appendix G and were developed in accordance with guidance (USEPA, 2000) specified by the Agencies. The cost estimates include periods of 30 years, in accordance with the guidance (USEPA, 2000), and 100 years, at the request of the Agencies. Discount factors for O&M and periodic costs include 7 percent, in accordance with the guidance (USEPA, 2000), and 1.5 percent (2016 Discount Rate for OMB Circular No. A-94 for the 30-Year Real Interest Rate on Treasury Notes and Bonds of Specific Maturities), at the request of the Agencies. There are no O&M costs associated with the pH alternatives. A summary of the capital costs for the pH alternatives and capital, O&M, and periodic costs for containment required to meet the minimum/threshold requirements discussed previously, is provided in Table 7.1 below. The alternatives are listed/ranked from most to least for added degree of permanence (i.e., most to least pH reduced [see Table 7.3]) in accordance with WAC 173-340-360(3)(e)(ii)(A), and thereafter from highest to lowest cost for alternatives that would not add any degree of permanence to a containment alternative (i.e., no pH reduction).

Table 7.1 Summary of pH Reduction/Enhanced Containment Alternatives Estimated Costs

Alternative	Capital	O&M/Periodic (30yrs;7%)	O&M/Periodic (30yrs;1.5%)	O&M/Periodic (100yrs;7%)	O&M/Periodic (100yrs;1.5%)
pH5	$174,488,040	$15,656,240	$30,652,600	$18,469,760	$70,539,760
pH2	$91,895,240	$15,656,240	$30,652,600	$18,469,760	$70,539,760
pH6	$101,386,040	$15,656,240	$30,652,600	$18,469,760	$70,539,760
pH3	$55,682,540	$15,656,240	$30,652,600	$18,469,760	$70,539,760
pH7	$50,548,440	$15,656,240	$30,652,600	$18,469,760	$70,539,760
pH4	$41,086,040	$15,656,240	$30,652,600	$18,469,760	$70,539,760
No Additional Action*	$38,700,240	$15,656,240	$30,652,600	$18,469,760	$70,539,760

~~Note~~Notes:
Costs for compliance monitoring are assumed to be included in a selected containment alternative.
* meaning no additional action will be conducted beyond implementing a containment alternative.

As shown in Table 7.1, the pH5 alternative ranked highest for adding a ~~little~~small degree of permanence would have the highest cost. The pH2 alternative ranked second for adding degree of permanence has a relatively high cost for the very ~~little~~small added degree of permanence. The lowest cost alternatives, pH4 and pH7, do not add any degree of permanence and might negatively impact a containment system that is the foundation of a successful remedy for the Site in terms of effectiveness and degree of permanence with respect to mitigating VOC.

Disproportionate Cost Analysis Summary

Table 7.2 presents a DCA summary table that provides relative benefit score to cost ratios for the pH Reduction/Enhanced Containment Alternatives using weighting percentages from Table 5.1. As shown in Table 7.2, the No Additional Action alternative has a benefit score to cost ratio of 1.03 that is greater than the benefit score to cost ratios for the other alternatives. The next highest ratio is 0.88 for the pH4 alternative, which is considerably lower than the ratio for the No Additional Action alternative. The benefit score to cost ratios for the remaining alternatives are less than No Additional Action alternative as well, which indicate that the costs exceed the benefits of these alternatives. The benefit score to cost ratios for pH2 of 0.47, pH5 of 0.28, and pH6 of 0.38 are the lowest and are disproportionate in cost compared to the other alternatives.

The following provides additional discussion regarding the relationship between costs and quantity of pH (ANC) potentially addressed, cash flow projections, and alternative durations.

The following table summarizes the quantity of pH (ANC) potentially addressed by each alternative as presented in Subsection 4.5 and based on the analysis in Appendix F. Figure 7.1 presents the information graphically.

Table 7.3 Summary of Estimated Quantity of pH (ANC) Potentially Addressed by each pH Alternative

Alternative	Estimated Quantity of pH (ANC) Potentially Addressed (Meq acid)	Estimated Percent of Total pH (ANC) (%)
pH5	188	23.3
pH2	91	11.2
pH6	188	23.3
pH3	91	11.2
pH7	188	23.3
pH4	91	11.2
No Additional Action	0	0

Note:
Estimated quantity of pH (ANC) in units of Megaequivalents acid. (See Appendix F)

The pH5 alternative adds a ~~little~~small degree of permanence greater than the other alternatives, would address up to 23.3 percent of the estimated total pH (ANC) for a cost of approximately $~~245M.~~190M (capital plus 30 years O&M at a discount rate of 7 percent). The pH2 alternative that is ranked second for adding degree of permanence would address about half of the ANC (11.2 percent) that the pH5 alternative would achieve, but for about ~~66~~57 percent of the cost of approximately $~~162M~~108M. As noted above, the remaining alternatives would not add any degree of permanence and would not address any additional pH compared to the pH2 and pH5 alternatives at costs ranging from $~~112~~54M to $~~172M~~117M. The two lowest cost enhanced containment alternatives, pH4 (approximately $~~112M~~54M) and pH7 (approximately $~~121M~~66M), might negatively impact a containment system that is the foundation of a successful remedy for the Site in terms of effectiveness and degree of permanence with respect to mitigating VOC. Additionally, the containment alternatives include a contingency for pH treatment that would cost approximately $27,000 (plus additional O&M) and might not be needed at all.

Figure 7.2 presents the relationship between estimated cost and estimated quantity of pH (ANC) potentially addressed by the alternatives. As shown on the figure the pH2 and pH5 alternatives would reduce relatively small quantities of pH for high costs. In terms of the other alternatives that would enhance containment, but not reduce pH, the slurry walls are more cost effective; however, they might affect the containment system negatively, as noted previously. Figure 7.3 presents the alternatives anticipated 30-year cash flow projections. As shown on this figure, there are no operation and maintenance costs anticipated (excluding O&M for containment) and therefore only capital costs are graphed. The conclusions that may be determined from this graph are the same as stated above for Figure 7.2. Figure 7.4 shows the anticipated durations for the different components of the alternatives. It is anticipated that all the pH alternatives could be completed within 4 years.

7.2.9 Summary

Each of the alternatives, except the No Additional Action alternative, would augment a reliable containment system. ~~However, none of the alternatives address all of the elevated pH at the Site.~~ The most aggressive pH alternative would potentially address 23.3 percent of the pH (ANC), leaving a minimum of 76.7 percent to be contained at the Site. Therefore, any potential concerns regarding migration of groundwater with elevated pH and/or extraction of groundwater with elevated pH would still exist. The potential benefits of some alternatives are minor and come at relatively high costs as indicated by their benefit score to cost ratios, which are all less than the No Additional Action alternative. In some cases (e.g., slurry walls), there might be negative effects to a containment system that is the foundation of a successful remedy for the Site in terms of effectiveness and degree of permanence with respect to mitigating VOC. The pH5 alternative that would potentially add a ~~little~~small degree of permanence to a containment alternative, greater than the other pH alternatives, is estimated to cost $136M ~~without considering~~in additional to the cost of containment. The pH Reduction/Enhanced Containment Alternatives in addition to a containment alternative to address Site conditions are not necessary to protect human health and the environment and would provide minimal additional protectiveness.

Based on the above evaluation, the identified preferred alternative is the No Additional Action pH Reduction/Enhanced Containment Alternative since the benefit score to cost ratios for the pH2 through pH7 pH alternatives are less than the No Additional Action alternative. Meaning, there would be no tangible degree of incremental benefit to justify selecting one of the pH2 through pH7 pH alternatives. Additionally, none of the pH alternatives would address more than 23.3 percent of the pH (ANC) and therefore elevated pH would still need to be reliably contained.

8. Select Preferred Remedy

Based on the evaluation presented in this FS, the preferred remedy consists of VOC Mass Reduction Alternative MSP combined with appropriate containment technologies from Containment Alternative C150. This alternative includes Common Elements (Subsection 4.2), containment, and VOC mass reduction as follows:

- Institutional Controls (ICs) - fence, use restrictions, soil management and Site-specific health and safety plans
- Groundwater Quality Monitoring
- Soil Vapor Monitoring
- PDCE Barrier for 605 & 709 Alexander Avenue Properties, Navy Todd Dump, N Landfill, and 709 Embankment Fill Area
- Sheet pile vertical barrier wall ~~adjacent to~~between the Site and the Hylebos

- VOC source area mass reduction by strategic groundwater pumping from nine extraction wells
- Hydraulic containment by groundwater pumping from eleven extraction wells (the nine ~~above~~ for VOC source area mass reduction by strategic groundwater pumping plus two additional wells)
- Ex situ treatment of extracted groundwater through a newly constructed conveyance and treatment system

The MSP alternative would reliably contain Site impacts ~~and would~~while significantly ~~reduce~~reducing mass ~~at a relatively quick rate and~~in the shortest time of all the alternatives for a reasonable cost, making it the most cost effective combination of containment and mass reduction/removal alternatives. This combination alternative is estimated to reduce the TCVOC mass outside areas of pH >10 s.u. by approximately ~~84~~98 percent over ~~10~~20 years while reliably achieving containment of Site impacts. If the above is selected as the preferred remedy for the Site, then it is recommended that the well locations and groundwater pumping rates be further optimized with the model developed for the Site during the design phase of the preferred remedy.

The recommended performance ~~standard~~objective for ~~CVOC~~TCVOC mass removal would be based on achieving 90 percent removal of the estimated mass of ~~CVOC~~TCVOC outside of the pH >10 s.u. at the site within 15 years~~ as outlined below:~~

~~25 percent of~~ . Based on current estimates derived using the ~~estimated CVOC~~site groundwater flow model, the TCVOC mass outside the high pH ~~(>~~(pH >10 s.u.) is approximately 331 thousand lbs. The expected rates of mass removal are as follows:

- 25 percent of the estimated TCVOC mass outside the high pH (pH >10 s.u.) will be removed by 2 years (approximately 12.5 percent per year for 2 years~~)~~). This is equivalent to approximately 82,750 lbs
- An additional 20 percent of the estimated ~~CVOC~~TCVOC mass outside high pH will be removed by 5 years ~~-~~(approximately 6.66 percent per year for 3 years~~)~~). This is equivalent to approximately 66,200 lbs
- An additional 25 percent of the estimated ~~CVOC~~TCVOC mass outside of the high pH will be removed by 10 years (approximately 5 percent per year for 5 years~~)~~). This is equivalent to approximately 82,750 lbs
- An additional 20 percent of the estimated ~~CVOC~~TCVOC mass outside of the high pH will be removed by 15 years (approximately 4 percent per year for 5 years~~)~~). This is equivalent to approximately 66,200 lbs

~~Once the CVOC mass removal performance objective of removing at least 90 percent of the estimated CVOC mass outside of the pH > 10 s.u. has been achieved or at such time that it is no longer feasible to pump groundwater with high concentrations of CVOC (i.e., CVOC within high pH) whichever occurs earlier, the remedy will be reassessed to focus on the objective of containment of remaining source zones and the groundwater plume to prevent expansion of the plume and to prevent discharges to the Hylebos above levels which could affect human health and the environment.~~

Note that estimated rates of mass removal were determined using the three-dimensional (3D) groundwater flow model that was specifically constructed and calibrated for the Site. The Site groundwater flow model provides a useful tool to evaluate the potential effectiveness of the groundwater mass reduction remedial alternatives that incorporate groundwater extraction. It is noted that the model assumes idealized mass transport controlled by advection and equilibrium sorption and all mass is assumed to be either dissolved in the groundwater or sorbed onto the aquifer matrix. Potential effects of non-aqueous phase liquids are not included. The potential effects of diffusion into low-permeability units or areas are not included. Additionally, the estimates do not include potential effects of high pH potentially reaching extraction wells, all contributing to the uncertainty of the mass estimates. However, the evaluation approach was applied consistently for all alternatives.

The recommended preferred remedy ~~provides~~ would protect human health and the environment in the short term and long term. It would provide both VOC mass reduction/removal at a relatively quick rate by strategic groundwater pumping and ~~pumps~~hydraulic containment reliably and effectively by pumping sufficient groundwater to achieve the Site model-based containment objectives.

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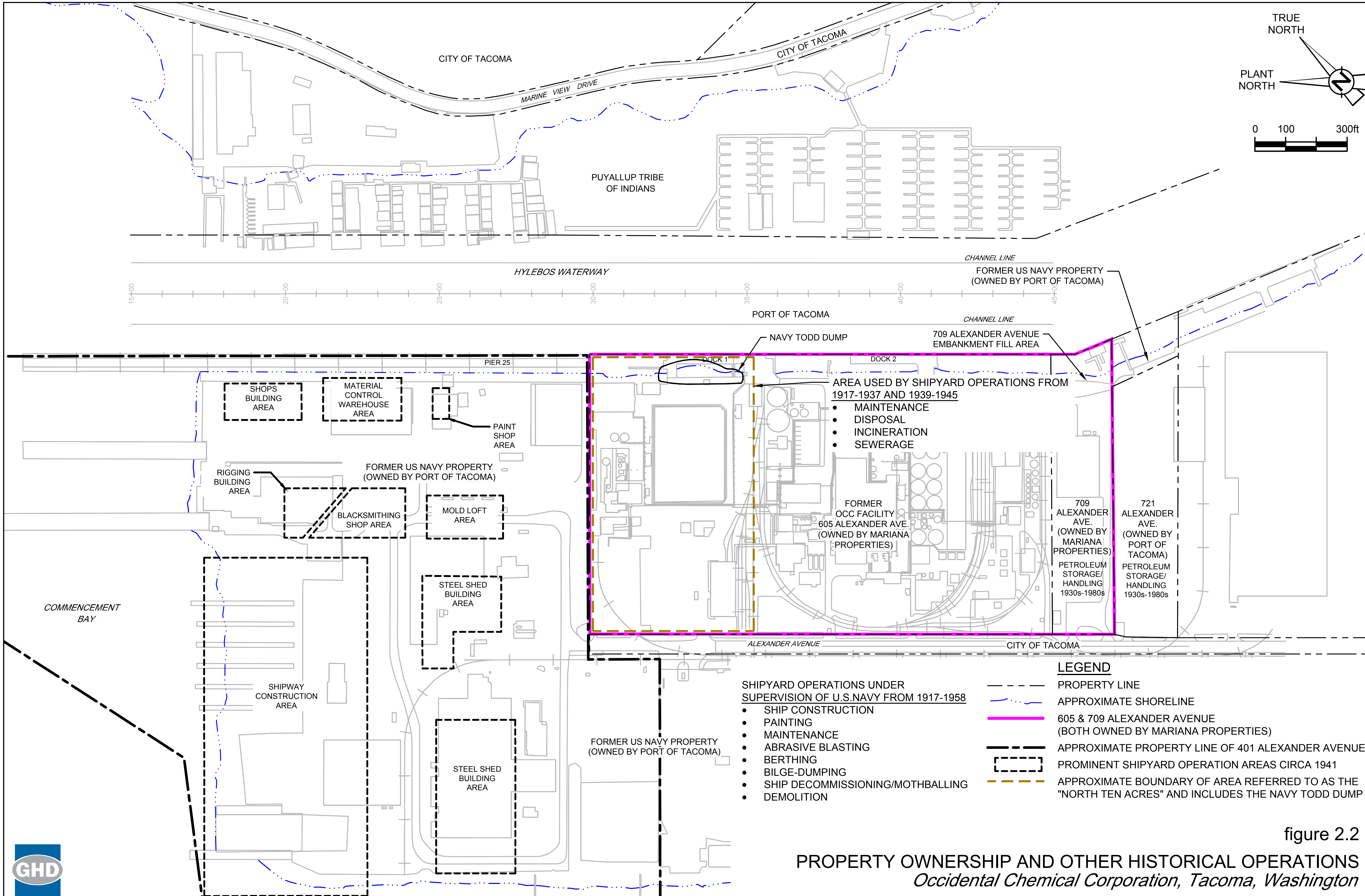


figure 2.2

PROPERTY OWNERSHIP AND OTHER HISTORICAL OPERATIONS

Occidental Chemical Corporation, Tacoma, Washington

07843-C2D2(139)GN-WA015 DEC 5, 2016

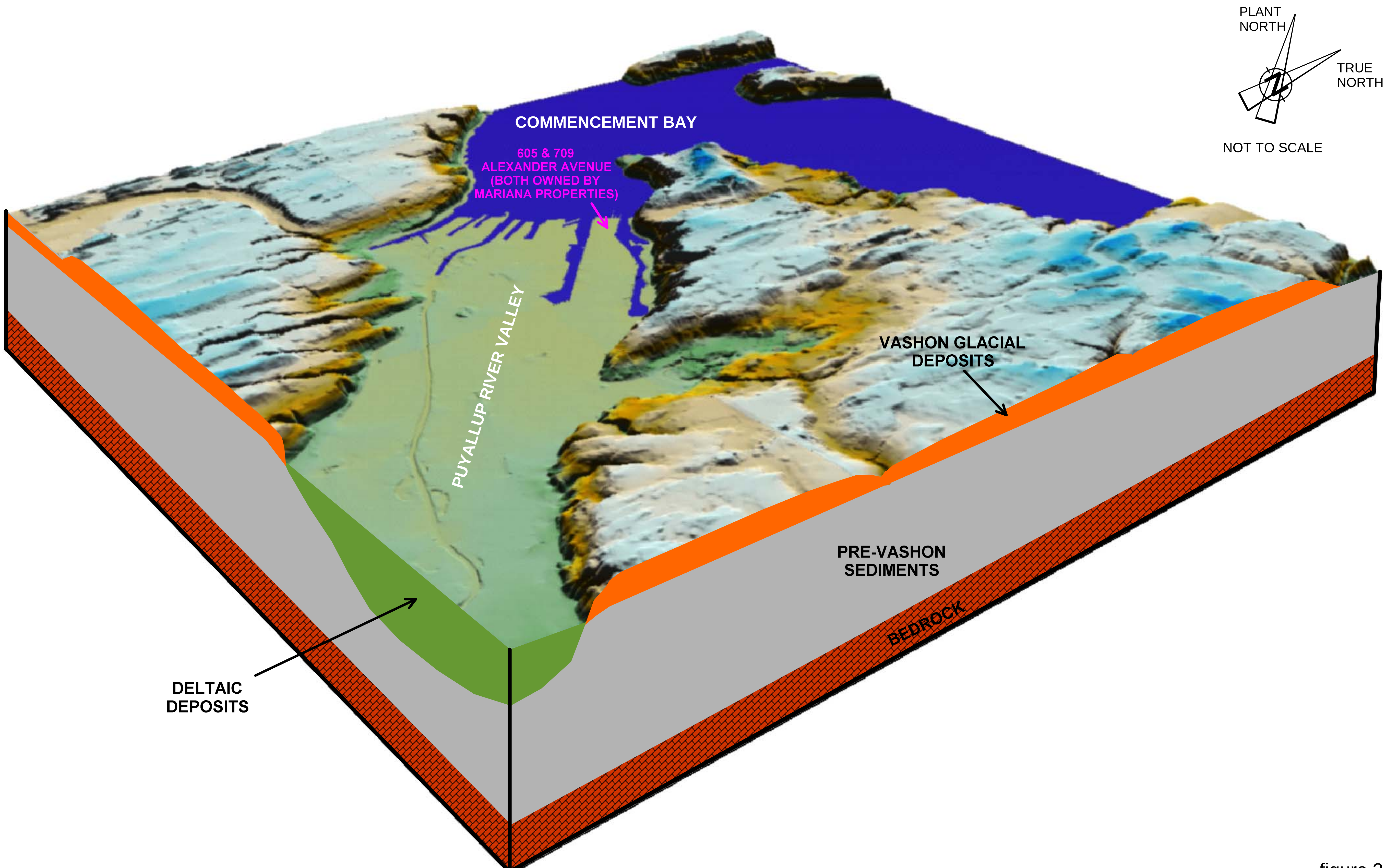


figure 2.3

REGIONAL GEOLOGY

Occidental Chemical Corporation, Tacoma, Washington

07843-C2D2(139)GN-WA-HYD (N:\HEG\07843\RPT139\Figures-Current\07843-C2D2(139)HEG-Fig 2.3.srf) DEC 9, 2016

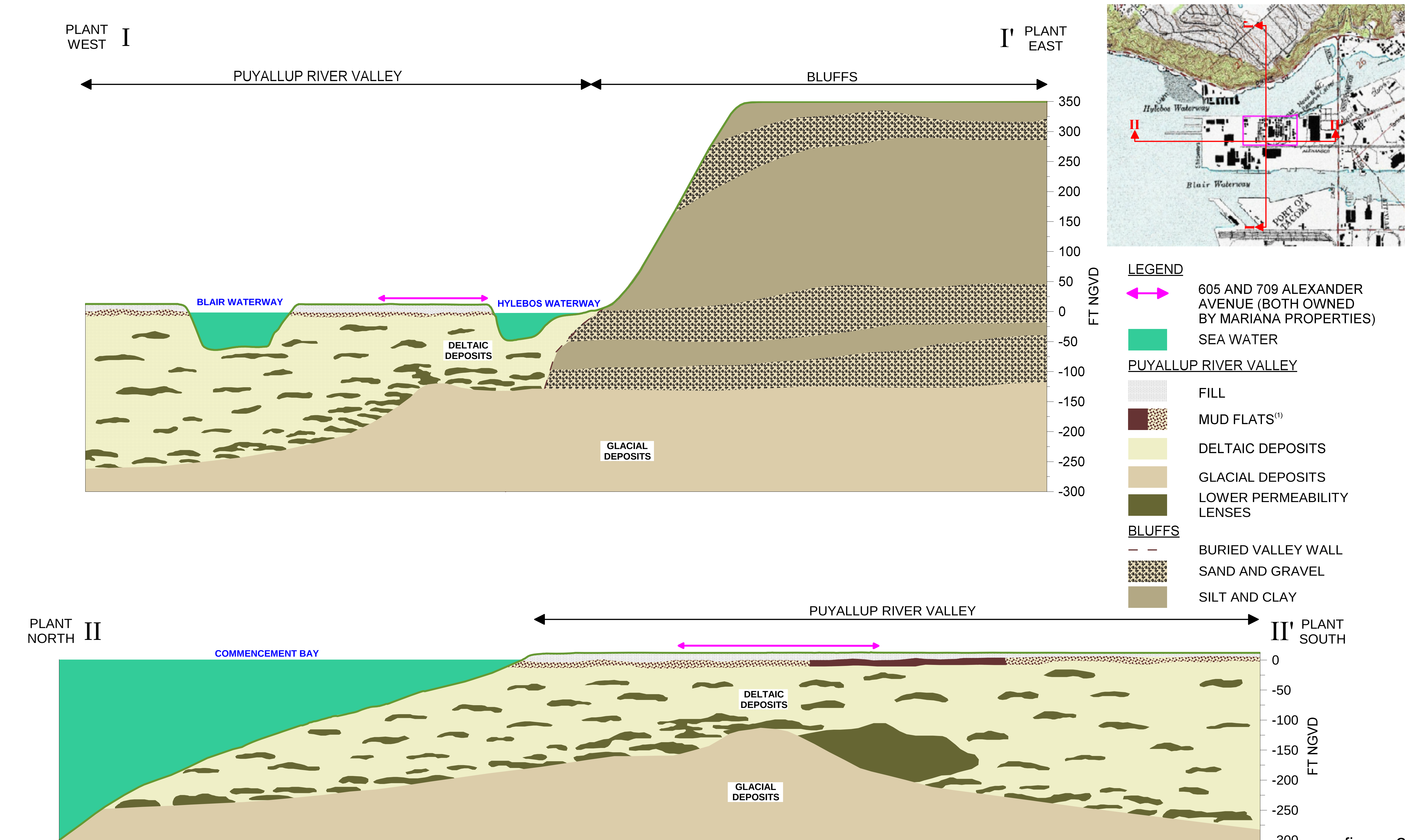
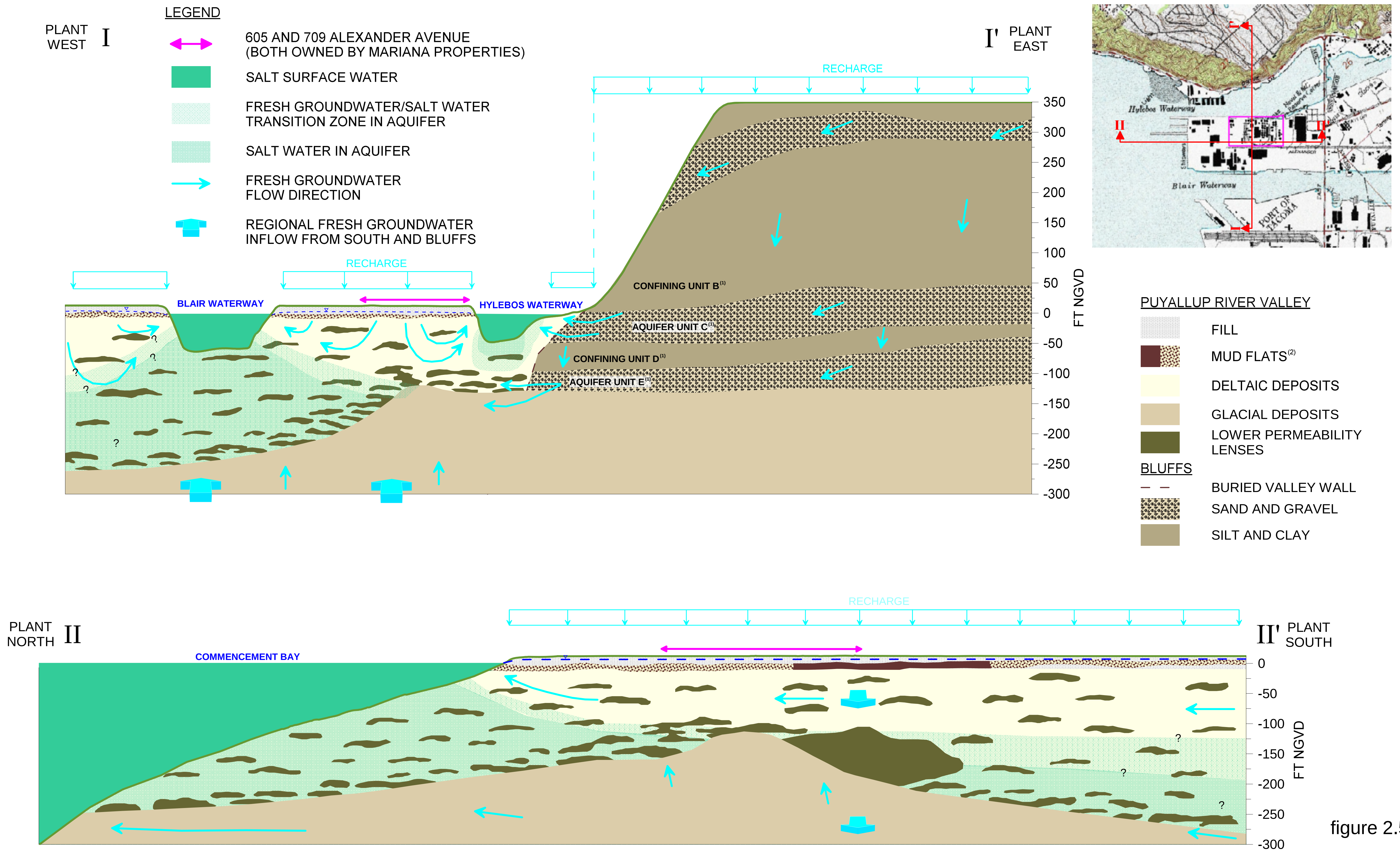


figure 2.4

NOTES:
(1) DARK BROWN INDICATES WHERE MUD FLATS ARE OBSERVED TO PROVIDE HYDRAULIC SEPARATION BETWEEN THE FILL AND DELTAIC DEPOSITS; BROWN DOT PATTERN INDICATES WHERE HYDRAULIC SEPARATION BY THE MUD FLATS IS NOT CONFIRMED

CONCEPTUAL SITE GEOLOGIC CONDITIONS
Occidental Chemical Corporation, Tacoma, Washington

07843-C2D2(139)GN-WA-HYD (N:\HEG\07843\RPT139\Figures-Current\07843-C2D2(139)HEG-Fig 2.4.srf) DEC 9, 2016



NOTES:
(1) SAVOCA ET AL. (2010)
(2) DARK BROWN INDICATES WHERE MUD FLATS ARE OBSERVED TO PROVIDE HYDRAULIC SEPARATION BETWEEN THE FILL AND DELTAIC DEPOSITS; BROWN DOT PATTERN INDICATES WHERE HYDRAULIC SEPARATION BY THE MUD FLATS IS NOT CONFIRMED
? FRESH GROUNDWATER/SALT WATER TRANSITION ZONE AND SALT WATER DISTRIBUTION ASSUMED

CONCEPTUAL SITE MODEL OF FRESH GROUNDWATER/SALT WATER DISTRIBUTION
Occidental Chemical Corporation, Tacoma, Washington

07843-C2D2(139)GN-WA-HYD (N:\HEG\07843\RPT139\Figures-Current\07843-C2D2(139)HEG-Fig 2.5.srf) DEC 9, 2016

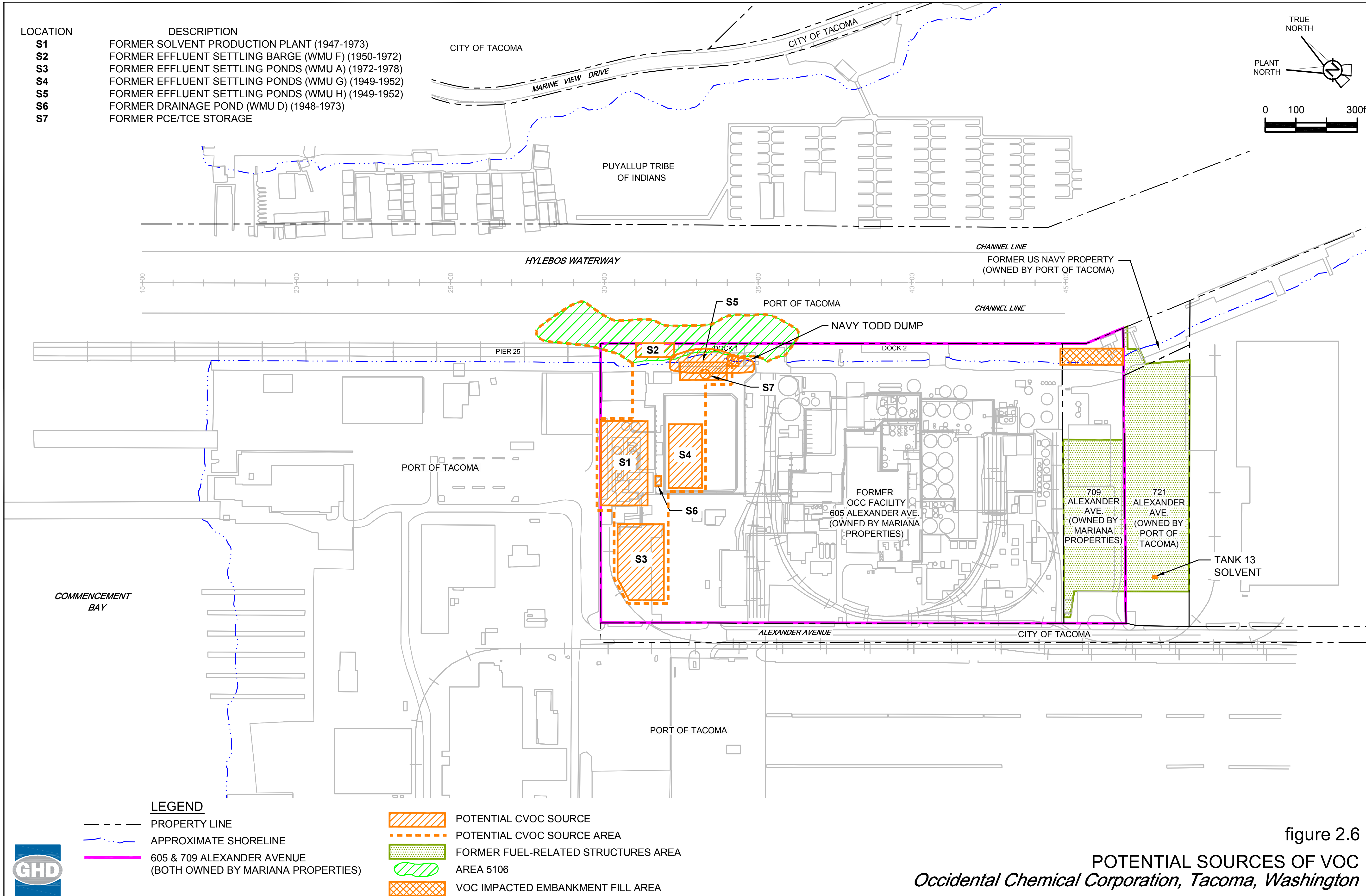
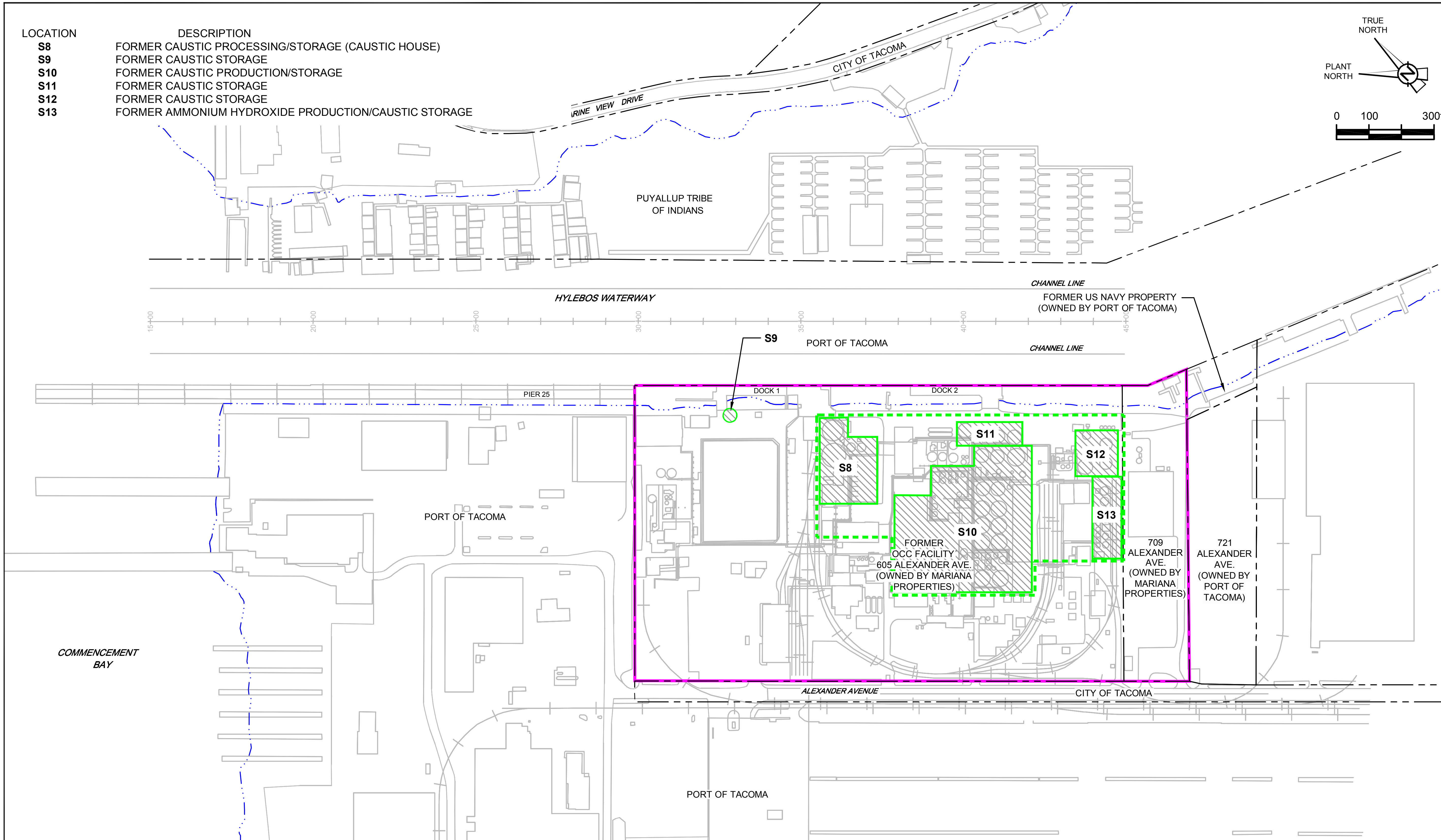


figure 2.6

POTENTIAL SOURCES OF VOC

Occidental Chemical Corporation, Tacoma, Washington

07843-C2D2(139)GN-WA016 MAY 24, 2016



LEGEND

- PROPERTY LINE
- APPROXIMATE SHORELINE
- 605 & 709 ALEXANDER AVENUE (BOTH OWNED BY MARIANA PROPERTIES)
- POTENTIAL CAUSTIC SOURCE
- POTENTIAL CAUSTIC SOURCE AREA

figure 2.7

POTENTIAL SOURCES OF CAUSTIC

Occidental Chemical Corporation, Tacoma, Washington

07843-C2D2(139)GN-WA017 APR 29, 2016

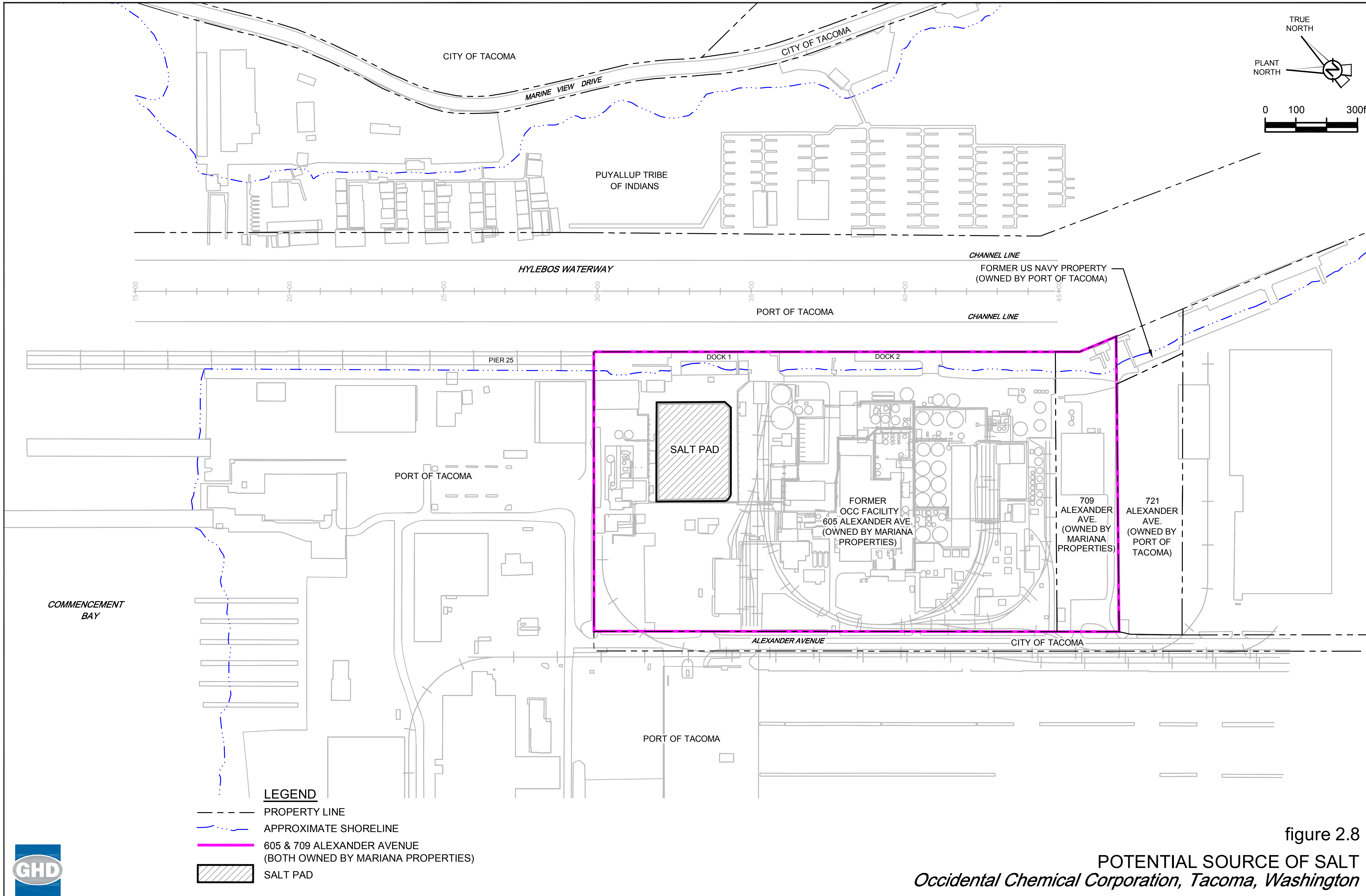


figure 2.8

POTENTIAL SOURCE OF SALT

Occidental Chemical Corporation, Tacoma, Washington

07843-C2D2(139)GN-WA018 APR 29, 2016

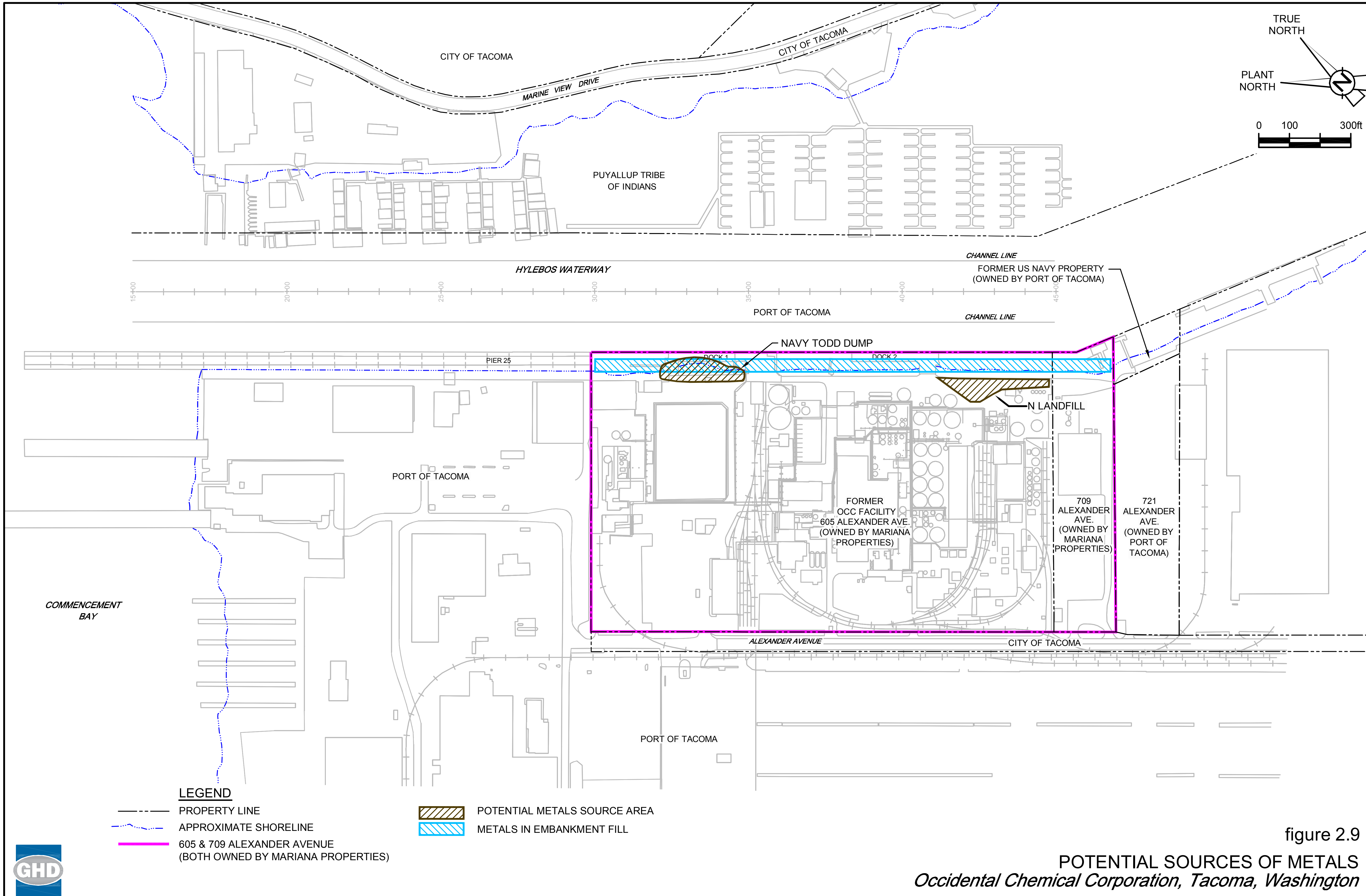


figure 2.9

POTENTIAL SOURCES OF METALS

Occidental Chemical Corporation, Tacoma, Washington

07843-C2D2(139)GN-WA019 APR 29, 2016

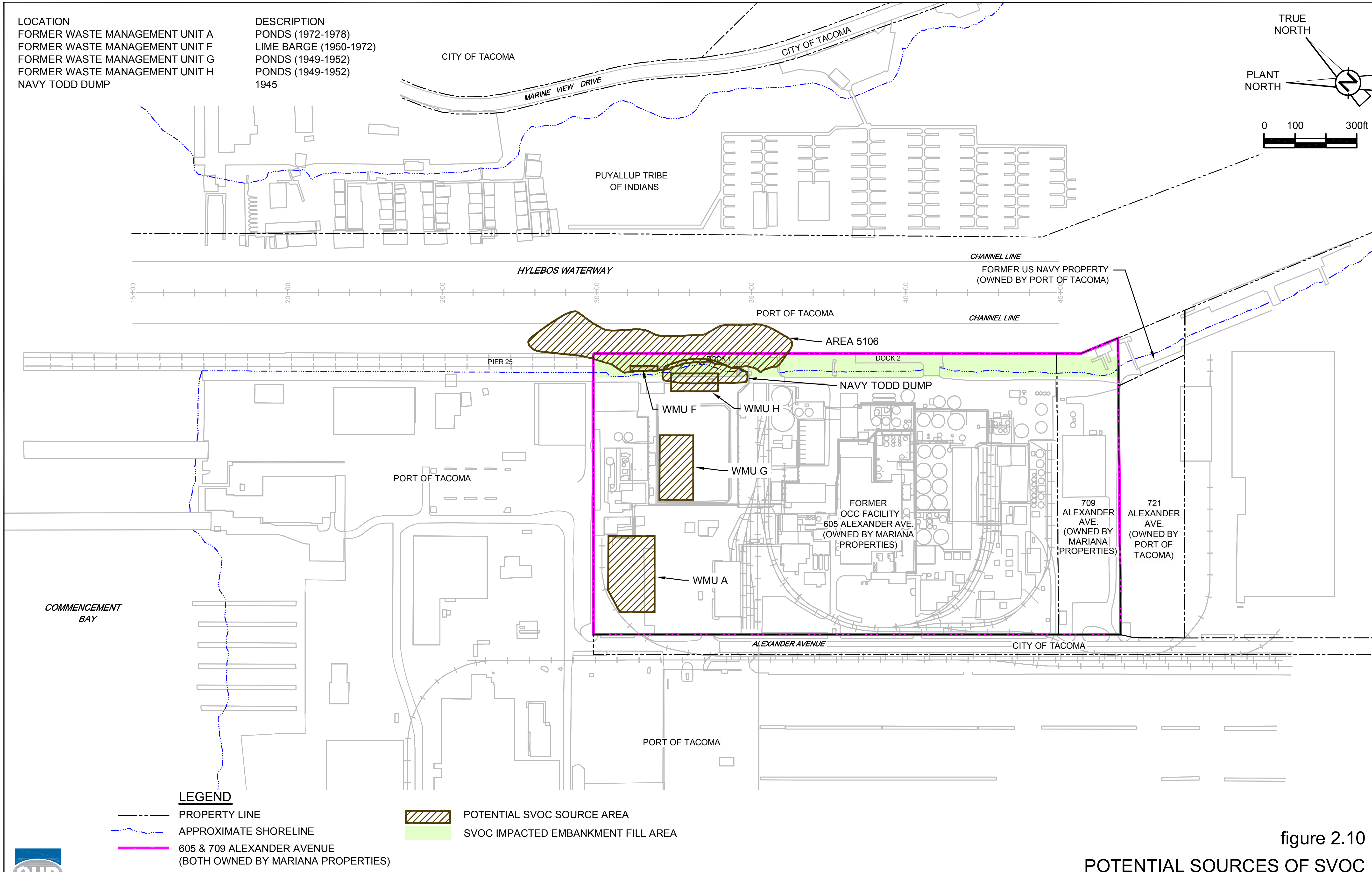


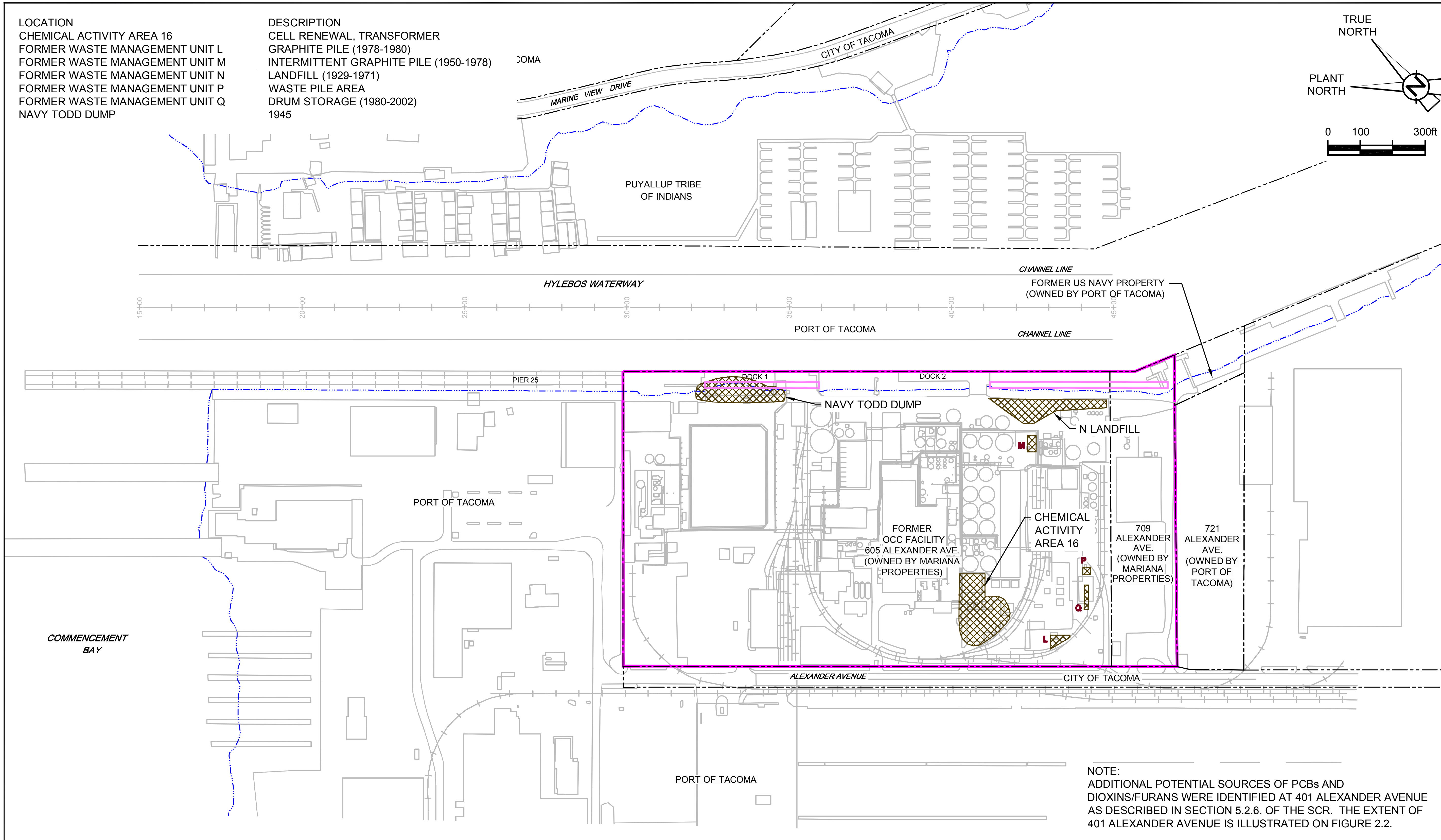
figure 2.10

POTENTIAL SOURCES OF SVOC

Occidental Chemical Corporation, Tacoma, Washington

07843-C2D2(139)GN-WA020 MAY 24, 2016

LOCATION	DESCRIPTION
CHEMICAL ACTIVITY AREA 16	CELL RENEWAL, TRANSFORMER
FORMER WASTE MANAGEMENT UNIT L	GRAPHITE PILE (1978-1980)
FORMER WASTE MANAGEMENT UNIT M	INTERMITTENT GRAPHITE PILE (1950-1978)
FORMER WASTE MANAGEMENT UNIT N	LANDFILL (1929-1971)
FORMER WASTE MANAGEMENT UNIT P	WASTE PILE AREA
FORMER WASTE MANAGEMENT UNIT Q	DRUM STORAGE (1980-2002)
NAVY TODD DUMP	1945



NOTE:
ADDITIONAL POTENTIAL SOURCES OF PCBs AND DIOXINS/FURANS WERE IDENTIFIED AT 401 ALEXANDER AVENUE AS DESCRIBED IN SECTION 5.2.6. OF THE SCR. THE EXTENT OF 401 ALEXANDER AVENUE IS ILLUSTRATED ON FIGURE 2.2.

LEGEND

- PROPERTY LINE
- APPROXIMATE SHORELINE
- 605 & 709 ALEXANDER AVENUE (BOTH OWNED BY MARIANA PROPERTIES)
- POTENTIAL SOURCE OF PCBs AND DIOXINS/FURANS
- PCBs IN EMBANKMENT FILL
- FORMER WASTE MANAGEMENT UNIT

figure 2.11

POTENTIAL SOURCES OF PCBs AND DIOXINS/FURANS

Occidental Chemical Corporation, Tacoma, Washington

07843-C2D2(139)GN-WA021 APR 29, 2016

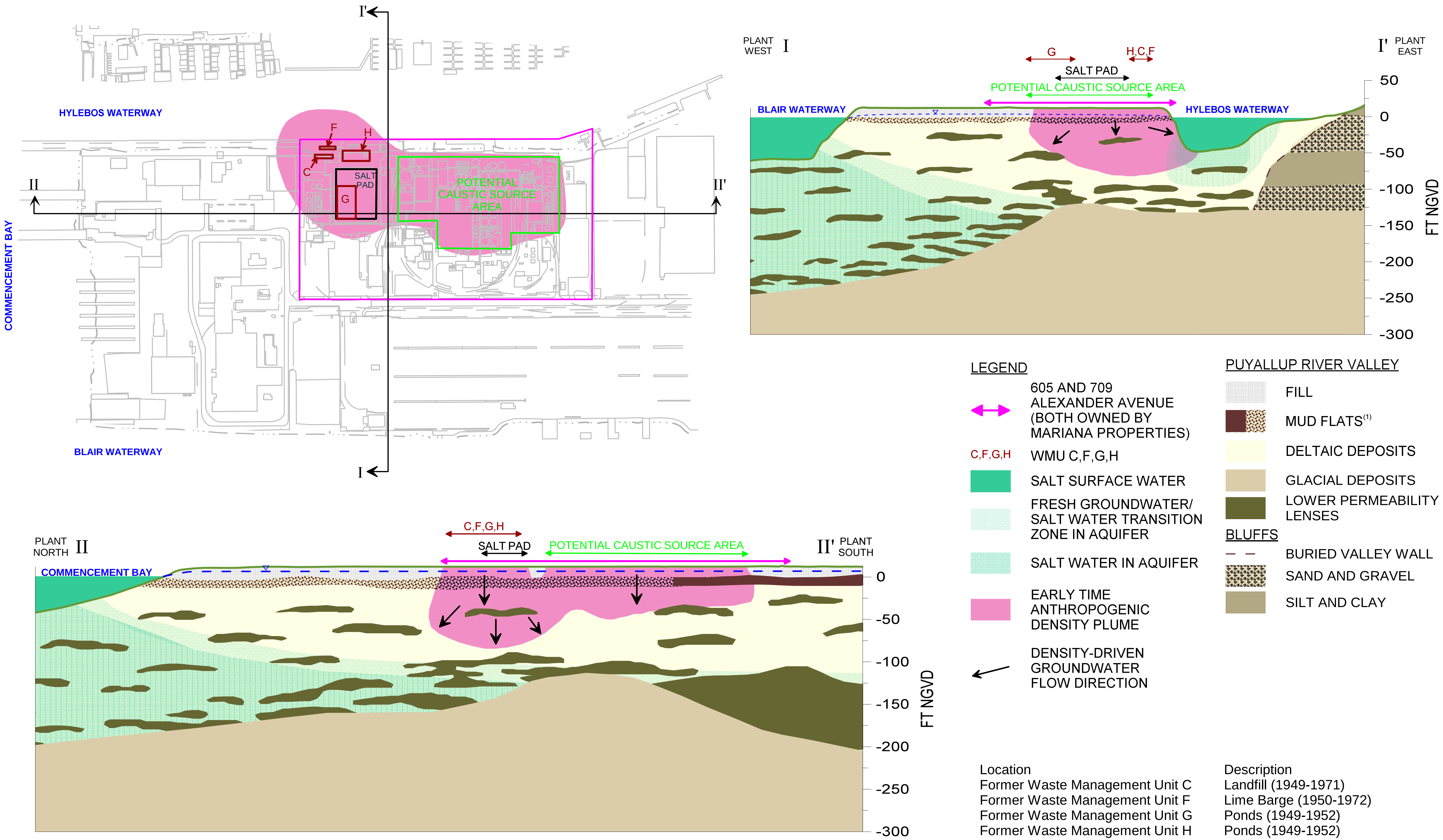


figure 2.12

GHD

NOTES:
(1) DARK BROWN INDICATES WHERE MUD FLATS ARE OBSERVED TO PROVIDE HYDRAULIC SEPARATION BETWEEN THE FILL AND DELTAIC DEPOSITS; BROWN DOT PATTERN INDICATES WHERE HYDRAULIC SEPARATION BY THE MUD FLATS IS NOT CONFIRMED

EARLY TIME ANTHROPOGENIC DENSITY PLUME

Occidental Chemical Corporation, Tacoma, Washington

07843-C2D2(139)GN-WA-HYD (N:\HEG\07843\RPT139\Figures-Current\07843-C2D2(139)HEG-Fig 2.12.srf) DEC 9, 2016

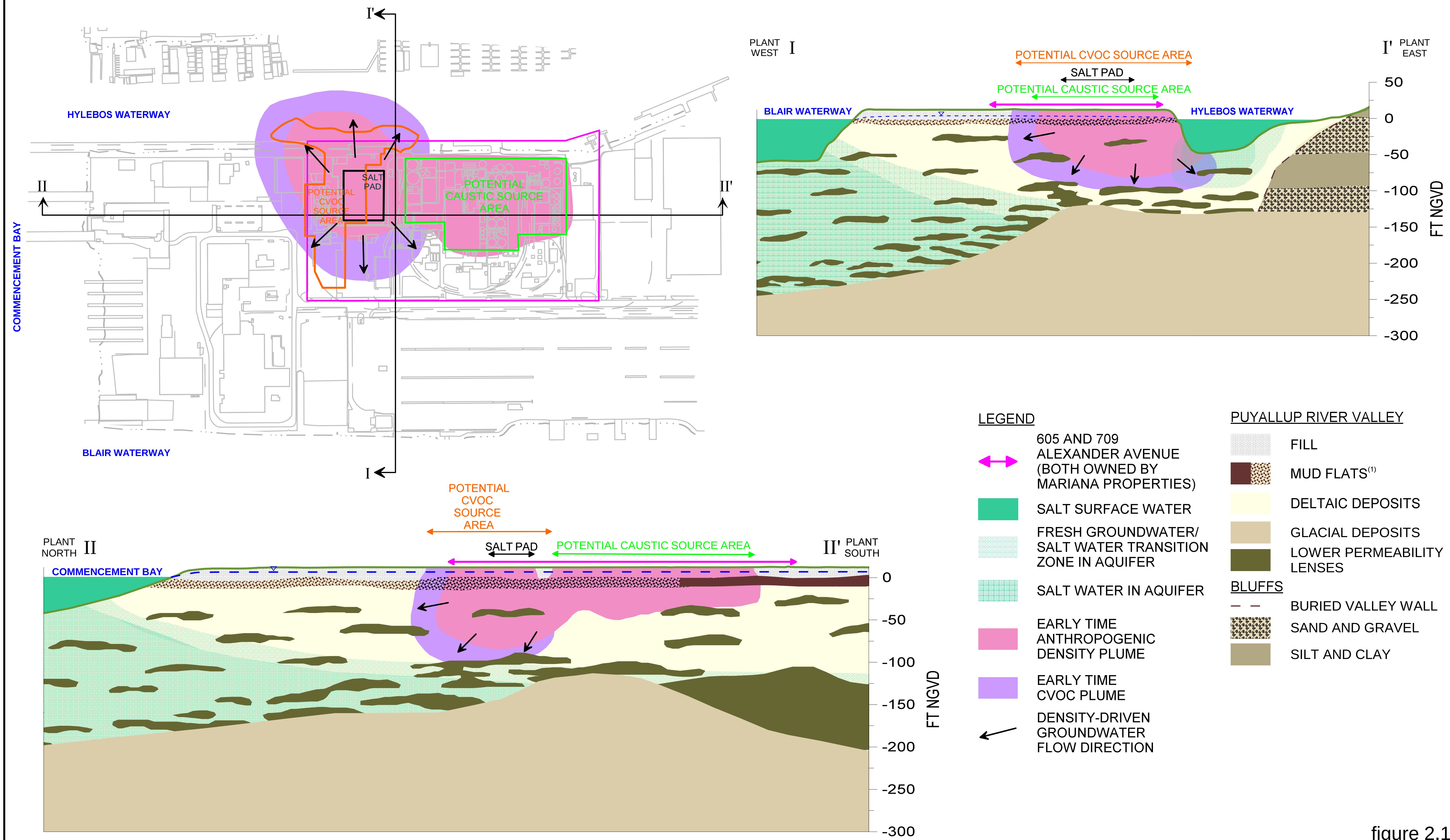


figure 2.13

NOTES:
(1) DARK BROWN INDICATES WHERE MUD FLATS ARE OBSERVED TO PROVIDE HYDRAULIC SEPARATION BETWEEN THE FILL AND DELTAIC DEPOSITS; BROWN DOT PATTERN INDICATES WHERE HYDRAULIC SEPARATION BY THE MUD FLATS IS NOT CONFIRMED

EARLY TIME ANTHROPOGENIC DENSITY PLUME INFLUENCE ON TOTAL CVOC PLUME MIGRATION

Occidental Chemical Corporation, Tacoma, Washington

07843-C2D2(139)GN-WA-HYD (N:\HEG\07843\RPT139\Figures-Current\07843-C2D2(139)HEG-Fig 2.13.srf) DEC 9, 2016

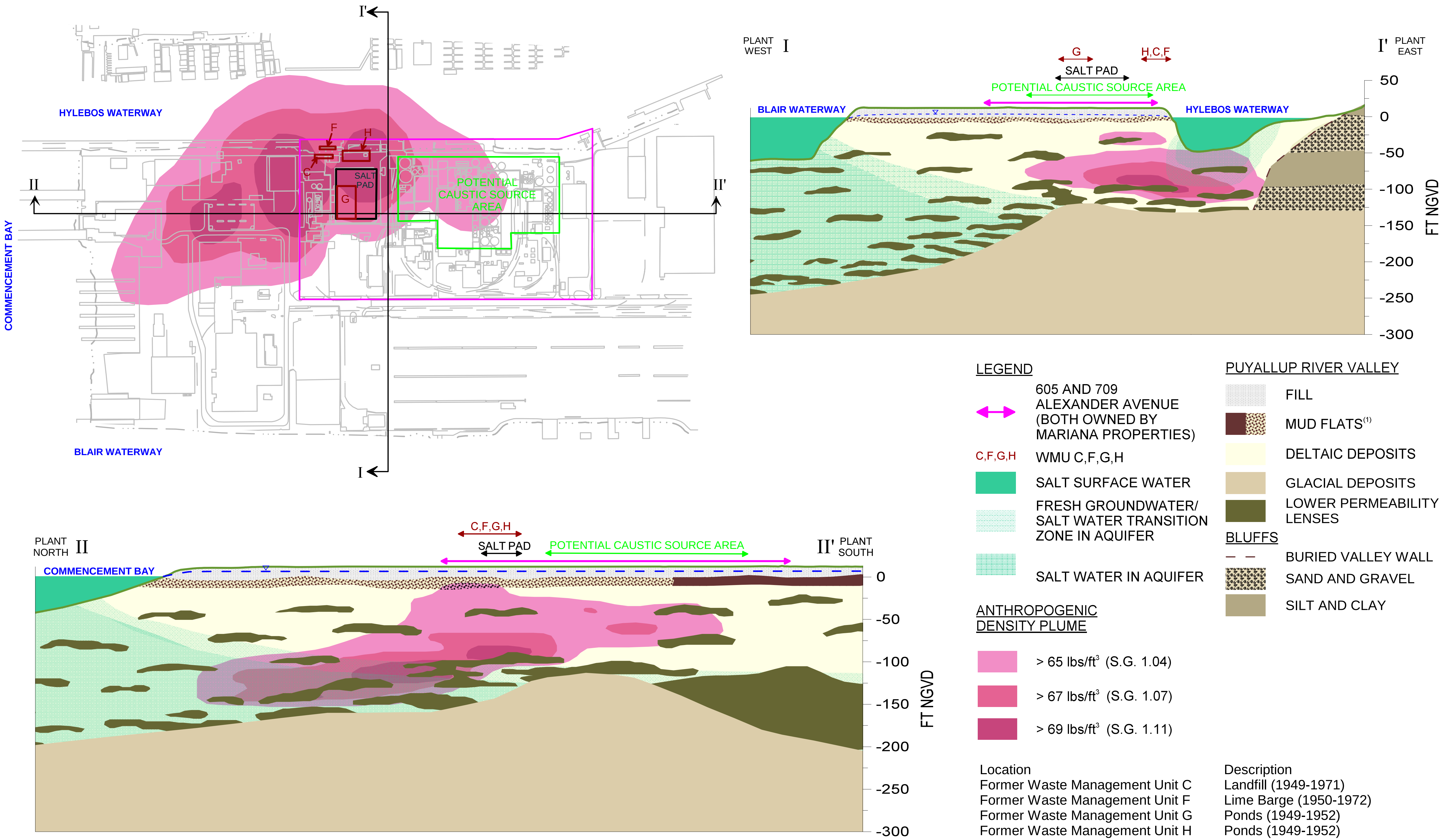


figure 2.14

NOTES:
(1) DARK BROWN INDICATES WHERE MUD FLATS ARE OBSERVED TO PROVIDE HYDRAULIC SEPARATION BETWEEN THE FILL AND DELTAIC DEPOSITS; BROWN DOT PATTERN INDICATES WHERE HYDRAULIC SEPARATION BY THE MUD FLATS IS NOT CONFIRMED

CURRENT ANTHROPOGENIC DENSITY PLUME
Occidental Chemical Corporation, Tacoma, Washington

07843-C2D2(139)GN-WA-HYD (N:\HEG\07843\RPT139\Figures-Current\07843-C2D2(139)HEG-Fig 2.14.srf) DEC 9, 2016

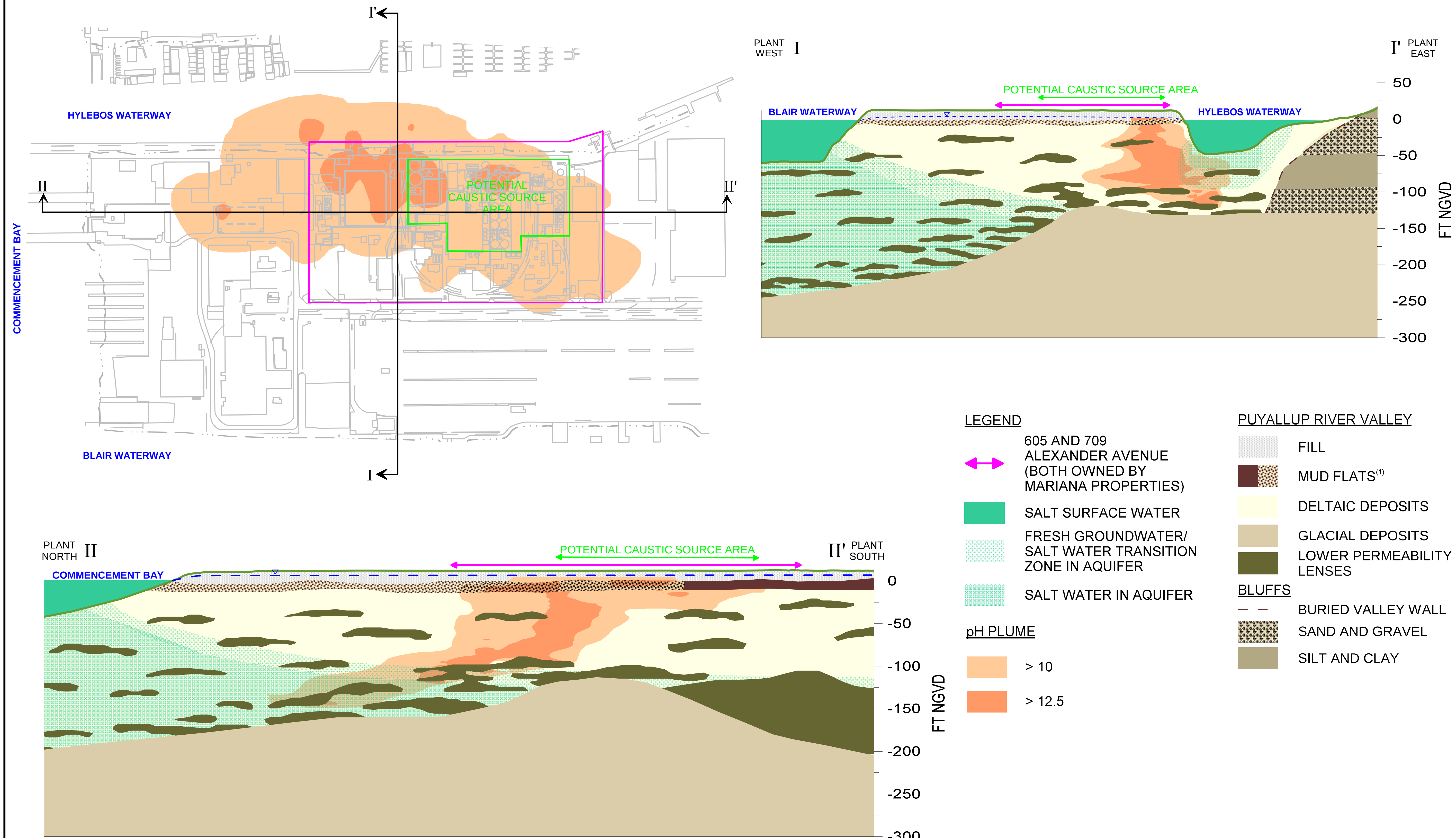


figure 2.15

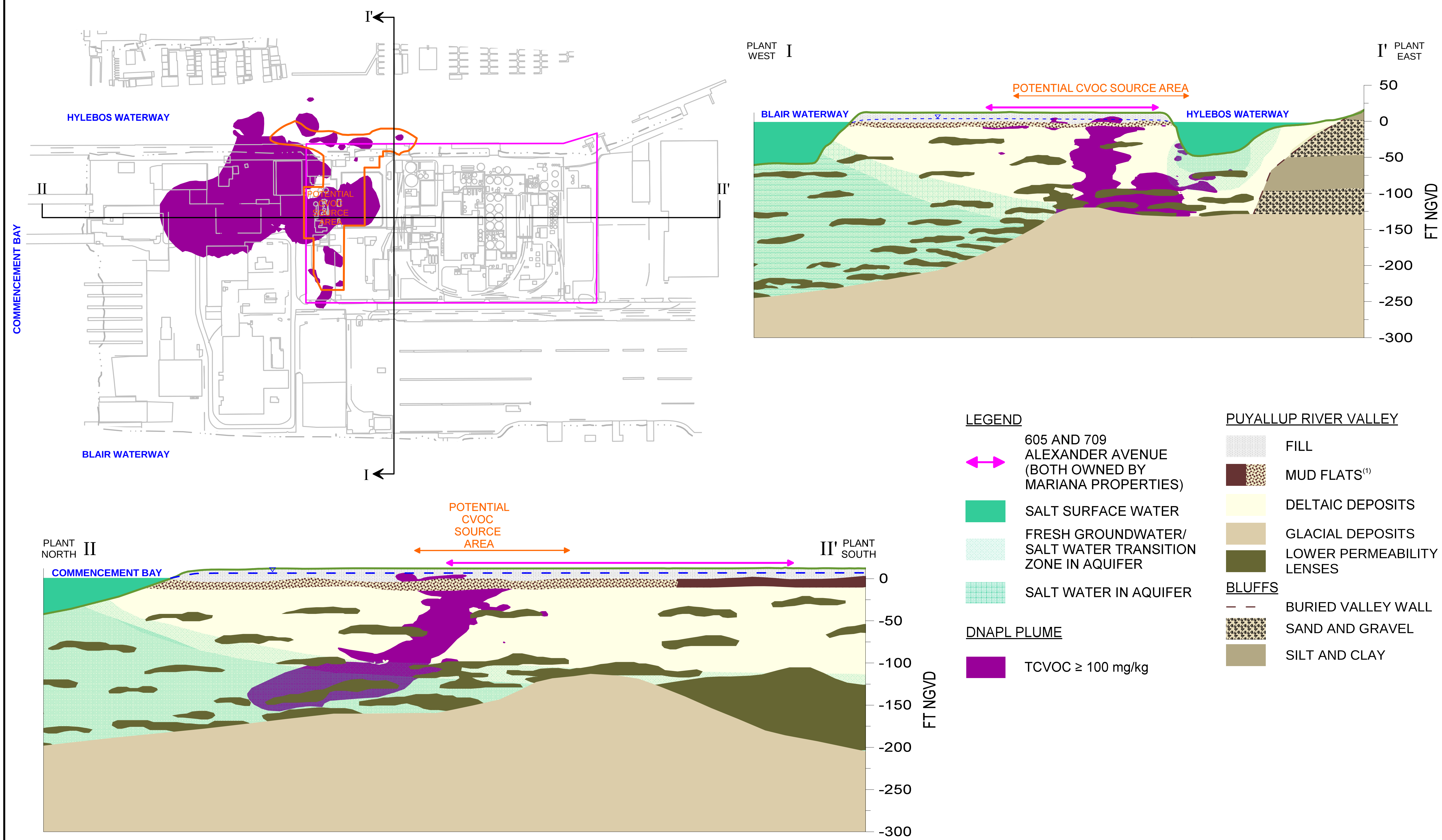
GHD

NOTES:
(1) DARK BROWN INDICATES WHERE MUD FLATS ARE OBSERVED TO PROVIDE HYDRAULIC SEPARATION BETWEEN THE FILL AND DELTAIC DEPOSITS; BROWN DOT PATTERN INDICATES WHERE HYDRAULIC SEPARATION BY THE MUD FLATS IS NOT CONFIRMED

pH PLUME

Occidental Chemical Corporation, Tacoma, Washington

07843-C2D2(139)GN-WA-HYD (N:\HEG\07843\RPT139\Figures-Current\07843-C2D2(139)HEG-Fig 2.15.srf) DEC 9, 2016



GHD

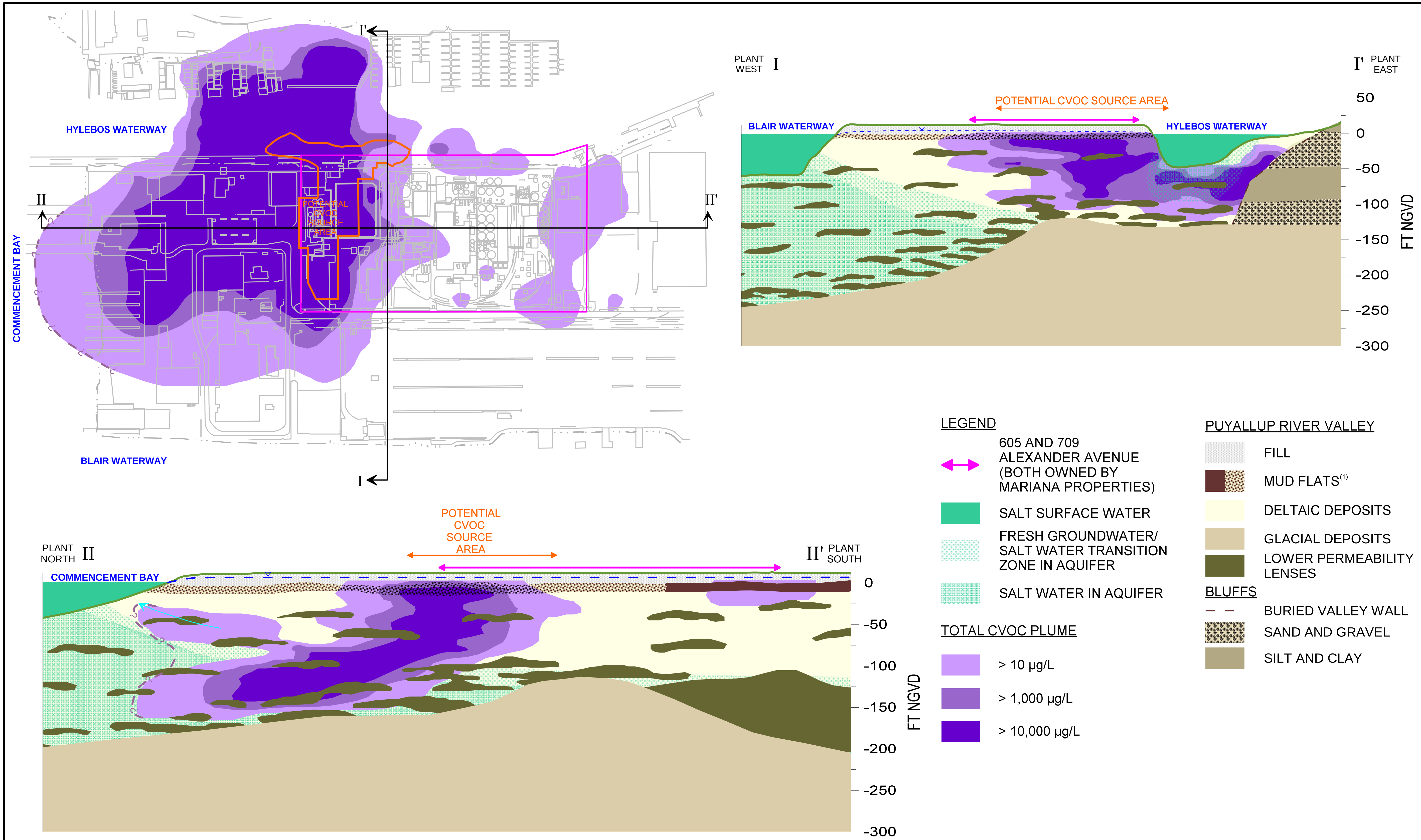
NOTES:
(1) DARK BROWN INDICATES WHERE MUD FLATS ARE OBSERVED TO PROVIDE HYDRAULIC SEPARATION BETWEEN THE FILL AND DELTAIC DEPOSITS; BROWN DOT PATTERN INDICATES WHERE HYDRAULIC SEPARATION BY THE MUD FLATS IS NOT CONFIRMED

figure 2.16

DNAPL DISTRIBUTION

Occidental Chemical Corporation, Tacoma, Washington

07843-C2D2(139)GN-WA-HYD (N:\HEG\07843\RPT139\Figures-Current\07843-C2D2(139)HEG-Fig 2.16.srf) DEC 9, 2016

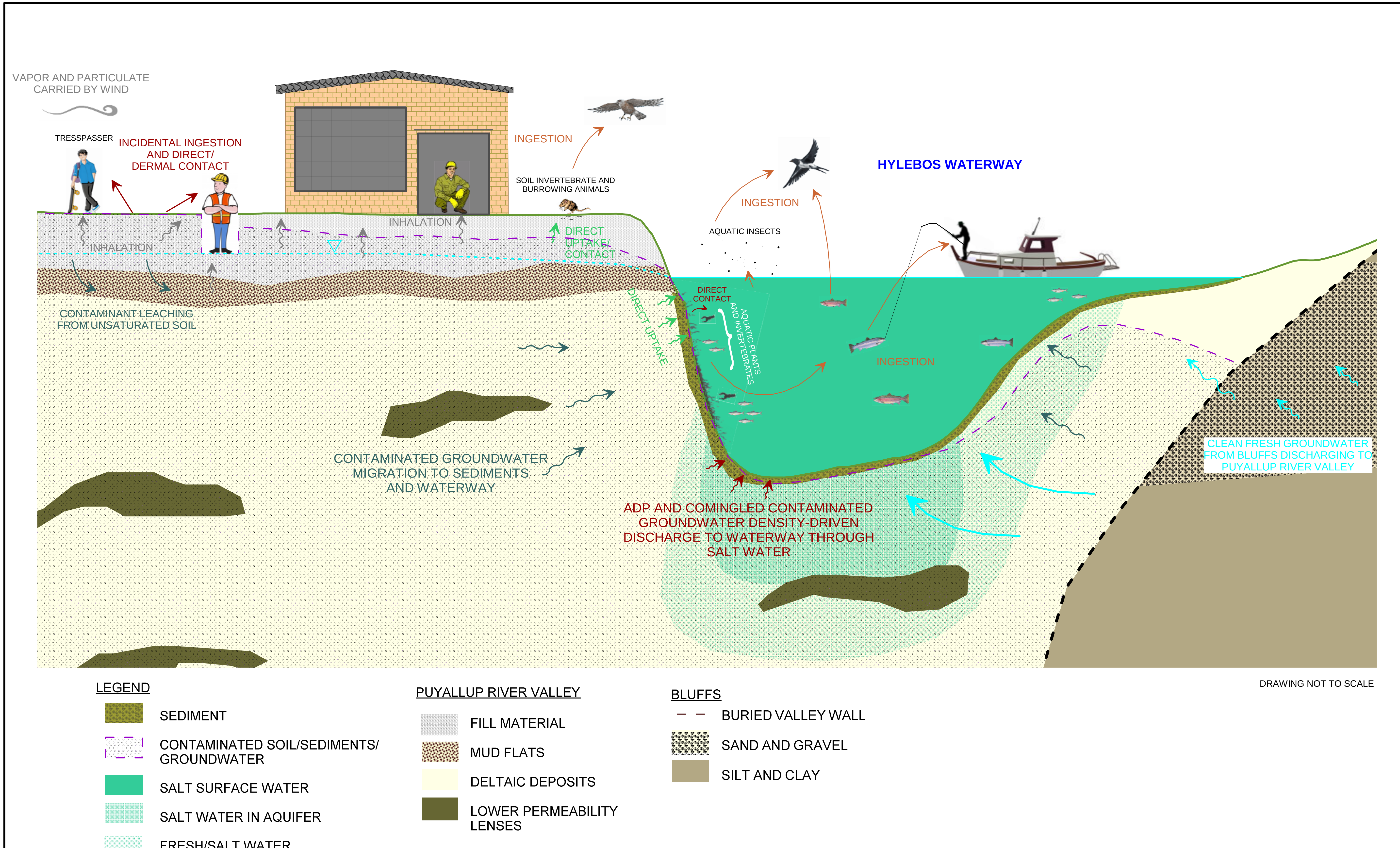


NOTES:
(1) DARK BROWN INDICATES WHERE MUD FLATS ARE OBSERVED TO PROVIDE HYDRAULIC SEPARATION BETWEEN THE FILL AND DELTAIC DEPOSITS; BROWN DOT PATTERN INDICATES WHERE HYDRAULIC SEPARATION BY THE MUD FLATS IS NOT CONFIRMED

figure 2.17

TOTAL CVOC PLUME IN GROUNDWATER

Occidental Chemical Corporation, Tacoma, Washington



GHD

figure 2.18

SCHEMATIC OF EXPOSURE PATHWAYS AND RECEPTORS

Occidental Chemical Corporation, Tacoma, Washington

07843-C2D2(139)GN-WA-HYD (N:\HEG\07843\RPT139\Figures-Current\07843-C2D2(139)HEG-Fig 2.18.srf) DEC 9, 2016

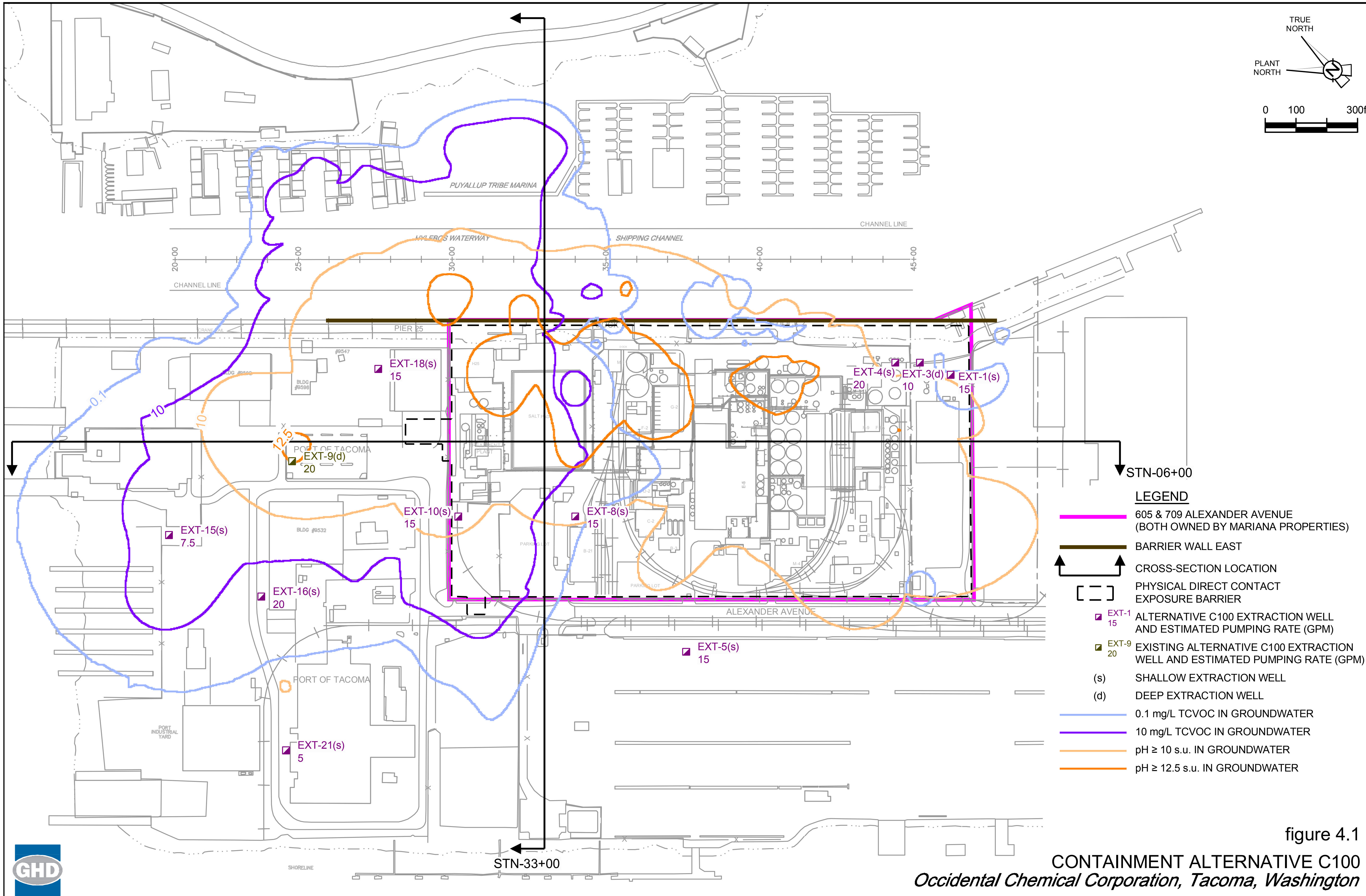


figure 4.1

CONTAINMENT ALTERNATIVE C100

Occidental Chemical Corporation, Tacoma, Washington

GHD

07843-C2D2(139)GN-WA032 JUN 13, 2016

DRAFT

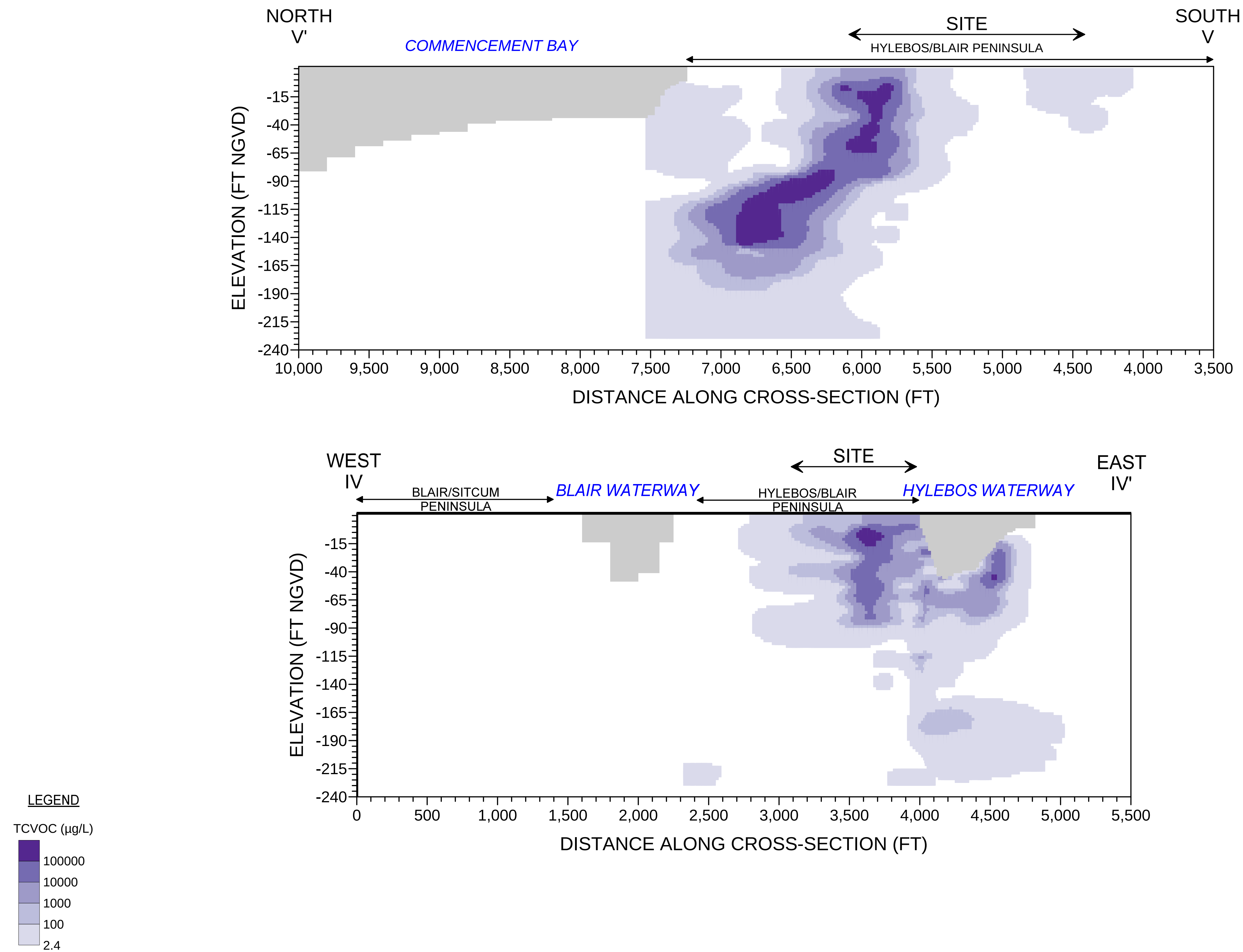


figure 4.2a

CONTAINMENT ALTERNATIVES CROSS-SECTIONS - TCVOC
CROSS-SECTIONS IV-IV' AND V-V'
Occidental Chemical Corporation, Tacoma, Washington

07843-C2D2(139)GN-WA-HYD (N:\HEG\07843\RPT139\Figures-Current\007843-C2D2-RPT139-Fig 4.2a.srf) MAY 24/2016

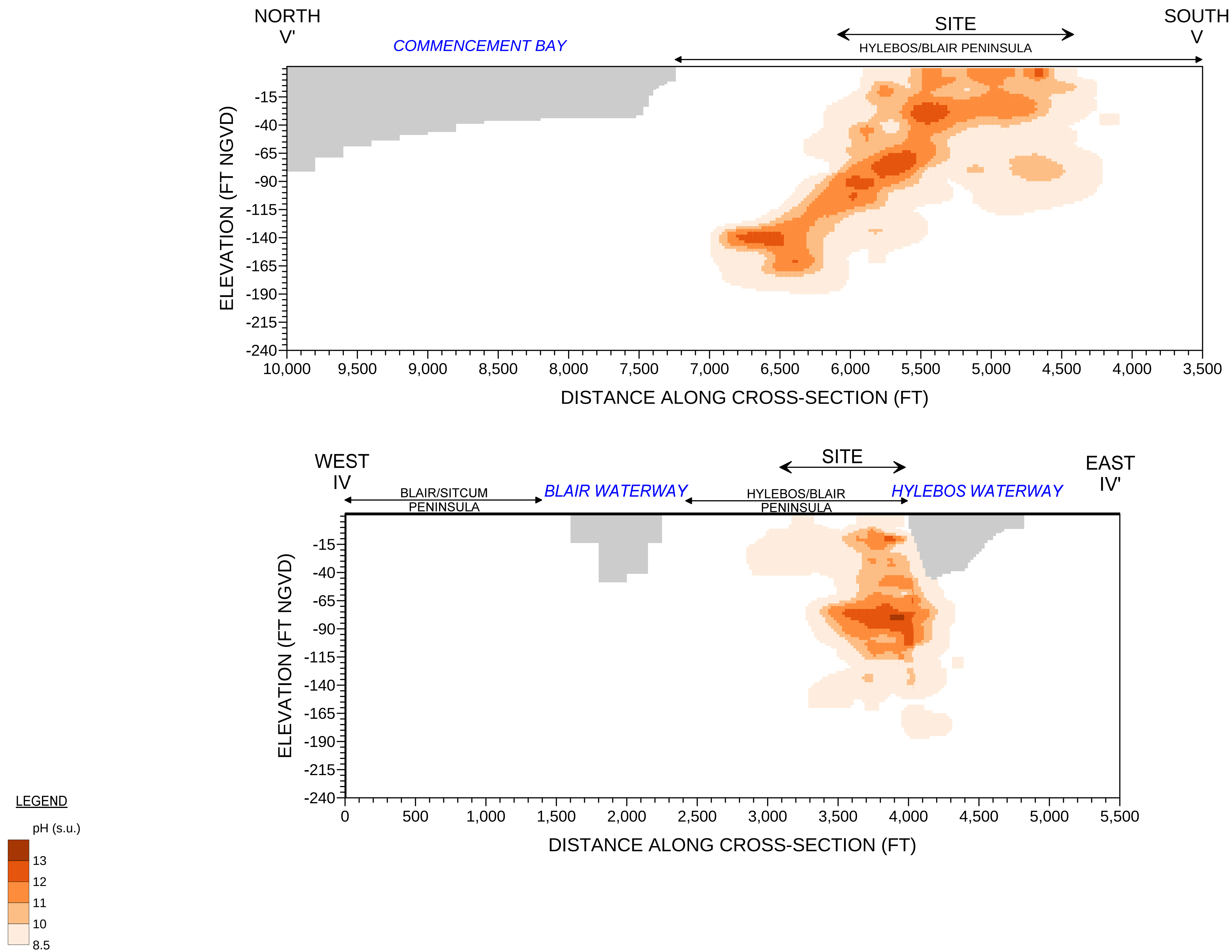
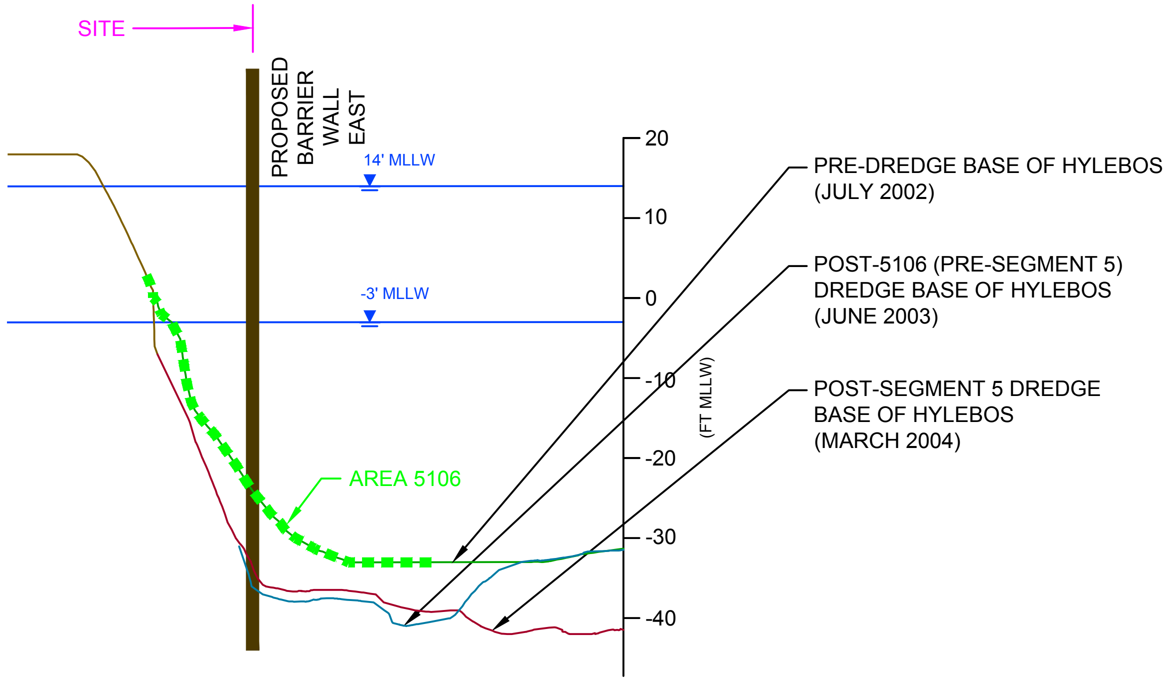


figure 4.2b

CONTAINMENT ALTERNATIVES CROSS-SECTIONS - pH
CROSS-SECTIONS IV-IV' AND V-V'
Occidental Chemical Corporation, Tacoma, Washington

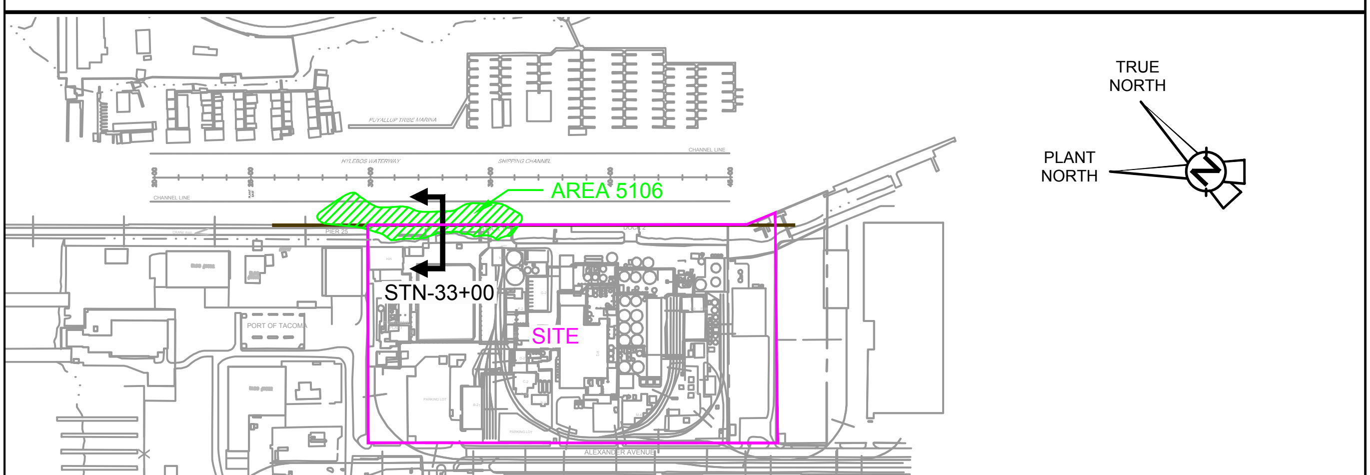


NOTES:

1. PRE-DREDGE BASE OF HYLEBOS (JULY 2002) PROVIDED BY DAVID EVANS AND ASSOCIATES INC., SURVEY JULY 24, 2002.
2. DREDGING, TREATMENT, AND DEWATERING OF AREA 5106 SEDIMENT BEGAN ON OCTOBER 15, 2002 AND CONTINUED UNTIL FEBRUARY 28, 2003.
3. POST-5106 (PRE-SEGMENT 5) DREDGE BASE OF HYLEBOS (JUNE 2003) PROVIDED BY PETERSON CONSULTING ENGINEERS, SURVEY JUNE 2003.
4. POST-SEGMENT 5 DREDGE BASE OF HYLEBOS (MARCH 2004) TAKEN FROM "FIGURE 8B SEGMENT 5 POST DREDGE SURVEY" OF THE "REMEDIAL ACTION CONSTRUCTION REPORT - SEGMENT 5 AND SLIP 1" (CRA, MARCH 25, 2015) BASED ON MARCH 2004 BATHYMETRY.

CROSS-SECTION

SCALES:
HORIZONTAL 1"=60' (ROTATION C)
2.5X VERTICAL EXAGGERATION



CROSS-SECTION LOCATION

SCALE: 1" = 800'

figure 4.3

SCHEMATIC CROSS-SECTION ALONG EMBANKMENT WITHIN AREA 5106

Occidental Chemical Corporation, Tacoma, Washington

GHD

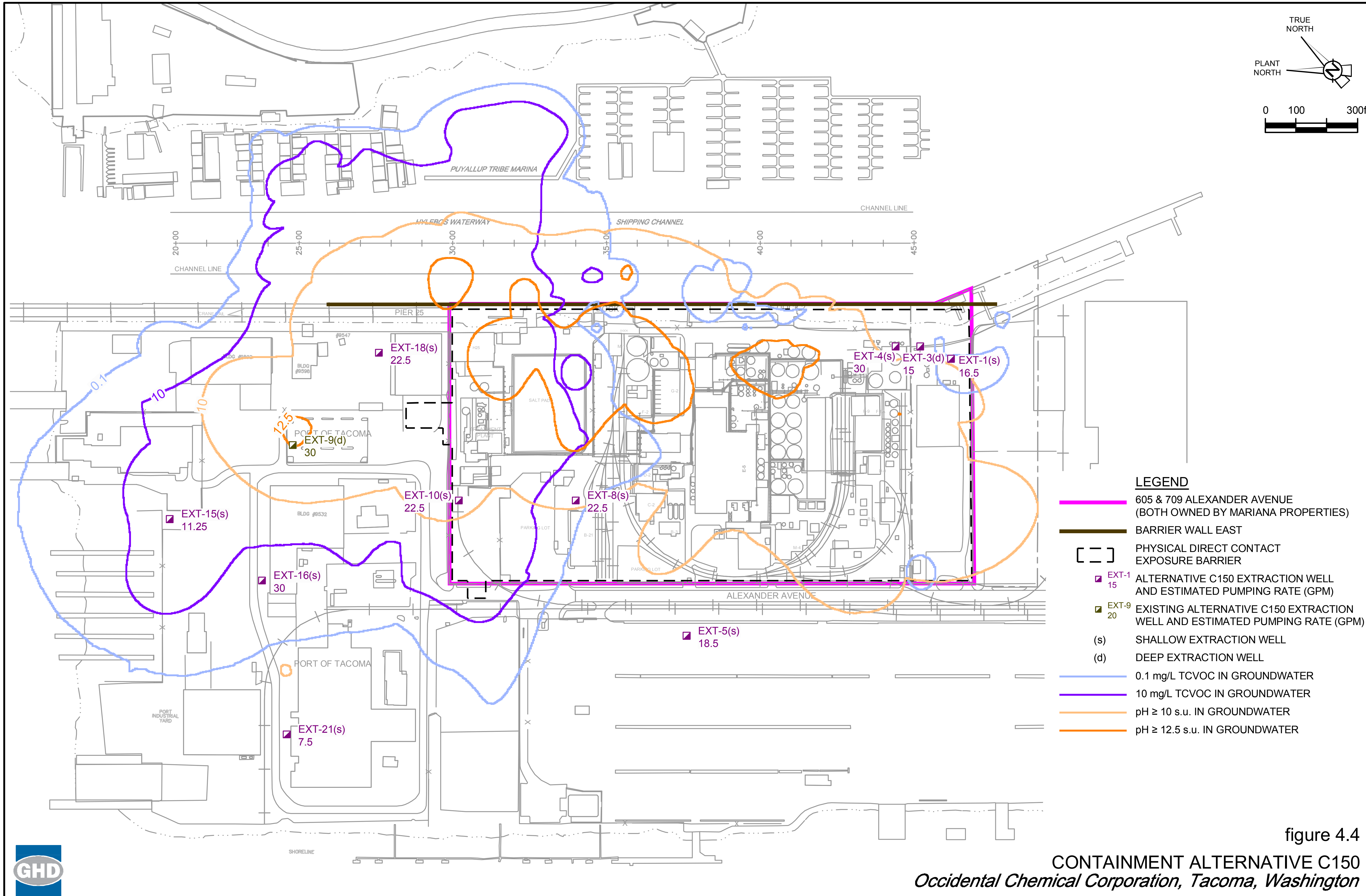


figure 4.4

CONTAINMENT ALTERNATIVE C150

Occidental Chemical Corporation, Tacoma, Washington

GHD

07843-C2D2(139)GN-WA033 MAY 24, 2016

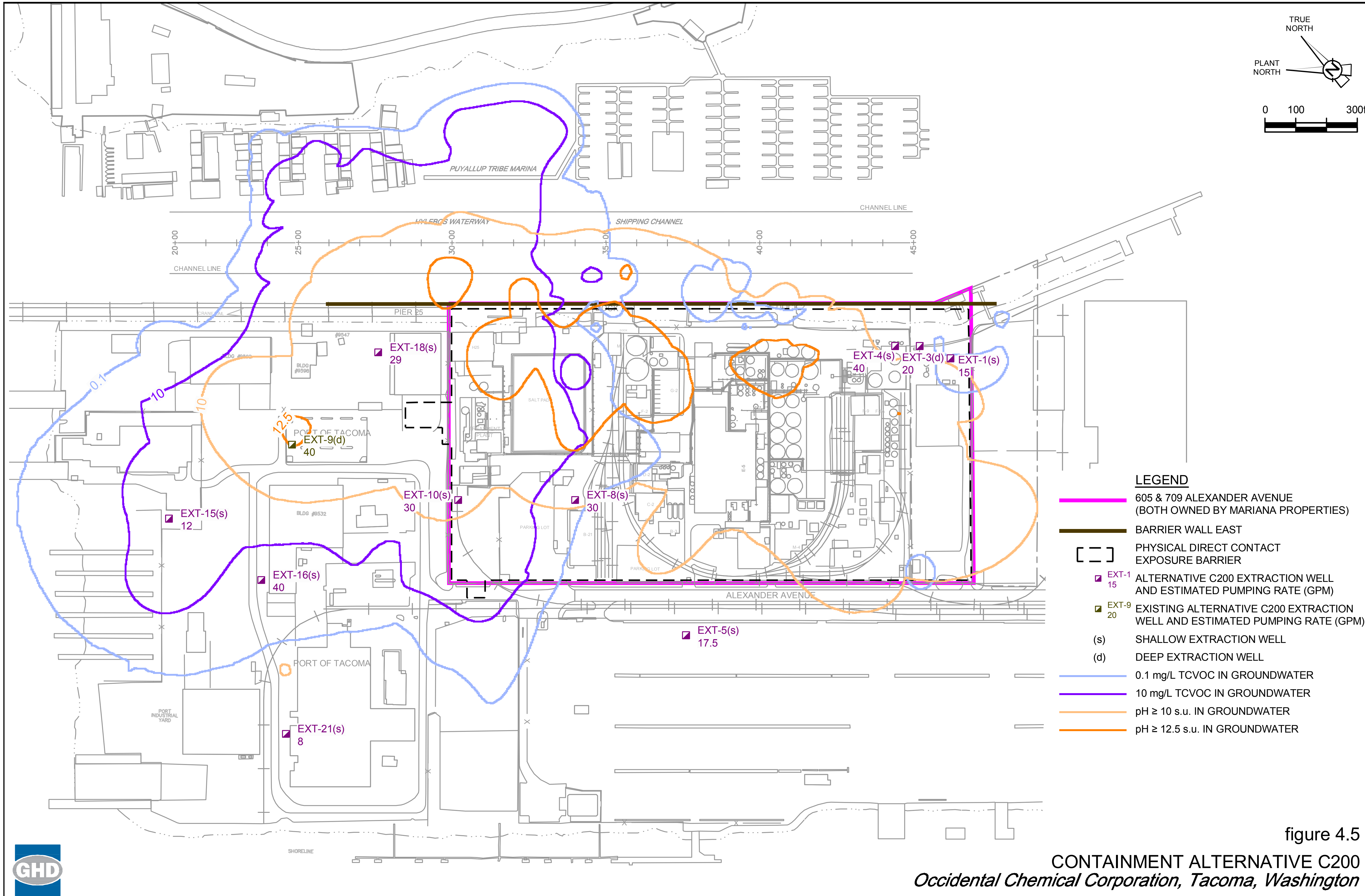


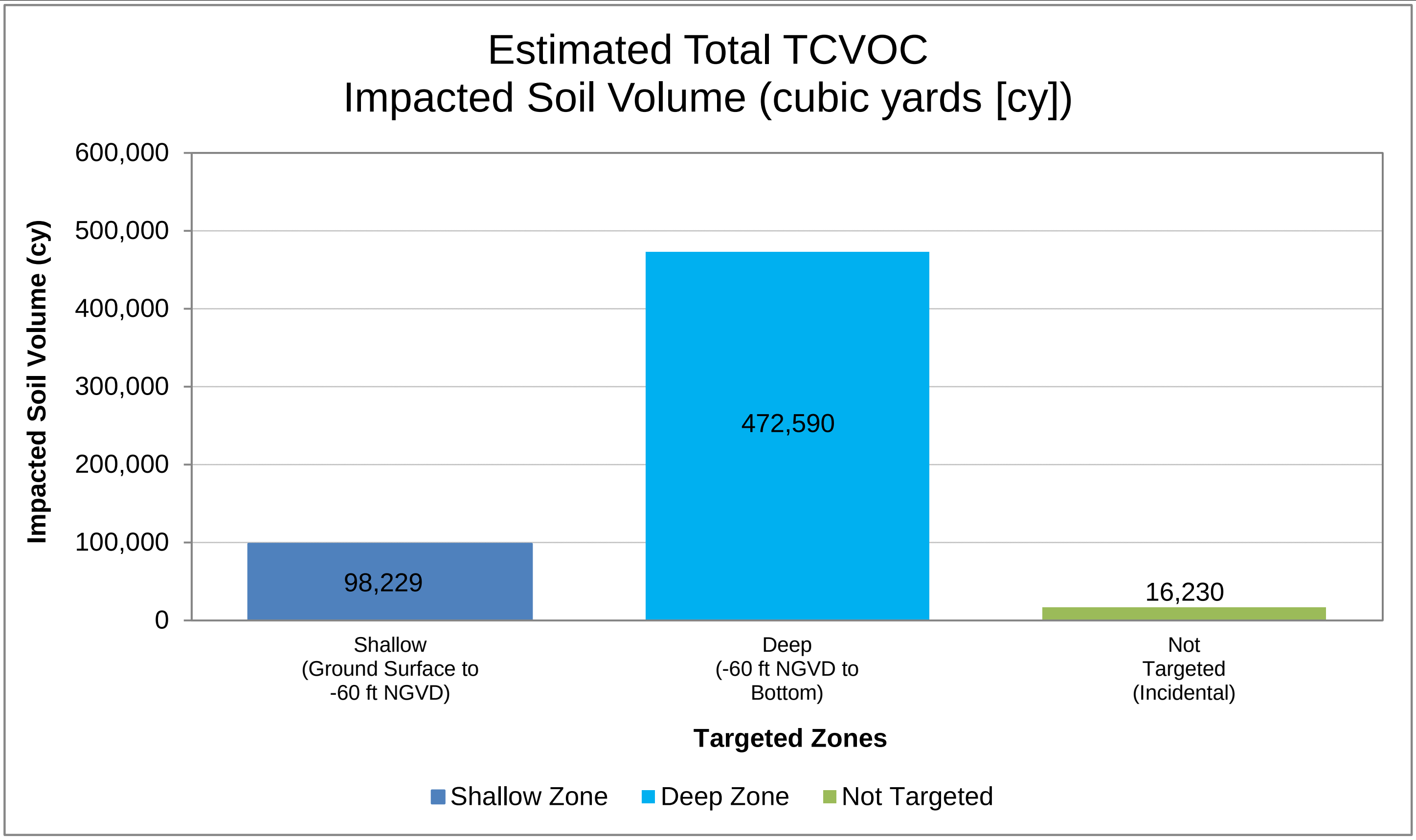
figure 4.5

CONTAINMENT ALTERNATIVE C200

Occidental Chemical Corporation, Tacoma, Washington

GHD

07843-C2D2(139)GN-WA034 JUN 13, 2016



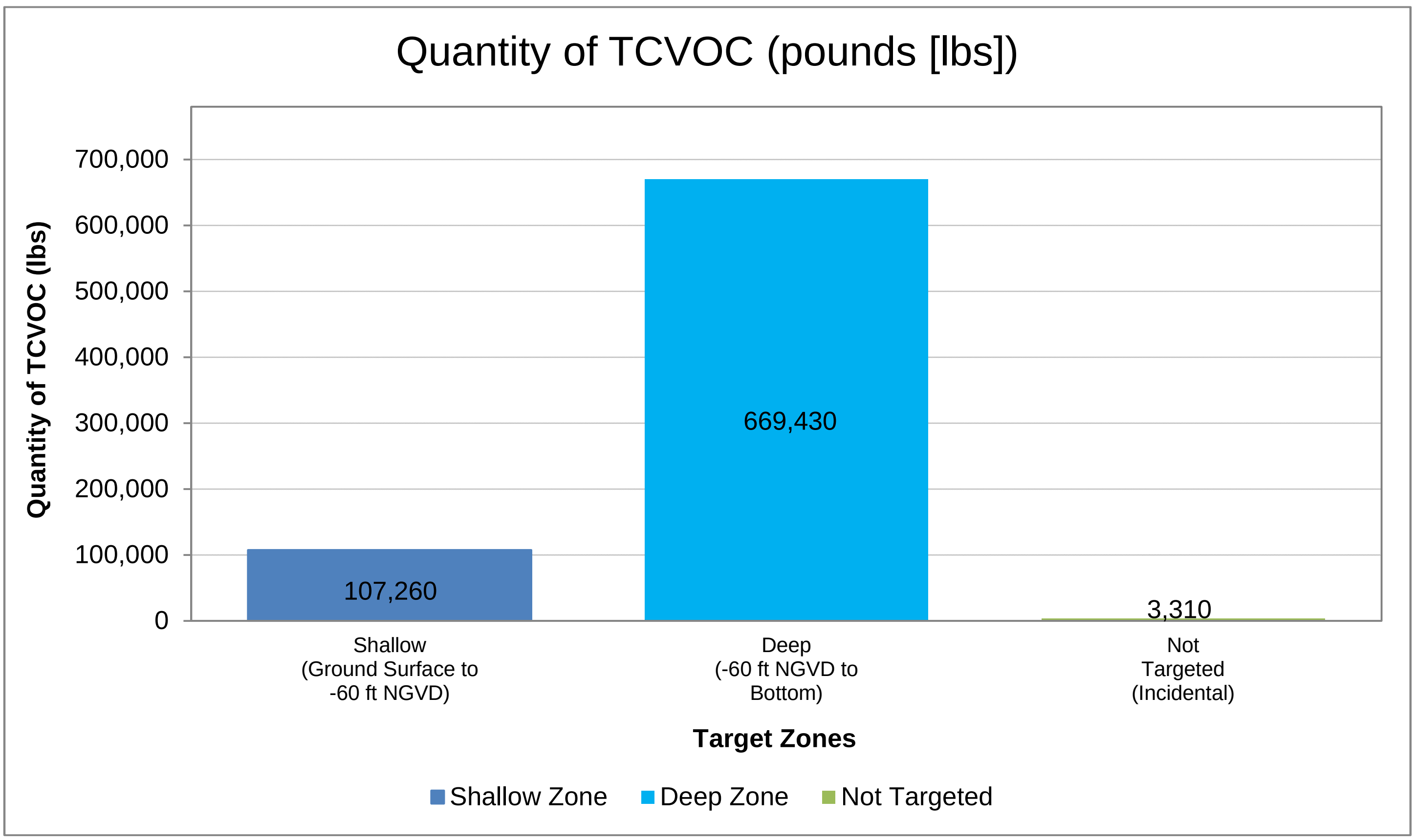


figure 4.6
TCVOC Mass Target Zones
Occidental Chemical Corporation, Tacoma, Washington

007843 (139)

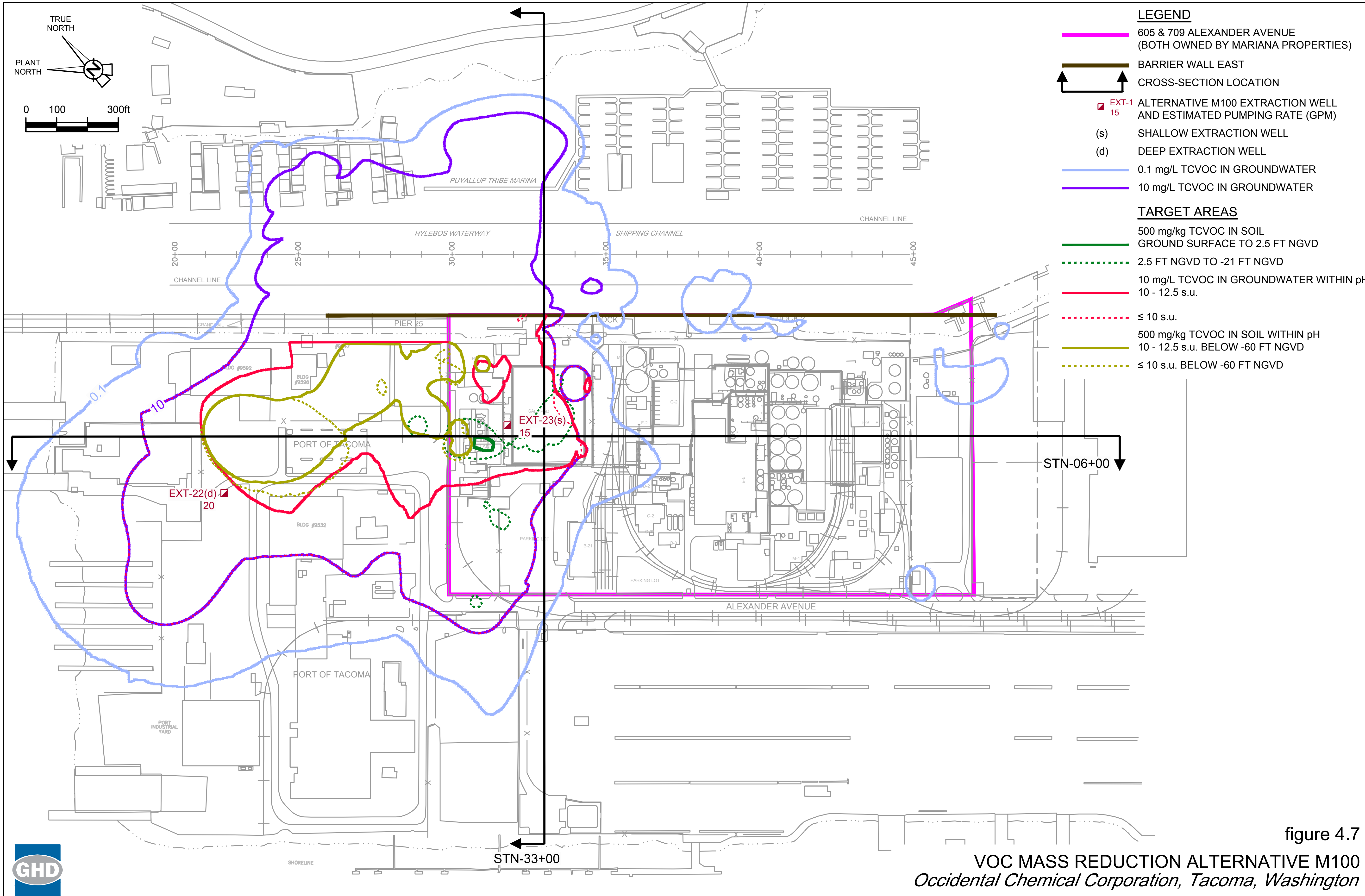


figure 4.7

VOC MASS REDUCTION ALTERNATIVE M100

Occidental Chemical Corporation, Tacoma, Washington

07843-C2D2(139)GN-WA035 DEC 5, 2016

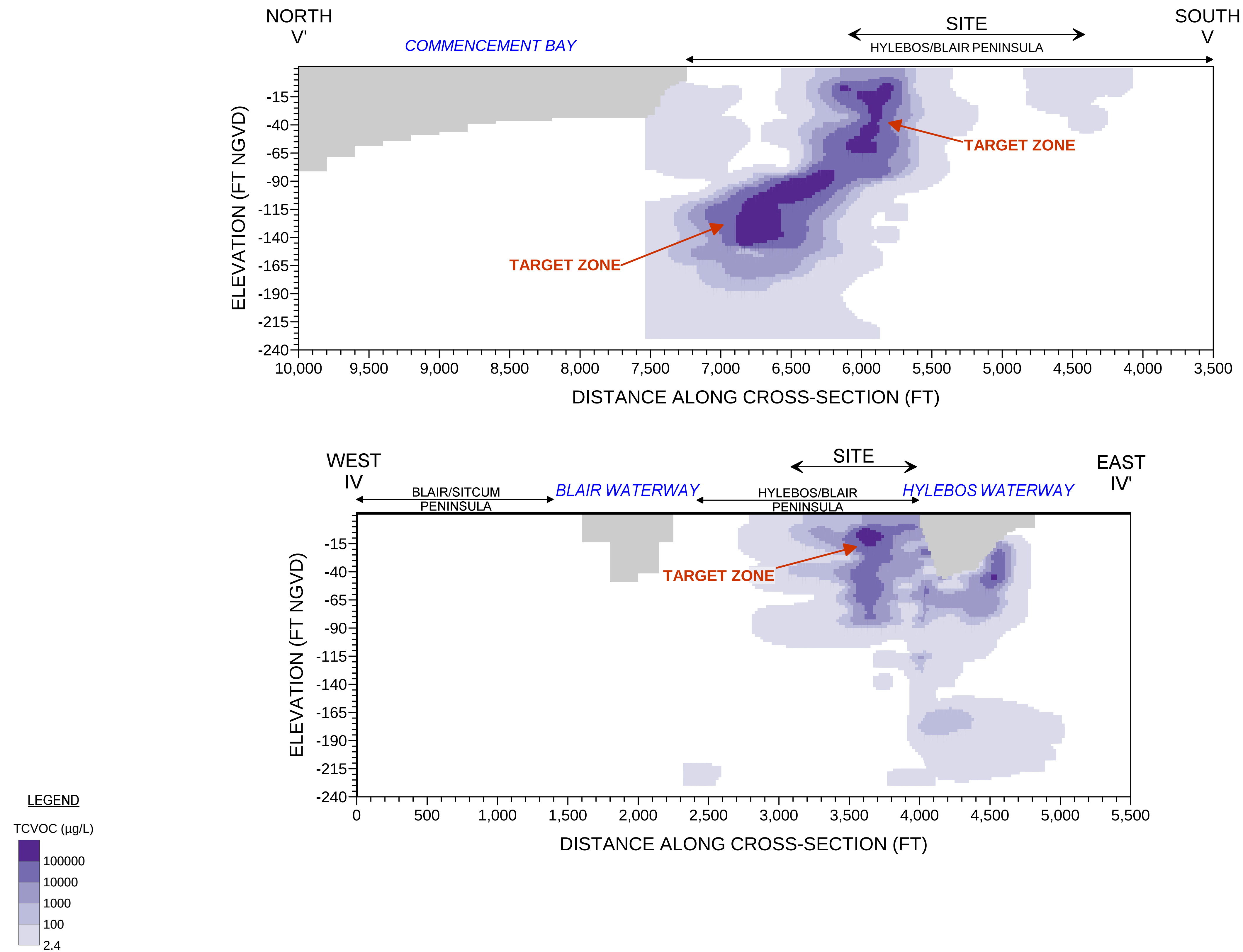


figure 4.8

VOC MASS REDUCTION ALTERNATIVES M100, M150, AND M200 CROSS-SECTIONS
CROSS-SECTIONS IV-IV' AND V-V'
Occidental Chemical Corporation, Tacoma, Washington

07843-C2D2(139)GN-WA-HYD (N:\HEG\07843\RPT139\Figures-Current\07843-C2D2(139)HEG-Fig 4.8.srf) DEC 9, 2016

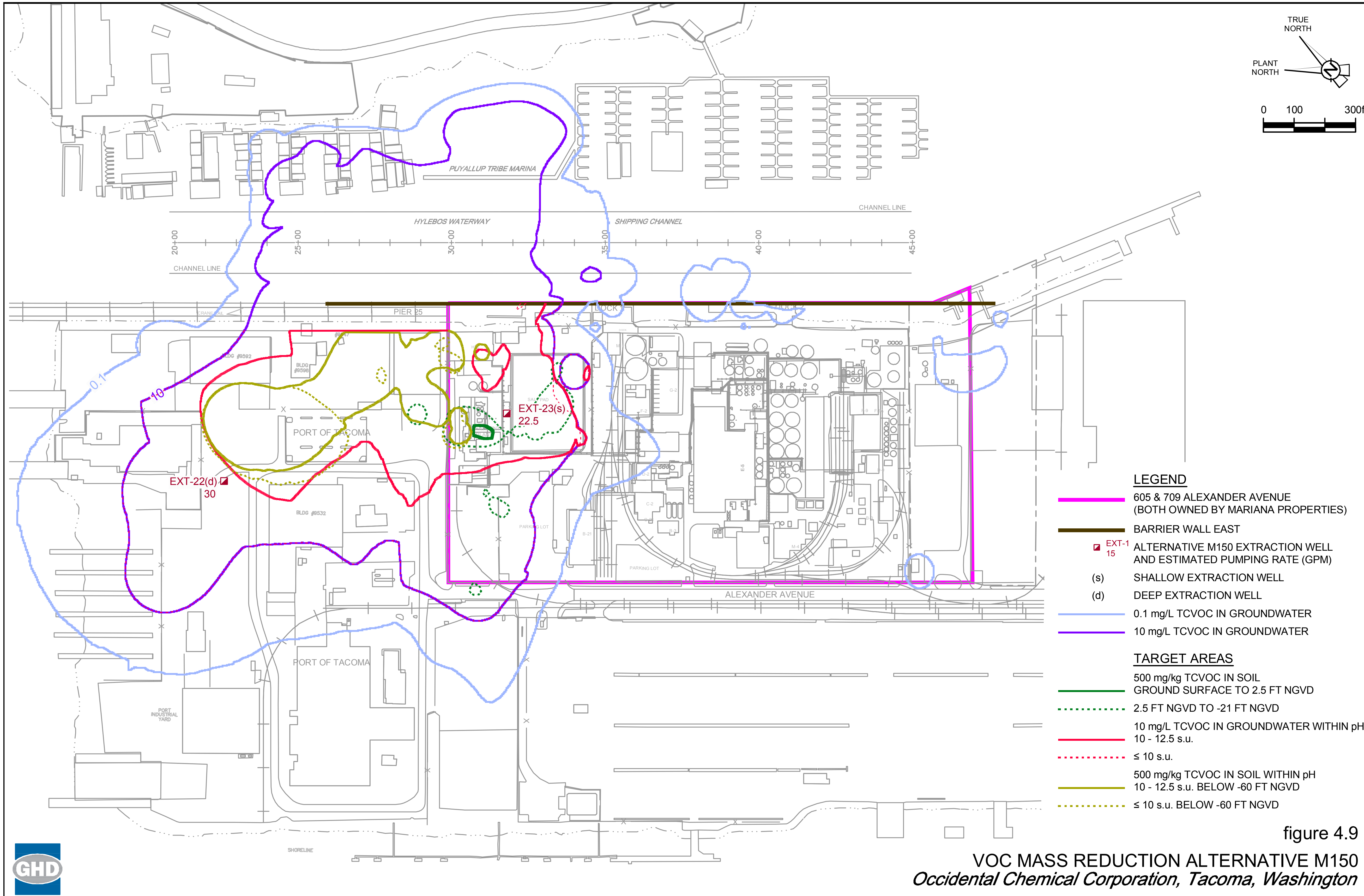


figure 4.9

VOC MASS REDUCTION ALTERNATIVE M150

Occidental Chemical Corporation, Tacoma, Washington

07843-C2D2(139)GN-WA036 JUN 13, 2016

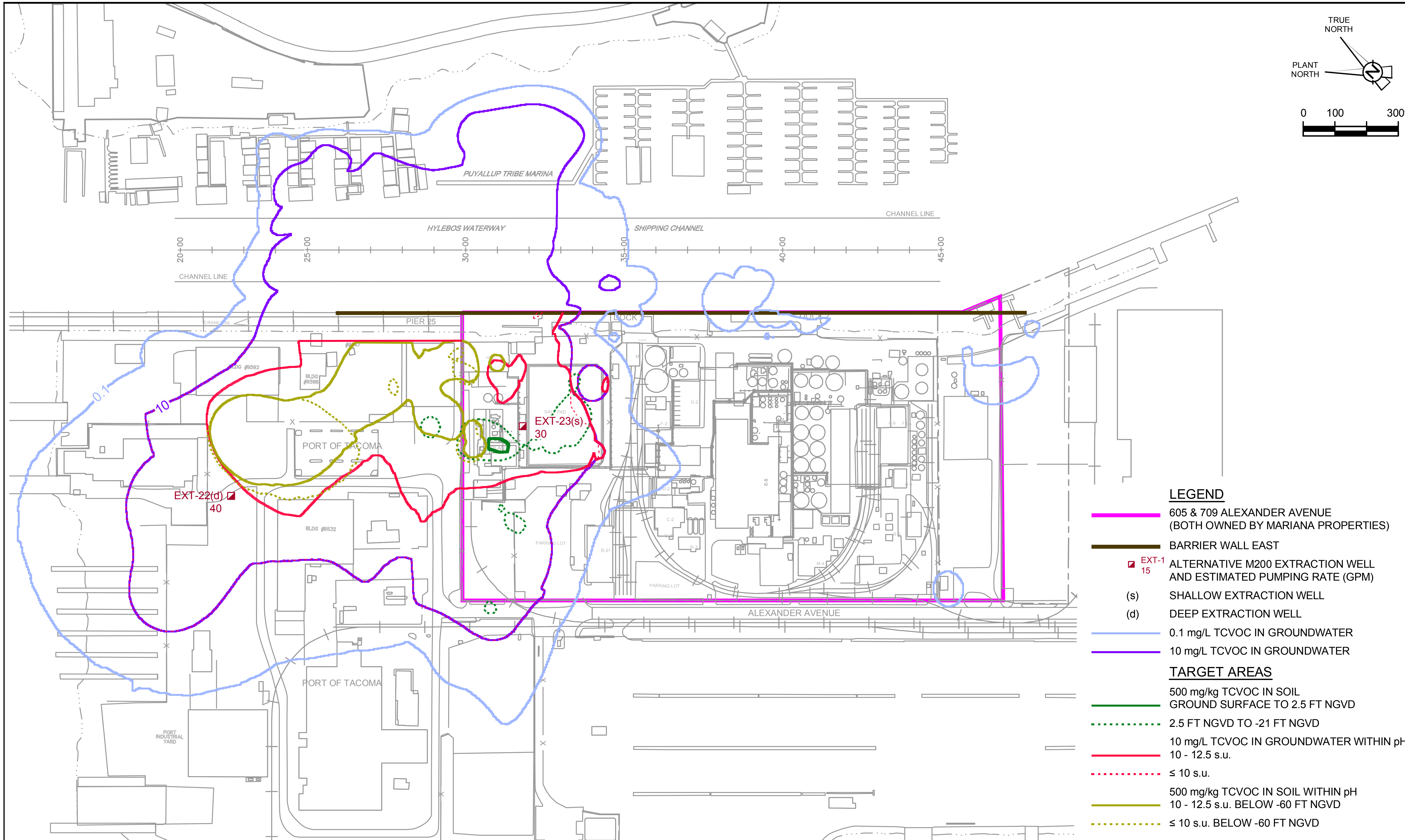


figure 4.10

VOC MASS REDUCTION ALTERNATIVE M200

Occidental Chemical Corporation, Tacoma, Washington

07843-C2D2(139)GN-WA037 JUN 13, 2016

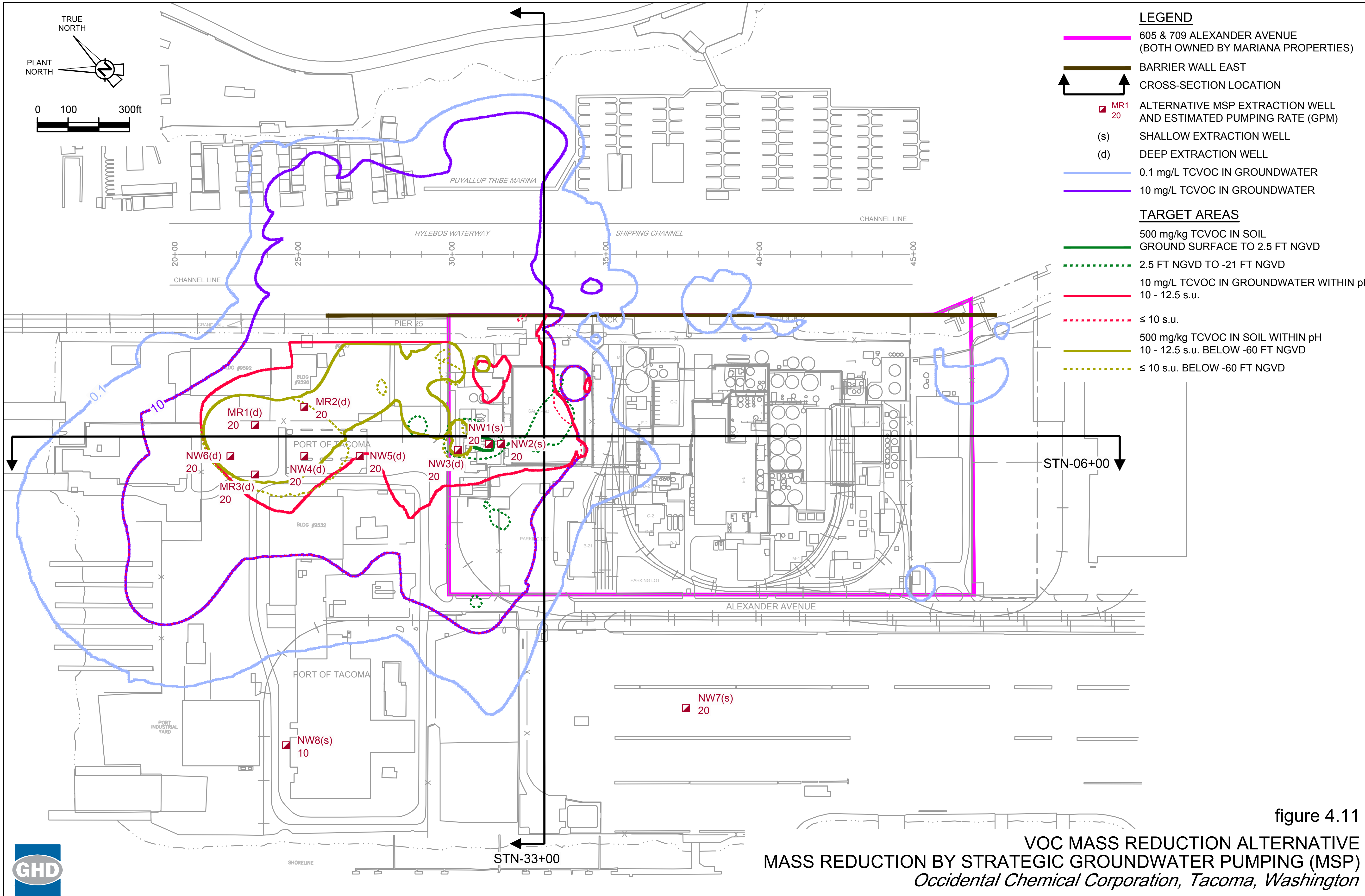


figure 4.11

VOC MASS REDUCTION ALTERNATIVE
MASS REDUCTION BY STRATEGIC GROUNDWATER PUMPING (MSP)
Occidental Chemical Corporation, Tacoma, Washington

GHD

07843-C2D2(139)GN-WA063 DEC 5, 2016

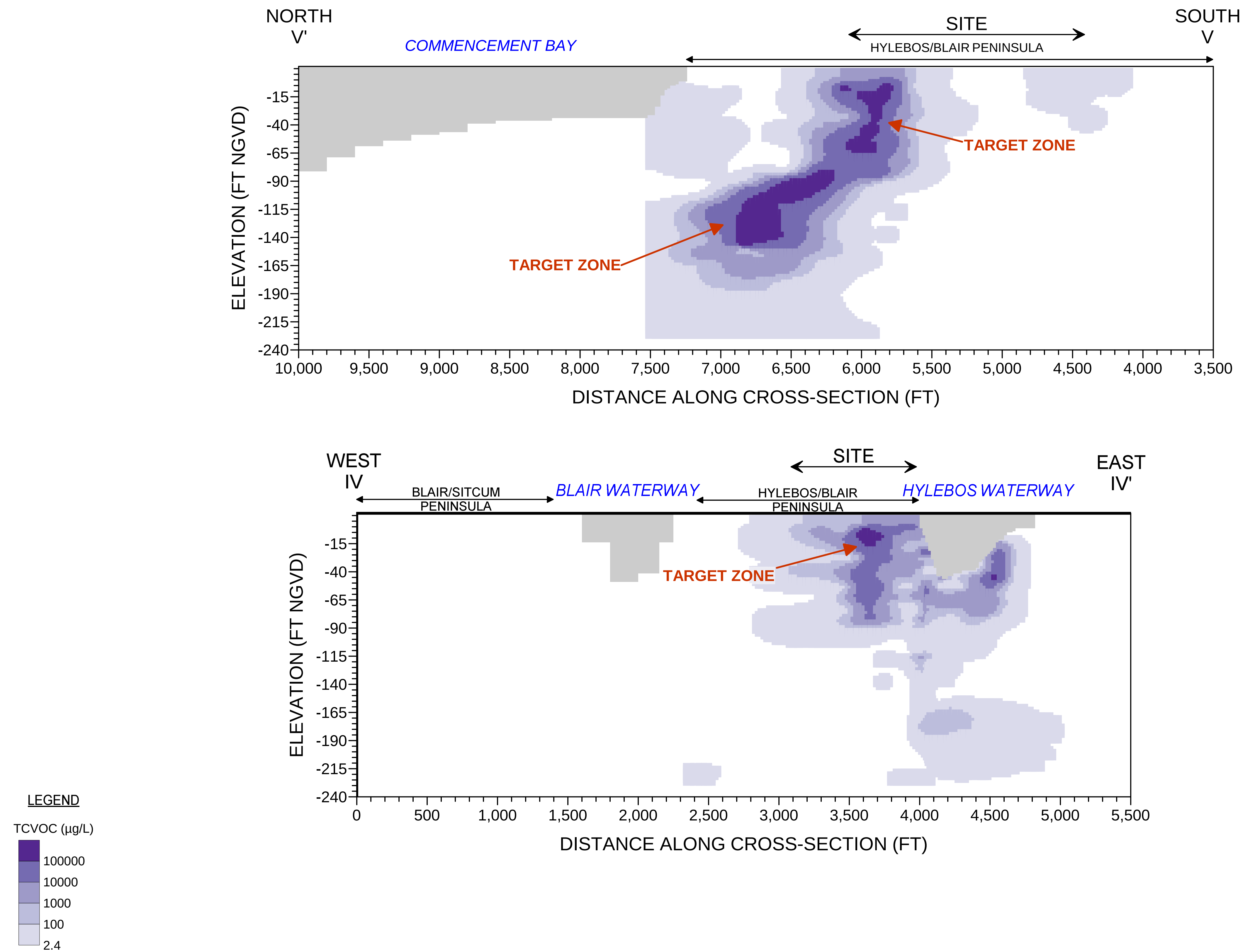


figure 4.12

VOC MASS REDUCTION ALTERNATIVE MSP CROSS-SECTIONS
CROSS-SECTIONS IV-IV' AND V-V'
Occidental Chemical Corporation, Tacoma, Washington

07843-C2D2(139)GN-WA-HYD (N:\HEG\07843\RPT139\Figures-Current\07843-C2D2(139)HEG-Fig 4.12.srf) December 9/2016

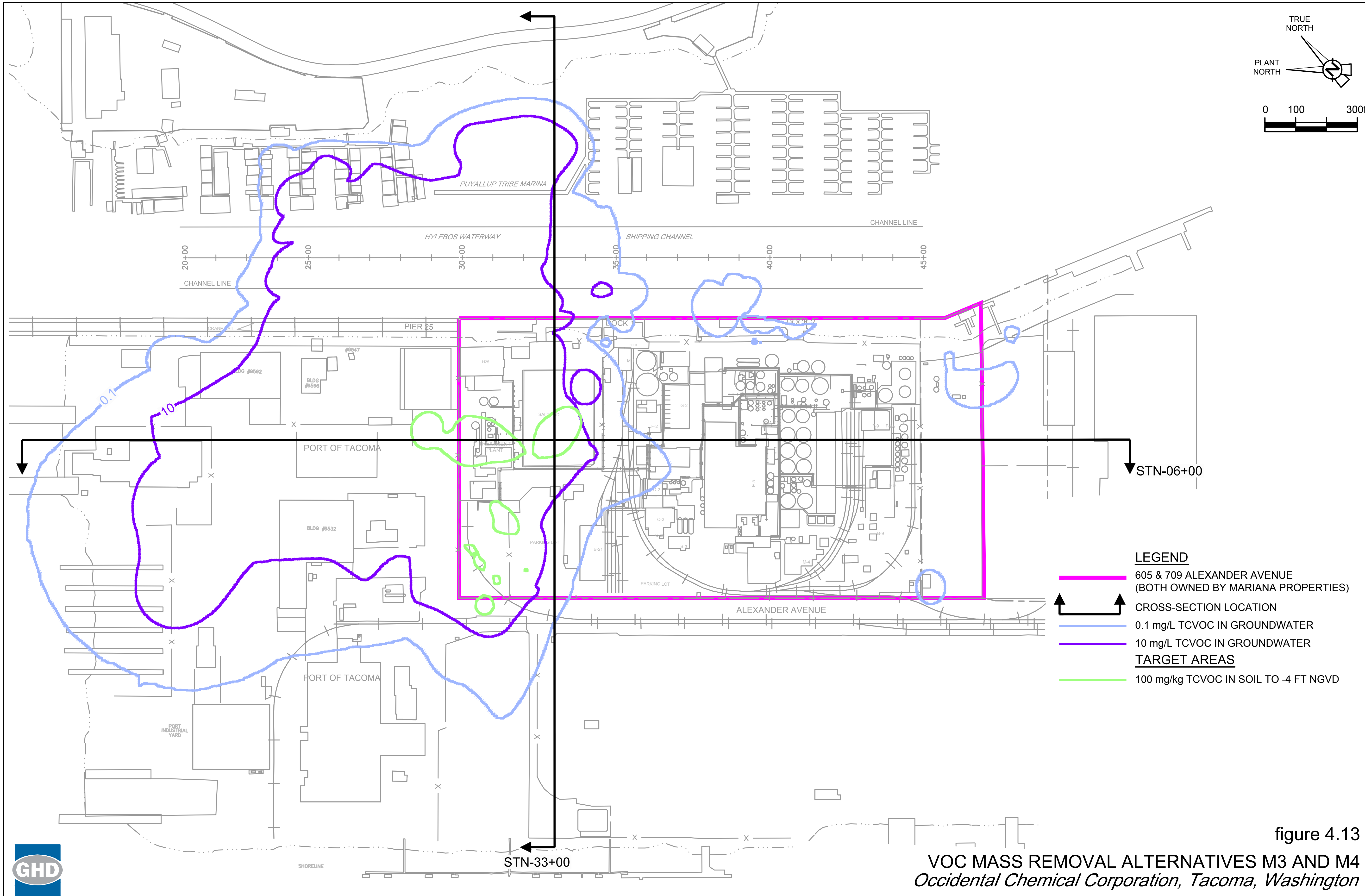
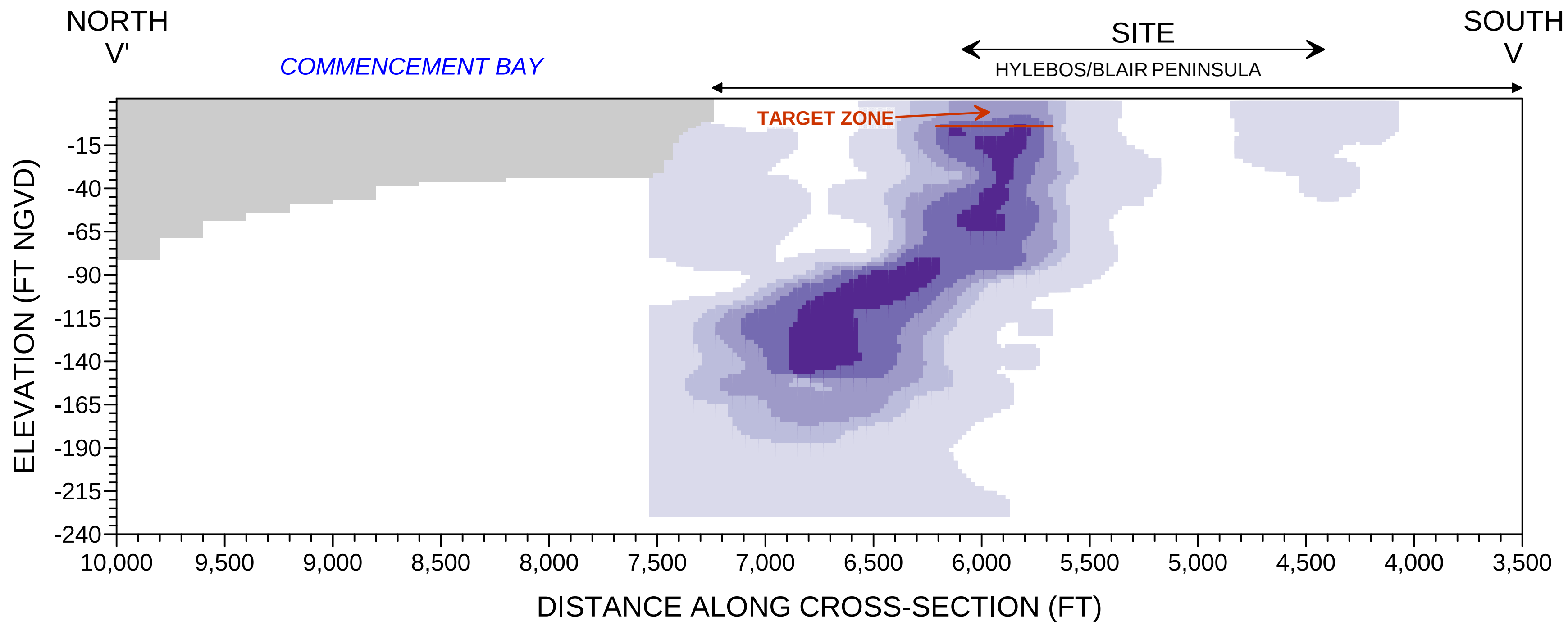


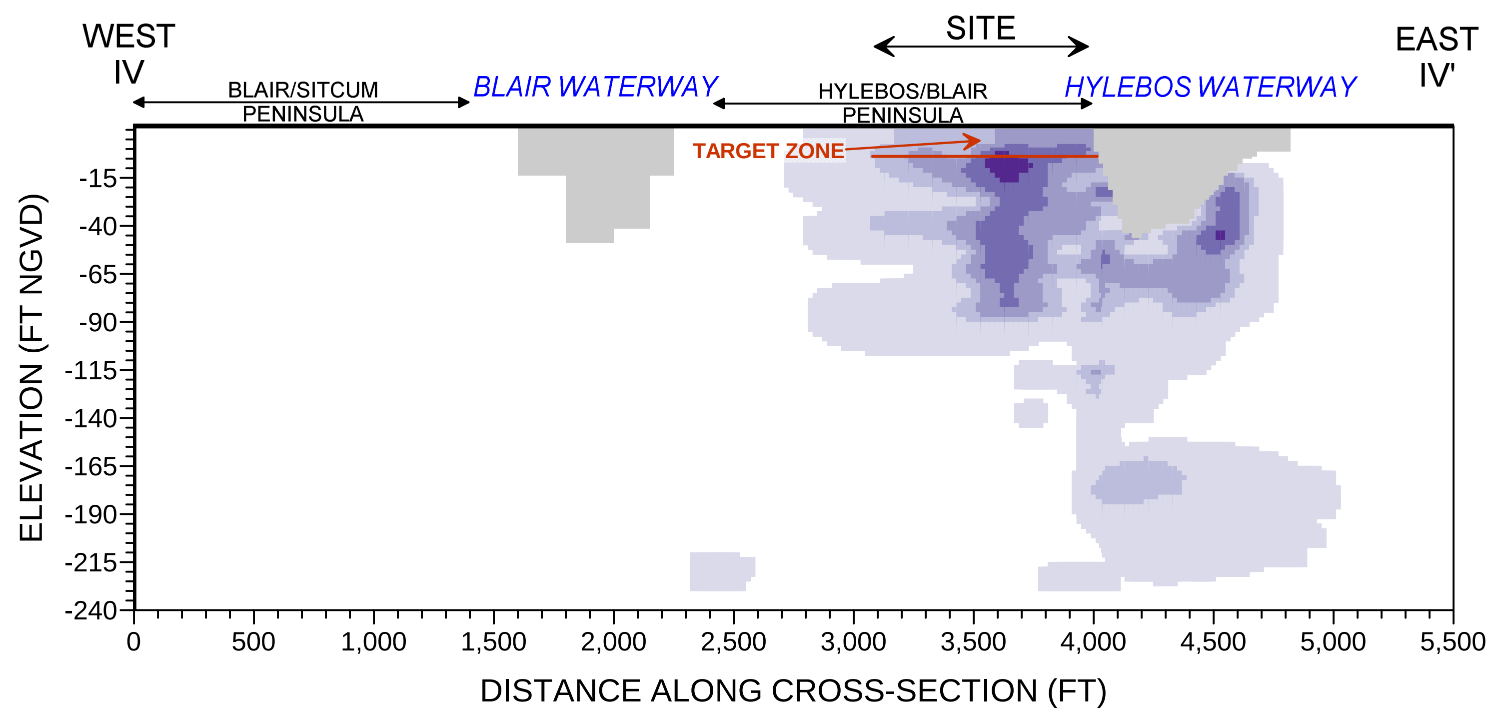
figure 4.13

VOC MASS REMOVAL ALTERNATIVES M3 AND M4

Occidental Chemical Corporation, Tacoma, Washington

07843-C2D2(139)GN-WA038 DEC 5, 2016





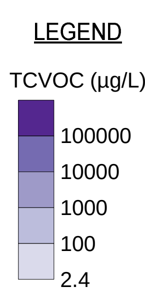


figure 4.14

VOC MASS REMOVAL ALTERNATIVES M3 AND M4 CROSS-SECTIONS
CROSS-SECTIONS IV-IV' AND V-V'
Occidental Chemical Corporation, Tacoma, Washington

07843-C2D2(139)GN-WA-HYD (N:\HEG\07843\RPT139\Figures-Current\07843-C2D2(139)HEG-Fig 4.14.srf) DEC 9, 2016

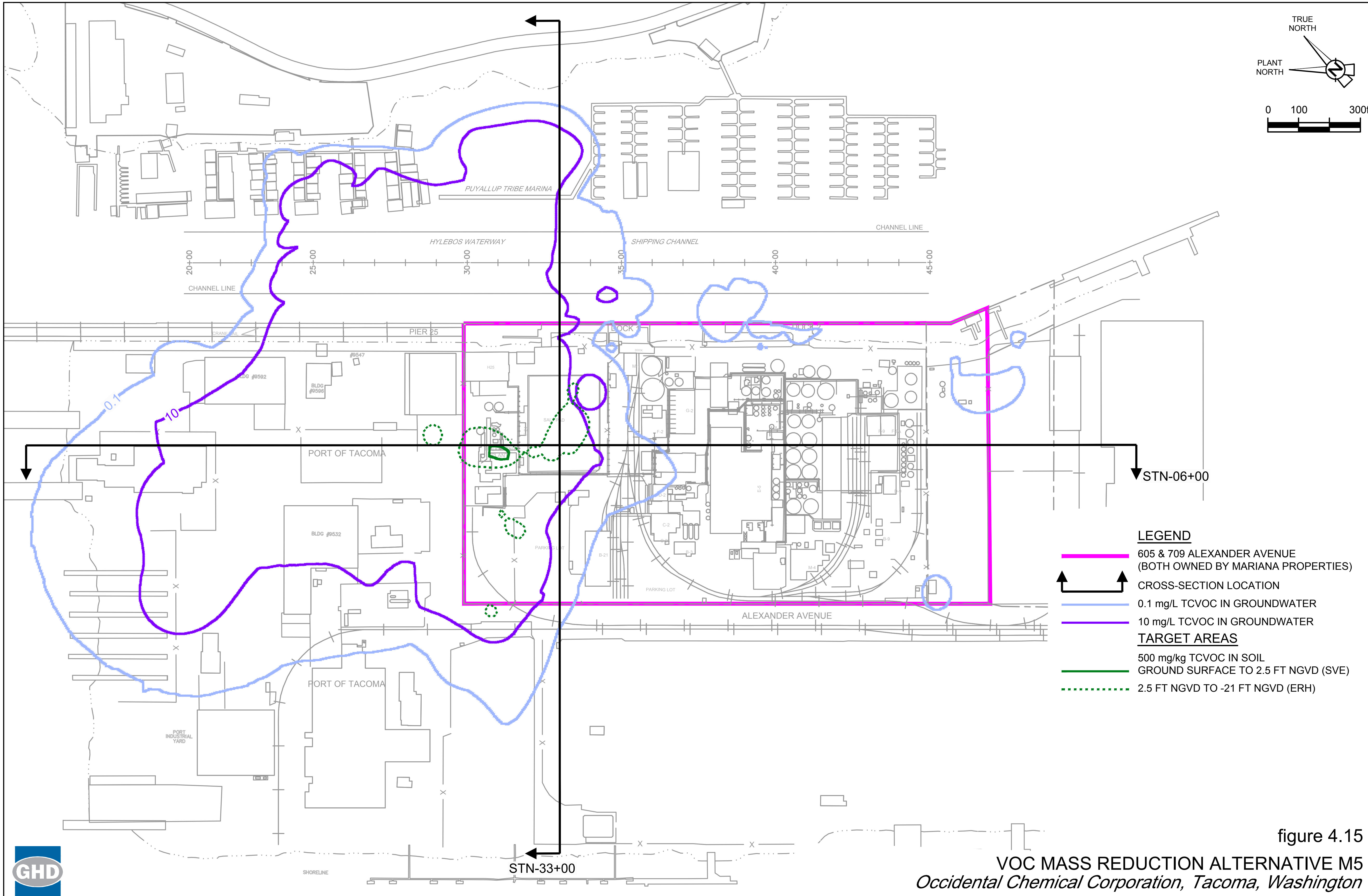


figure 4.15

VOC MASS REDUCTION ALTERNATIVE M5

Occidental Chemical Corporation, Tacoma, Washington

GHD

07843-C2D2(139)GN-WA039 DEC 5, 2016

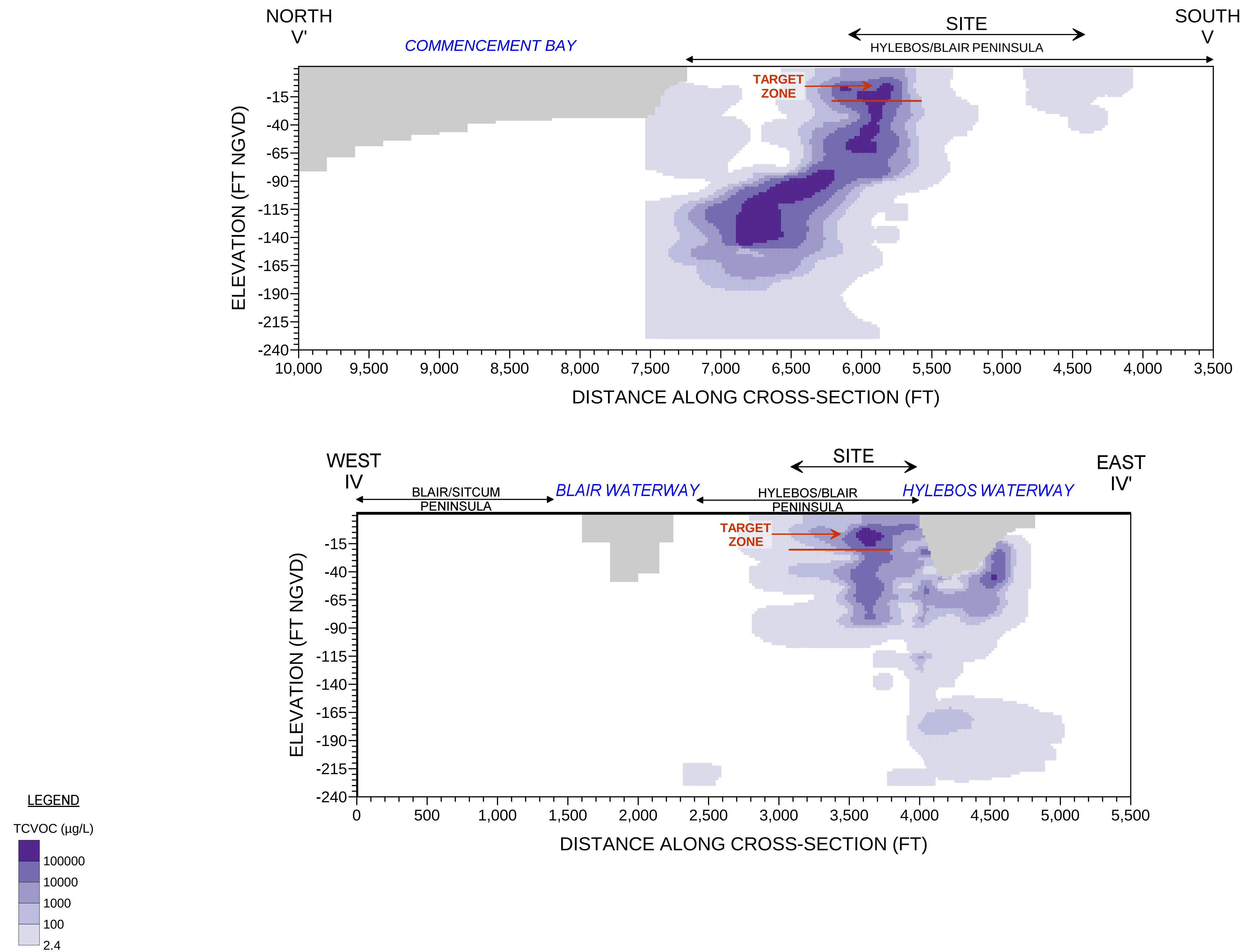


figure 4.16

VOC MASS REDUCTION ALTERNATIVE M5 CROSS-SECTIONS
CROSS-SECTIONS IV-IV' AND V-V'
Occidental Chemical Corporation, Tacoma, Washington

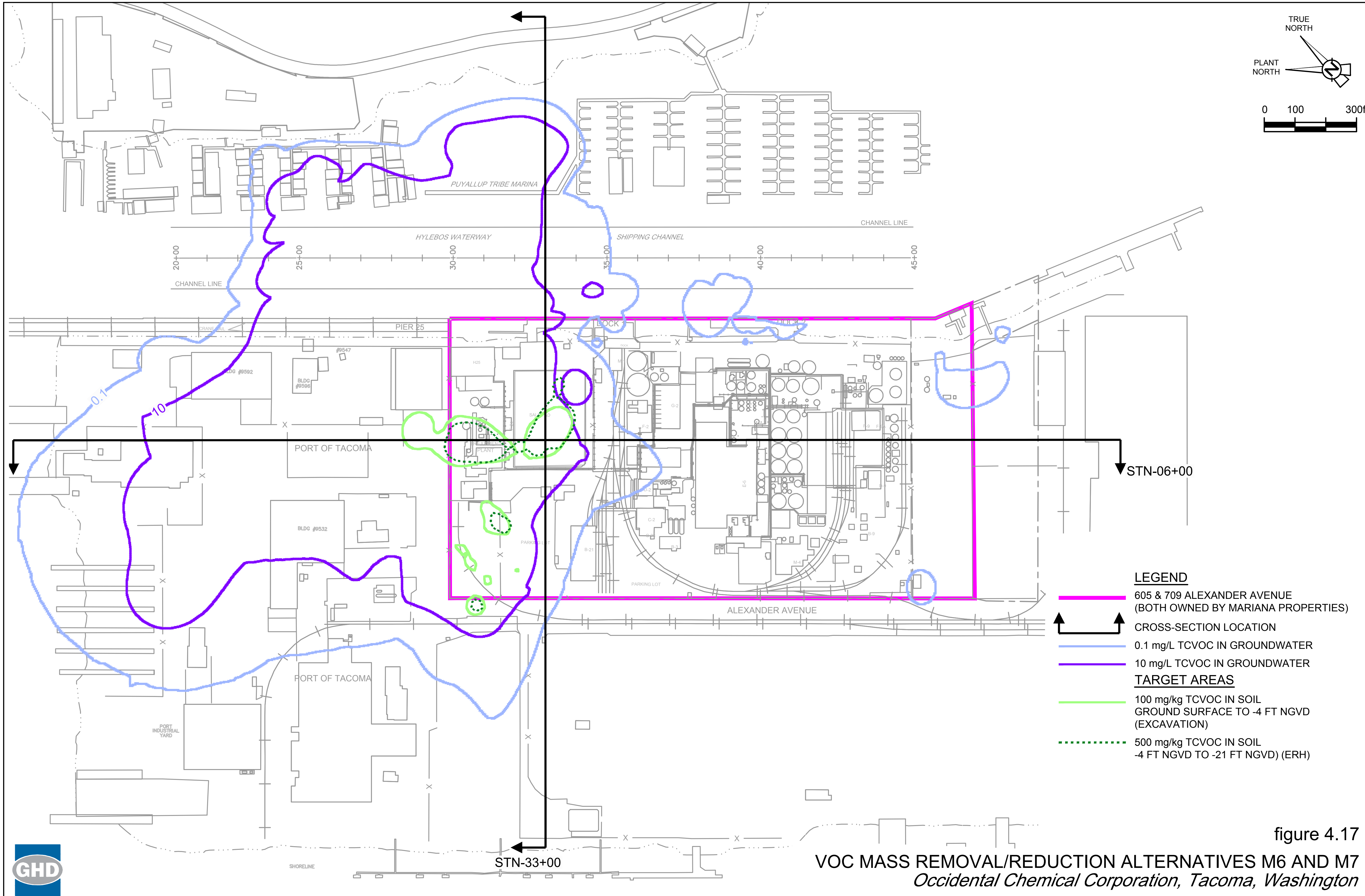


figure 4.17

VOC MASS REMOVAL/REDUCTION ALTERNATIVES M6 AND M7

Occidental Chemical Corporation, Tacoma, Washington

07843-C2D2(139)GN-WA040 DEC 5, 2016

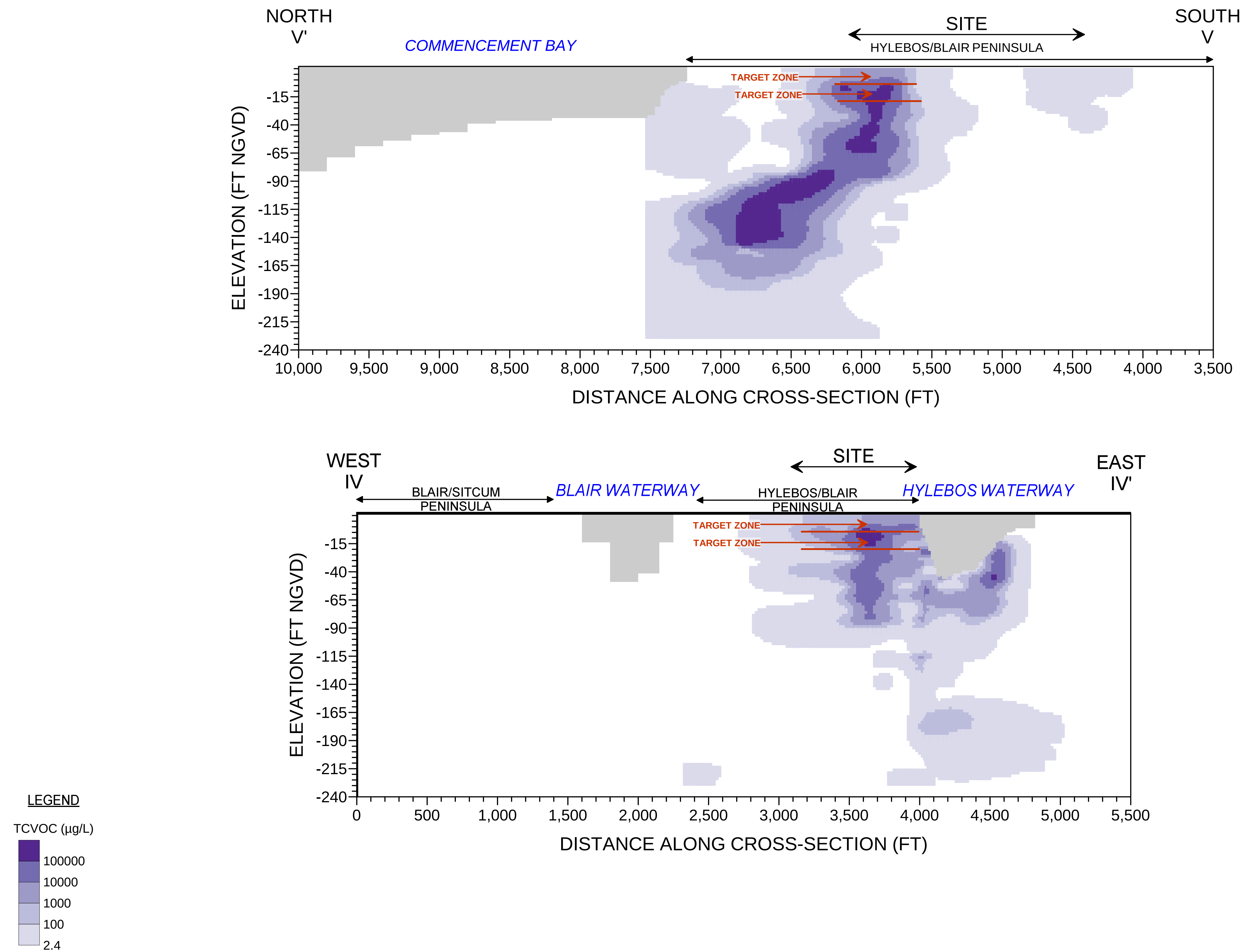


figure 4.18

VOC MASS REMOVAL/REDUCTION ALTERNATIVES M6 AND M7 CROSS-SECTIONS
CROSS-SECTIONS IV-IV' AND V-V'
Occidental Chemical Corporation, Tacoma, Washington

07843-C2D2(139)GN-WA-HYD (N:\HEG\07843\RPT139\Figures-Current\07843-C2D2(139)HEG-Fig 4.18.srf) DEC 9, 2016

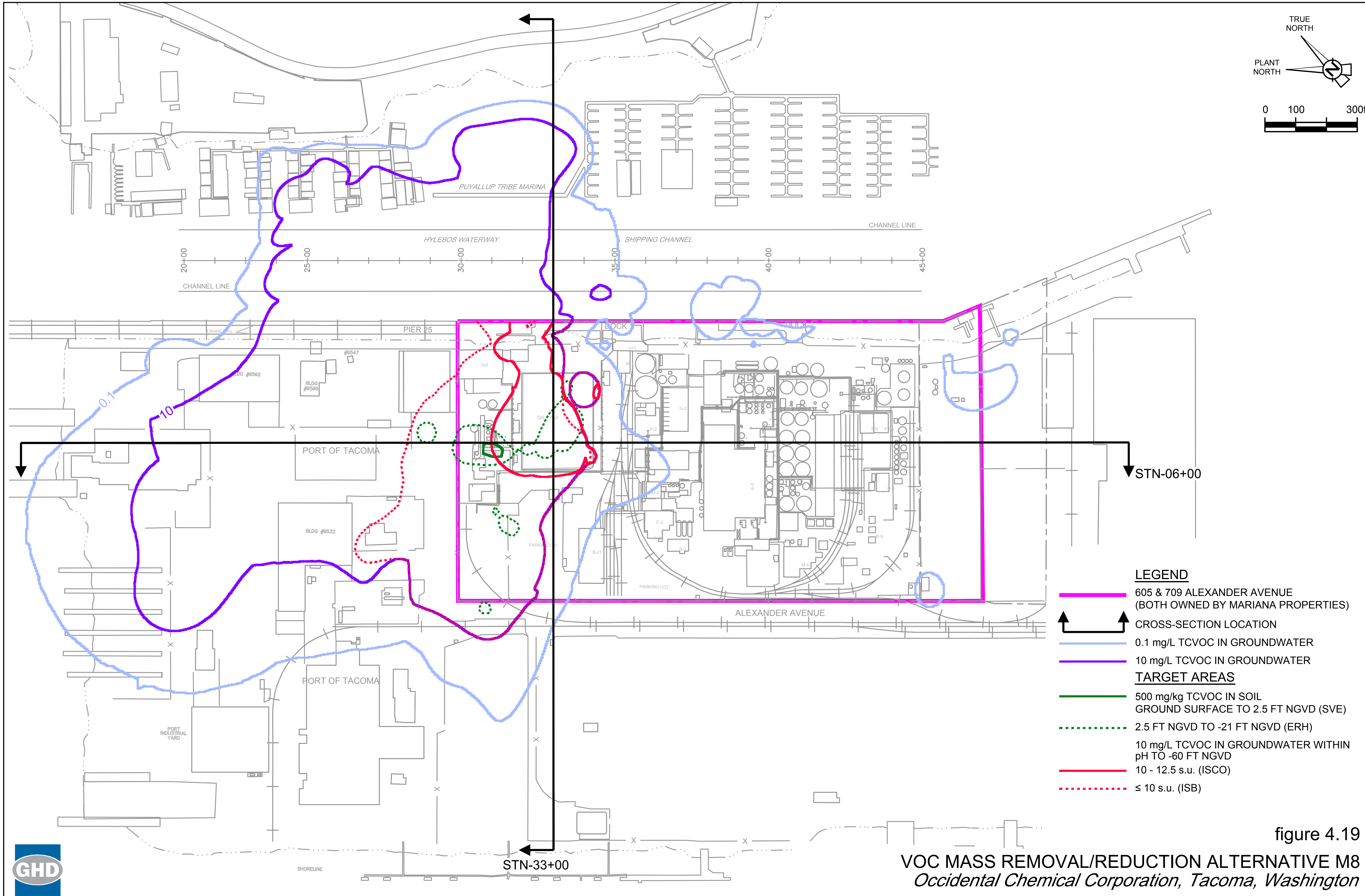


figure 4.19

VOC MASS REMOVAL/REDUCTION ALTERNATIVE M8

Occidental Chemical Corporation, Tacoma, Washington

07843-C2D2(139)GN-WA041 DEC 5, 2016

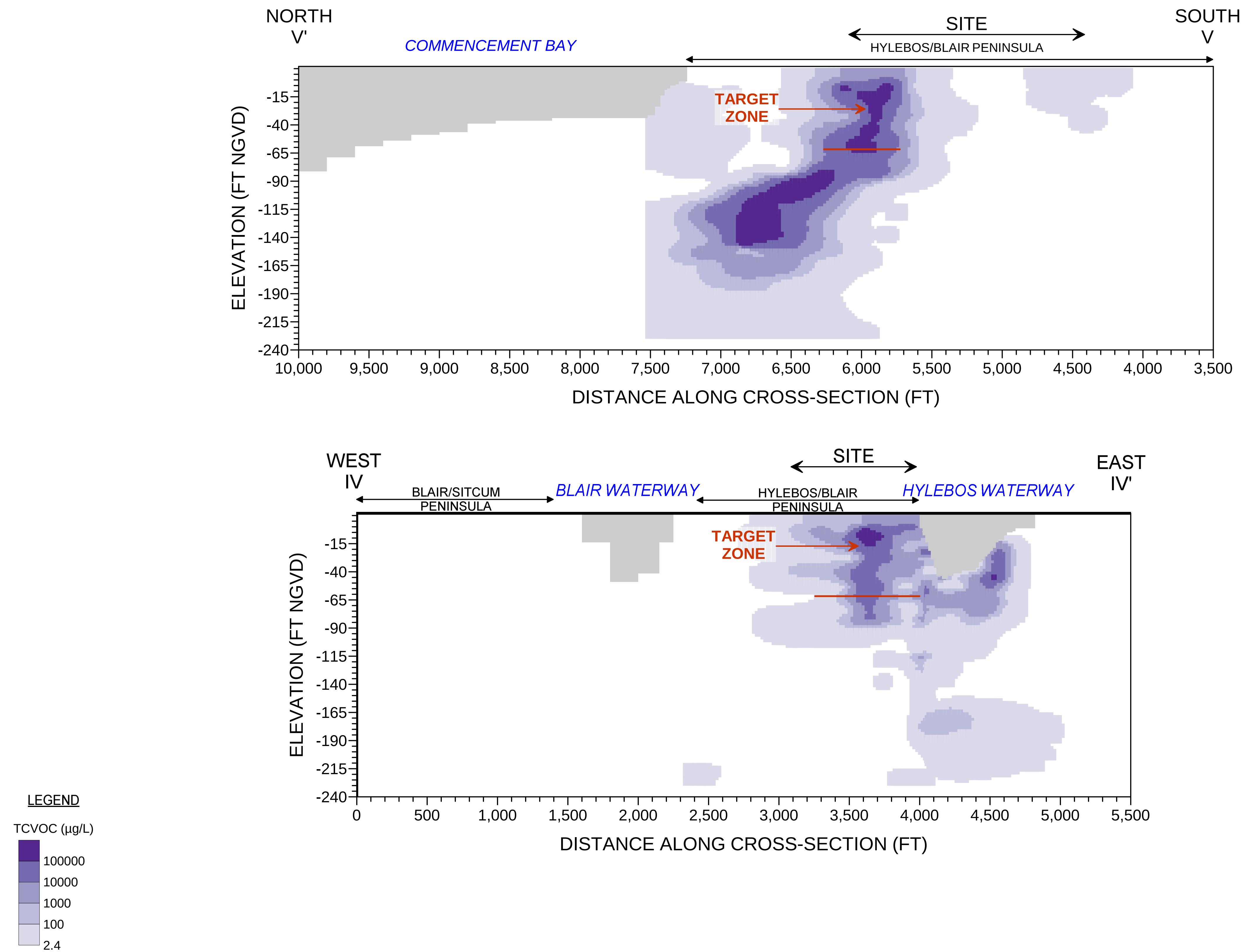


figure 4.20

VOC MASS REMOVAL/REDUCTION ALTERNATIVE M8 CROSS-SECTIONS
CROSS-SECTIONS IV-IV' AND V-V'
Occidental Chemical Corporation, Tacoma, Washington

07843-C2D2(139)GN-WA-HYD (N:\HEG\07843\RPT139\Figures-Current\07843-C2D2(139)HEG-Fig 4.20.srf) DEC 9, 2016

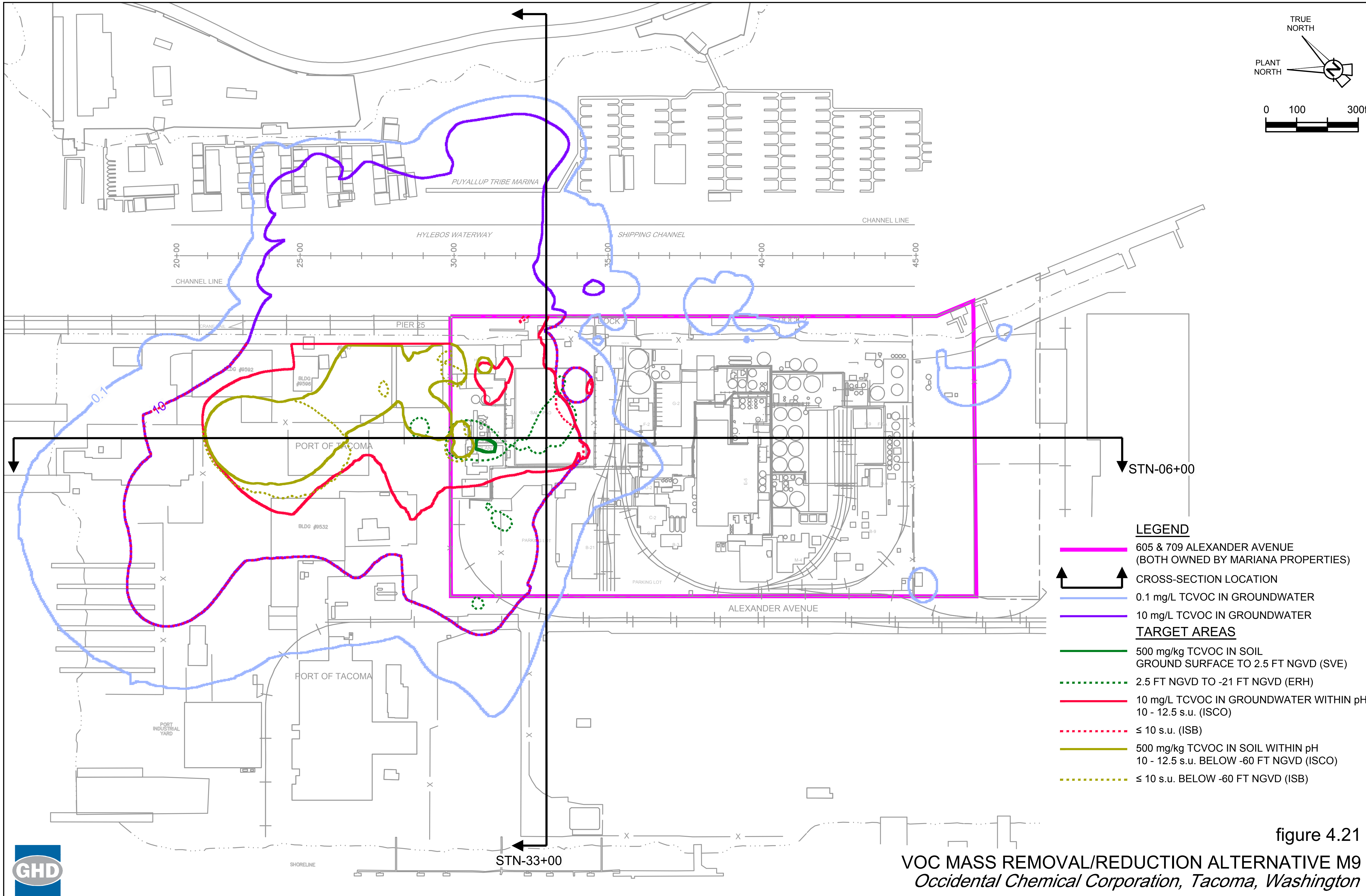


figure 4.21

VOC MASS REMOVAL/REDUCTION ALTERNATIVE M9

Occidental Chemical Corporation, Tacoma, Washington

07843-C2D2(139)GN-WA042 DEC 5, 2016

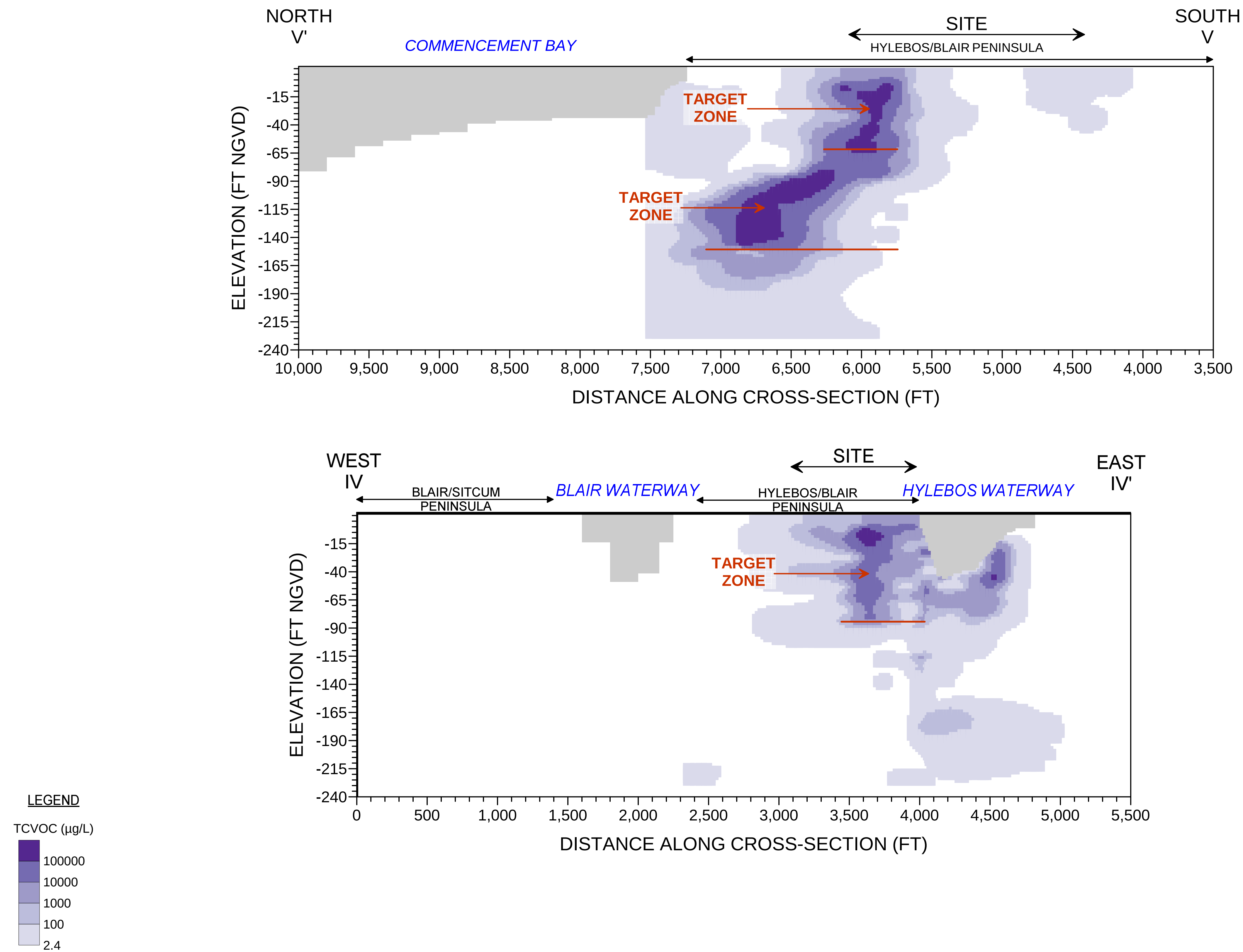
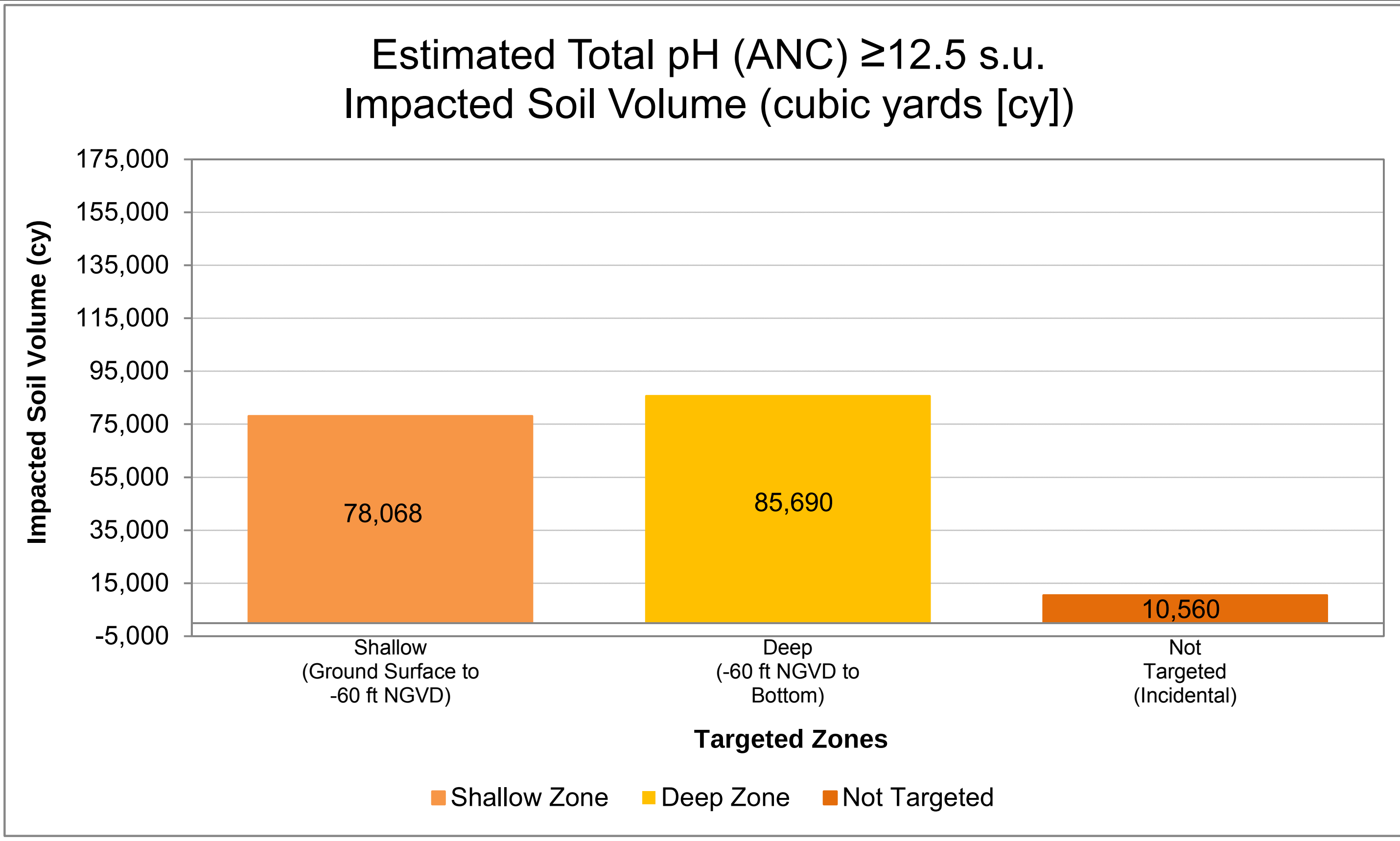


figure 4.22

VOC MASS REMOVAL/REDUCTION ALTERNATIVE M9 CROSS-SECTIONS
CROSS-SECTIONS IV-IV' AND V-V'
Occidental Chemical Corporation, Tacoma, Washington



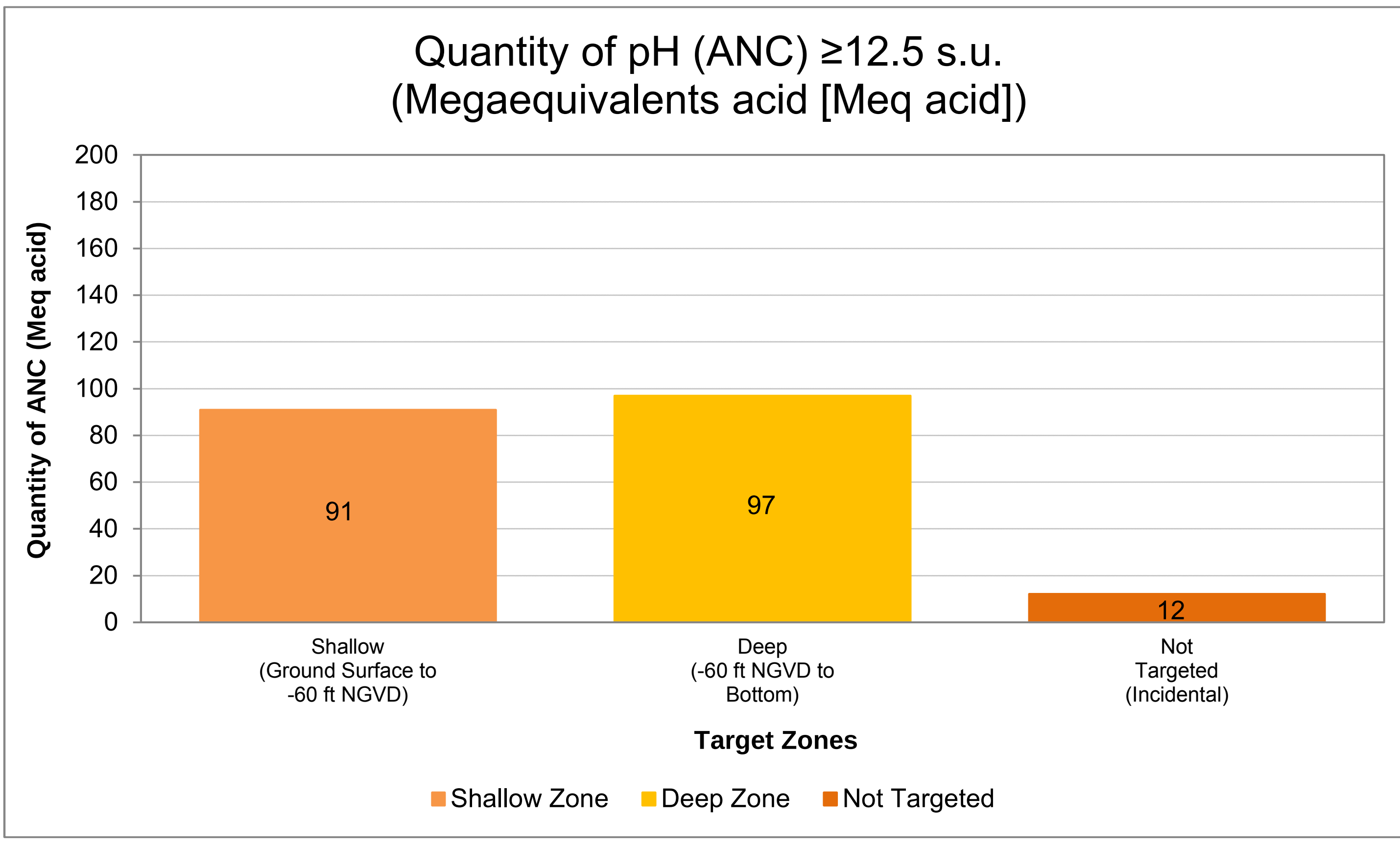


figure 4.23
pH Target Zones
Occidental Chemical Corporation, Tacoma, Washington

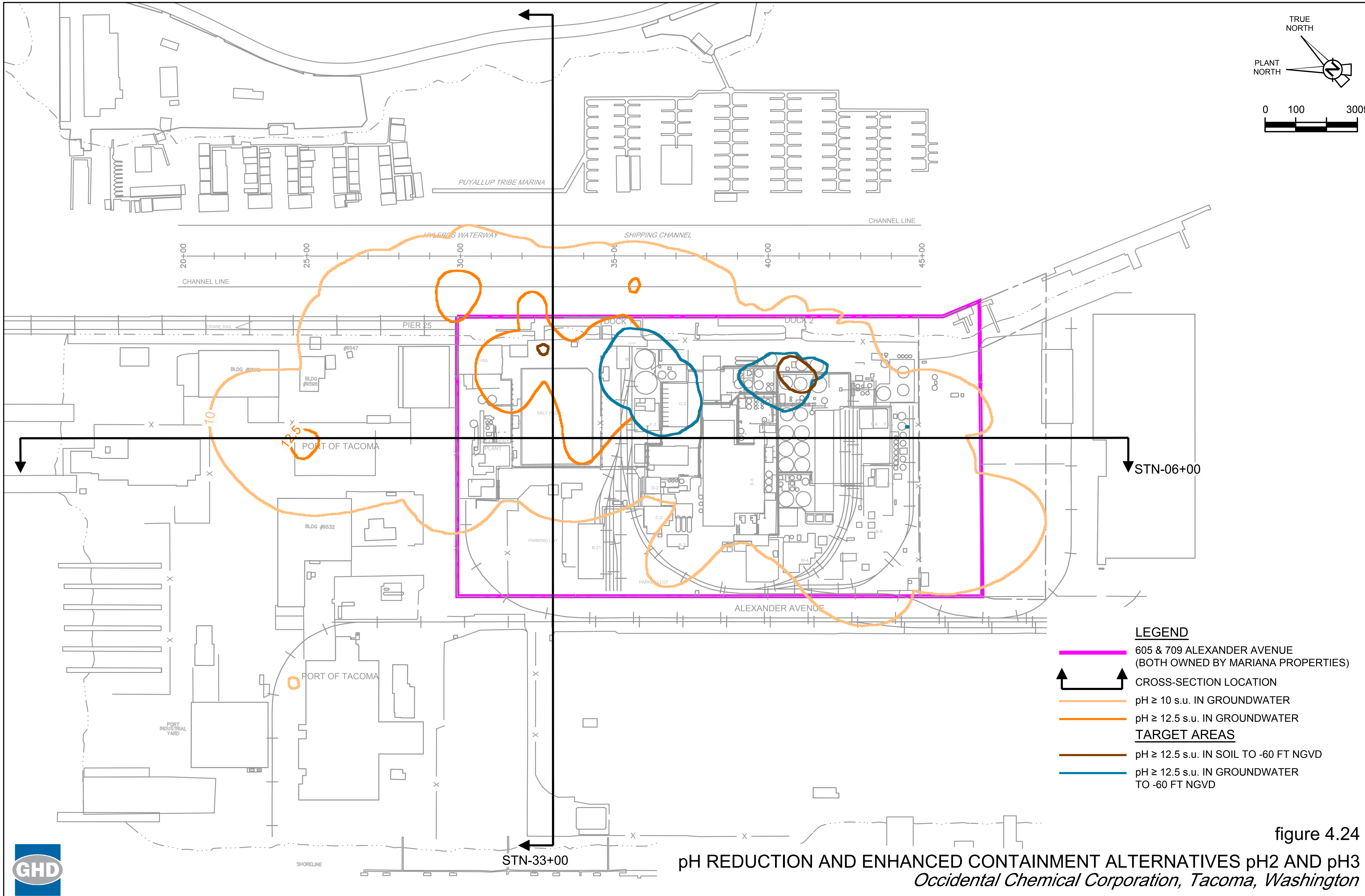
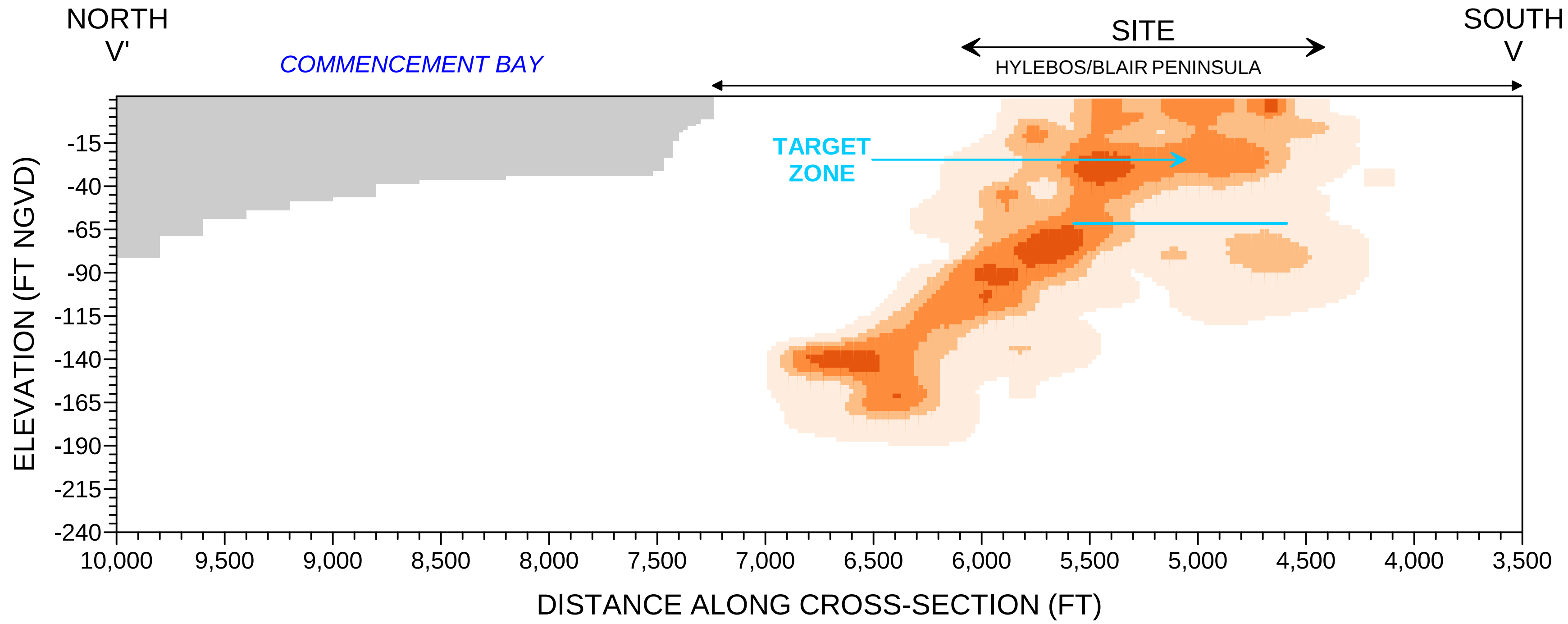


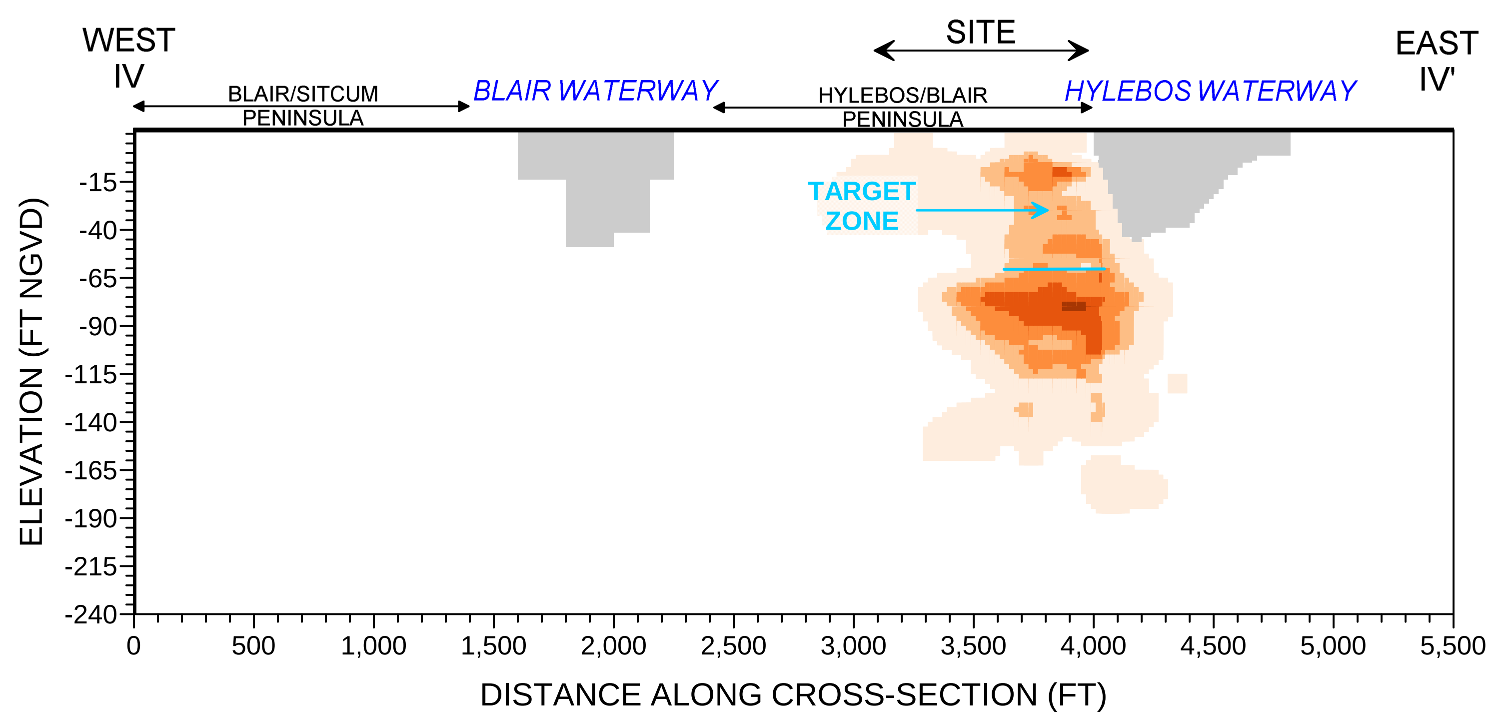
figure 4.24

pH REDUCTION AND ENHANCED CONTAINMENT ALTERNATIVES pH2 AND pH3

Occidental Chemical Corporation, Tacoma, Washington

07843-C2D2(139)GN-WA045 DEC 5, 2016





LEGEND

pH (s.u.)

13
12
11
10
8.5

figure 4.25

pH REDUCTION/ENHANCED CONTAINMENT ALTERNATIVES pH2, pH3, AND pH4 CROSS-SECTIONS
CROSS-SECTIONS IV-IV' AND V-V'
Occidental Chemical Corporation, Tacoma, Washington

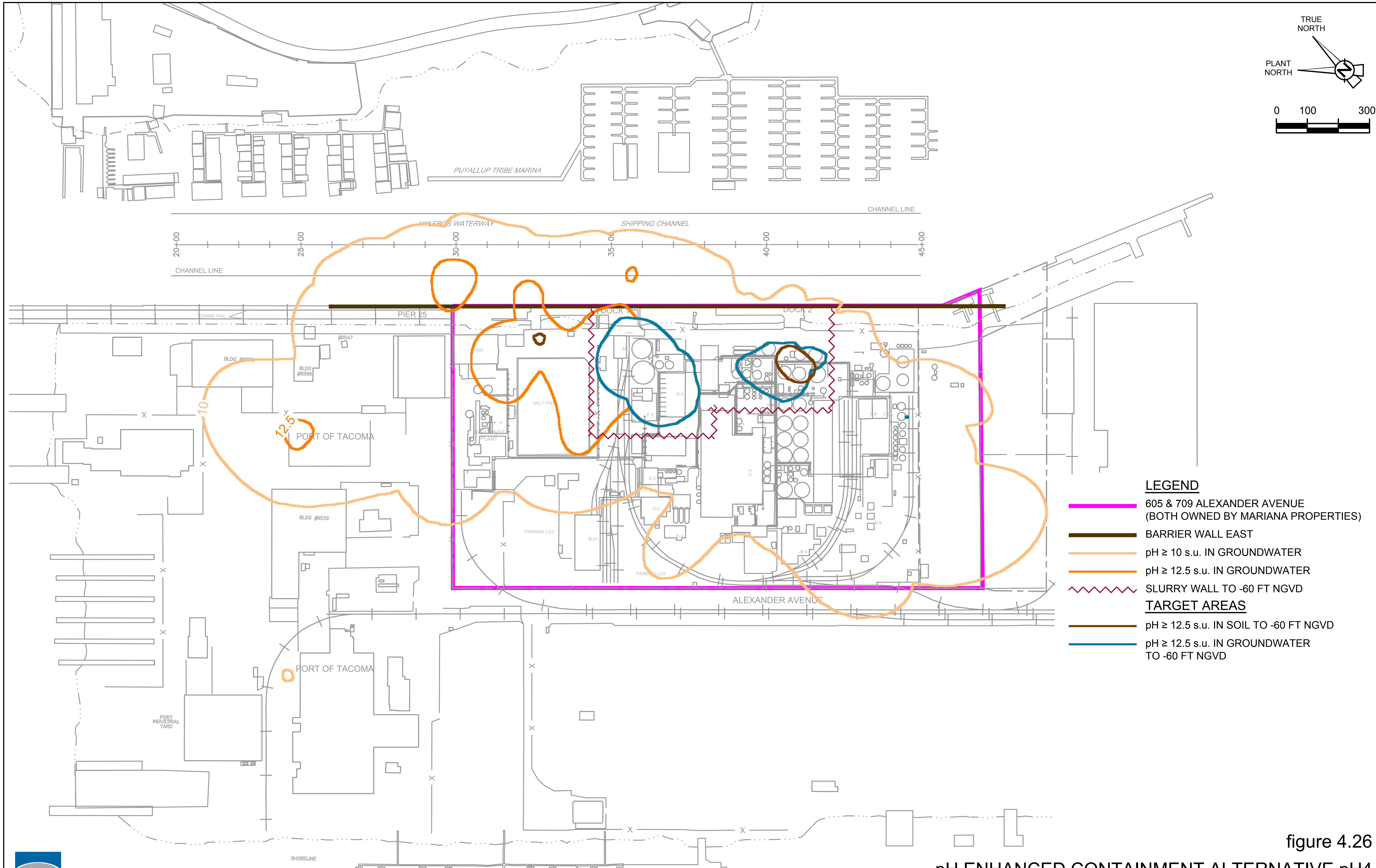


figure 4.26

pH ENHANCED CONTAINMENT ALTERNATIVE pH4

Occidental Chemical Corporation, Tacoma, Washington

07843-C2D2(139)GN-WA046 DEC 5, 2016

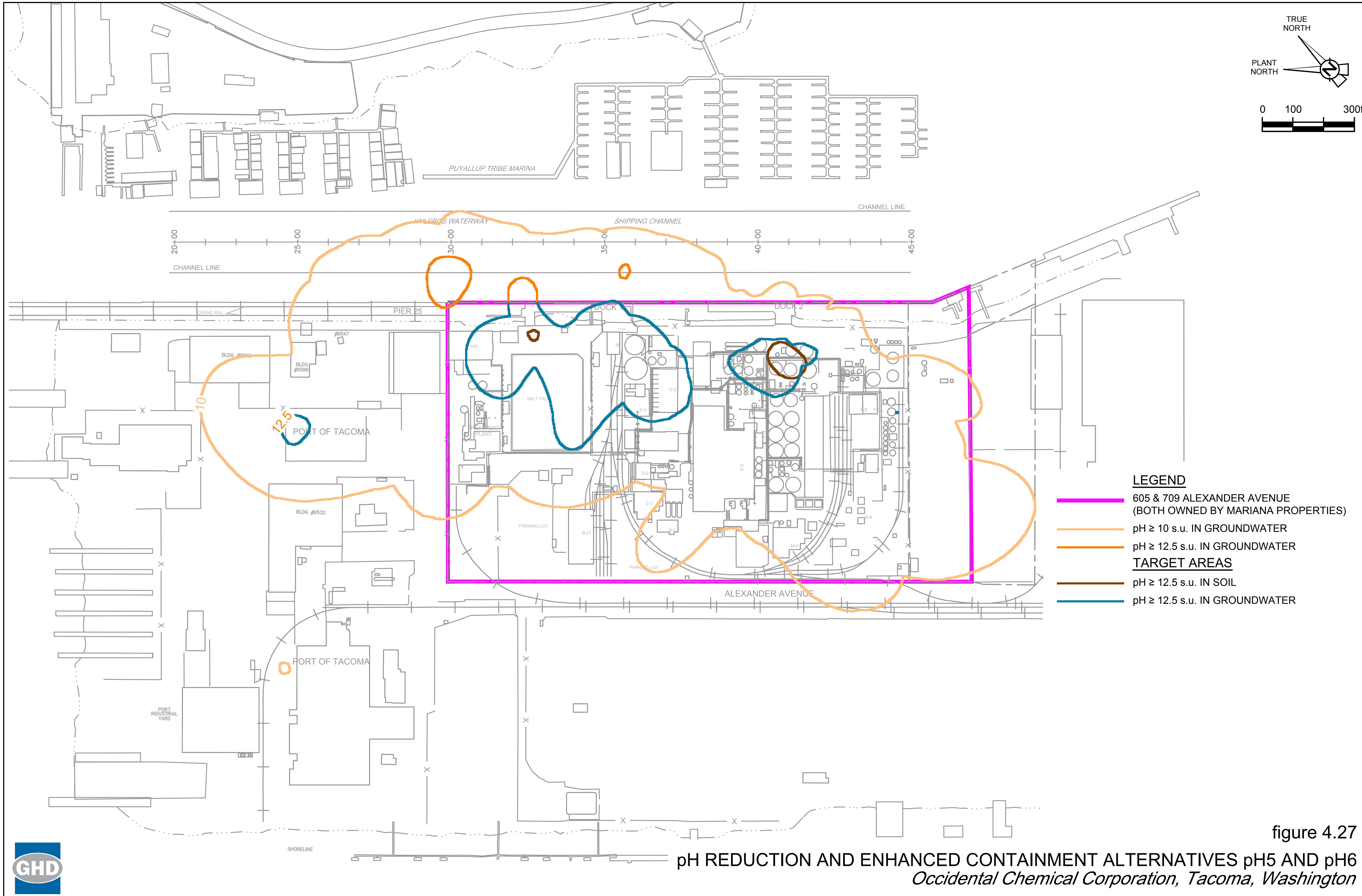


figure 4.27

pH REDUCTION AND ENHANCED CONTAINMENT ALTERNATIVES pH5 AND pH6

Occidental Chemical Corporation, Tacoma, Washington

07843-C2D2(139)GN-WA047 DEC 5, 2016

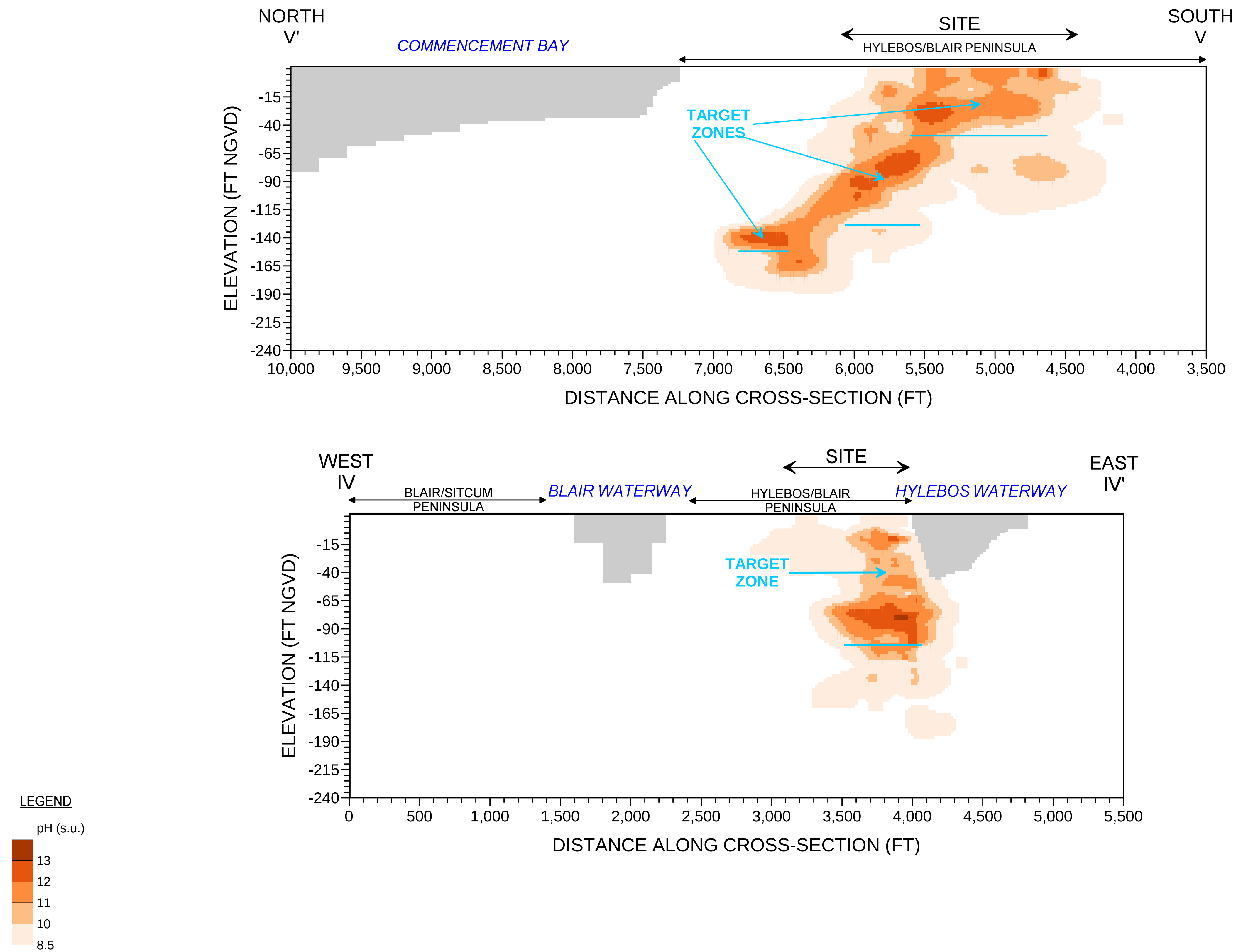


figure 4.28

pH REDUCTION/ENHANCED CONTAINMENT ALTERNATIVES pH5, pH6, AND pH7 CROSS-SECTIONS
CROSS-SECTIONS IV-IV' AND V-V'
Occidental Chemical Corporation, Tacoma, Washington

07843-C2D2(139)GN-WA-HYD (N:\HEG\07843\RPT139\Figures-Current\07843-C2D2(139)HEG-Fig 4.28.srf) DEC 9, 2016

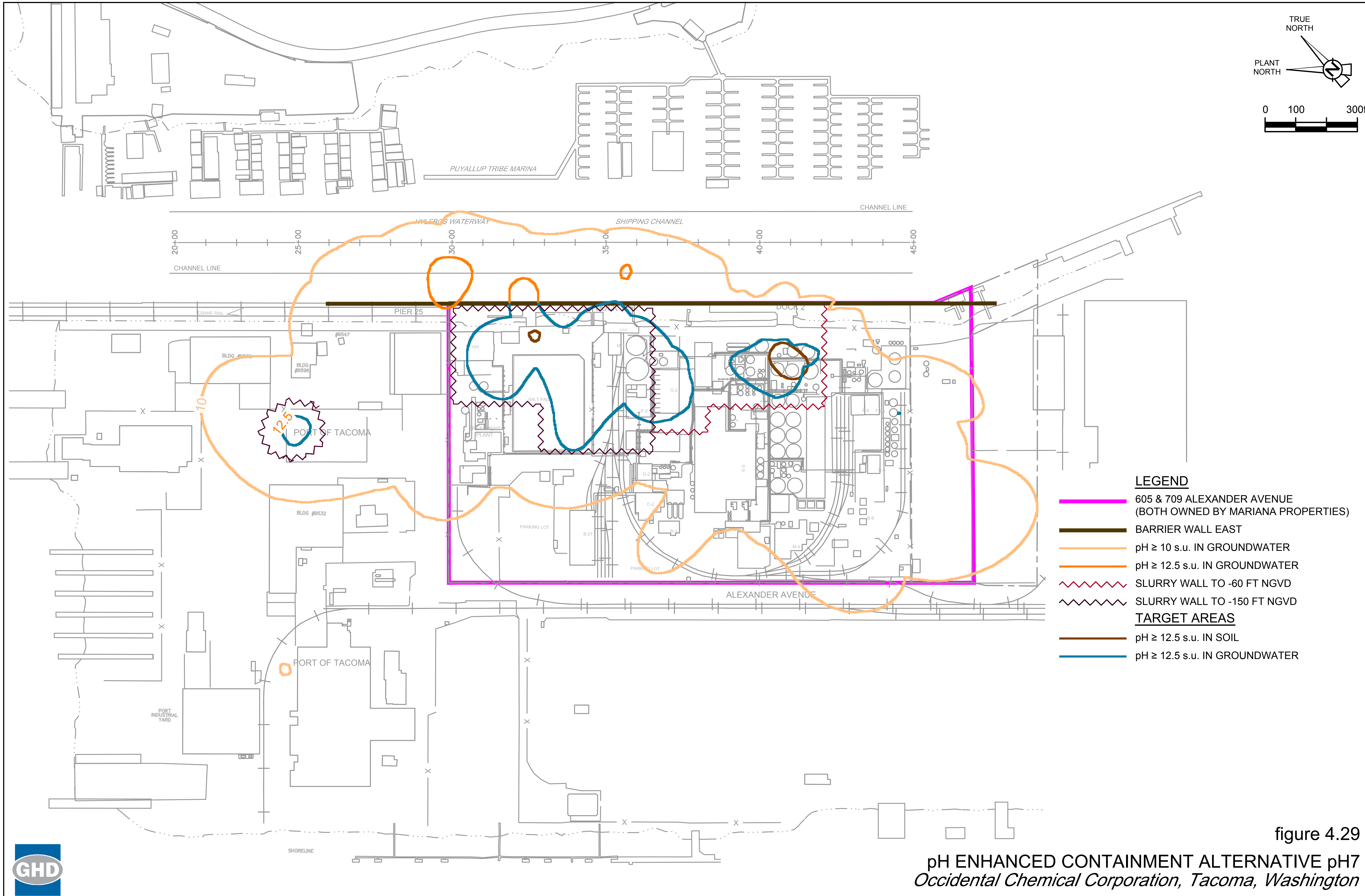


figure 4.29

pH ENHANCED CONTAINMENT ALTERNATIVE pH7

Occidental Chemical Corporation, Tacoma, Washington

07843-C2D2(139)GN-WA048 DEC 5, 2016

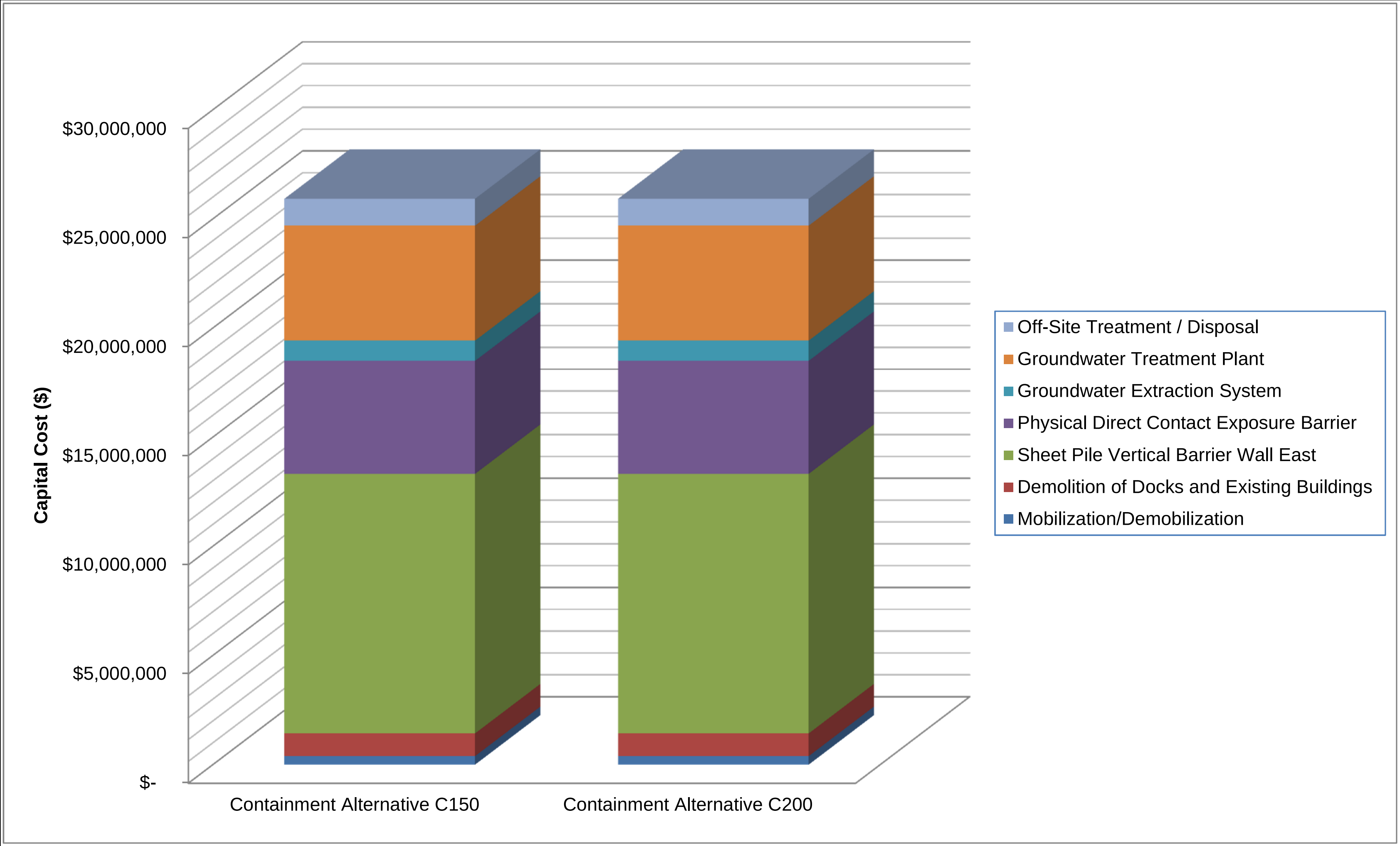


figure 5.1

Containment Alternatives Common Elements Capital Cost Distribution

Occidental Chemical Corporation, Tacoma, Washington

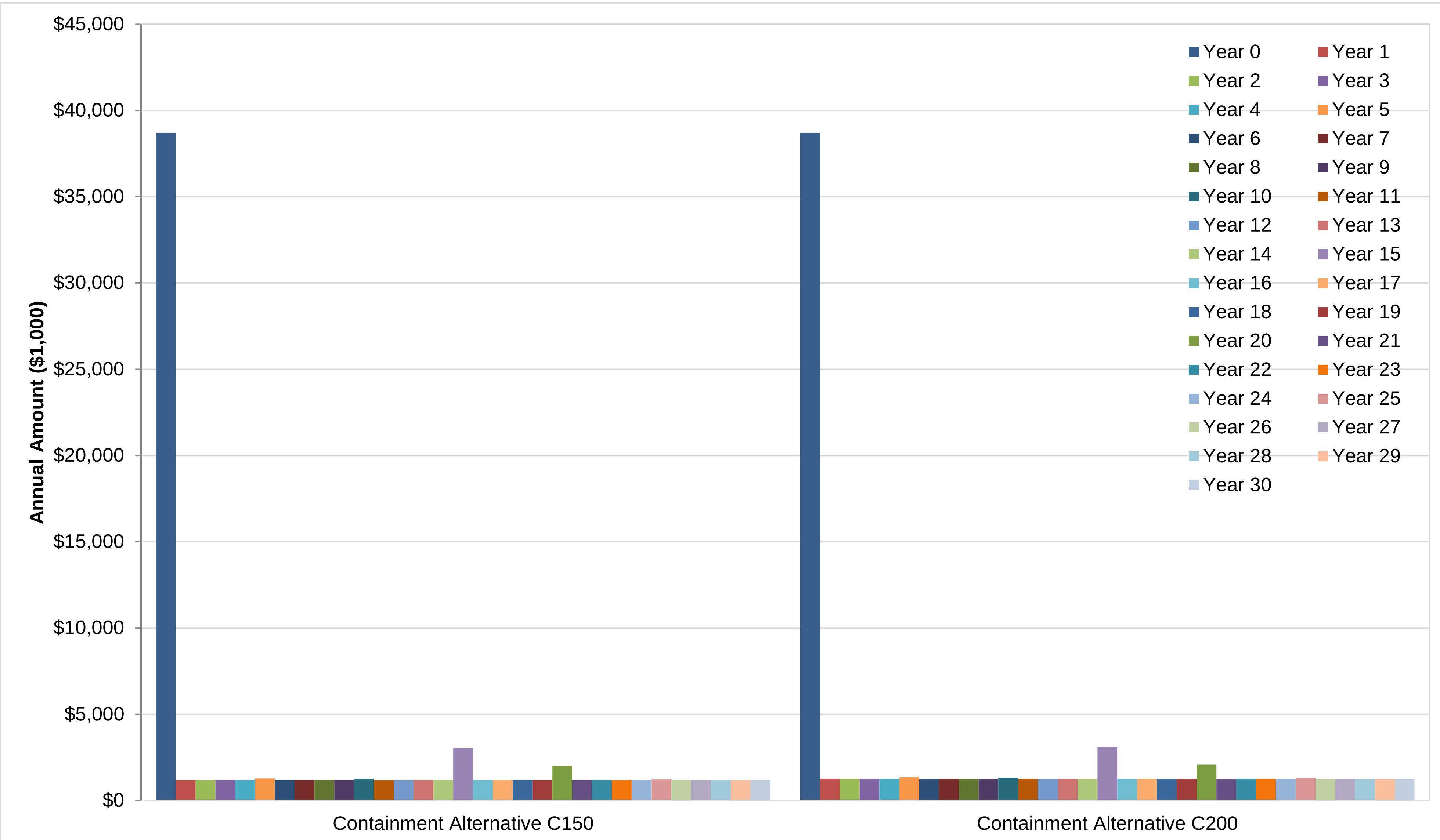
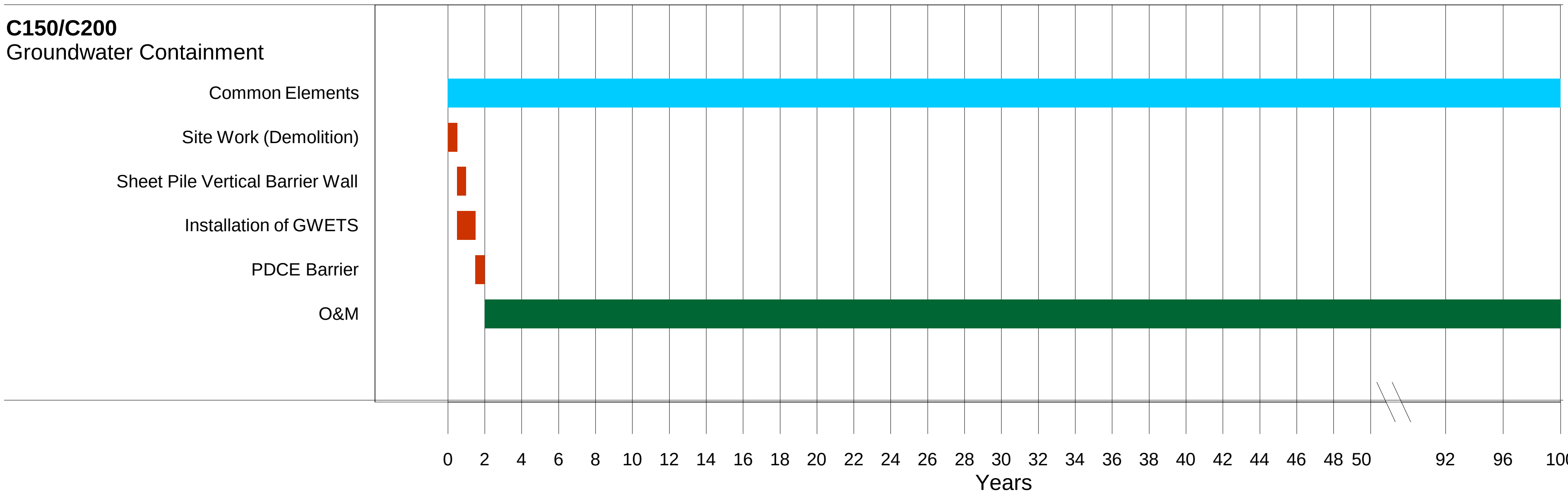


figure 5.2

Containment Alternatives 30-Year Cash Flow Projections

Occidental Chemical Corporation, Tacoma, Washington

007843 (139)



LEGEND

- CONSTRUCTION/INSTALLATION ACTIVITIES
- COMMON ELEMENTS INCLUDING INSTITUTIONAL CONTROLS AND MONITORING
- OPERATION AND MAINTENANCE ACTIVITIES

NOTES:
GWETS GROUNDWATER EXTRACTION AND TREATMENT SYSTEM
PDCE PHYSICAL DIRECT CONTACT EXPOSURE

OCCIDENTAL CHEMICAL CORPORATION
TACOMA, WASHINGTON

JOB NUMBER 007843-C2D2-403
DATE December 9, 2016

CONTAINMENT ALTERNATIVES TECHNOLOGIES
ESTIMATED DURATIONS

FIGURE 5.3

Hg file: I:\Hg\05000 to 09999\07843 - Tacoma\FS - cost estimates\cost estimate summaries\7843-Containment Durations.grf

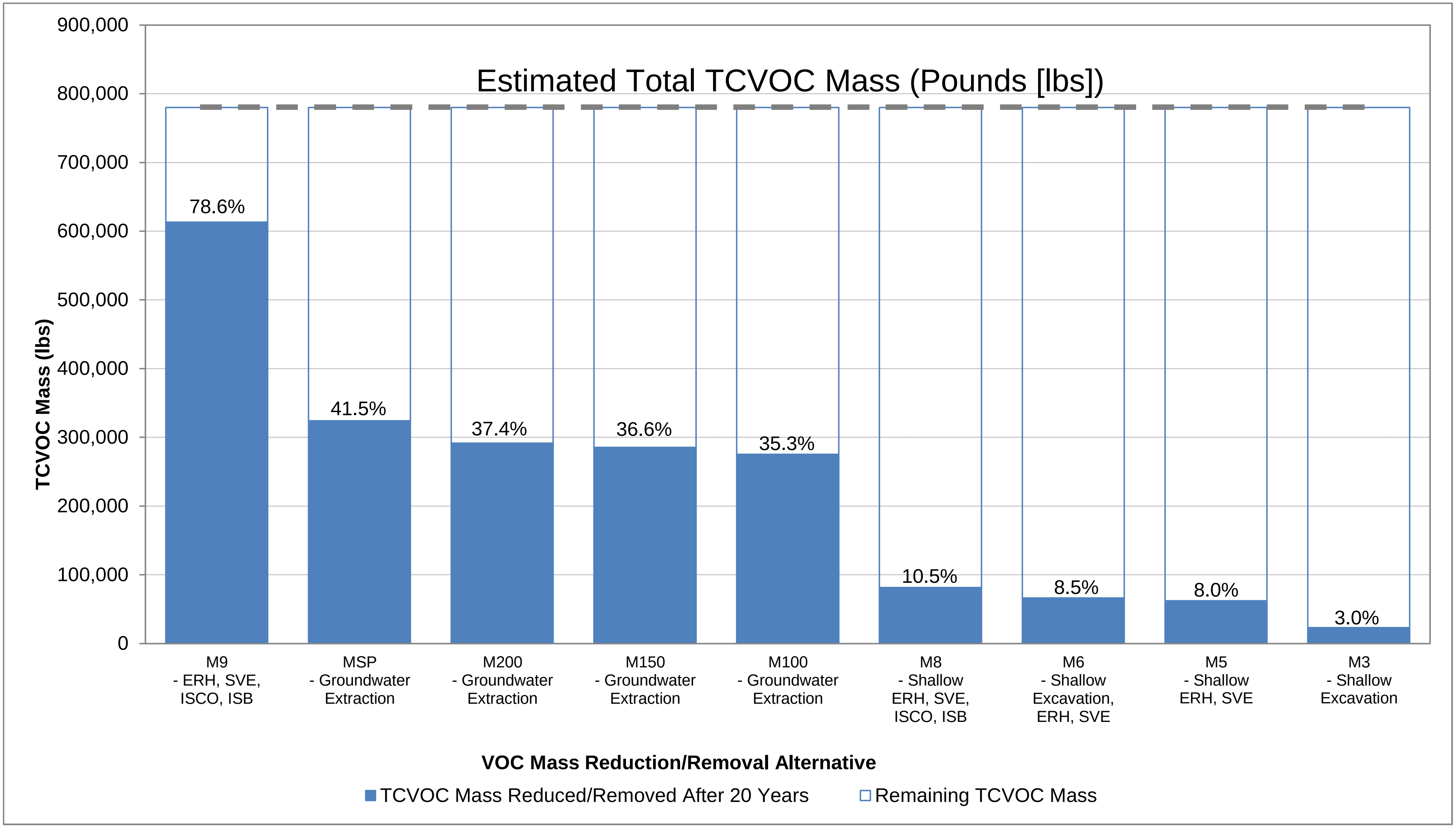


figure 6.1

TCVOC Mass Reduced/Removed by Alternatives Comparison

Occidental Chemical Corporation, Tacoma, Washington

007843 (139)

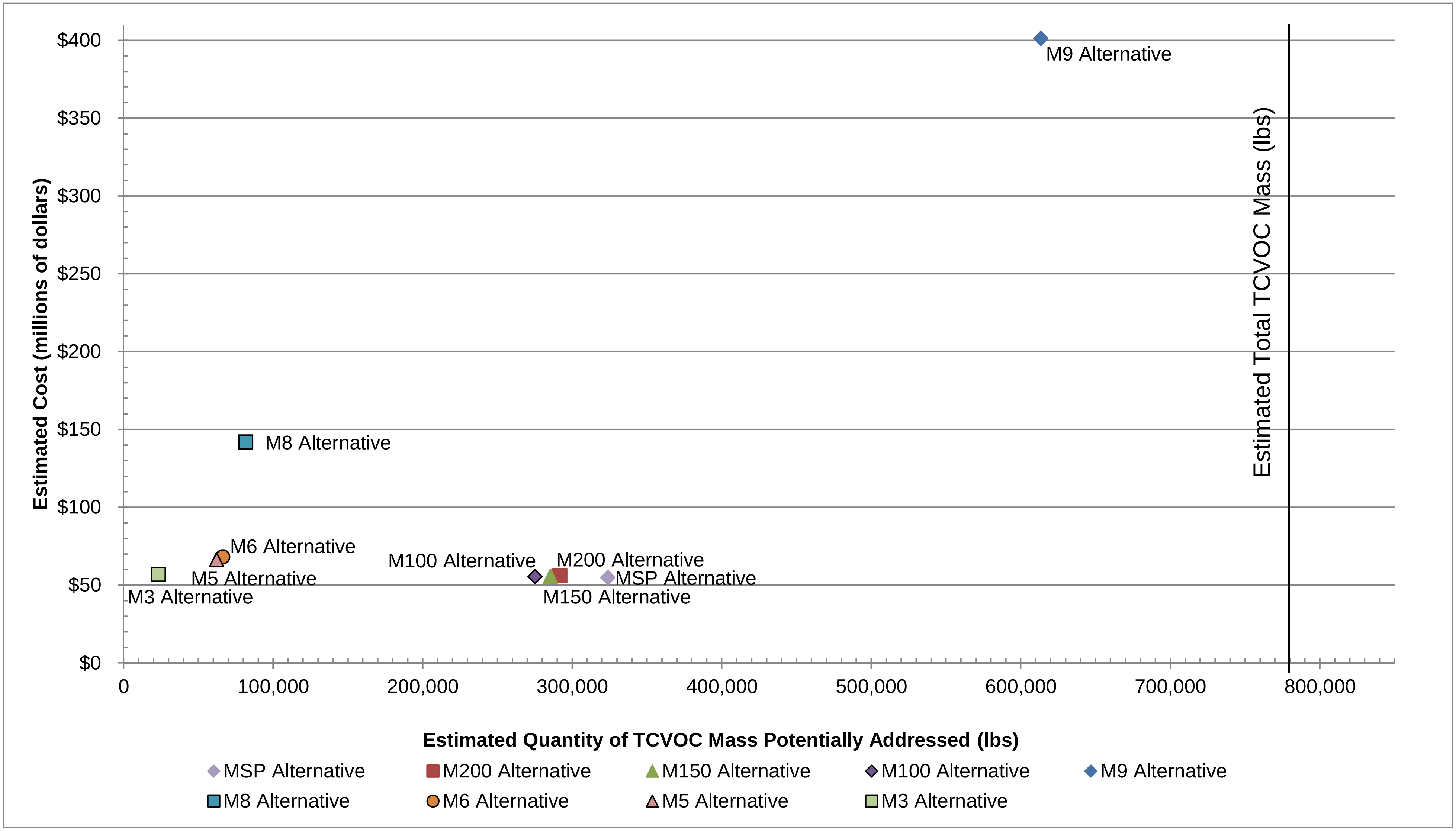


figure 6.2

Relationship Between Estimated Cost and Estimated Quantity of TCVOC Mass Potentially Addressed

Occidental Chemical Corporation, Tacoma, Washington

007843 (139)

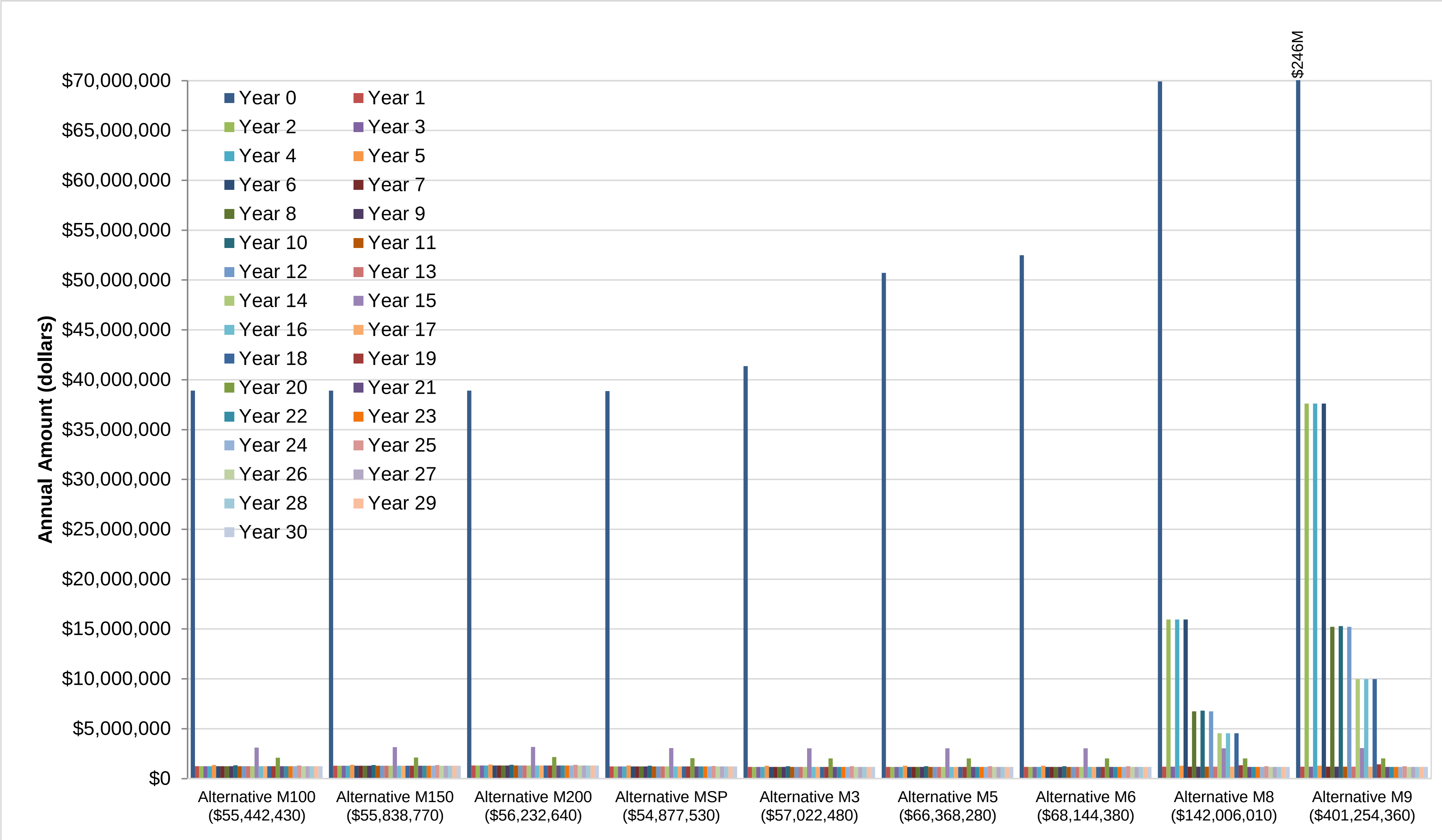
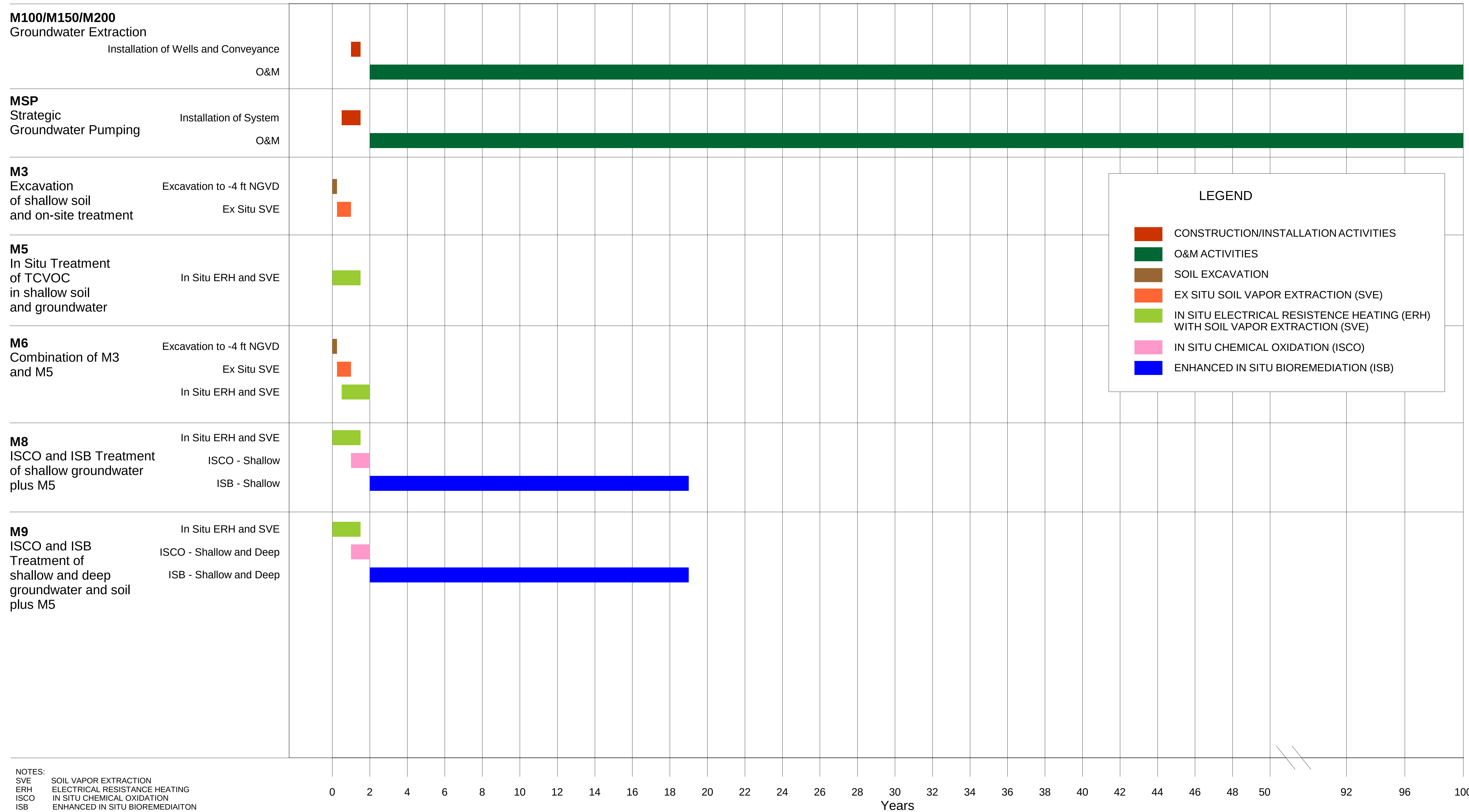


figure 6.3

VOC Mass Alternatives 30-Year Cash Flow Projections

Occidental Chemical Corporation, Tacoma, Washington

007843 (139)



NOTES:
SVE SOIL VAPOR EXTRACTION
ERH ELECTRICAL RESISTANCE HEATING
ISCO IN SITU CHEMICAL OXIDATION
ISB ENHANCED IN SITU BIOREMEDIAITON

OCCIDENTAL CHEMICAL CORPORATION
TACOMA, WASHINGTON

VOC MASS ALTERNATIVES TECHNOLOGIES
ESTIMATED DURATIONS

007843-C2D2-403
January 17, 2017

FIGURE 6.4

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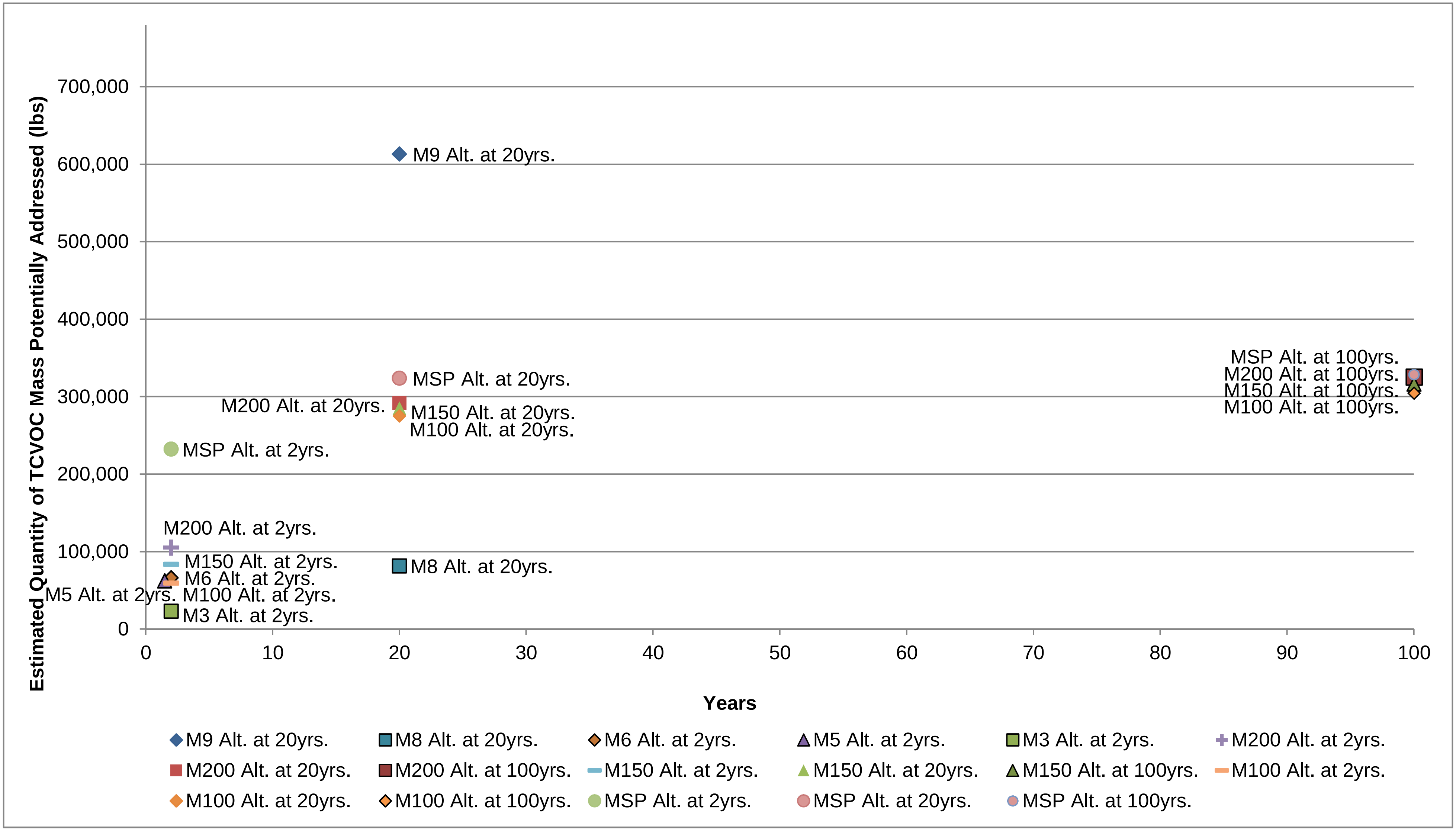


GHD

figure 6.5

Relationship Between Estimated Time and Estimated Quantity of TCVOC Mass Potentially Addressed

Occidental Chemical Corporation, Tacoma, Washington

007843 (139)

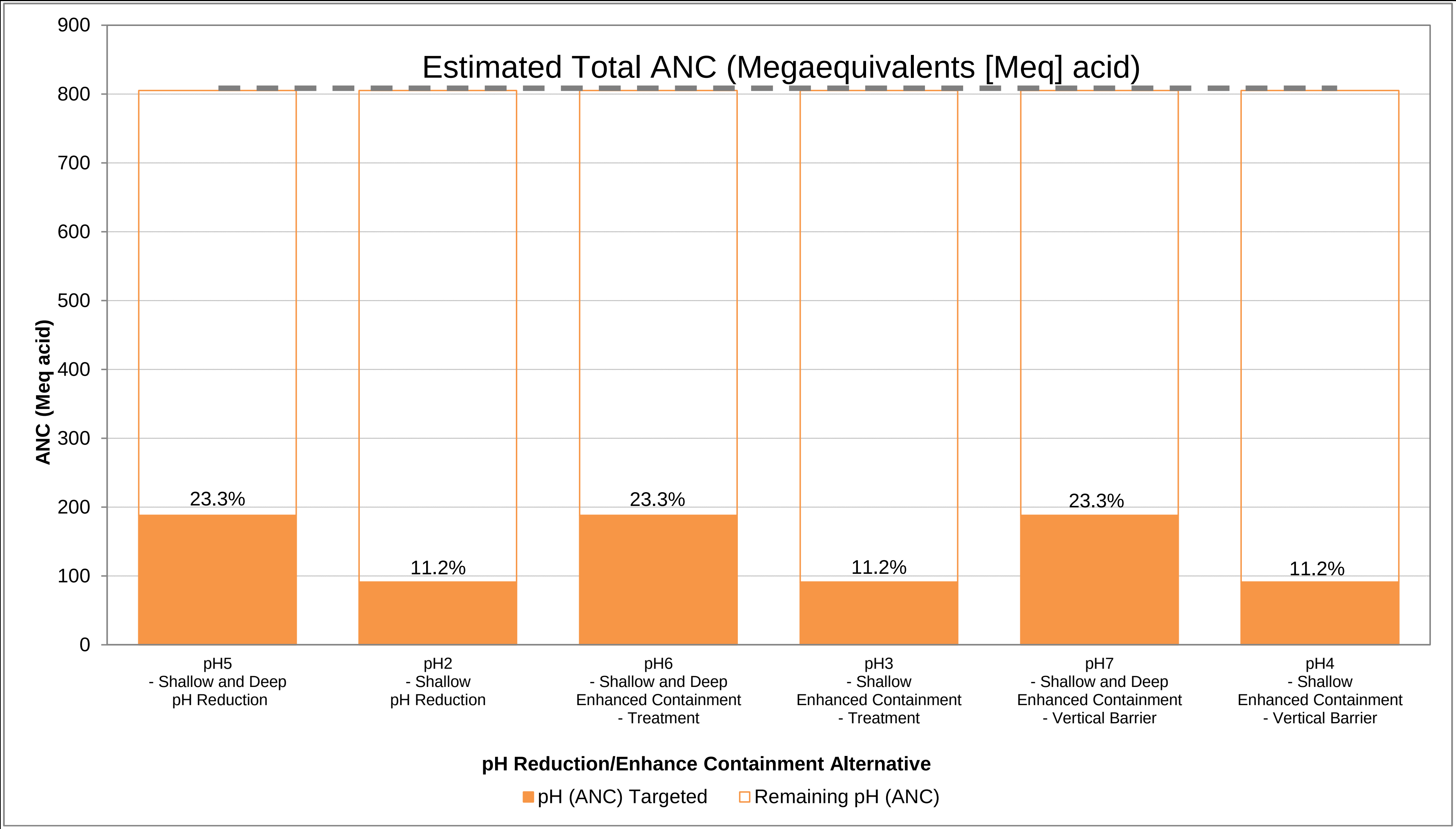


figure 7.1

pH (ANC) Targeted by Alternatives Comparison

Occidental Chemical Corporation, Tacoma, Washington

007843 (139)

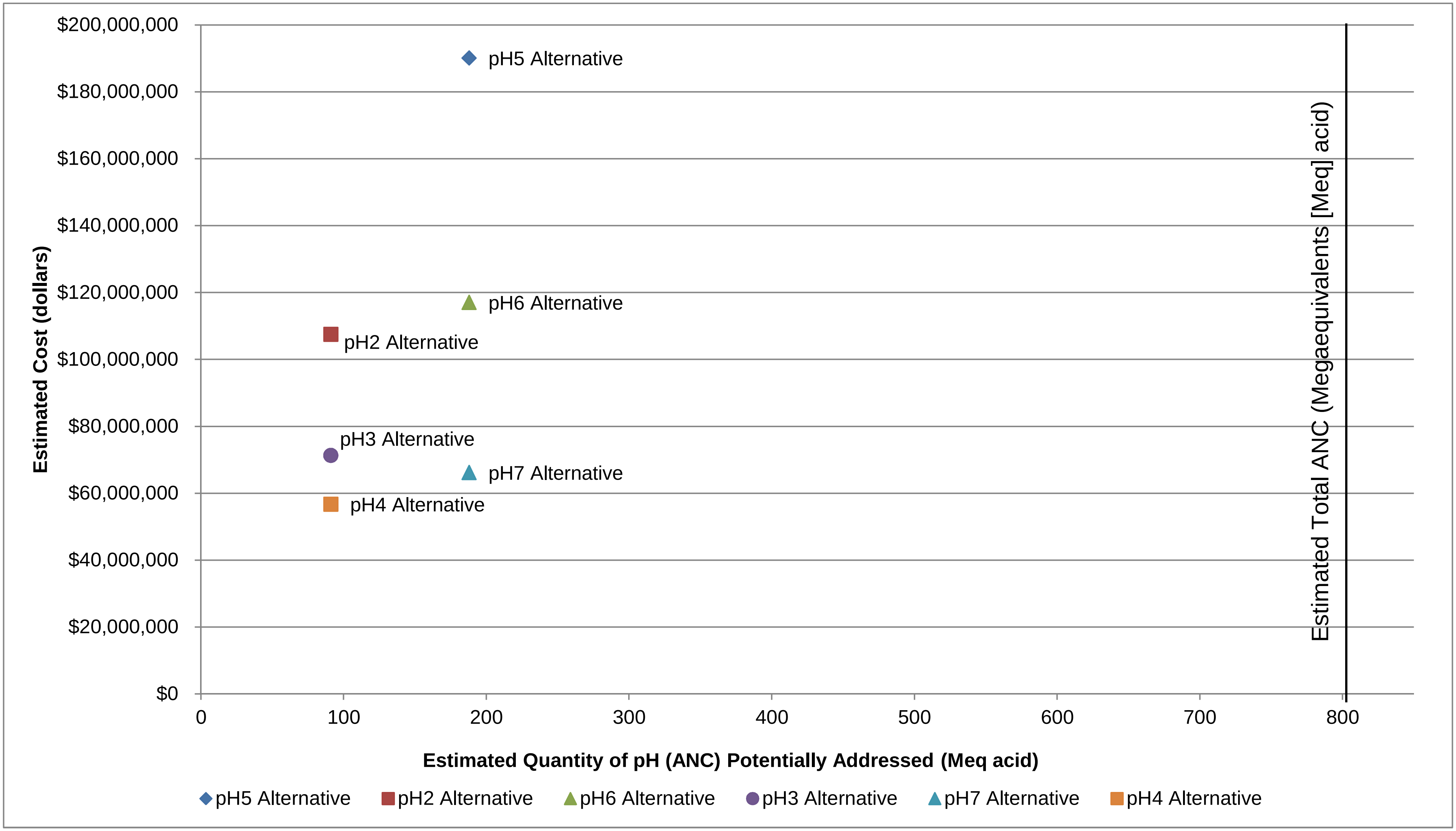


figure 7.2
Relationship Between Estimated Cost and Estimated Quantity of pH (ANC) Potentially Addressed
Occidental Chemical Corporation, Tacoma, Washington

007843 (139)

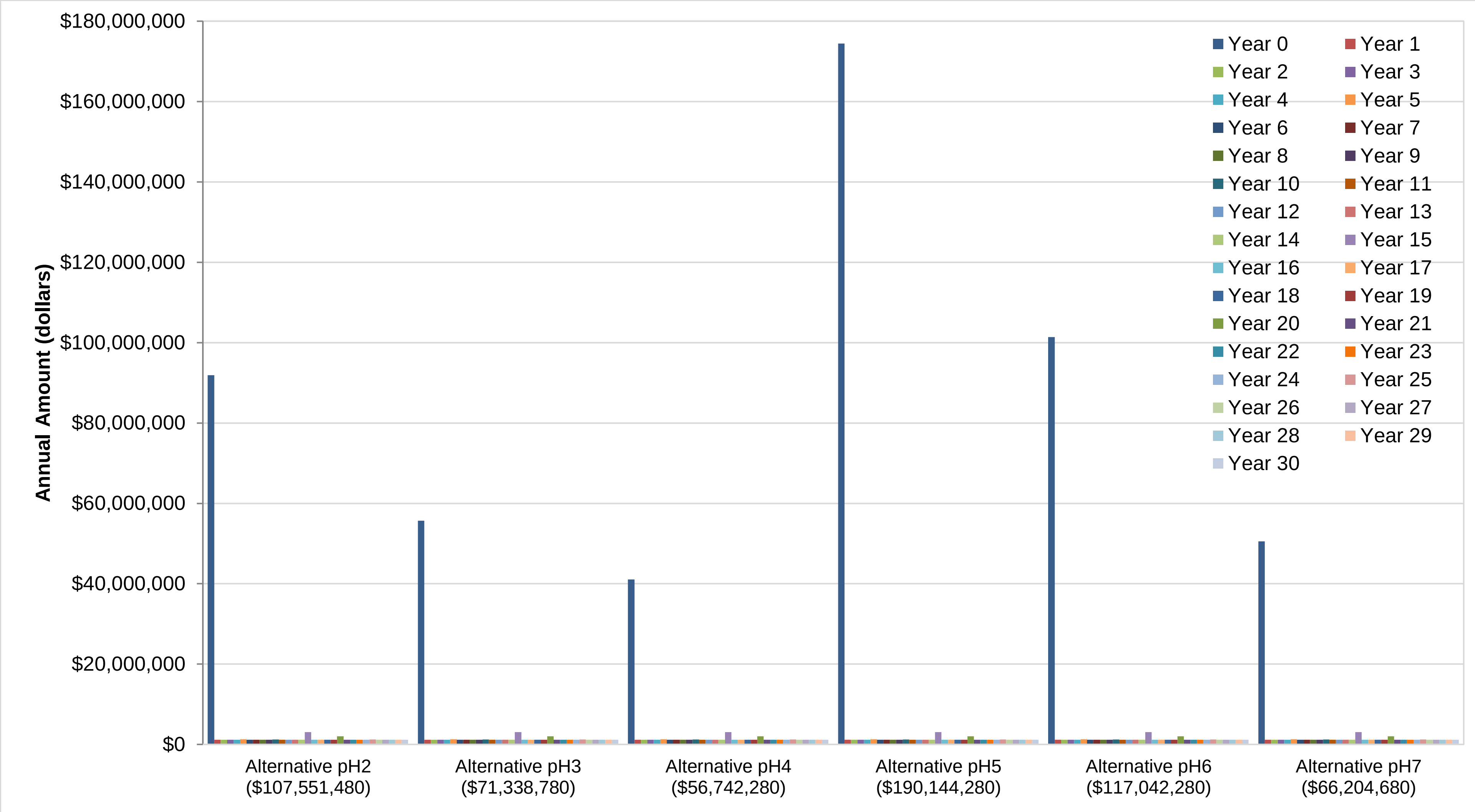
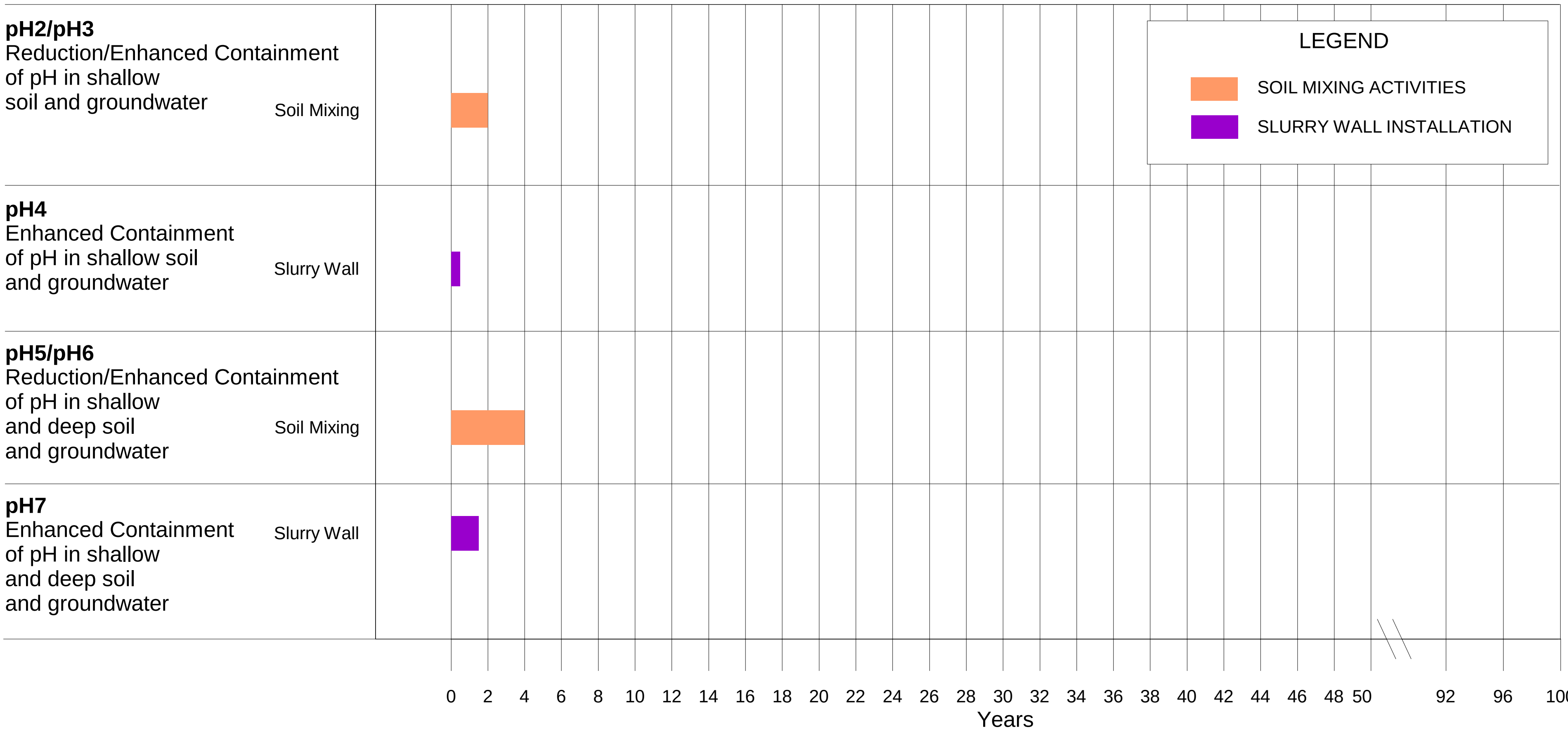


figure 7.3
pH Alternatives 30-Year Cash Flow Projections
Occidental Chemical Corporation, Tacoma, Washington

007843 (139)



OCCIDENTAL CHEMICAL CORPORATION
TACOMA, WASHINGTON

JOB NUMBER 007843-C2D2-403
DATE December 9, 2016

pH ALTERNATIVES TECHNOLOGIES
ESTIMATED DURATIONS

FIGURE 7.4

Hg file: I:\Hg\05000 to 09999\07843 - Tacoma\FS - cost estimates\cost estimate summaries\pH Durations.grf

Table 2.1

Sitewide COC and Media
Occidental Chemical Corporation
Tacoma, Washington

Contaminant of Concern (COC)	Groundwater	Porewater	Unsaturated Soil	Saturated Soil	Sediment	Indoor Air
VOCs						
1,1,2,2-Tetrachloroethane	√	-	-	√	NA	-
1,1,2-Trichloroethane	√	-	-	√	NA	-
1,1-Dichloroethene	√	-	-	√	NA	-
Carbon tetrachloride	√	-	√	√	NA	√
Chloroform (Trichloromethane	√	-	√	√	NA	√
Ethylbenzene	√	-	NA	NA	-	√
Methylene chloride	√	-	-	√	NA	-
Tetrachloroethene	√	-	√	√	-	√
cis-1,2-Dichloroethene	√	NA	NA	NA	NA	NA
trans-1,2-Dichloroethene	-	-	-	√	NA	-
Trichloroethene	√	-	√	√	NA	√
Vinyl chloride	√	√	√	√	NA	√
1,1,1-Trichloroethane	NA	NA	NA	NA	NA	-
1,2,4-Trimethylbenzene	NA	NA	NA	NA	NA	√
1,4-Dichlorobenzene	NA	NA	NA	NA	NA	√
Benzene	-	-	-	-	NA	√
m & p-Xylenes	-	-	-	-	NA	√
Naphthalene	-	-	-	√	NA	√
o-Xylene	-	-	-	-	NA	-
Styrene	NA	NA	NA	NA	NA	-
Toluene	-	-	-	-	NA	-
SVOCs						
1,2,4-Trichlorobenzene	NA	-	NA	NA	-	√
bis(2-Ethylhexly) phthalate	NA	-	NA	NA	-	√
Hexachlorobutadiene	√	-	√	√	-	√
Hexachlorobenzene	√	-	√	√	-	NA
Pentachlorophenol	√	-	√	√	-	NA
Acenaphthene	-	-	-	-	NA	NA
Acenaphthylene	NA	NA	NA	NA	NA	NA
Anthracene	-	-	-	-	NA	NA
Benz(a)anthracene	-	-	√	√	NA	NA
Benzo(a)pyrene	-	-	√	√	NA	NA
Benzo(b)fluoranthene	-	-	√	√	NA	NA
Benzo(k)fluoranthene	-	-	√	√	NA	NA
Chrysene	-	-	√	√	NA	NA
Dibenz(a,h)anthracene	-	-	√	√	NA	NA
Fluoranthene	-	-	-	-	NA	NA
Fluorene	-	-	-	-	NA	NA
Indeno(1,2,3-cd)pyrene	-	-	√	√	NA	NA
2-Methylnaphthalene	-	-	-	-	NA	NA
Naphthalene	-	-	-	√	NA	NA
Phenanthrene	NA	NA	NA	NA	NA	NA
Pyrene	-	-	-	-	NA	NA

Table 2.1

Sitewide COC and Media
Occidental Chemical Corporation
Tacoma, Washington

Contaminant of Concern (COC)	Groundwater	Porewater	Unsaturated Soil	Saturated Soil	Sediment	Indoor Air
Pesticides/PCBs						
4,4'-DDD	-	-	-	√	-	NA
4,4'-DDE	-	-	√	√	-	NA
4,4'-DDT	√	-	-	√	-	NA
Total PCBs	√	-	√	√	-	NA
Dioxin-Furan (2,3,7,8 TCDD)	NA	-	NA	NA	NA	NA
Metals						
Antimony	NA	-	NA	NA	-	NA
Arsenic	√	-	√	√	-	NA
Cadmium	NA	-	NA	NA	-	NA
Chromium, total	√	-	√	√	NA	NA
Copper	√	-	√	√	-	NA
Lead	√	-	√	√	-	NA
Mercury	√	-	√	√	-	-
Nickel	√	-	√	√	-	NA
Silver	NA	-	NA	NA	-	NA
Thallium	√	-	-	√	NA	NA
Zinc	√	-	√	√	-	NA
Other						
pH	√	-	NA	NA	NA	NA

Notes:

√ COC exceeds criterion in media indicated.
\- COC does not exceed criterion in media.
NA COC does not apply to the media or there is no established criteria.

Table 3.3

Remedial Action Goals and General Response Actions
Occidental Chemical Corporation
Tacoma, Washington

Environmental Medium	Remedial Action Objectives [1]	General Response Actions
Groundwater	1. Prevent discharge of contaminated groundwater to Hylebos Waterway and Commencement Bay resulting in surface water contaminant concentrations exceeding AWQC and applicable health based standards for aquatic life and human consumption of resident fish and shellfish. 2. Prevent discharge of contaminated groundwater to sediments in the Hylebos Waterway and Commencement Bay at concentrations that will re-contaminate the sediments above sediment quality standards for Site contaminants and applicable health based standards for aquatic life and human consumption of resident fish. 3. Prevent use of aquifer groundwater for drinking water, irrigation, or industrial purposes which would result in unacceptable risks to human health. 4. Prevent further migration of the contaminant plume and high pH plume to prevent the spread of contaminated groundwater to the Hylebos waterway, Commencement Bay, and non-impacted portions of the aquifer.	No Action Institutional Controls Containment/Extraction In-Situ Treatment Ex-Situ Treatment
Surface Water	1. Prevent marine ecological receptors from contacting surface waters that have contaminant concentrations that exceed surface water cleanup levels. 2. Prevent migration of hazardous substances, pollutants or contaminants to the surface waters at concentrations that exceed surface water cleanup levels. 3. Control bioaccumulation exposures to human receptors associated with releases to surface water from the Site.	General Response Actions for groundwater, sediment, and soil are protective of surface water

Table 3.3

Remedial Action Goals and General Response Actions
Occidental Chemical Corporation
Tacoma, Washington

Environmental Medium	Remedial Action Objectives [1]	General Response Actions
Soil	1. Prevent human health risks associated with direct contact, ingestion or inhalation of shallow soil contaminated above levels for industrial use 2. Prevent terrestrial ecological receptors from contacting soils that have contaminant concentrations that exceed industrial soil cleanup levels. 3. Prevent migration of hazardous substances, pollutants or contaminants from soil to the surface waters at concentrations that exceed surface water cleanup levels	No Action Institutional Controls Containment In-Situ Treatment Ex-Situ Treatment Removal Disposal
Indoor Air	1. Prevent human exposure to hazardous substances, pollutants, or contaminants from subsurface soil vapor at concentrations in excess of applicable standards and risk based cleanup levels.	No Action Institutional Controls Containment/Extraction In-Situ Treatment Ex-Situ Treatment

Note:

(1) Remedial Action Objectives (RAOs) for groundwater, sediment, soil, and indoor air are based on revisions captured in a February 10, 2015 email communication from Kevin Rochlin (USEPA Project Manager) in consultation with Ecology.

Table 3.4

Potential Applicable Local, State, and Federal Laws and Relevant and Appropriate Requirements
Occidental Chemical Corporation
Tacoma, Washington

Topic	Standard or Requirement	Regulatory Citation: Federal	Regulatory Citation: State and Local	Project-Specific Comments
Hazardous Substance Cleanup	Washington State Cleanup Standards; Cleanup Screening Levels (CSL)		Model Toxics Control Act (MTCA) (RCW 70.105D; WAC 173-340)	Applicable to determining cleanup of hazardous waste sites to protect human health and the environment.
Surface Water Quality	Surface water quality standards. National Recommended Water Quality Criteria (WQC); National Toxics Rule (NTR); State Water Quality Standards (WQS); Clean Water Act and NPDES Requirements Model Toxics Control Act (MTCA)	WQC per Clean Water Act Section 304(a) (33 USC § 1314) NTR at 40 CFR 131.36(b)(1) as applied to Washington, 40 CFR 131.36(d)(14) 40 CFR 122-125	Water Pollution Control Act (RCW 90.46); WQS (WAC 173-201A); Aquatic Life Criteria (ALC) numerical criteria (WAC 173-201A-240)	Relevant to remedial actions impacting contaminant migration to surface water and groundwater. Applicable to remedial actions involving discharge to a POTW. Substantive requirements will be applicable to any alternative that discharges effluent to surface water.
	State Waste Discharge Program; Clean Water Act Pretreatment Requirements	40 CFR Part 403 and 405-471	WAC-173-216	Applicable if the option of discharge to the sanitary sewer (POTW) is part of a remedy. Substantive requirements must be met.
Solid Waste Disposal	Requirements for solid waste handling management and disposal	Solid Waste Disposal Act (42 U.S.C 6901-6992K; 40 CFR 257-258)	Solid Waste Management (RCW 70.95; WAC 173-350)	Substantive requirements for non-dangerous or non-hazardous waste generated during remedial activities unless wastes meet recycling or other exemptions will be complied with.
Waste Treatment, Storage, and Disposal	Dangerous or Hazardous Waste Management Ecology Dangerous Waste Regulations	Resource Conservation and Recovery Act, Hazardous Waste (42 U.S.C §§ 6901-6992K, 40 CFR 260-279)	Dangerous Waste Management (RCW 70.105; WAC 173-303)	Applicable if remedial activities include land disposal of RCRA hazardous waste, such as that generated from excavation of waste that is characterized as hazardous.
	Transportation of Hazardous Waste	49 CFR 170-189		Applicable to remedial activities that involve the off-Site transportation of hazardous waste
Land Disposal of Waste	Management and disposal of materials containing polychlorinated biphenyls (PCBs)	Toxic Substances Control Act (15 U.S.C § 2605; 40 CFR 761.61(c))	Dangerous Waste Management (RCW 70.105; WAC 173-303- 140, 141)	Any dangerous or hazardous waste land disposal shall meet substantive land disposal requirements.
	Hazardous Waste Land Disposal Restrictions	Resource Conservation and Recovery Act Land Disposal Restrictions (42 U.S.C §§ 6901-6992K; 40 CFR 268)		
Dredge/Fill and Other In-Water Construction Work	Discharge of dredged/fill material into navigable waters or wetlands	Clean Water Act Sections 401, 404 (33 U.S.C §§ 1341, 1344; 40 CFR 121.2 (content of 401 certifications), 230 (disposal sites/mitigation), 232 (definitions/exemptions); 33 CFR 320, 322-3, 328-30 (Army Corps of Engineers 404 Permitting))	Hydraulic Code Rules (RCW 77.65; WAC 220-110) Dredged Materials Management Program (DMMP) (RCW 79.105.500; WAC 332-30-166 (3))	Applicable to construction of barrier wall east.
	Navigation and Commerce	Rivers and Harbor Act Section 10 (33 U.S.C. § 403)		Unauthorized obstruction or alteration of navigable waterways is prohibited. In-water dredging and disposal are not anticipated.

Table 3.4

Potential Applicable Local, State, and Federal Laws and Relevant and Appropriate Requirements
Occidental Chemical Corporation
Tacoma, Washington

Topic	Standard or Requirement	Regulatory Citation: Federal	Regulatory Citation: State and Local	Project-Specific Comments
Endangered Species and Critical Habitat	Taking or jeopardy to endangered or threatened species; adverse modification of critical habitat	Endangered Species Act (16 U.S.C.§§ 1531-1544; 50 CFR 17 (listings, prohibitions), 402 (interagency consultations), 222-224 (endangered and threatened marine species), 226.212 (critical habitat for Northwest salmon and steelhead))		It is unlawful to take (or possess, deliver, carry, transport or ship) any endangered species, or violate any regulation re-endangered or threatened species. EPA in consultation with the Services shall insure any authorized action is not likely to jeopardize endangered or threatened species or adversely modify critical habitat, absent an exemption.
Migratory Birds	Taking or adversely affecting migratory birds	Migratory Bird Treaty Act, (16 U.S.C §§ 703-712; 50 CFR 10 and 21)		Applicable to avoid adversely affecting migratory bird species as defined in federal regulations, including individual birds and their nests.
Eagles	Taking or harming eagles	Bald and Golden Eagle Protection Act (16 U.S.C. § 668, 50 CFR 22)	Bald Eagle Protection Rules (RCW 77.12.655; WAC 232-12-292)	Taking or harming of eagles, their eggs, nests or young is prohibited; substantive requirements for the protection of bald eagle habitat including nesting, perching and roosting at the site will be met.
Floodplain Protection	Adverse impacts; potential harm	Floodplain Management Procedures (40 CFR 6, Appendix A, Section 6, see also Executive Order 11988)		Applicable to avoid potential adverse impacts and to minimize impacts for which no practical alternative exists.
Shoreline Management	Construction and development		Shoreline Management Act RCW 90.58; WAC 173-26; City of Tacoma Shoreline Master Program; Pierce County Shoreline Master Program (18S.10.010 Title.21)	Master plans within their jurisdiction apply within 200 feet of the shoreline to the extent they impose or establish more stringent requirements.
Air Emissions	Ambient air quality standards; fugitive emission/fugitive dust	Clean Air Act (42 U.S.C. §§ 7401-7671q; 40 CFR 50)	Washington Clean Air Act (RCW 70.94; WAC 173-400)	Some treatment alternatives may impact ambient air quality. Substantive requirements will be applicable if alternative results in emission from treatment processes.
	National Ambient Air Quality Standards (NAAQS)	40 CFR Part 50		Applicable to treatment alternatives that may emit pollutants to the air, establishes standards to protect health and welfare.
	National Emission Standards for Hazardous Air Pollutants (NESHAPs)	40 CFR Part 261		Applicable to treatment alternatives that my emit toxic pollutants to the air.
	State Environmental Policy Act (SEPA)		WAC 192-11	SEPA checklist may be required prior to construction of the remediation system.
Native American Graves and Sacred Sites	Protections	Native American Graves Protection and Repatriation Act (25 U.S.C. §§ 3001 et seq.); American Indian Religious Freedom Act (42 U.S.C. §§ 1196 et seq.)		Requirements for the protection of Native American remains, funerary objects and associated cultural artifacts when burial sites are encountered; and protection of tribal exercise of traditional tribal religions, including traditional cultural properties, sites and archeological resources. See also Executive Order 13007 which requires federal agencies to avoid physical damage to tribal sacred sites, and interfering with access of tribes thereto.

Table 3.4

Potential Applicable Local, State, and Federal Laws and Relevant and Appropriate Requirements
Occidental Chemical Corporation
Tacoma, Washington

Topic	Standard or Requirement	Regulatory Citation: Federal	Regulatory Citation: State and Local	Project-Specific Comments
Noise	Permissible noise levels		Noise Control Act (RCW 70.107;WAC 173-60-040-050)	Maximum levels at specified times for specified durations are WAC 173-60-040, subject to exemptions in WAC 173-60-050, including 050(3)(a) (sounds originating from temporary construction sites as a result of construction activity) and (3)(f) (sounds created by emergency equipment and work necessary in the interests of law enforcement or for health, safety or welfare of the community).
Historic Preservation		National Historic Preservation Act Section 106 (16 U.S.C. § 470; 36 CFR 800)		Potentially applicable if potential remedial activity on the site, building, structure, or object included or eligible for inclusion in the National Register of Historic Places.
Groundwater Quality	EPA Underground Injection Control (UIC) Program Regulations	40 CFR 144 and 146		To be considered for any in situ remediation technologies that involve injection into an aquifer.
Construction	City of Tacoma requirements			Establishes criteria for review and analysis of all development, including grading, erosion control, and property development. Requires permits for excavation of soil in excess of 50 cubic yards and construction and demolition activities. SEPA checklist required if soil excavation is greater than 500 cubic yards. Permit required for connection if effluent water from the treatment system to the storm drain system. Even though it is necessary to meet the substantive provisions of these permits, appropriate permits should be obtained from the City for future site work in the spirit of cooperation.
	Tacoma Power			Permits required for power connections and wiring for remediation systems.

Table 4.1

Identified Alternatives and Groupings
Occidental Chemical Corporation
Tacoma, Washington

Group	Identification Nomenclature	Technology/ Process Options Included
Containment		No action
	C100	Barrier wall east, physical direct contact exposure (PDCE) barrier, hydraulic containment
	C150	Barrier wall east, physical direct contact exposure (PDCE) barrier, hydraulic containment with up to 50 percent more pumping
	C200	Barrier wall east, physical direct contact exposure (PDCE) barrier, hydraulic containment with up to 100 percent more pumping
VOC Mass Removal / Reduction		No additional action
	M100	VOC source area groundwater (gw) extraction
	M150	VOC source area gw extraction with up to 50 percent more pumping
	M200	VOC source area gw extraction with up to 100 percent more pumping
	MSP	VOC source area mass reduction by strategic groundwater pumping
	M3	VOC source area shallow soil excavation (TCVOC≥100mg/kg) to -4 ft. NGVD with on-site treatment
	M4	VOC source area shallow soil excavation (TCVOC≥100mg/kg) to -4 ft. NGVD with off-site treatment/ disposal
	M5	VOC source area shallow soil treatment (TCVOC≥500mg/kg) using ERH in saturated zone 2.5 ft. to -21 ft. NGVD and SVE in vadose zone
	M6	VOC source area shallow soil treatment (TCVOC≥500mg/kg) using ERH from -4 ft. to -21 ft. NGVD with SVE to collect soil gas from ERH, and soil excavation to -4 ft. NGVD with on-site treatment
	M7	VOC source area shallow soil treatment (TCVOC≥500mg/kg) using ERH from -4 ft. to -21 ft. NGVD with SVE to collect soil gas from ERH, and soil excavation to -4 ft. NGVD with off-site treatment/ disposal
	M8	VOC shallow gw treatment (TCVOC≥10,000µg/L) using ISCO within pH 10-12.5s.u. and ISB within pH <10s.u. to -60 ft. NGVD, VOC source area shallow soil treatment (TCVOC≥500mg/kg) using SVE in vadose zone and ERH in saturated zone 2.5 ft.to -21 ft. NGVD
	M9	VOC shallow and deep gw treatment (TCVOC≥10,000µg/L) using ISCO within pH 10-12.5s.u. and ISB within pH <10s.u., VOC source area shallow and deep soil treatment (TCVOC≥500mg/kg) using SVE in vadose zone, ERH in saturated zone 2.5 ft. to -21 ft. NGVD, and ISCO/ ISB below -60 ft. NGVD
pH ≥12.5s.u. Reduction / Enhanced Containment		No additional action
	pH2	pH ≥12.5s.u. in shallow soil and gw treatment using in situ mixing (persulfate) to -60 ft. NGVD
	pH3	pH ≥12.5s.u. in shallow soil and gw treatment using in situ mixing (cement) to -60 ft. NGVD
	pH4	Enhance containment of pH ≥12.5s.u. in shallow gw using slurry walls to -60 ft. NGVD
	pH5	pH ≥12.5s.u. in shallow and deep soil and gw treatment using in situ mixing (persulfate)
	pH6	pH ≥12.5s.u. in shallow and deep soil and gw treatment using in situ mixing (cement)
	pH7	Enhance containment of pH ≥12.5s.u. in shallow and deep gw using slurry walls

Notes:

ERH	electrical resistance heating
ISCO	in situ chemical oxidation
ISB	in situ bioremediation
TCVOC	total chlorinated volatile organic compounds
ft. NGVD	feet above/below National Geodetic Vertical Datum
mg/kg	milligrams per kilogram
µg/L	micrograms per liter
s.u.	standard units of pH

Table 5.1

Disproportionate Cost Analysis Criteria Site-Specific Weighting Percentages and Rationale
Occidental Chemical Corporation
Tacoma, Washington

Evaluation Criteria and WAC Citations	Weighting Percentages and Rationales	Considerations
Protectiveness: WAC 173-340-360(3)(f)(i)	**30%:** highest weighting percentage because it is a minimum or threshold requirement	Protection of human health and environment; Comply with clean up standards; Comply with applicable state and federal laws; Provide compliance monitoring
Permanence: WAC 173-340-360(3)(f)(ii)	**20%:** higher weighting percentage because of MTCA requirement to use permanent solutions to maximum extent practicable	Reduction in quantity of hazardous substances
Effectiveness Over the Long Term: WAC 173-340-360(3)(f)(iv)	**20%:** higher weighting percentage because of MTCA requirement to try and achieve a reasonable restoration time frame	Degree of certainty that the remedial alternative will be effective over the long term; Reliability of institutional and engineering controls
Management of Short-term Risks: WAC 173-340-360(3)(f)(v)	**10%: W**eighting percentage assigned because the short-term risks for the proposed alternatives are manageable with standard industry practice	Ease of managing short-tem risks
Technical and Administrative Implementability: WAC 173-340-360(3)(f)(vi)	**10%: W**eighting percentage assigned because the technologies are all considered to be readily implementable	Technical complexity of technologies; Administrative (legal, regulatory, and monitoring) requirements
Consideration of Public Concerns: WAC 173-340-360(3)(f)(vii)	**10%:** Weighting percentage assigned because 2016 porewater / sediment data alleviates the main issues raised by public in during Public Comment Period from October 23, 2015 to February 1, 2016	Consider potential public support for each alternative

Notes:
The Cost criterion [WAC 173-340-360(3)(f)(iii)] is not listed above because it is not weighted or ranked in the disproportionate cost analysis (DCA).
WAC - Washington Administrative Code.
MTCA - Model Toxics Control Act Regulation and Statute.

Table 5.3

Disproportional Cost Analysis (DCA) - Containment Alternatives
Occidental Chemical Corporation
Tacoma, Washington

			Alternative C150	Alternative C200
Threshold Criteria				
	Protection of Human Health and the Environment		Yes	Yes
	Compliance with Cleanup Standards		Yes	Yes
	Compliance with Applicable State and Federal Laws		Yes	Yes
	Provision for Compliance Monitoring		Yes	Yes
Weighted Benefits Rankings/Scores for DCA (1 [lowest] to 10 [highest])[1]				
Weighted Criteria (refer to Table 5.1 for explanation of weighting)			Benefit Scoring	Benefit Scoring
	30%	Overall Protectiveness	9	9
	20%	Permanence	5	5
	20%	Long-Term Effectiveness	8	8
	10%	Management of Short-Term Risk	8	8
	10%	Implementability	8	8
	10%	Consideration of Public Concerns	5	5
	Total Benefit Score (weighted)[2]		7.4	7.4
Alternatives Costs[3]				
	Estimated Costs (-30% to +50%; 30-years at 7% discount rate)			
		Capital	$ 38,700,240	$ 38,700,240
		Operation and Maintenance/Periodic	$ 15,656,240	$ 16,490,000
		Total Estimated Alternative Cost	$ 54,356,480	$ 55,190,240
	Unit Benefit per Cost Ratio[4] (multiplied by 10,000,000)		1.36	1.34

Notes:

[1] Higher scores equate to a higher level of relative benefit.

[2] The Total Benefit Score (weighted) was calculated by multiplying each Benefit Score by multiplying each Benefit Score by the corresponding Weighted Criteria percent, then summing the weighted values.

[3] Alternative costs in Appendix G.

[4] Unit Benefit per Cost Ratio calculated by dividing the Total Benefit Score (weighted) by the total alternative cost (in 10 millions). A higher ratio indicates the most benefit for the associated cost.

Table 6.2

Disproportional Cost Analysis (DCA) - VOC Mass Reduction/Removal Alternatives
Occidental Chemical Corporation
Tacoma, Washington

		Alternative MSP	Alternative M9	Alternative M200	Alternative M150	Alternative M100	Alternative M8	Alternative M6	Alternative M5	Alternative M3	Alternative No Additional Action
Threshold Criteria[1]											
Protection of Human Health and the Environment		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Compliance with Cleanup Standards		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Compliance with Applicable State and Federal Laws		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Provision for Compliance Monitoring		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Weighted Benefits Rankings/Scores for DCA (1 [lowest] to 10 [highest])[2]											
Weighted Criteria (refer to Table 5.1 for explanation of weighting)											
30%	Overall Protectiveness	9	9	9	9	9	9	9	9	9	9
20%	Permanence	6	8	5	5	5	4	3	3	2	1
20%	Long-Term Effectiveness	7	7	7	7	7	7	7	7	7	1
10%	Management of Short-Term Risk	8	5	8	8	8	5	7	7	8	10
10%	Implementability	9	6	9	9	9	7	9	9	9	10
10%	Consideration of Public Concerns	5	5	5	5	5	5	5	5	5	5
Total Benefit Score (weighted)[3]		7.5	7.3	7.3	7.3	7.3	6.6	6.8	6.8	6.7	5.6
Alternatives Costs[4]											
Estimated Costs (-30% to +50%; 30-years at 7% discount rate)											
	Capital	$ 38,854,780	$ 354,880,940	$ 38,903,190	$ 38,903,190	$ 38,903,190	$ 114,264,240	$ 52,488,140	$ 50,712,040	$ 41,366,240	$ 38,700,240
	Operation and Maintenance/Periodic	$ 16,022,750	$ 46,373,420	$ 17,329,450	$ 16,935,580	$ 16,539,240	$ 27,741,770	$ 15,656,240	$ 15,656,240	$ 15,656,240	$ 15,656,240
	Total Estimated Alternative Cost	$ 54,877,530	$ 401,254,360	$ 56,232,640	$ 55,838,770	$ 55,442,430	$ 142,006,010	$ 68,144,380	$ 66,368,280	$ 57,022,480	$ 54,356,480
Unit Benefit per Cost Ratio[5] (multiplied by 10,000,000)		1.37	0.18	1.30	1.31	1.32	0.46	1.00	1.02	1.17	1.03

Notes:
[1] Meeting threshold criteria assumes containment technologies are part of an overall remedy.
[2] Higher scores equate to a higher level of relative benefit.
[3] The Total Benefit Score (weighted) was calculated by multiplying each Benefit Score by multiplying each Benefit Score by the corresponding Weighted Criteria percent, then summing the weighted values.
[4] Alternative costs in Appendix G.
[5] Unit Benefit per Cost Ratio calculated by dividing the Total Benefit Score (weighted) by the total alternative cost (in 10 millions). A higher ratio indicates the most benefit for the associated cost.

Table 7.2

Disproportional Cost Analysis (DCA) - pH Reduction/Enhanced Containment Alternatives
Occidental Chemical Corporation
Tacoma, Washington

		Alternative pH5	Alternative pH2	Alternative pH6	Alternative pH3	Alternative pH7	Alternative pH4	Alternative No Additional Action
Threshold Criteria[1]								
Protection of Human Health and the Environment		Yes	Yes	Yes	Yes	Yes	Yes	Yes
Compliance with Cleanup Standards		Yes	Yes	Yes	Yes	Yes	Yes	Yes
Compliance with Applicable State and Federal Laws		Yes	Yes	Yes	Yes	Yes	Yes	Yes
Provision for Compliance Monitoring		Yes	Yes	Yes	Yes	Yes	Yes	Yes
Weighted Benefits Rankings/Scores for DCA (1 [lowest] to 10 [highest])[2]								
Weighted Criteria (refer to Table 5.1 for explanation of weighting)								
30%	Overall Protectiveness	9	9	9	9	9	9	9
20%	Permanence	3	2	1	1	1	1	1
20%	Long-Term Effectiveness	3	2	1	1	1	1	1
10%	Management of Short-Term Risk	5	5	4	5	6	7	10
10%	Implementability	4	6	4	6	5	7	10
10%	Consideration of Public Concerns	5	5	5	5	5	5	5
Total Benefit Score (weighted)[3]		5.3	5.1	4.4	4.7	4.7	5	5.6
Alternatives Costs[4]								
Estimated Costs (-30% to +50%; 30-years at 7% discount rate)								
	Capital	$ 174,488,040	$ 91,895,240	$ 101,386,040	$ 55,682,540	$ 50,548,440	$ 41,086,040	$ 38,700,240
	Operation and Maintenance/Periodic	$ 15,656,240	$ 15,656,240	$ 15,656,240	$ 15,656,240	$ 15,656,240	$ 15,656,240	$ 15,656,240
	Total Estimated Alternative Cost	$ 190,144,280	$ 107,551,480	$ 117,042,280	$ 71,338,780	$ 66,204,680	$ 56,742,280	$ 54,356,480
Unit Benefit per Cost Ratio[5] (multiplied by 10,000,000)		0.28	0.47	0.38	0.66	0.71	0.88	1.03

Notes:

[1] Meeting threshold criteria assumes containment technologies are part of an overall remedy.

[2] Higher scores equate to a higher level of relative benefit.

[3] The Total Benefit Score (weighted) was calculated by multiplying each Benefit Score by multiplying each Benefit Score by the corresponding Weighted Criteria percent, then summing the weighted values.

[4] Alternative costs in Appendix G.

[5] Unit Benefit per Cost Ratio calculated by dividing the Total Benefit Score (weighted) by the total alternative cost (in 10 millions). A higher ratio indicates the most benefit for the associated cost.

Appendices

Appendix A
State of Washington Department of Ecology - Groundwater Non-Potable Determination

STATE OF WASHINGTON

DEPARTMENT OF ECOLOGY

Lacey HQ ● 300 Desmond Dr. ● Lacey, Washington 98503 ● (360) 407-6000

March 30th, 2015

TO: Kerry Graber, HWTR

FROM: Charles San Juan, LHG, TCP-HQ *Charles San Juan*

SUBJECT: Groundwater Non-Potability Designation, former Occidental Chemical (OCC) Site, Tacoma.

<u>Summary</u>

This transmittal provides both the legal framework and technical justification for designating the Occidental site groundwater as non-potable (unfit for human consumption). Briefly, this non-potability designation is based on two components within MTCA Section 720. First, Ecology has determined that site groundwater is not a current source or future source of drinking water. Second, Ecology, as well as CRA (2014), have determined that site groundwater contains naturally occurring saltwater levels, which renders it unfit for human consumption. Lastly, Ecology (1995) has completed a Comprehensive Ground Water Protection Program (CGWPP). If a state has completed a CGWPP, then the EPA remediation program may defer to the state for groundwater current / future use designations (EPA, 1997). This means that Ecology now has jurisdiction for this current / future use designation, per prior agreement with EPA.

<u>Conceptual Site Model</u>

The groundwater non-potability designation means the human ingestion of groundwater exposure pathway does not apply to this site. Therefore, the final cleanup remedy for this site will be based on two exposure pathways: 1) groundwater discharge to surface water, which includes marine sediments /aquatic life and 2) vapor intrusion (human inhalation of indoor air).

<u>Organization of this Transmittal</u>

There are four parts to this document. A brief synopsis of each part is as follows:

- Part I contains background information (site description, land use, geology / hydrogeology, etc).
- Part II provides information on the MTCA Section 720 criteria for designating non-potable groundwater. Part II also contains an analysis of current fresh / saltwater conditions.
- Part III provides information on the EPA guidelines / criteria for groundwater non-potability.

- Part IV provides a conclusion and summary observations.

Part I – Background Information

Site Description

The Occidental Chemical (OCC) property (605 and 709 Alexander Avenue) is located within a man-made peninsula of land that extends roughly 0.8 miles northwest into Commencement Bay (Figure 1). The Port of Tacoma (POT) is the primary owner / operator for this area. The Occidental "site" (where hazardous substances are located, MTCA Section 200) is part of the EPA Commencement Bay Nearshore/Tideflats (CB/NT) Superfund Site. An affiliate of OCC (Mariana Properties), now owns the 605 Alexander Avenue parcel. The 709 Alexander parcel has also been conveyed to Mariana Properties (CRA, 2014).

Historical OCC Operations

Chlorinated solvents (TCE / PCE), were manufactured at the OCC facility from approximately 1947 – 1973. Historical solvent releases from former OCC operations have impacted the peninsula soil, groundwater and adjoining Hylebos Waterway sediment (CRA, 2014).

Land Use / History

Historical transcontinental railroad traffic to Commencement Bay resulted in the need for rail to sea transport. However, the flat tidal mud flats were not suitable for deep draft vessels. Consequently, to accommodate shipping traffic, five man-made peninsulas were constructed (from tidal mud flats dredge / fill). The former OCC site is located on the peninsula that intersects both the Blair and Hylebos waterways.

Site Geology / Hydrogeology

The former OCC site is located at the mouth of the Puyallup River valley, which empties to Commencement Bay. Several creeks also discharge to Commencement Bay (Ruston, Mason, Asarco, Puget, Hylebos and Wapato). Historically, the hydrogeology of this area was tidal marsh / estuary, as well as Puyallup River deltaic deposits. A key point is that the OCC site is located on land reclaimed from the sea. Therefore, the natural state (or occurrence) of underlying groundwater has probably always been more of a fresh / saltwater mix (brackish).

Part II – MTCA Section 720 Criteria

Groundwater Non-Potability Criteria

Non-potable groundwater is defined in MTCA Section 720 (Chapter 173-340 WAC). Groundwater may be deemed non-potable if it is demonstrated that it is not a current or future drinking water source. There are several criteria for non-potability. A brief description of key criteria as well as whether it applies to this OCC site is provided herein.

Yield

If the groundwater yield is less than 0.5 gpm on a "sustainable" basis, then it can be assumed that the groundwater is non-potable. This criteria is not met at the Occidental Site because yields greater than 0.5 are routinely observed in groundwater extraction wells and in groundwater monitoring wells.

Natural Background Concentrations

If there are naturally occurring substances that render groundwater non-potable, then the aquifer can be designated as non-potable. The OCC site groundwater has been impacted by salinity intrusion from the surrounding waterways. Therefore, this site does qualify for the natural background (salinity) non-potability designation. The remainder of this section speaks to two substances that were used to quantify naturally occurring salinity levels: total dissolved solids (TDS) and bromide.

Total Dissolved Solids

Per the Section 720 regulations, groundwater with naturally occurring total dissolved solids (TDS) levels > 10,000 mg/L may be deemed non-potable. TDS measures minerals and salts dissolved in water. TDS are typically those compounds that cannot be removed by traditional water filters. The EPA secondary drinking water standard for TDS is 500 mg/L.

As part of a salinity intrusion study (CRA, 2013), groundwater TDS levels were measured. Most of the groundwater TDS data is from the 2012-13 sampling events, however, some of the wells have historical TDS levels as well (CRA "e-dat" database). A query of the 2012-13 groundwater TDS data resulted in 361 records, from wells with depths from 0 to -175 ft elevation.

However, OCC did use salt (sodium chloride) to produce chlorine gas and caustic soda (CRA, 2014). This salt was stored on a 1.6 acre salt pad (land surface). This historical chlorine gas / soda production has resulted in a significant groundwater caustic plume, with pH levels in the 11-12 range. This in turn has resulted in what has come to be known as the anthropogenic density plume (ADP). This ADP is a mixture of caustic soda, lime sludge and solvent residue (CRA, 2014).

Therefore, given that sodium chloride was used in historical OCC operations, TDS may not be a reliable measure of what is truly "naturally occurring". However, for 2012-13, there are wells with higher TDS levels (> 10,000 mg/L) that are located outside the pH / ADP footprint. As a footnote, OCC's manufacturing operations were from 1929 – 2002 (CRA, 2014). Therefore, the 2012-13 groundwater TDS data was collected ten years after OCC ceased operations. Consequently, some fraction of the 2012-13 groundwater TDS data set is thought to be suitable for a non-potability designation.

Thus, data from what is thought to be non-impacted (i.e. background) wells was used to assess salinity (from TDS). The following methods were used to filter / process the 2012-13 groundwater TDS data:

- Reduce the data to those wells west and south of the former OCC plant. This results in 100 data records, from wells ranging in depth from 0 to -150 ft elevation.

- Subdivide the data into 25 ft thick intervals (layers) and sort the data by elevation (e.g. 0 to -25, -25 to -50 ft, etc). The was done to accommodate various wells screened over different depths (elevations).

- Calculate the average groundwater TDS level for each 25 ft interval.

The resulting overall average groundwater TDS level is 10,600 mg/L (100 records). Spatially, it appeared that there were higher TDS levels more to the west (along the Blair Waterway; Figure 2). TDS levels did increase over depth (elevation). Specifically, the average groundwater TDS level from 0 to -50 ft elevation was < 5,000 mg/L. However, the average TDS level from -50 to -150 ft elevation was between ~20,000 and 25,000 mg/L (Table 1; Figure 3 TDS v. depth plot; Figure 4 interval / box plots). This suggests that there is a freshwater lens from roughly 0 to -50 ft elevation, with denser seawater from -50 to -150 ft elevation.

A conclusion that can be derived from this evaluation is that peninsula groundwater contains naturally high TDS levels (> 10,000 mg/L), which makes it unfit for human consumption. Ideal drinking water has 0 – 50 mg/L TDS and hard to marginally-acceptable water has 200 – 400 mg/L TDS. For this data set (2012-13), about 80% of the levels exceeded the EPA secondary MCL of 500 mg/L. Likewise, 40% of the data set was greater than 10,000 mg/L TDS. Historical OCC operations (pH / ADP plume) may have biased some of these TDS levels. However, again, this data set was filtered / reduced to account for potential anthropogenic impacts. Therefore, the weight of evidence points to groundwater with naturally occurring salinity levels that are unfit for human consumption.

<u>Percent Seawater</u>

In 2013, a site salt / freshwater equilibrium study was conducted (CRA, 2013). The objective of this study was to determine natural saltwater / freshwater equilibrium conditions. For this study, ten common seawater ions (boron, bromide, calcium, chloride, iodide, magnesium, potassium, sodium, strontium, and sulfate) were measured. Of these ten, it was determined that several were used in historical OCC operations (e.g. calcium, iodide and magnesium) and were therefore unsuitable for the salinity intrusion analysis. In the end, bromide was used to assess fresh / saltwater equilibrium.

Percent seawater levels were calculated using a mixing equation with estimated background concentrations for bromide in freshwater and in saltwater. As with the TDS data, average percent seawater levels were calculated from 25 ft elevation intervals (from 0 to -175 ft). Average saltwater levels based on the observed bromide concentrations range from roughly 10 to 50% over depth (Table 2). Like TDS, average percent seawater levels increased over depth and again, like TDS, percent seawater levels peaked at -50 to -75 ft (Figure 5). The -50 to -75 elevation peak was then followed by a gradual decline in percent levels to -175 ft elevation. Percent seawater interval and box plots are also provided in Figure 6.

To better understand percent seawater levels over depth (elevation), the data were spatially mapped (using kernel smoothing and filled contours; Figure 7). Results are as follows:

- 0 to -25 ft – predominantly freshwater across the peninsula, with smaller seawater lenses both northeast and southeast of the former OCC property.

- -25 to -50 ft – more salinity intrusion along the northeast tip of the peninsula as well as a freshwater lens that sort of centers (or follows) Alexander Avenue.

- -50 to -75 ft – most of the peninsula is now predominantly seawater, however, there is freshwater lens that centers beneath the former OCC property.

- -75 to -100 ft – most of the peninsula is predominantly seawater, however, there is freshwater lens more to the west (towards the Blair Waterway).

- -100 to -125 ft – most of the peninsula is predominantly seawater, however, there is a freshwater from the OCC property trending northwest.

- -125 to -150 ft – most of the peninsula is predominantly seawater, however, the northwest trending freshwater lens (from the OCC property) is more pronounced.

- -150 to -175 ft – there's really not enough data points (only 5) to draw any meaningful conclusion. However, what you observe is a freshwater lens along the north tip of the peninsula.

In summary, as with the TDS data, it appears that there is a freshwater lens within the middle of the peninsula, from about 0 to -50 ft elevation. However, below -50 ft elevation, saltwater levels gradually increased and then declined.

From this evaluation, it can be concluded that in its natural state, the peninsula groundwater is a mix of both fresh / seawater. There are higher freshwater levels near land surface, however, seawater levels increase over depth. Consequently, in its natural state (high salinity), this groundwater is unfit for human consumption.

Effect of Pumping on the Distribution of Saltwater

The distribution of saltwater and freshwater at the Occidental site inferred from the TDS and bromide data consists of a relatively thin freshwater lens that is underlain and surrounded laterally by saltwater. The lateral extent of the shallow freshwater lens is constrained by saltwater from Commencement Bay to the north, the Blair Waterway to the west, and the Hylebos Waterway to the east. The aquifer that contains the freshwater lens is an unconfined aquifer comprised of fluvial and deltaic deposits. There are no stratigraphic layers or boundaries to separate the freshwater lens from the surrounding saltwater. Pumping fresh groundwater at the site will cause additional saltwater intrusion from both lateral boundaries and from underlying saltwater zones. Zones of freshwater that might be considered for water supply would be highly susceptible to saltwater contamination from surrounding and underlying areas.

Fresh / Saltwater Equilibrium Summary

Both TDS and percent seawater increase significantly at elevations below roughly -50 ft. This is consistent with the site conceptual model for fresh / saltwater conditions. Specifically, CRA (2014) has previously defined fresh / saltwater conditions as follows: less dense freshwater (from precipitation recharge) near land surface, followed by denser seawater over depth. Prior tidal studies (CRA, 2014) have found that peninsula groundwater at depths greater than 25 ft is tidally influenced. However, groundwater at depths less than15 ft is not generally tidally influenced. Again, this points to a freshwater lens near land surface, with denser seawater over depth. Also, the bottom of the Hylebos Waterway is -35 ft MLLW (-47 ft NGVD;. The bottom of the Hylebos is at approximately -50 ft elevation (CRA, 2014), which is where TDS and percent seawater levels generally increase. However, there is deeper submarine groundwater discharge, from the east side of the Hylebos Waterway (i.e. the "bluffs" area, CRA, 2014). This deeper recharge is fresh groundwater, from upland areas at higher elevations. Prior to the peninsula construction, the natural state of the discharging groundwater was likely brackish. The increased TDS and percent seawater levels over depth support this historical model.

Other MTCA Non-Potability Criteria

Aside from yield and naturally occurring substances, there are several other criteria that may be used to designate groundwater non-potable. A brief discussion is as follows:

- Groundwater is located at a depth that makes it technically impracticable for use. This criteria would not apply as the groundwater table is < 25 ft from land surface. A groundwater treatment / extraction system has also been operating for nearly 20 years now.

- It is unlikely that hazardous substances will be transported from the site to a drinking water source. This criteria would apply as the peninsula is bounded by marine water. The closest public supply well (City of Tacoma tideflats well ACN703; 775 feet deep) is roughly 0.6 miles southeast (and up-gradient) of the former OCC property.

- The site is located near or within close proximity to surface water, i.e. the "Harbor Island" rule exemption. If a site is near or abuts a marine waterway, then you may conclude that there is an "extremely low probability" of future human consumption of groundwater. As a footnote, the rule does not provide any criteria as to how this decision is made. However, Harbor Island (Duwamish River estuary) is used as an example and this OCC site matches that type of scenario. Therefore, this OCC site does qualify for the Harbor Island rule exemption.

Part III – EPA Criteria

Underground Source of Drinking Water (USDW)

Like Ecology, EPA also uses the TDS 10,000 mg/L threshold to define what is an "underground source of drinking water" (USDW; 40 CFR) Section 144.3). Per federal regulations, you may also create or designate "exempted aquifers" (40 CFR Section 146.4). The criteria for exempted aquifers is similar to Ecology's MTCA Section 720. As a footnote, EPA's criteria for exempted aquifers is groundwater with TDS levels > 3,000 and < 10,000 mg/L ("freshwater" is TDS < 3,000 mg/L). Lastly, the USDW criteria has also been incorporated into EPA's Underground Injection Control (UIC) program. For example, EPA Region V has published guidance on how to apply USDW criteria to states with UIC programs (e.g. Michigan, Indiana, etc.).

Comprehensive State Groundwater Protection Program (CGWPP)

Both Ecology / EPA have jurisdiction for this former OCC site cleanup. This is a federal EPA superfund site; therefore, the CERCLA provisions do apply. However, if a state has a Comprehensive State Groundwater Protection Plan (CGWPP), then EPA may defer to the state for determinations of current / future groundwater use (EPA, 1997). A State of Washington CGWPP was completed by Ecology (1995). This CGWPP was endorsed by EPA (2002).Therefore, per these directives, Ecology now has the authority to determine groundwater current / future use. In this case, Ecology has decided that the former OCC site groundwater is not a current or potential source of drinking water.

Part IV – Conclusion

Based on the weight of evidence, this peninsula groundwater (former OCC plant) is unfit for human consumption. Although there is a freshwater lens near land surface, the underlying and surrounding groundwater has much higher salinity levels. These salinity levels do vary over depth. However, for the most part, levels exceed drinking water standards (e.g. TDS > 500 mg/L). From a practical standpoint, no one would ever drill a well and use this peninsula groundwater for drinking water. If this were to occur, then the groundwater would have to be treated (desalinization). This would be very costly and seems impracticable from a future use standpoint. For that matter, the historical natural state of groundwater entering (or discharging to) Commencement Bay was likely always brackish. Therefore, this peninsula groundwater does meet the MTCA Section 720 non-potability criteria.

.<u>References</u>

CRA (2013). Salt Water / Freshwater Evaluation Results. CRA technical memorandum (Michael Mateyk and Jody Vaillancourt, CRA to Clint Babcock; March 8th, 2013.

CRA (2014). Site Characterization Report (SCR). Groundwater and Sediment Remediation, Occidental Chemical Corporation, Tacoma, Washington. August-2014, 007843, Report No. 128

Ecology (1995). Washington State Ground Water Protection Program Core Program Assessment Document (July, 1995). Note: this document published prior to advent (or use) of Ecology publication numbers.

EPA (1997). The Role of CSGWPPs in EPA Remediation Programs (memorandum from Timothy Fields to Region I – X administrators; April 4th, 1997). OSWER Directive 9283.1-09

EPA (2002). Endorsement of State of Washington Core Comprehensive Ground Water Protection Program (letter from John Iani, EPA Region X to Kirk Cook, Ecology; February 1st, 2002).

Table 1 – Average Groundwater TDS Levels (2012-13) Over Depth (Elevation).

Layer	Elevation	Elevation	n	Average TDS
	ft	ft		mg/L
1	0	-25	36	1,481
2	-25	-50	26	4,656
3	-50	-75	11	22,873
4	-75	-100	11	22,214
5	-100	-125	8	25,050
6	-125	-150	8	23,684
			100	

Table 2 – Average Percent Seawater (2012-13) Over Depth (Elevation).

Layer	Elevation	Elevation	n	Average Percent Seawater
	ft	ft		%
1	0	-25	79	8.5%
2	-25	-50	76	26.1%
3	-50	-75	40	53.9%
4	-75	-100	45	48.7%
5	-100	-125	32	42.0%
6	-125	-150	26	45.2%
7	-150	-175	6	38.1%
			304	

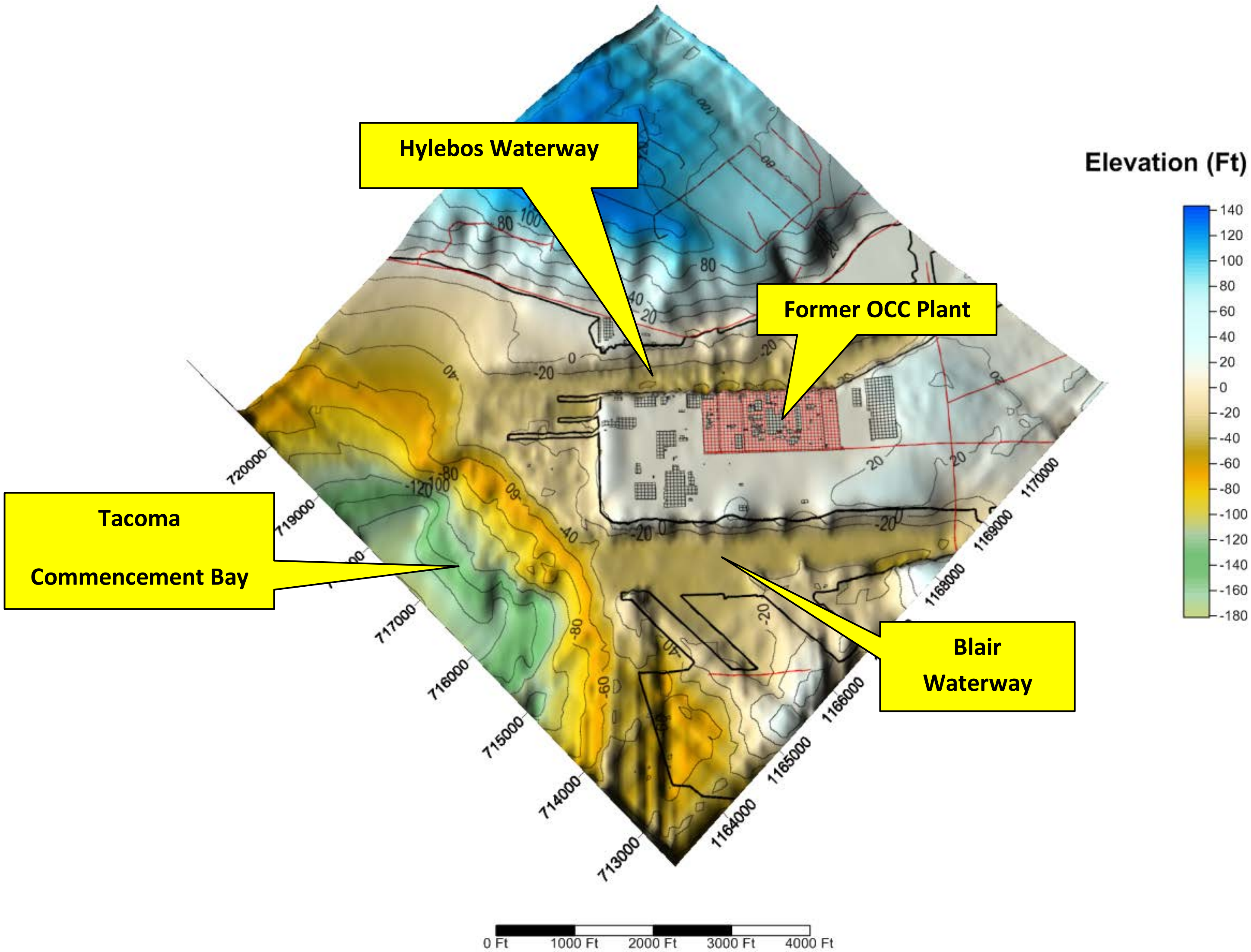


Figure 1 – 3D Land Surface and Bathymetry (Commencement Bay, Tacoma).

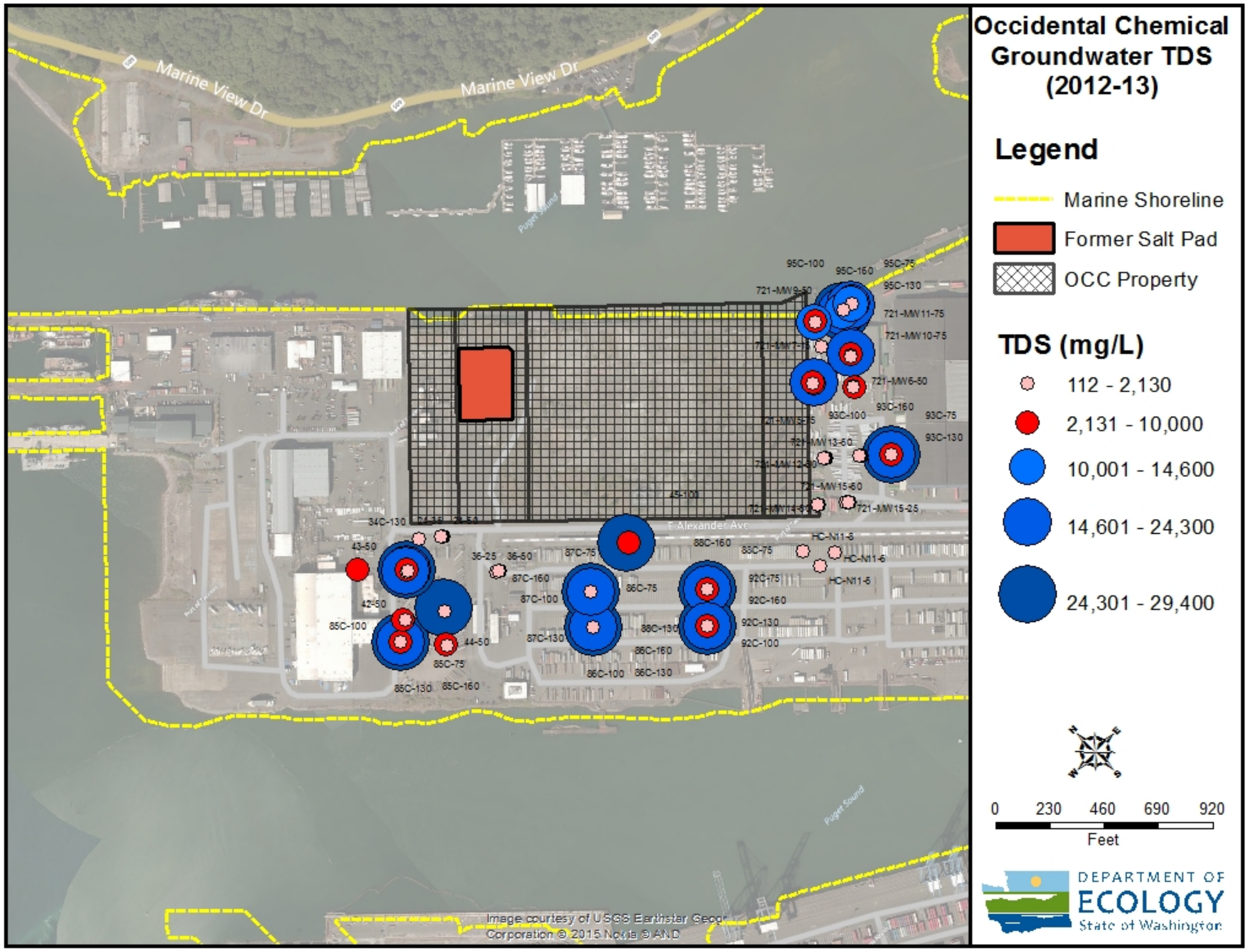


Figure 2 – Groundwater TDS Levels (2012-13).

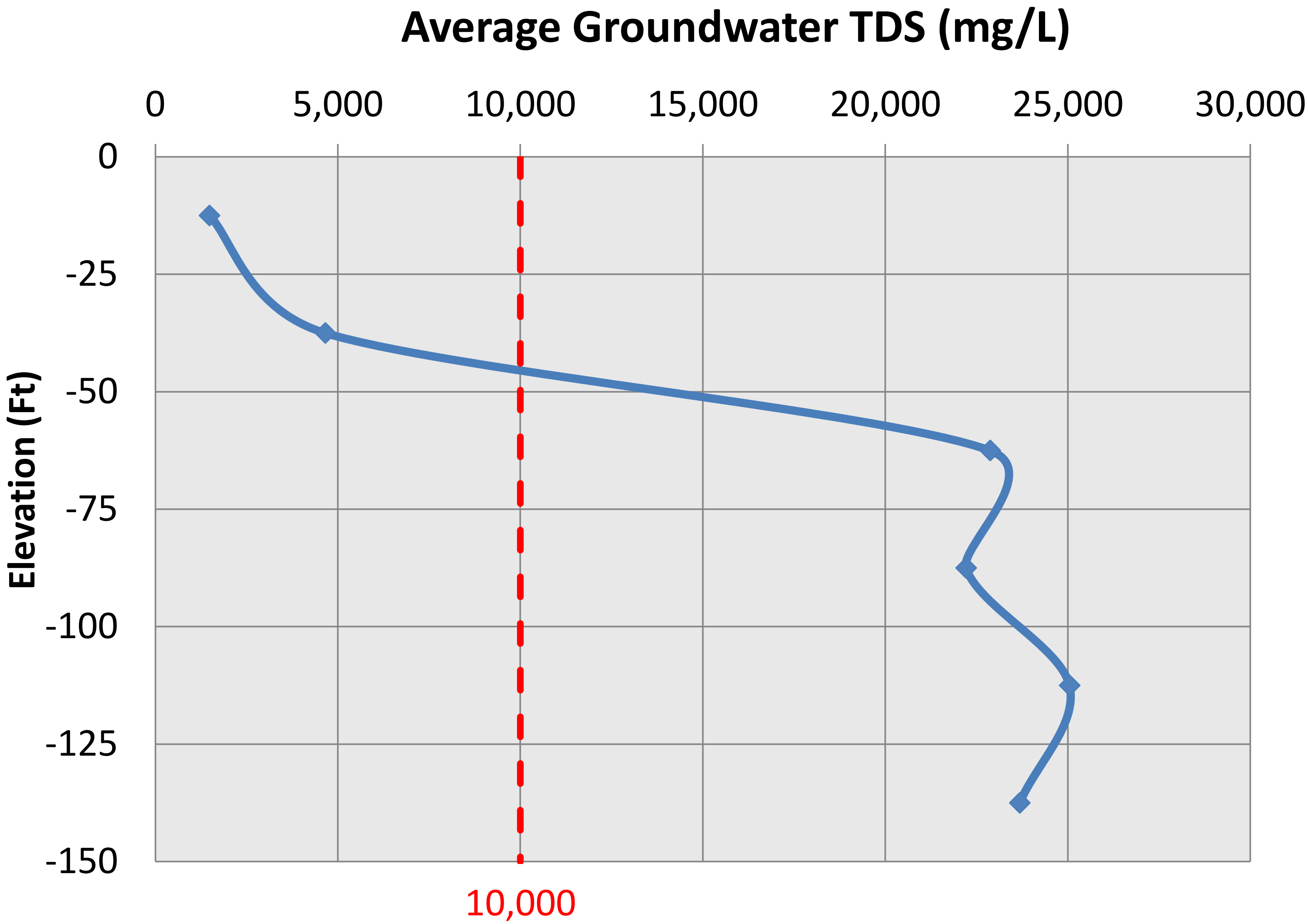
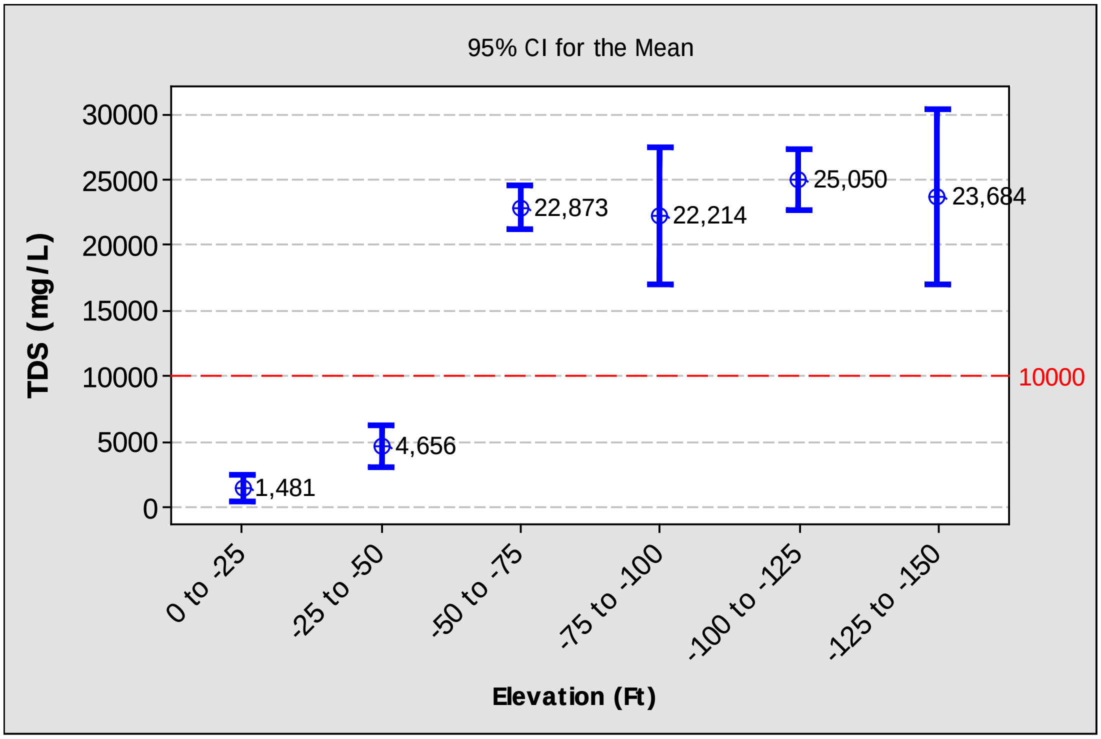


Figure 3 – Groundwater TDS Levels v. Depth (Elevation).

Interval Plot (with Average Values Labeled)



Box Plot (with Median Values Labeled)

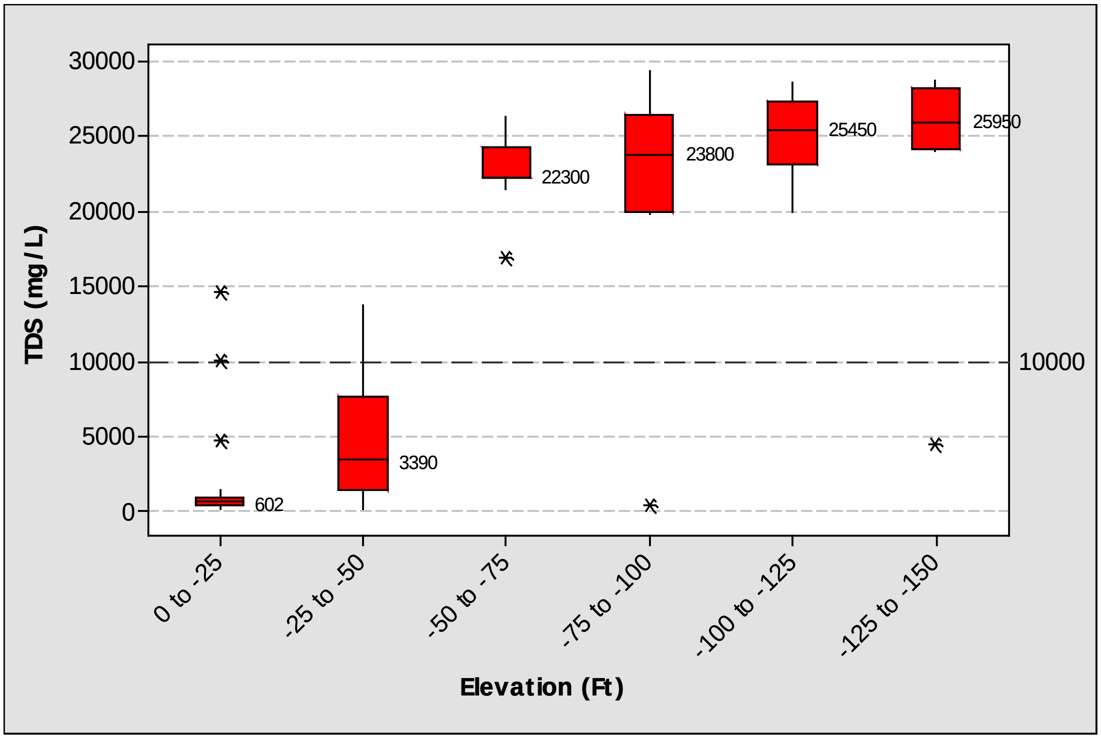


Figure 4 – Groundwater TDS Histogram and Box Plot (2012-13 Data).

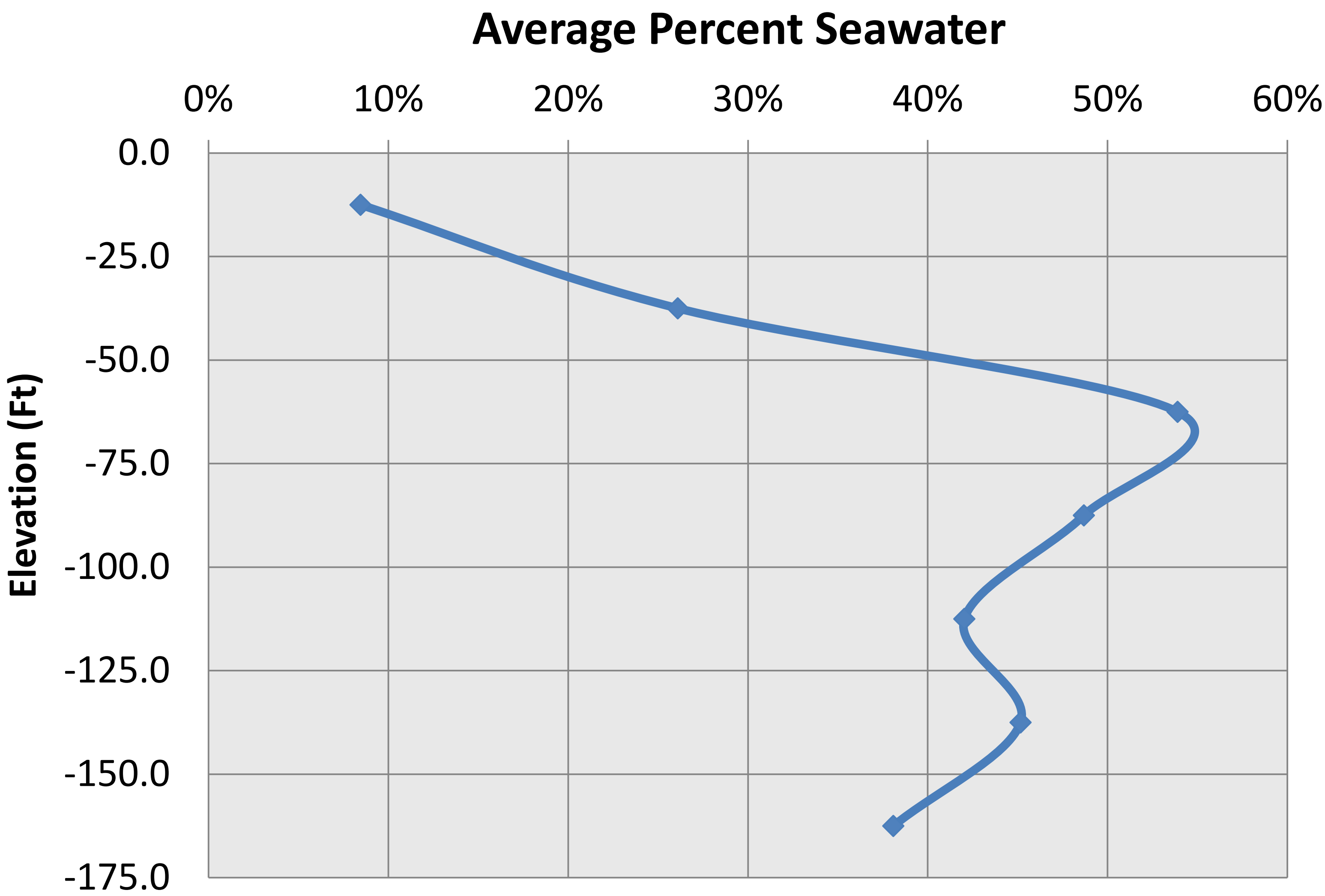
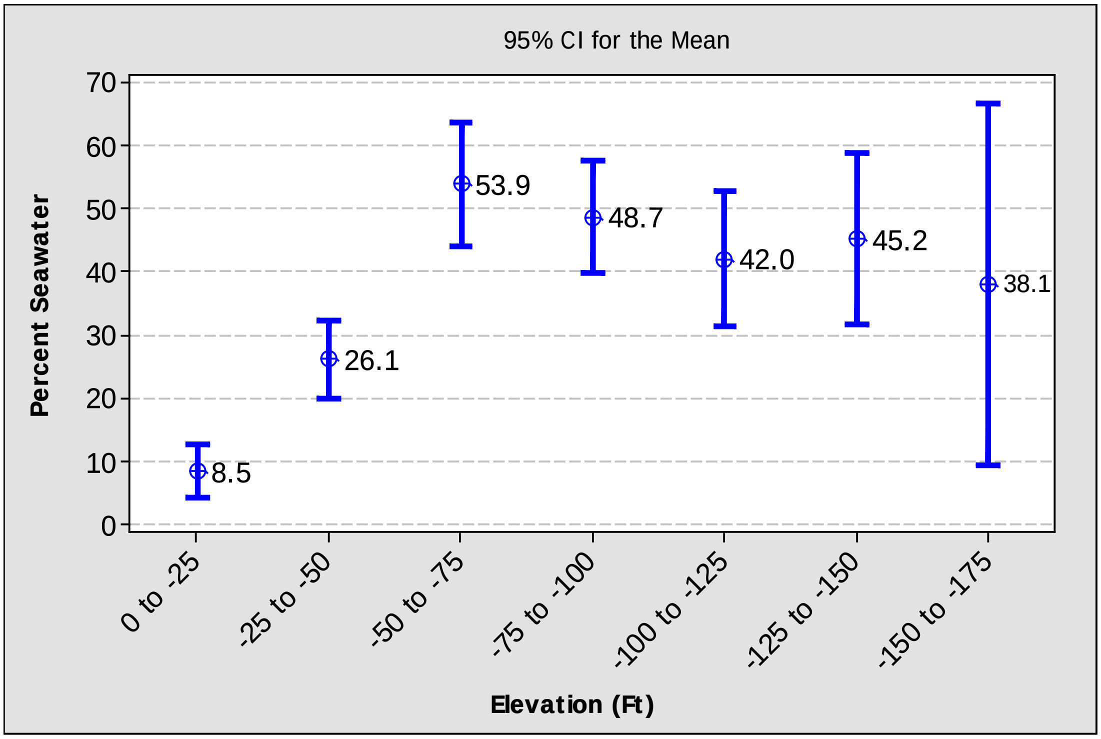


Figure 5 – Average Percent Seawater v. Depth (Elevation).

Interval Plot (with Average Values Labeled)



Box Plot (with Median Values Labeled)

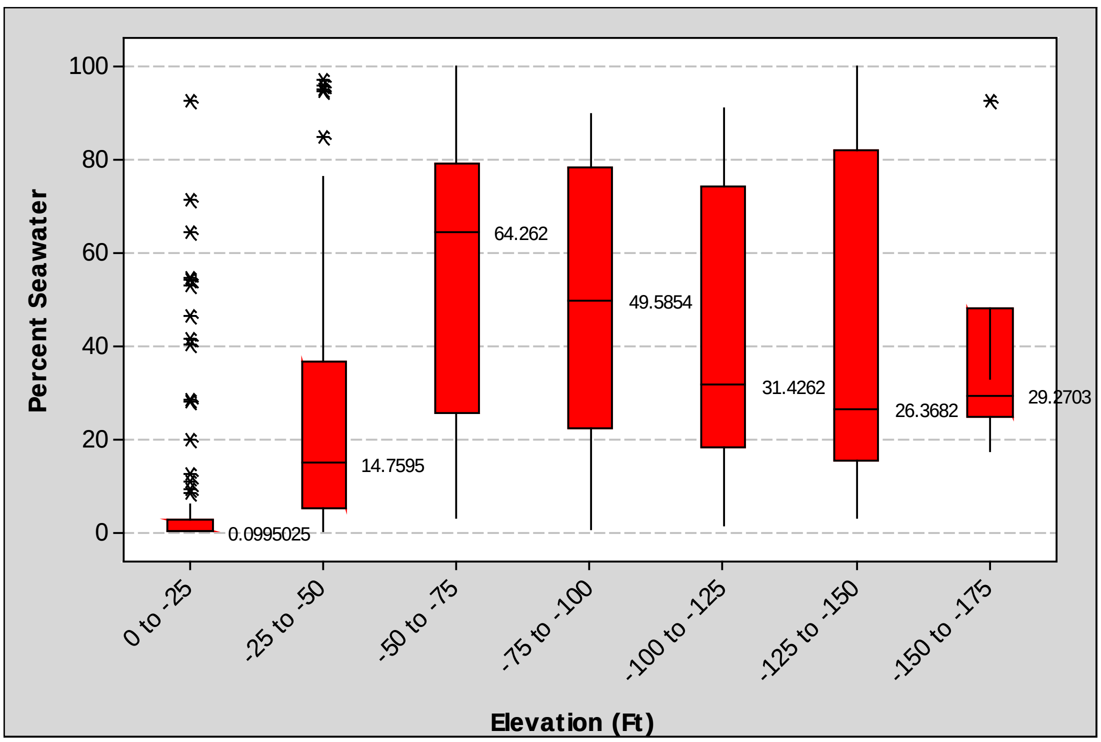
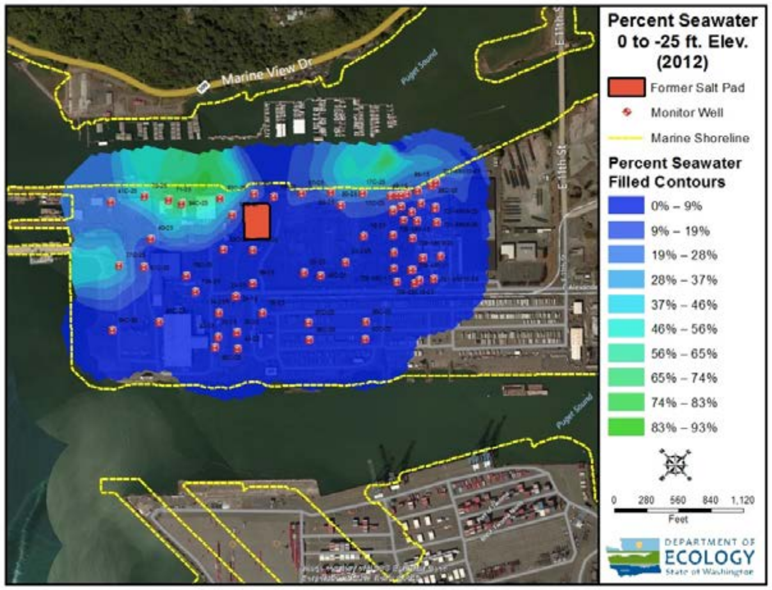
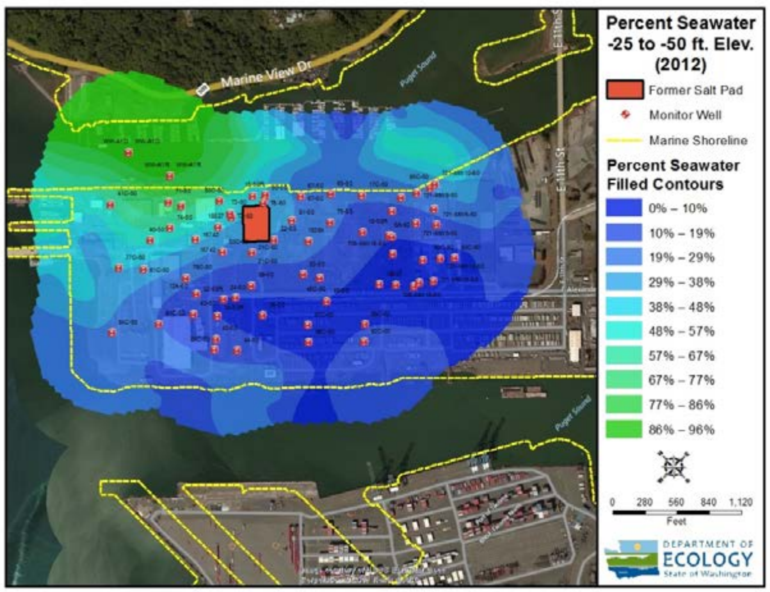


Figure 6 – Percent Seawater Interval and Box Plots.

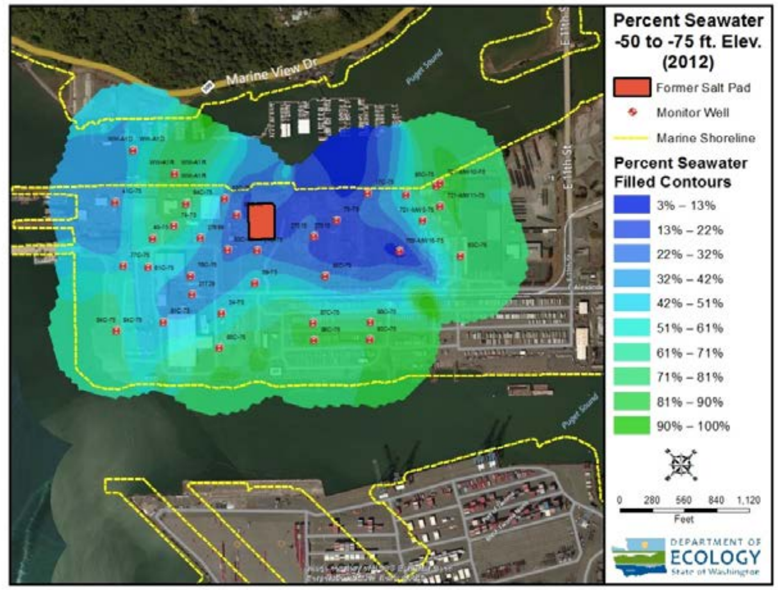
0 to -25 Ft Elevation



-25 to -50 Ft Elevation



-50 to -75 Ft Elevation



-75 to -100 Ft Elevation

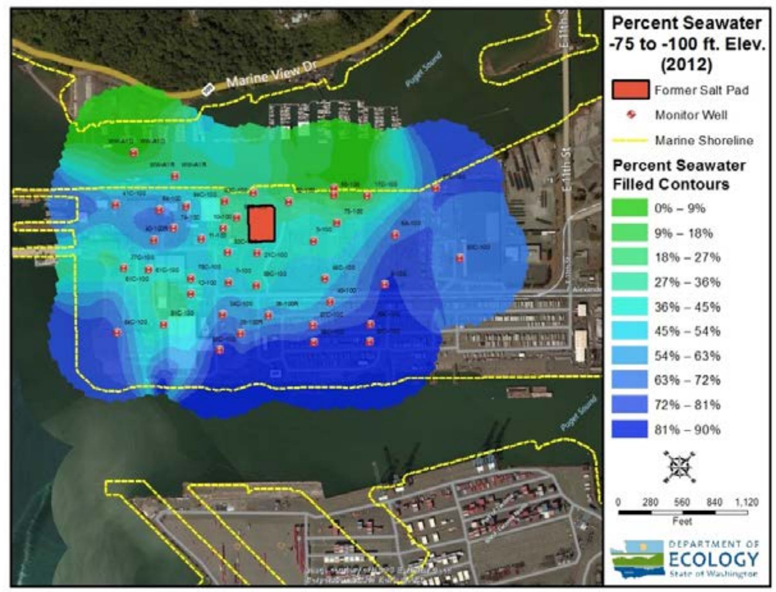
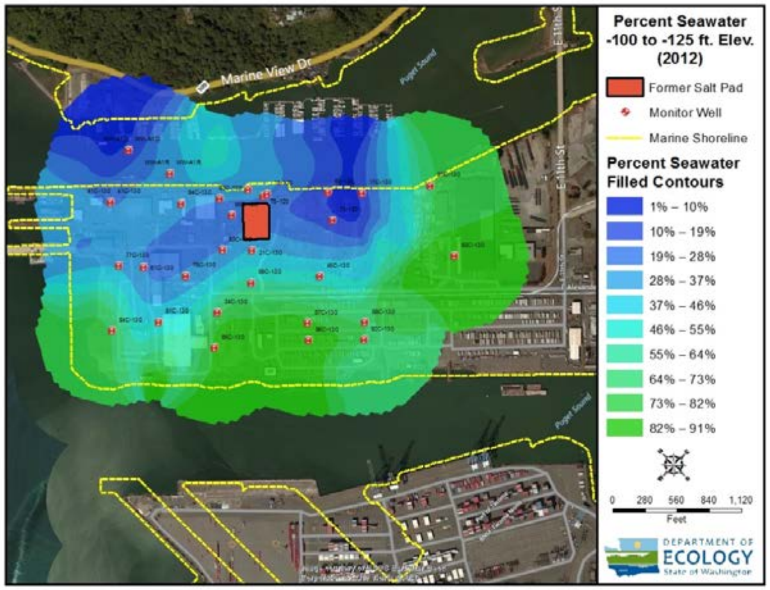
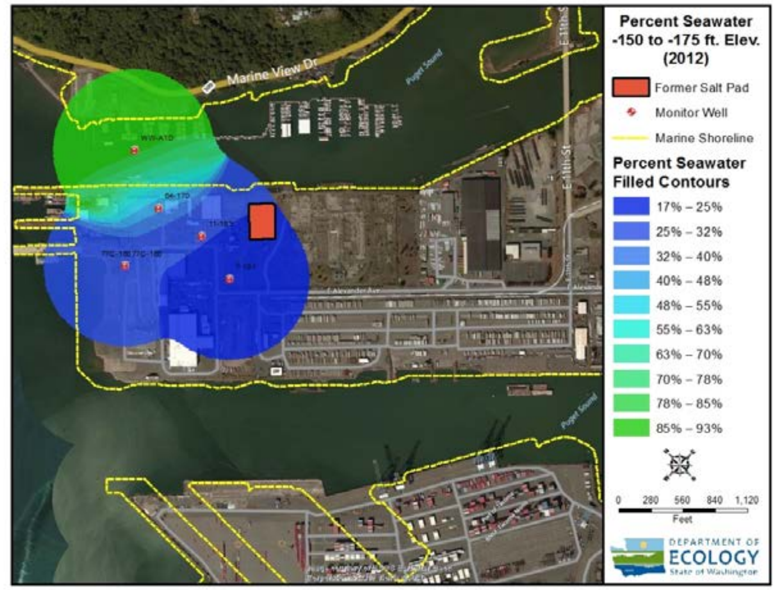


Figure 7 – Percent Seawater Levels Over Depth (Elevation, Ft).

-100 to -125 Ft Elevation



-150 to -175 Ft Elevation



-125 to -150 Ft Elevation

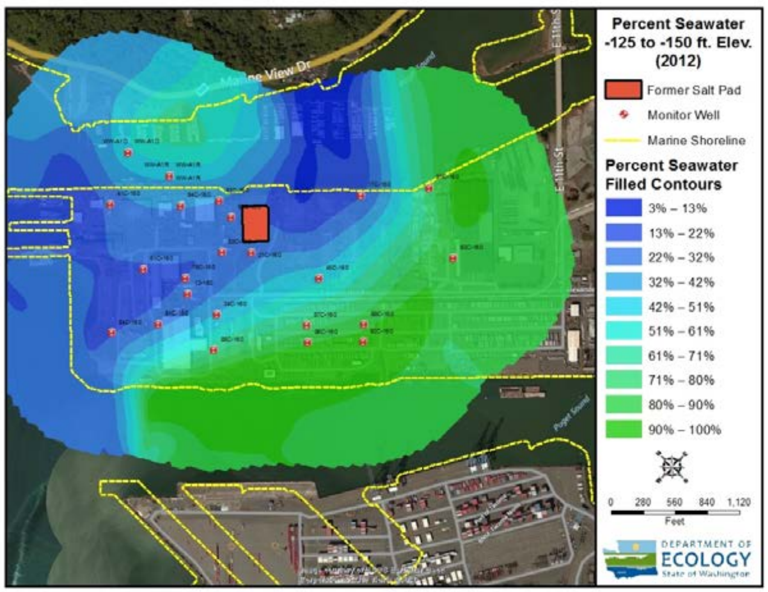


Figure 7 (Cont.)

Appendix B
Delineation of Areas of Potential Principal Threat Waste (PTW)

Appendix B Delineation of Areas of Potential Principal Threat Waste Former Occidental Petroleum Site - Tacoma, Washington

1. Introduction

This appendix presents the rationale used for identification and delineation of areas of potential principal threat waste (PTW) at the former Occidental Chemical Facility (Site) located in Tacoma, Washington. The concept of PTW originally developed by United States Environmental Protection Agency (USEPA) was applied to potential "source material" at a site. "Source material" is defined in USEPA, 1991[1] as "…material that includes or contains hazardous substances, pollutants or contaminants that act as a reservoir for migration of contaminants to ground water, to surface water, to air, or acts as a source for direct exposure."

The Site characterization identified two major potential source materials that have impacted groundwater. They are: dense non-aqueous phase liquids (DNAPLs) resulting from solvent production; and caustic-impacts that have resulted in elevated pH in the soil and groundwater.

The following sections of this Appendix present the regulatory framework for the determination of potential PTW and the evaluation of the potential "source material" at the Site with respect to this framework. Finally, the areas of potential PTW are identified.

2. Regulatory Framework

The regulatory framework regarding the identification and remediation of source materials and PTW includes WAC 173-340-350, WAC 173-340-370, and the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) [40 CFR 300.430 (a) (1) (iii)]. The concept of PTW and low-level threat waste was initially developed by USEPA in the NCP. While MTCA does not specifically call out PTW, it does identify in WAC 173-340-350 and WAC 173-340-370 the requirements for dealing with source materials (hazardous substances) with the same characteristics attribute to PTW by USEPA.

The concept of PTW is to be applied on a site-specific basis when characterizing "source material" (as defined above). Considerations that should be taken into account when categorizing waste are presented in USEPA, 1991. Some examples of source materials provided in USEPA, 1991 are: drummed waste, contaminated soil and debris, pooled DNAPL, LNAPL, etc. Contaminated groundwater is generally not considered source material.

In general, MTCA and the NCP consider hazardous substances/PTW to be those source materials that are:

- Highly toxic
- Highly mobile that generally cannot be reliably contained
- Would present a significant risk to human health or the environment should exposure occur

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1 USEPA, 1991. A Guide to Principal Threat Waste and Low Level Waste, OSWER Superfund Publication 9380.3-06FS, November, 1991.

Both MTCA and the NCP establish an expectation that treatment will be used to address hazardous substances/PTW at a site wherever practicable. This is clearly stated in WAC 173-340-370 (1) as follows:

"The department expects that treatment technologies will be emphasized at sites containing liquid wastes, areas contaminated with high concentrations of hazardous substances, highly mobile materials, and/or discrete areas of hazardous substances that lend themselves to treatment."

However, both MTCA and the NCP also acknowledge that hazardous substances/PTW may be contained rather than treated due to difficulties in treating the source material. Ecology's position is stated in Focus No. 94-130 as follows: "**Protecting Human Health and the Environment.** The cleanup action selected must either remove or destroy the contamination, restoring the site to cleanup levels, or contain the contamination in such a way that will minimize future exposure of humans and ecological receptors (plants and animals)."[2]

As stated in the preamble to the NCP (55 FR at 8703, March 8, 1990), there may be situations where PTW may be contained rather than treated due to difficulties in treating the wastes. Specific situations that may limit the use of treatment are summarized in USEPA (1991) as follows:

- Treatment technologies are not technically feasible or are not available within a reasonable timeframe.
- The extraordinary volume of materials or complexity of the site make implementation of treatment technologies impracticable.
- Implementation of a treatment-based remedy would result in a greater overall risk to human health and the environment due to risks posed to workers or the surrounding community during implementation.
- Severe effects across environmental media resulting from implementation would occur.

The decision to treat or contain hazardous substances/PTW is made on a site-specific basis through the remedy selection process (USEPA, 1991 and WAC 173-340-360).

3. Evaluation of Potential DNAPL Source Material

Chlorinated solvents were produced at the Site from 1947 to 1973. Trichloroethene (TCE) was produced over this entire period, while tetrachloroethene (PCE) was produced from 1960 to 1973. The former solvent production plant and associated waste management units (WMUs) are shown on Figure 1. A single area around the former solvent production plant and associated WMUs is also shown on Figure 1 and described as the "CVOC Source Area." The chlorinated solvents were present in the solvent residue released to the environment and would have behaved as a DNAPL.

The distribution of DNAPL in the subsurface is shown on Figure 2. As described in Section 4.8 and Appendix S of the draft SCR, confirmed DNAPL source zones were identified in the 15-, 25-, 100-, 130-, and 160-foot depth zones. Free-phase DNAPL was not encountered during Site investigations. The DNAPL composition was determined from soil analyses and found to be primarily PCE and TCE. Therefore, the DNAPL source material would be considered toxic.

None of the DNAPL source zones are highly mobile. This conclusion is reached for two reasons. Firstly, no free-phase or pooled DNAPL was encountered at the Site. Secondly, solvent production at the Site

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2 Ecology, Focus No. 94-130, page 4, November 2007 (revised 2013).

ceased in 1973 (41 years ago). TCE and PCE DNAPLs have high density (compared to groundwater), low viscosity and high mobility, so that migration in relatively permeable media would cease within a few months to a few years following the time of release (USEPA, 2009)[3]. As a result, the current DNAPL distribution is likely stable and is already reliably contained naturally by the local geology.

Exposure to the confirmed DNAPL source zones is unlikely, especially for the zones located within the 100-, 130-, and 160-foot depth zones. However, should exposure occur it could result in an unacceptable risk or hazard.

Based on the facts that the confirmed DNAPL source zones contain toxic material and that exposure to these zones, if it was to occur, could result in significant risk to human and environmental receptors, they potentially could be considered PTW. The areas where DNAPL source material potentially could be considered PTW are shown on Figures 3a (15- and 25-foot depth zones) and 3b (100-, 130- and 160-foot depth zones).

4. Evaluation of Caustic Source Material

Caustic soda (sodium hydroxide) was produced at the Site over the period of 1929 to 2002. Locations of historical production and handling of caustic soda are shown on Figure 4. A single area around these production and handing areas is shown on Figure 4 as the "Caustic Source Area." The caustic soda released to the subsurface resulted in elevated soil alkalinity. Elevated soil alkalinity in the Caustic Source Area is an on-going source of elevated groundwater pH and is considered source material.

In order to determine which portion of the elevated caustic soil is potential PTW, an examination of the soil and groundwater pH was undertaken. In order to define potential PTW with respect to caustic waste, pH greater than and equal to 12.5 s.u. was selected. A pH of 12.5 s.u. is the lower limit that defines a caustic waste as being characteristic for corrosivity (40 CFR 261.22).

During the Comprehensive Site Investigation (CSI), the pH source area was evaluated through the installation of 10 soil borings to a depth of 50 feet below ground surface. The area of investigation was selected because of the elevated groundwater pH found at shallow depths. The locations of the soil borings are shown on Figure 5. Soil pH was measured at regular intervals as drilling progressed. The soil pH data were presented in Table 4.14 of the draft SCR. These data were used to create a soil pH 4DIM with Mining Visualization System/Environmental Visualization System software package (MVS/EVS). The EVS domain was limited to the pH source area of investigation, as this is the area with adequate soil data for kriging. The extent of soil with pH greater than and equal to 12.5 s.u. is shown on Figure 5.

There is limited soil pH data within the entire Caustic Source Area depicted on Figure 4, e.g., in the area of the Caustic House (S8 on Figure 4). As a result, it was necessary to also examine the groundwater pH plume to see where pH above 12.5 s.u. occurs in the groundwater. Although contaminated groundwater is generally not considered to be source material, the soil that the groundwater is in contact with could be considered source material. The extent of the groundwater pH plume at 12.5 s.u. as determined from EVS is shown in plain view on Figure 6. A north-south elevation view from EVS of soil and the groundwater with pH greater than and equal to 12.5 s.u. is shown on Figure 7. The soil co-located with the groundwater plume that is equal or greater than 12.5 s.u. potentially could be considered PTW.

Based on historical knowledge of caustic production, soil pH data, and groundwater pH data, the areas of caustic impacted soil that potentially could be considered PTW are shown on Figure 8.

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[3] USEPA, 2009. Assessment and Delineation of DNAPL Source Zones at Hazardous Waste Sites. Publication EPA.

5. Summary

The DNAPL and caustic source material that could potentially be considered hazardous substances/PTW were identified following the guidance presented in MTCA, the NCP, and USEPA, 1991. All confirmed DNAPL source zones were considered to be potential PTW because of their toxic composition and the significant risk that could result should exposure occur. All unsaturated and saturated soil where the soil or groundwater pH was equal to or greater than 12.5 s.u. was considered potential PTW because they are considered to be characteristically hazardous for corrosivity (40 CFR 261.22).

Both MTCA and the NCP have an expectation for treatment of hazardous substance/PTW, wherever practicable. At this Site, the complete treatment of hazardous substance/PTW may be considered impracticable for the following reasons:

- Feasible treatment technologies are not available
- Very large volumes of hazardous substances/PTW
- Complex geologic and geochemical conditions
- Potential for increased risks during implementation of treatment

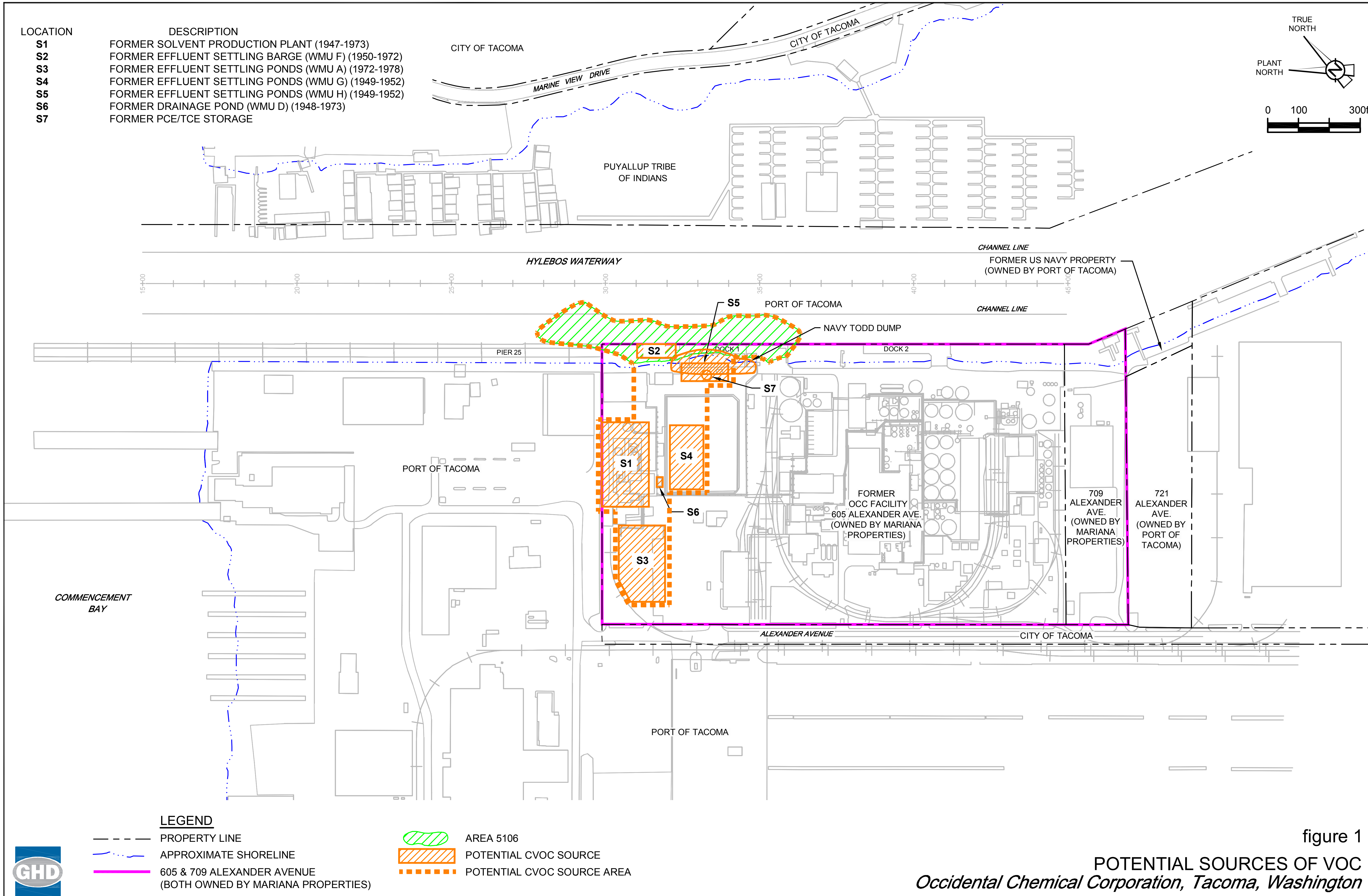
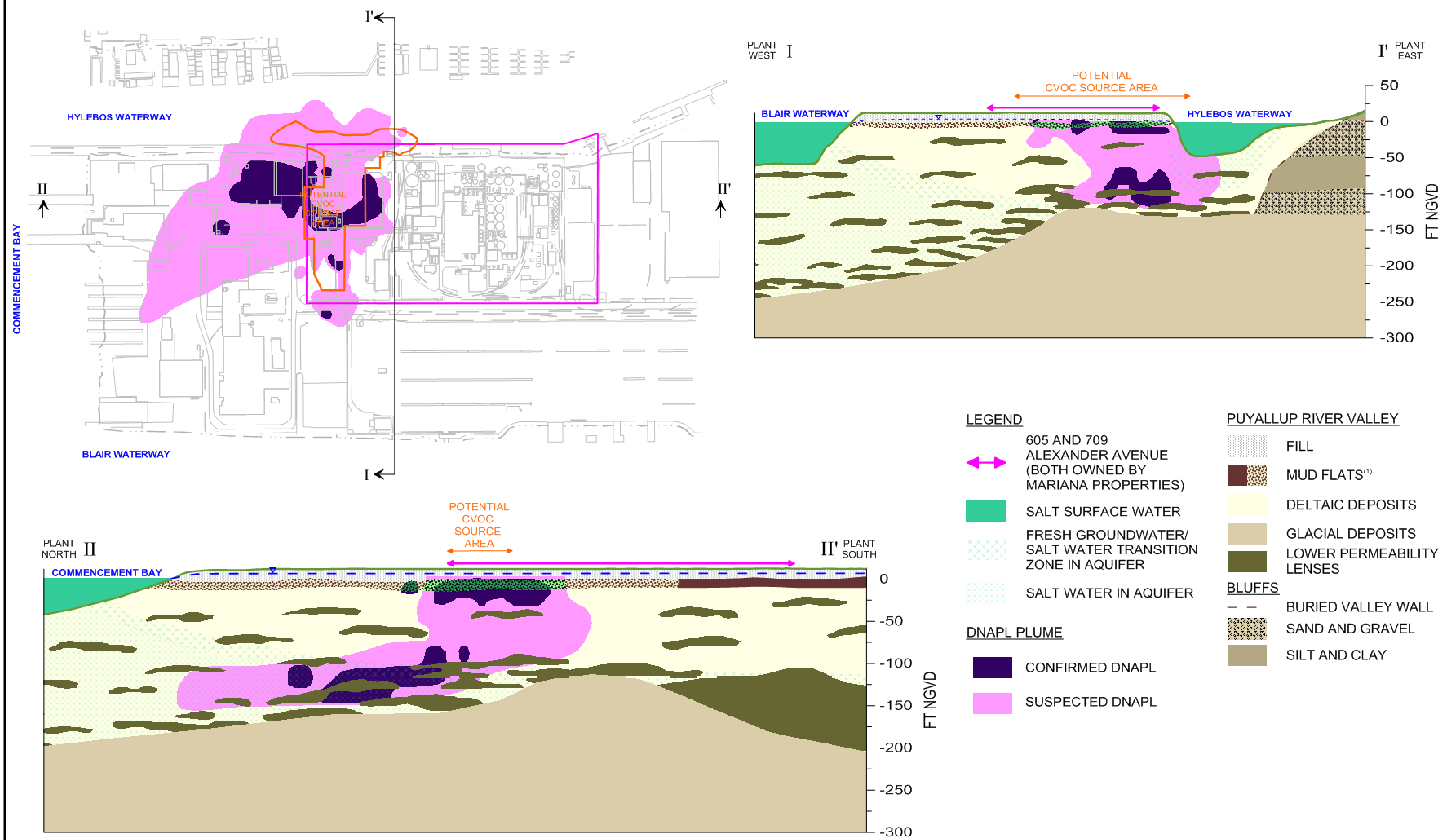


figure 1

POTENTIAL SOURCES OF VOC

Occidental Chemical Corporation, Tacoma, Washington

07843-C2D2(139)GN-WA049 MAY 24, 2016



NOTES:
(1) DARK BROWN INDICATES WHERE MUD FLATS ARE OBSERVED TO PROVIDE HYDRAULIC SEPARATION BETWEEN THE FILL AND DELTAIC DEPOSITS; BROWN DOT PATTERN INDICATES WHERE HYDRAULIC SEPARATION BY THE MUD FLATS IS NOT CONFIRMED

figure 2

DNAPL DISTRIBUTION

Occidental Chemical Corporation, Tacoma, Washington

07843-C2D2(139)GN-WA-HYD N:\HEG\07843\RPT139\Appendix B\Figures\007843-Rpt139_AppB_DNAPL.srf)April 29/2016

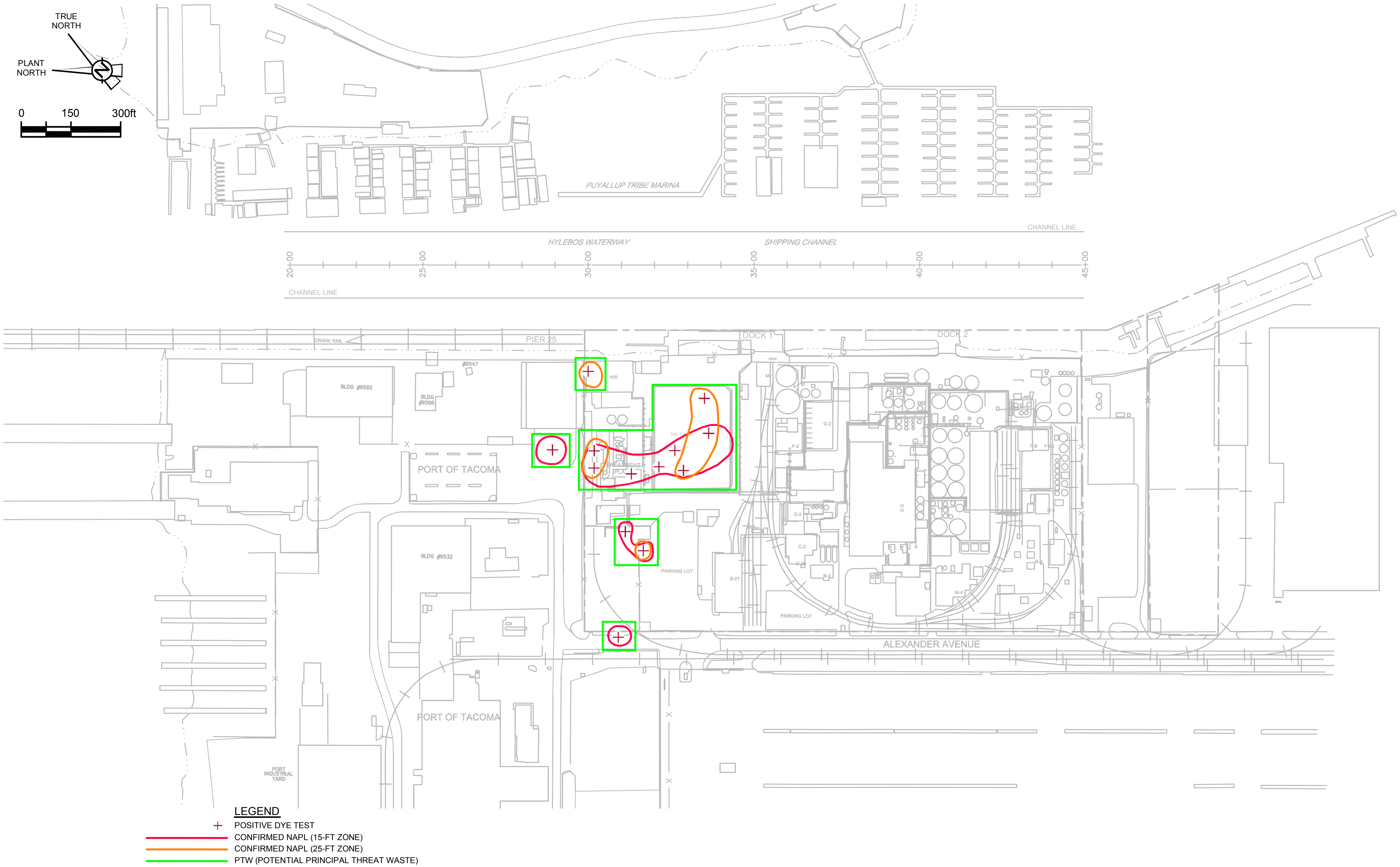


figure 3a

CONFIRMED DNAPL SOURCE ZONES - 15-FT AND 25-FT ZONES

Occidental Chemical Corporation, Tacoma, Washington

07843-C2D2(139)GN-WA050 APR 27, 2016

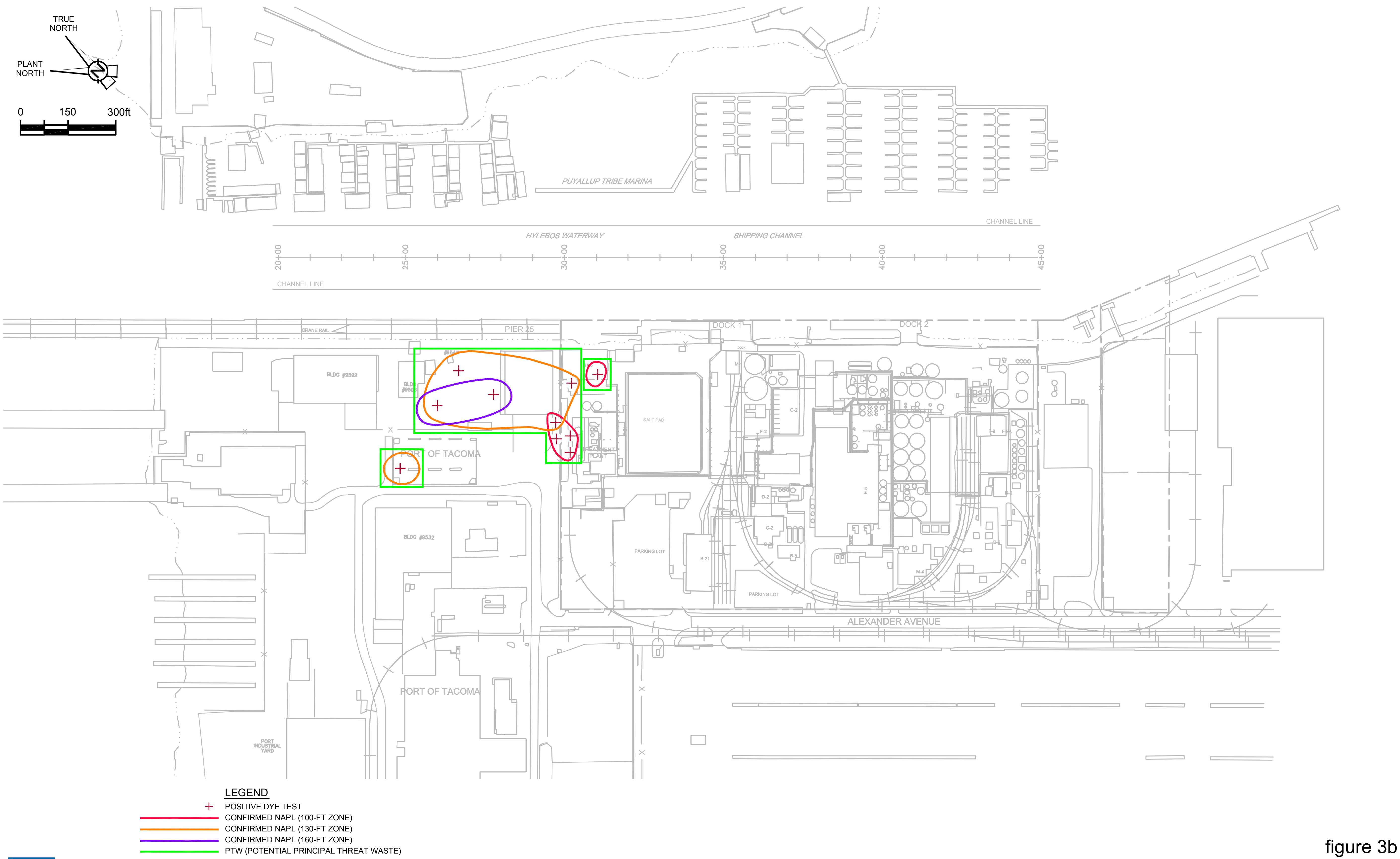


figure 3b

CONFIRMED DNAPL SOURCE ZONES - 100-FT, 130-FT AND 160-FT ZONES

Occidental Chemical Corporation, Tacoma, Washington

07843-C2D2(139)GN-WA051 APR 27, 2016

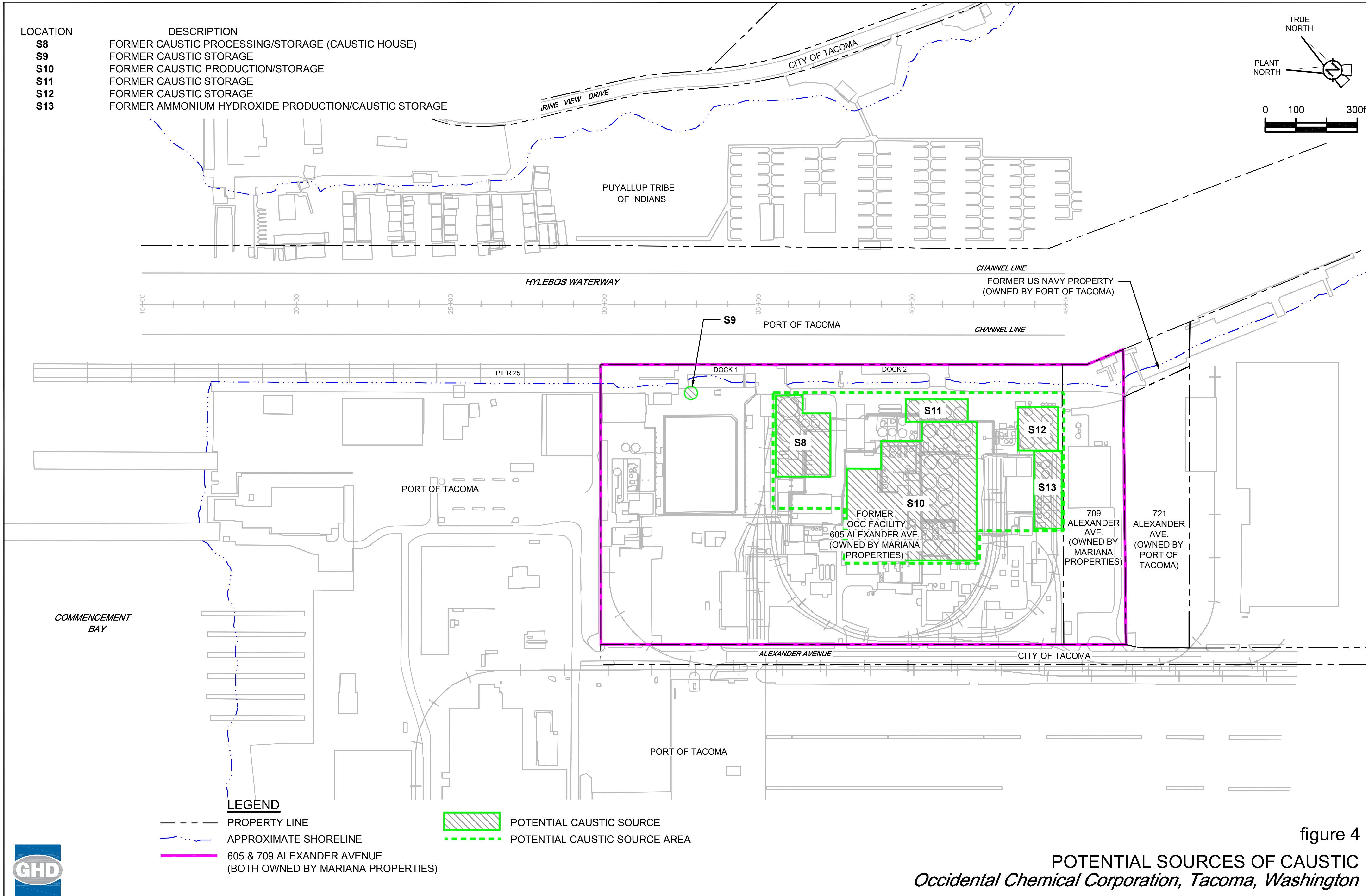


figure 4

POTENTIAL SOURCES OF CAUSTIC

Occidental Chemical Corporation, Tacoma, Washington

07843-C2D2(139)GN-WA052 APR 29, 2016

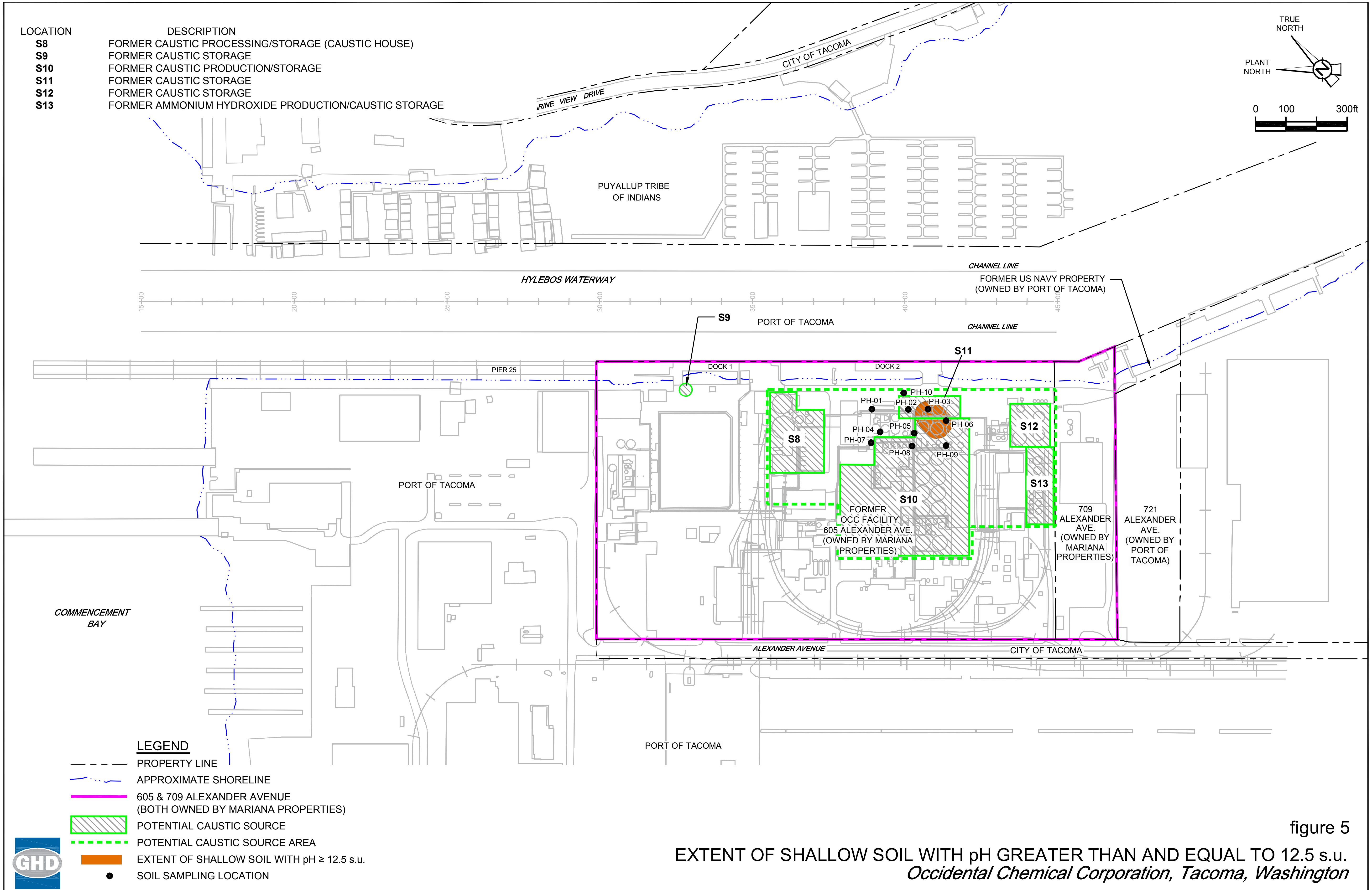


figure 5

EXTENT OF SHALLOW SOIL WITH pH GREATER THAN AND EQUAL TO 12.5 s.u.

Occidental Chemical Corporation, Tacoma, Washington

07843-C2D2(139)GN-WA053 APR 29, 2016

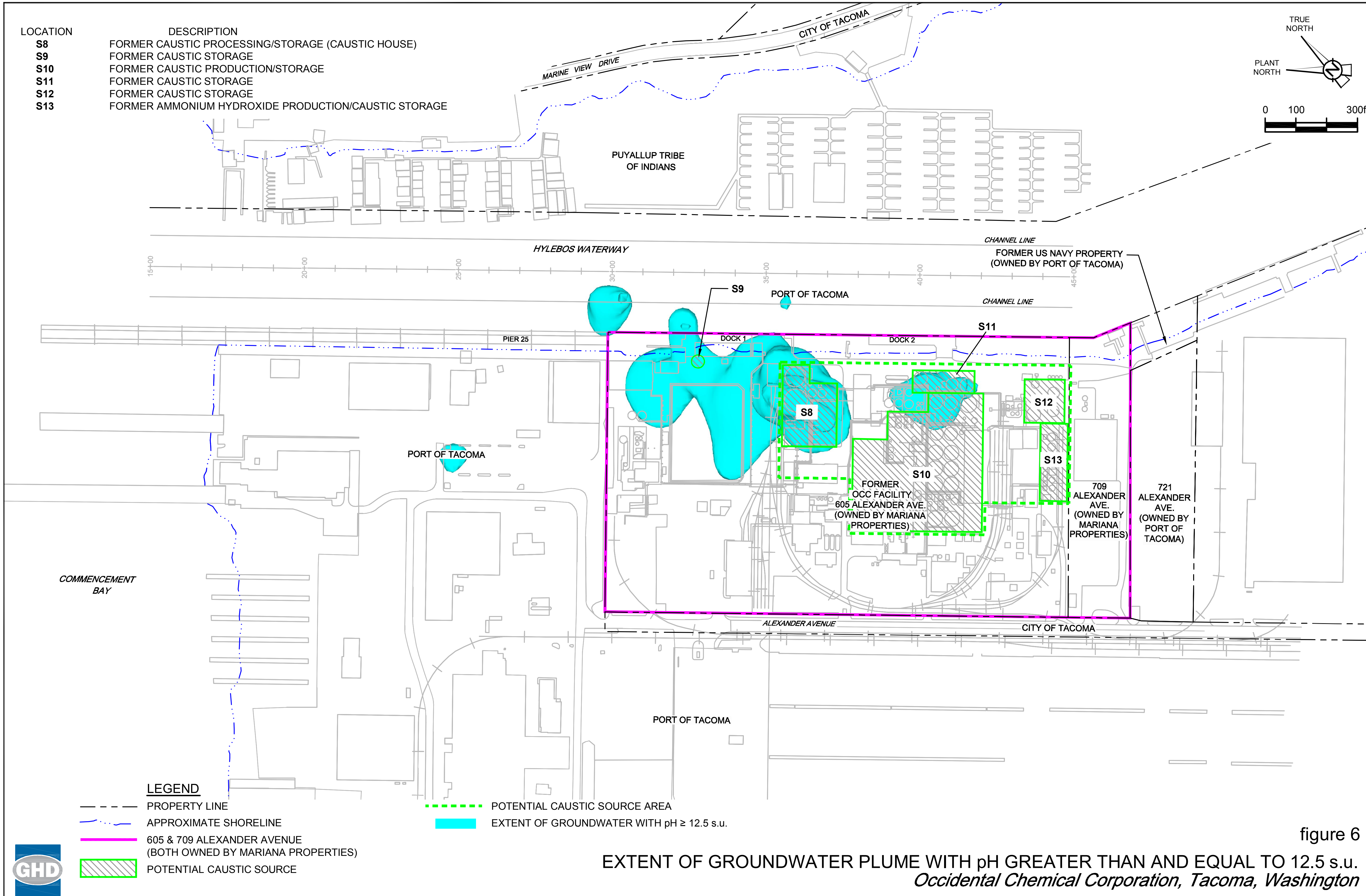


figure 6

EXTENT OF GROUNDWATER PLUME WITH pH GREATER THAN AND EQUAL TO 12.5 s.u.

Occidental Chemical Corporation, Tacoma, Washington

07843-C2D2(139)GN-WA054 APR 29, 2016

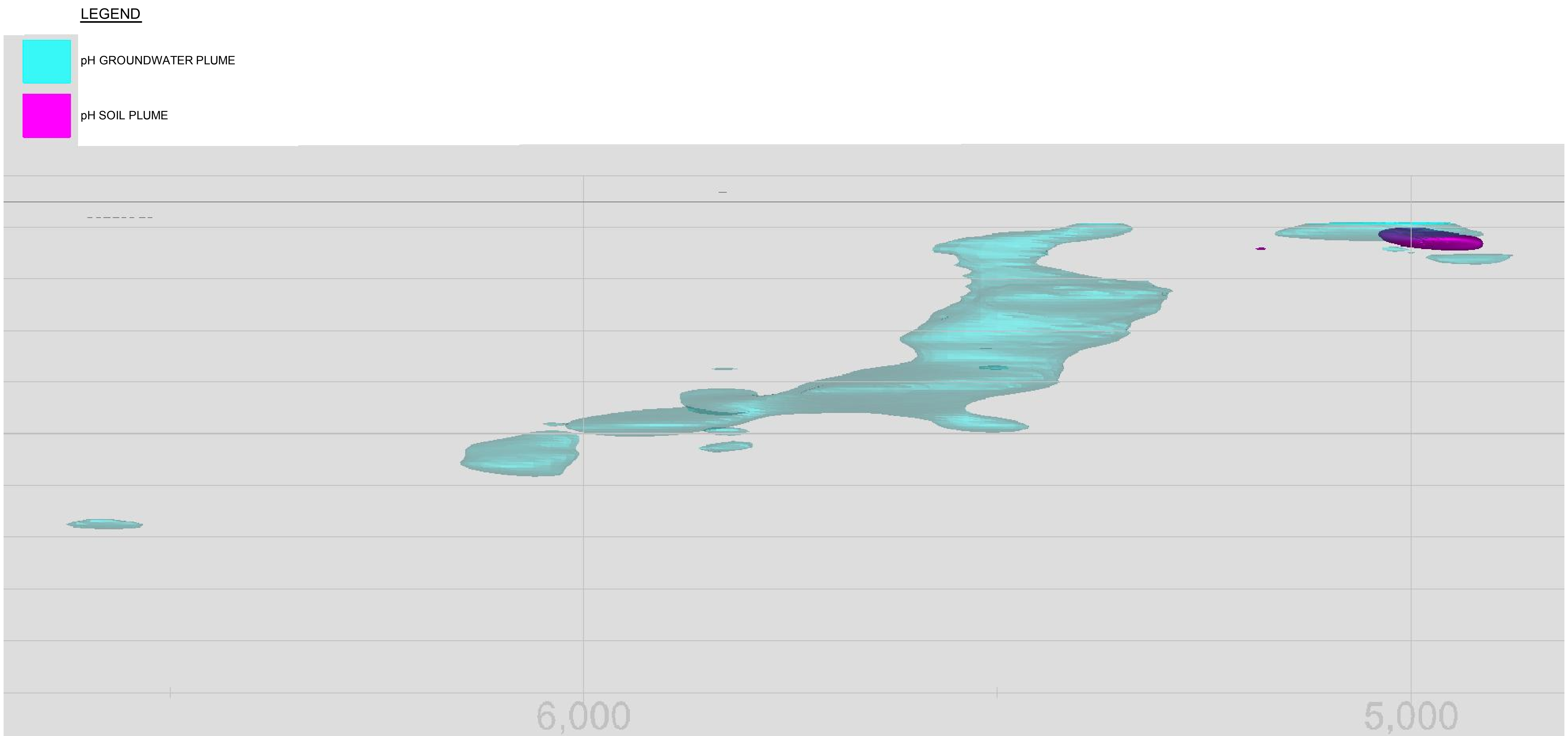


figure 7

NORTH-SOUTH ELEVATION VIEW OF SOIL AND GROUNDWATER WITH pH GREATER THAN AND EQUAL TO 12.5 s.u.

Occidental Chemical Corporation, Tacoma, Washington

07843-C2D2(139)GN-WA055 APR 20, 2016

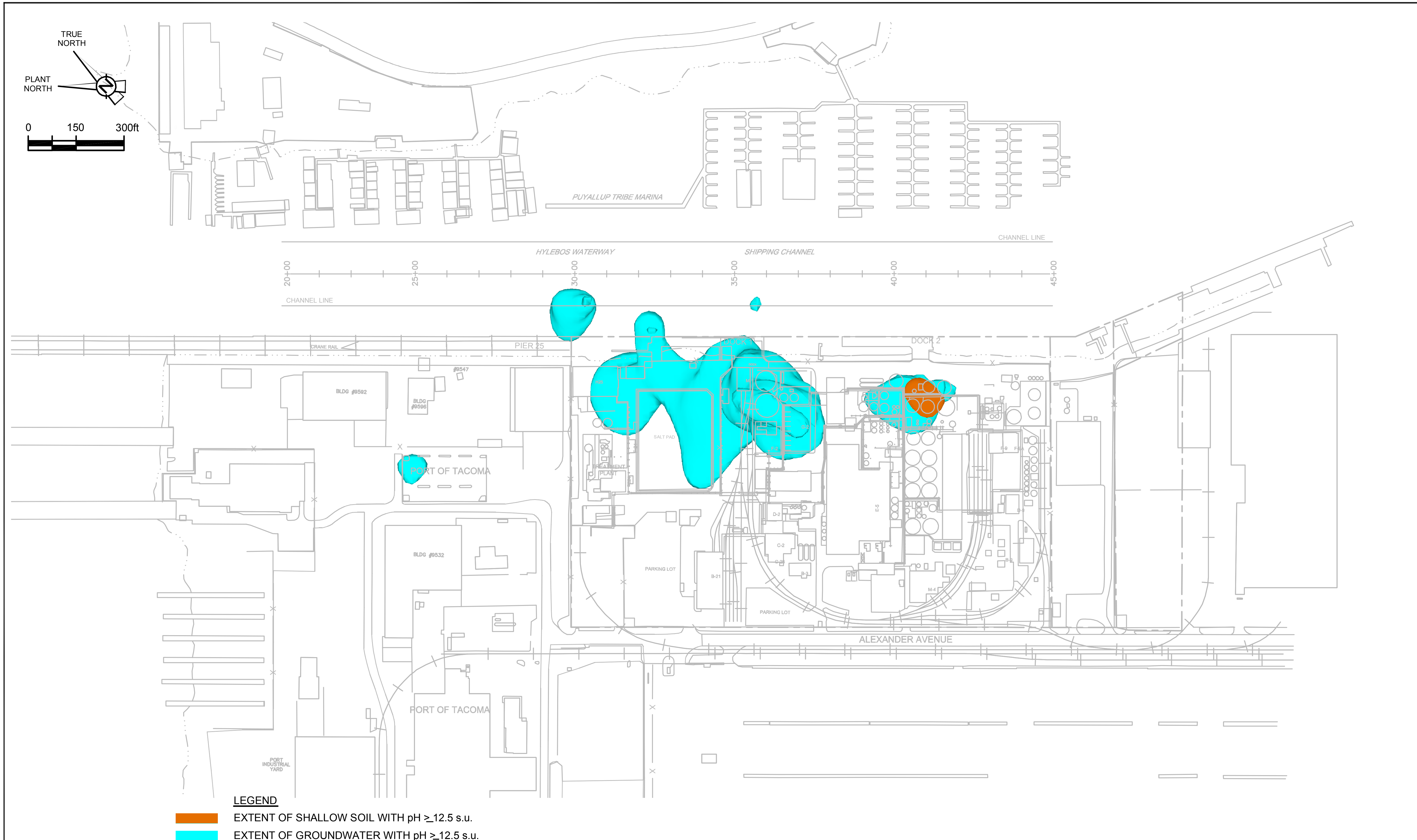


figure 8

POTENTIAL PTW RELATED TO CAUSTIC SOURCE MATERIAL

Occidental Chemical Corporation, Tacoma, Washington

07843-C2D2(139)GN-WA056 APR 27, 2016

Appendix C
Technical Memorandum - Revised DNAPL Mass Estimates

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TECHNICAL MEMORANDUM

To:	Clint Babcock	Ref. No.:	007843
From:	Mike Mateyk/kf/75 MGM	Date:	November 11, 2014
cc:	Ian Richardson		
Re:	**Revised DNAPL Mass Estimates** **Former Occidental Chemical Corporation Facility - Tacoma, Washington**		

1.0 Introduction

This Technical Memorandum (TM) presents revised dense non-aqueous phase liquid (DNAPL) mass estimates for the former Occidental Chemical Facility (Site) located in Tacoma, Washington. DNAPL mass estimates were originally provided in the August 2014 Draft Site Characterization Report (SCR). Two methods were used to estimate DNAPL mass. The first method used the NAPL source zones developed by the procedures described in Kueper-Davies[1]. The second method used NAPL source zones developed through the kriging of NAPL saturations calculated using an analytical model called NAPL Calculator (NAPLCALC). There was a large variation in the estimated confirmed DNAPL mass between the two methods.

At the October 1, 2014 Technical Team meeting, the DNAPL mass estimates were discussed. It was decided that a range in DNAPL mass could be provided; but a best estimate was required for future reference. It was agreed to develop a DNAPL mass estimate by calculating the mass of total chlorinated volatile organic compounds (TCVOCs) in soil using the EVS/MVS model. In addition, the assumptions used in the Kueper-Davies method were re-visited to determine if any revisions were required

The following sections of this TM present the procedures and results for the revised Kueper-Davies method and the EVS method.

2.0 Revised Kueper-Davies Calculations

The Kueper-Davies method is a qualitative procedure used to delineate DNAPL source zone areas. In order to estimate DNAPL mass based on these areas, a thickness must be assigned to each delineated DNAPL source zone; as well as a NAPL saturation. For the estimate provided in the draft SCR, the DNAPL source

1 USEPA, 2009. Assessment and Delineation of DNAPL Source Zones at Hazardous Waste Sites. Publication EPA/600/R-09/119.

zone thickness was assigned the total thickness of the zone grouping plan in which it was located. This was considered conservative (i.e., maximizes the DNAPL mass). A DNAPL saturation of 1 percent was then applied to the total source zone volume.

The application of a 1 percent NAPL saturation to the entire source zone volume is the equivalent of applying a DNAPL saturation of approximately 2.3 percent of the pore volume (based on a total porosity of 0.43)[2]. A review of the calculated DNAPL saturations determined using NAPLCALC indicates that the application of 2.3 percent DNAPL saturation over the entire source zone pore volume would result in an overestimate of the DNAPL mass. Therefore, it was decided to revise the Kueper-Davies mass estimate to factor in the soil porosity and apply a DNAPL saturation of 1 percent of the pore volume. This revision results in a total confirmed NAPL mass of approximately 2.7 million pounds. A summary of the distribution of confirmed DNAPL mass by zone grouping plan is provided in Table 1.

3.0 EVS Method

A third method was used to estimate DNAPL mass which was based on the mass of total chlorinated VOCs (TCVOCs) in the soil/porous media. This mass was calculated using the EVS/MVS model for the Site. The data set used in the development of the TCVOC soil model included all available soil data. However, there were 11 locations where a positive dye test confirmed the presence of DNAPL, but there was no co-located soil sample. There were also 8 locations where there was a positive dye test result, but the co-located soil sample had concentrations of TCVOCs below the portioning threshold (Kueper-Davies calculation #4). Neglecting to take into account the positive dye test results from these 19 samples would result in a DNAPL mass estimate that is biased low. These locations, along with their associated CVOC concentrations, where present, are presented in Table 2.

To include these 19 locations in the DNAPL mass calculation using EVS, TCVOC values must be entered at each location. The average TCVOC value at the remaining 47 locations with positive dye test results and co-located soil samples was used for the 19 locations. Table 3 presents the locations with positive dye test results and CVOC concentrations above the NAPL portioning threshold. The average TCVOC value for these samples is 12,436 milligrams per kilogram (mg/kg). This average CVOC value from locations in Table 3 was used to complete the data set for the EVS/MVS program so that each location with a positive dye test result had an appropriate TCVOC concentration.

This new, complete, data set was then used to create a 3-D model of the soil TCVOC concentrations using EVS/MVS. The model conventions and settings used in the development of this TCVOC 4DIM were identical to those used in the generation of 4DIMs in the SCR (see Appendix O of the SCR). In order to calculate the mass within EVS, a threshold concentration must be established. The 4DIM was reviewed to examine the size and shape of the volume under different concentrations. At a threshold concentration of 100 mg/kg the size and shape of the TCVOC volume roughly corresponded to the areal extent of the potential DNAPL zones determined using by the Kueper-Davies method (see Figure 1). The calculated mass of TCVOCs above this threshold of 100 mg/kg was 780,000 lbs.

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2 Conestoga-Rovers & Associates, 2014. Draft Site Characterization Report. Ref. No.7843 (128), August.

4.0 Summary

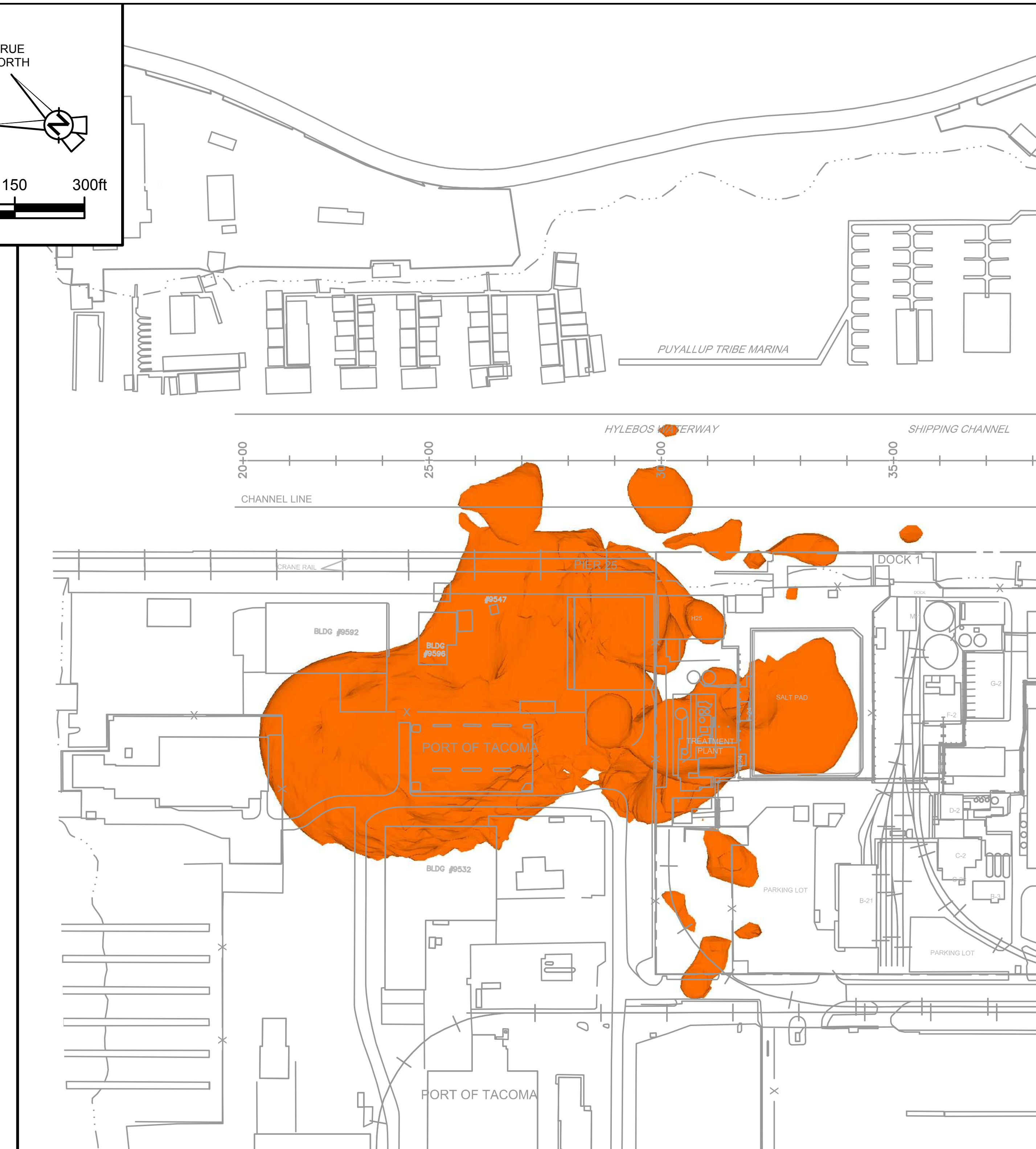
A summary of the estimated confirmed DNAPL mass obtained by each method is presented below:

Method	***NAPL Mass (pounds)***
NAPLCALC	606,000
EVS	780,000
Kueper-Davies	2,770,000

The mass of confirmed DNAPL is likely within the ranged of values determined by the NAPLCALC and Kueper-Davies methods. However, the mass determined using the EVS method is considered the "best" estimate and should be used going forward.

It is important to note, that a precise determination of the NAPL mass is not required for the evaluation of treatment alternatives in the Feasibility Study (FS). It is the volume of impacted soil/porous media which contains the NAPL that determines the practicability and cost of any treatment alternatives.

EXTENT OF POTENTIAL NAPL (KUEPER-DAVIES)



TCVOC IN SOIL @ 100 mg/kg

figure 1

TCVOC AND NAPL EXTENTS

Occidental Chemical Corporation, Tacoma, Washington

CRA

07843-A6(MEMO075)GN-WA001 OCT 28/2014

TABLE 1

REVISED DNAPL MASS IN EACH DEPTH ZONE
KUEPER-DAVIES METHOD WITH POROSITY
OCCIDENTAL CHEMICAL CORPORATION
TACOMA, WASHINGTON

Depth Zone	Calculated DNAPL Mass (lbs)
15-foot	503,889
25-foot	225,496
50-foot	none
75-foot	none
100-foot	164,413
130-foot	1,602,655
160-foot	271,777
TOTAL	**2,768,231**

TABLE 2

POSITIVE DYE TEST
NAPL INVESTIGATION - VAS AND SOIL SAMPLING
OCCIDENTAL CHEMICAL CORPORATION
TACOMA, WASHINGTON

Location Name	*Mid-screen* (ft NGVD)	*Total CVOC (Comprehensive 2013)* (mg/kg)	*Threshold Chemical Concentration Calculated* (unitless)
MW-EXT-9-INT	-126.19	No Soil Sampled	N/A
MW-EXT-9-INT	-131.19	No Soil Sampled	N/A
SB-A	1.63	No Soil Sampled	N/A
WMUA-34	-2.62	No Soil Sampled	N/A
WMUA-40	-2.23	No Soil Sampled	N/A
WMUA-41	-4.65	No Soil Sampled	N/A
WMUG-12	-3.46	No Soil Sampled	N/A
WMUR-01	-4.67	No Soil Sampled	N/A
WMUR-01	-13.17	No Soil Sampled	N/A
WMUR-09	-7.12	No Soil Sampled	N/A
WMUR-06	-125.81	No Soil Sampled	N/A
WMUA-41	3.35	11	0.10
WMUA-41	-10.65	43.27	0.02
WMUG-14	-12.01	0.097	0.00
WMUR-09	1.88	13.056	0.12
WMUR-09	-0.12	86.3	0.79
WMUR-09	-1.12	65.2	0.60
WMUR-10	-108.31	120.5	0.85
WMUR-10 (1)	-136.11	171.9	0.08

Note:

(1) Reported concentration and Kueper-Davies calculation #4 is for soil sample collected at -137.61

TABLE 3

TCVOC AND NAPL THRESHOLD VALUES FOR POSITIVE DYE TEST SAMPLES
NAPL INVESTIGATION
OCCIDENTAL CHEMICAL CORPORATION
TACOMA, WASHINGTON

Location Name	*Mid-screen Soil Sample*	*Mid-screen Dye Test (ft NGVD)*	*1,1-Dichloroethene (ug/kg)*	*cis-1,2-Dichloroethene (ug/kg)*	*Tetrachloroethene (ug/kg)*	*trans-1,2-Dichloroethene (ug/kg)*	*Trichloroethene (ug/kg)*	*Vinyl chloride (ug/kg)*	*Threshold Chemical Concentration Calculation (unitless)*	*Total CVOC (ug/kg)*
SB-B-DEEP	-134.95	-135.70 *	960	6,400	120,000	780	290,000	--	1.63	416,400
SB-B-DEEP	-138.95	-138.20 *	1,100	9,800	210,000	770	350,000	--	2.57	569,800
SB-B-DEEP	-133.45	-133.20 *	1,600	13,000	340,000	770	490,000	910	4.02	843,910
SB-B-DEEP	-130.45	-130.70 *	5,200	34,000	1,100,000	2,600	1,500,000	--	12.83	2,634,000
SB-B-DEEP	-140.45	-140.70 *	2,000	23,000	2,100,000	--	1,700,000	--	22.37	3,823,000
WMUA-34	-3.12	-3.12	--	38,000	6,400,000	--	8,400,000	--	73.96	14,838,000
WMUA-34	-3.12	-3.62	--	38,000	6,400,000	--	8,400,000	--	73.96	14,838,000
WMUA-40	-1.13	-0.23 *	--	3,000	130,000	--	16,000	28	1.22	149,028
WMUA-40	-1.13	-1.23 *	--	3,000	130,000	--	16,000	28	1.22	149,028
WMUA-41	-3.65	-2.65 *	--	--	3,300,000	--	77,000	--	30.47	3,377,000
WMUA-41	-6.15	-6.15	--	22,000	180,000	--	100,000	--	1.84	302,000
WMUA-41	-3.65	-3.65	--	--	3,300,000	--	77,000	--	30.47	3,377,000
WMUG-01	-6.23	-6.23	--	--	10,000,000	--	120,000	--	92.13	10,120,000
WMUG-03	-6.92	-6.92	--	69	270,000	--	57,000	--	2.58	327,069
WMUG-03	-17.42	-17.42	350	370	280,000	160	320,000	--	3.15	600,370
WMUG-03	-5.92	-5.92	260	150	1,400,000	--	170,000	--	13.17	1,570,150
WMUG-06	-8.07	-7.07 *	250	1,400	400,000	--	830,000	3,600	5.17	1,235,000
WMUG-06	-4.07	-5.07 *	180	2,200	1,200,000	--	250,000	1,600	11.48	1,453,800
WMUG-06	-6.07	-6.07	68	370	190,000	23	200,000	180	2.11	390,550
WMUG-10	-9.07	-8.07 *	--	--	98,000	--	470,000	--	1.75	568,000
WMUG-10	-4.57	-4.57	--	--	120,000	--	160,000	310	1.39	280,310
WMUG-10	-7.07	-7.07	--	--	32,000,000	--	58,000,000	--	398.52	90,000,000
WMUG-12	-5.46	-5.46	--	--	450,000	--	89,000	--	4.30	539,000
WMUR-01	-12.17	-11.17 *	--	--	210,000	--	21,000	520	1.97	231,520
WMUR-01	-12.17	-11.67 *	--	--	210,000	--	21,000	520	1.97	231,520
WMUR-01	-2.67	-2.67	--	--	340,000	--	--	--	3.12	340,000
WMUR-01	-10.17	-10.17	--	--	810,000	--	98,000	--	7.62	908,000
WMUR-01	-7.67	-7.67	--	--	2,000,000	--	1,200,000	--	20.54	3,200,000
WMUR-01	-4.17	-4.17	--	--	3,100,000	--	88,000	--	28.65	3,188,000
WMUR-01	-87.67	-87.67	1,900	300,000	5,600,000	2,400	2,500,000	18,000	56.10	8,418,000
WMUR-03	-100.02	-99.72 *	9,100	460,000	7,400,000	11,000	11,000,000	7,800	88.03	18,867,800
WMUR-03	-100.02	-100.22 *	9,100	460,000	7,400,000	11,000	11,000,000	7,800	88.03	18,867,800
WMUR-04	-99.14	-99.14	--	26,000	5,900,000	--	5,000,000	--	63.24	10,926,000
WMUR-05/83C	-11.54	-11.54	31	18,000	93,000	210	100,000	220	1.04	209,022
WMUR-06/94C	-126.21	-126.21	690,000	580,000	120,000,000	140,000	53,000,000	--	1199.45	173,580,000
WMUR-07	-112.14	-112.14	--	760	320,000	--	330,000	--	3.54	650,760
WMUR-07	-109.04	-109.14	--	8,600	15,000,000	7,900	17,000,000	--	168.47	32,008,600
WMUR-08	-99.07	-99.17 *	18,000	--	15,000,000	250,000	7,200,000	--	150.99	22,200,000
WMUR-09	-12.82	-12.62 *	--	--	180,000	--	13,000	--	1.68	193,000
WMUR-09	-17.62	-17.62	--	1,900	400,000	--	390,000	--	4.38	791,900
WMUR-09	-9.62	-9.62	--	1,300	530,000	--	690,000	--	6.11	1,221,300
WMUR-09	-79.62	-79.62	--	9,100	540,000	--	1,100,000	--	6.95	1,649,100
WMUR-09	-7.62	-7.62	--	1,300	960,000	--	450,000	--	9.63	1,411,300
WMUR-09	-82.12	-82.12	--	39,000	7,700,000	--	12,000,000	--	92.39	19,739,000
WMUR-10	-135.91	-135.61 *	--	180,000	1,800,000	--	300,000	--	17.16	2,280,000
WMUR-10	-114.61	-114.61	1,400	4,100	170,000	--	280,000	--	2.07	454,100
WMUR-10	-126.11	-126.11	180,000	530,000	61,000,000	--	49,000,000	--	649.28	110,530,000
									Average CVOC	**12,436,131**

Note:
* Vertical separation between dye test results and soil sample ≤ 1 ft

Appendix D
Technical Memorandum - Analysis of TCVOCs Concentrations in Soil to Determine Zones for Potential Targeted Remediation

Memorandum

To:	Clint Babcock	Ref. No.:	007843
From:	Robert Harris/wg/79	Date:	June 13, 2016
CC:	Ian Richardson		

Re: **Analysis of TCVOC Concentrations in Soil to Determine Zones for Potential Targeted Remediation**

The technical memorandum (TM) presents the analysis of total chlorinated volatile organic compounds (TCVOC) in soil to identify zones for potential targeted remediation at the Occidental Chemical Corporation (OCC) Site in Tacoma, Washington. The purpose of the analysis is to determine the concentration threshold below which the benefit of additional mass removal declines significantly (i.e., diminishing returns), which would result in escalating effort and time to target limited additional mass.

Selecting a concentration threshold of TCVOC for potential targeted remediation requires determining a point at which the benefit of treating additional mass diminishes significantly because of a large increase of soil volume (containing the mass) to remediate. Therefore, this analysis is focused on the relationship between masses of TCVOC in soil and the estimated remediation soil volumes containing the corresponding TCVOC masses.

Concentration Thresholds Evaluated

The following concentration thresholds were evaluated in the analysis.

1. 10,000 milligrams per kilogram (mg/kg)
2. 7,500 mg/kg
3. 5,000 mg/kg
4. 2,500 mg/kg
5. 1,000 mg/kg
6. 500 mg/kg
7. 250 mg/kg
8. 100 mg/kg

The above provides a wide range and sufficient number of concentrations to study the relationship between mass and estimated remediation soil volume. The 10,000 mg/kg threshold was selected as the upper bound because a small number and size of volumes appear at this concentration. The 100 mg/kg threshold was selected as the lower bound consistent with Revised DNAPL Mass Estimates (CRA memorandum, November 11, 2014). The calculated mass of TCVOC above the threshold of 100 mg/kg was 780,000 pounds (lbs).

Determining Chemical Masses and Estimated Soil Remediation Volumes

The EVS software was used to determine chemical masses and soil volumes at each concentration threshold based on a porosity of 0.43, soil density of 1.61 grams per cubic centimeter (gm/cc), and chemical density of 1.623 gm/cc. These parameters are those within the current EVS plume models. Furthermore, the volumes were segregated into shallow and deep zones, the cut off being -60 feet (ft) National Geodetic Vertical Datum (NGVD) consistent with the feasibility study agreed approach for evaluation.

The shallow zone was further segregated into elevations above -21 feet (ft) NGVD and elevations between -21 and -60 ft NGVD. This segregation was done because there is no mass between -21 and -60 ft NGVD for thresholds from 10,000 mg/kg to 1,000 mg/kg and insignificant mass when compared to the total mass for thresholds from 500 mg/kg to 100 mg/kg. At the 100 mg/kg threshold, approximately 11 percent of the total mass (780,000 lbs) is located above -21 ft NGVD in the shallow zone and 85 percent of the mass is located in the deep zone (below -60 ft NGVD). The remaining approximately 3 percent is located between -21 and -60 ft NGVD.

Estimated remediation soil volumes were calculated by multiplying the plan view area of the soil volumes produced from EVS by the plume volume thickness (difference of top and bottom elevations) and adding ten percent, accounting for a factor of safety for remedial implementation. The plan view areas were determined using the calculation tool in AutoCAD™.

The shallow zone is discussed below, followed by discussion of the deep zone.

Shallow Zone (≥ -21 ft NGVD)

TCVOC ≥ 10,000 mg/kg Threshold

One volume was identified in the shallow zone (≥ -21 ft NGVD) for TCVOC ≥ 10,000 mg/kg concentration threshold as shown in plan view on Figure 1.

The calculated values for this threshold are summarized in the following table.

	Total
Area [square feet(sf)]	1,390
Soil volume [cubic yards (cy)]	138
Chemical mass (lbs)	4,262
Elevation at top of volume (ft NGVD)	0
Elevation at bottom of volume (ft NGVD)	-7
Estimated Remediation Soil Volume (cy)	396

The shallow zone estimated remediation volume for the 10,000 mg/kg threshold is 396 cy.

TCVOC ≥ 7,500 mg/kg Threshold

Two volumes were identified in the shallow zone for TCVOC ≥ 7,500 mg/kg concentration threshold as shown in plan view on Figure 2. The difference from the 10,000 mg/kg threshold is that one additional volume was identified.

The calculated values for this threshold are summarized in the following table.

			Total
Area (sf)	2,703	239	2,942
Soil volume (cy)	360.5	4.5	365
Chemical mass (lbs)	9,452	99	9,551
Elevation at top of volume (ft NGVD)	1	-6	-
Elevation at bottom of volume (ft NGVD)	-8	-8	-
Estimated Remediation Soil Volume (cy)	991	19.5	1,011

The shallow zone estimated remediation volume for the 7,500 mg/kg threshold is 1,011 cy.

TCVOC ≥ 5,000 mg/kg Threshold

Three volumes were identified in the shallow zone for TCVOC ≥ 5,000 mg/kg concentration threshold as shown in plan view on Figure 3. The difference from the 7,500 mg/kg threshold is that one additional volume was identified.

The calculated values for this threshold are summarized in the following table.

				Total
Area (sf)	5,654	819	19	6,492
Soil volume (cy)	884	34	0.3	918
Chemical mass (lbs)	18,040	581	4	18,625
Elevation at top of volume (ft NGVD)	1	-6	3	-
Elevation at bottom of volume (ft NGVD)	-9	-9	1	-
Estimated Remediation Soil Volume (cy)	2,303	100	1.5	2,405

The shallow zone estimated remediation volume for the 5,000 mg/kg threshold is 2,405 cy.

TCVOC ≥ 2,500 mg/kg Threshold

Four volumes were identified in the shallow zone for TCVOC ≥ 2,500 mg/kg concentration threshold as shown in plan view on Figure 4. The difference from the 5,000 mg/kg threshold is that one additional volume was identified.

The calculated values for this threshold are summarized in the following table.

					Total
Area (sf)	9,552	2,377	280	23	12,232
Soil volume (cy)	2,160	173	15	0.2	2,348
Chemical mass (lbs)	30,391	1,865	137	1.5	32,395
Elevation at top of volume (ft NGVD)	2	-5	3	-9	-

					Total
Elevation at bottom of volume (ft NGVD)	-11	-9	0.5	-11	-
Estimated Remediation Soil Volume (cy)	5,059	387	29	2	5,477

The shallow zone estimated remediation volume for the 2,500 mg/kg threshold is 5,477 cy.

TCVOC ≥ 1,000 mg/kg Threshold

Nine volumes were identified in the shallow zone for TCVOC ≥ 1,000 mg/kg concentration threshold as shown in plan view on Figure 5. The difference from the 2,500 mg/kg threshold is that additional volumes were identified.

The calculated values for this threshold are summarized in the following table.

										Total
Area (sf)	14,456	8,746	1,427	1,225	473	360	243	163	4	27,097
Soil volume (cy)	4,855	1,222	130	158	19.6	8	4.7	3.8	0.3	6,401
Chemical mass (lbs)	41,992	5,953	628.4	541.4	65.4	26.1	14.2	12	1	49,234
Elevation at top of volume (ft NGVD)	2	-3	5	-3	-2	-9	-17	-6	-2	-
Elevation at bottom of volume (ft NGVD)	-16	-12	-1	-12	-5	-12	-20	-7	-3	-
Estimated Remediation Soil Volume (cy)	10,601	3,207	349	449	57.8	44	29.7	6.6	0.2	14,744

The shallow zone estimated remediation volume for the 1,000 mg/kg threshold is 14,744 cy.

TCVOC ≥ 500 mg/kg Threshold

Six volumes were identified in the -21 ft NGVD shallow zone for TCVOC ≥ 500 mg/kg concentration threshold as shown in plan view on Figure 6. There was three less volume than at the 1,000 mg/kg threshold because volumes combined. An additional three volumes were identified between -21 and -60 ft NGVD and make up less than 0.01 percent of the total DNAPL mass of 780,000 mg/kg.

The calculated values for this threshold are summarized in the following table.

							Total
Area (sf)	21,713	19,870	2,996	2,943	1,034	249	48,805
Soil volume (cy)	4,034	8,111	412	549	102	10.2	13,218
Chemical mass (lbs)	11,218	48,327	1,201	1,284	219	17	62,266
Elevation at top of volume (ft NGVD)	-3	3	5	-2	-2	-1	-
Elevation at bottom of volume (ft NGVD)	-21	-17	-1	-12	-7	-4	-
Estimated Remediation Soil Volume (cy)	12,827	16,190	732.4	1,199	211	30.4	31,190

The area of 21,713 sf is a combination of four areas previously identified for the TCVOC ≥ 1,000 mg/kg concentration threshold. These combined areas have varying depths and thicknesses. Therefore the thickness of the total area was adjusted to 14.5 ft based on averaging thicknesses of 18 ft (maximum thickness) and 11 ft (thickness of the largest of the combined areas).

The shallow zone estimated remediation volume for the 500 mg/kg threshold is 31,190 cy.

TCVOC ≥ 250 mg/kg Threshold

Five volumes were identified in the -21 ft NGVD shallow zone for TCVOC ≥ 250 mg/kg concentration threshold as shown in plan view on Figure 7. There was one less volume than at the 500 mg/kg threshold because volumes combined. An additional ten small volumes were identified between -21 and -60 ft NGVD that make up less than 0.5 percent of the total DNAPL mass of 780,000 mg/kg.

The calculated values for this threshold are summarized in the following table.

						Total
Area (sf)	61,775	6,808	5,126	1,948	58	75,715
Soil volume (cy)	24,174	1,263.7	959.4	266	2.9	26,666
Chemical mass (lbs)	71,235	1,941	1,701	364	2	75,243
Elevation at top of volume (ft NGVD)	3	-1	5	-1	-9	-
Elevation at bottom of volume (ft NGVD)	-21	-12	-2	-7	-11	-
Estimated Remediation Soil Volume (cy)	60,402	3,100	1,462	476	4.7	65,445

The shallow zone estimated remediation volume for the 250 mg/kg threshold is 65,445 cy.

TCVOC ≥ 100 mg/kg Threshold

Six volumes were identified in the -21 ft NGVD shallow zone for TCVOC ≥ 100 mg/kg concentration threshold as shown in plan view on Figure 8. The difference from the 250 mg/kg threshold is that some volumes combined and additional volumes were identified. At this threshold, the largest volume in the -21 ft NGVD shallow zone is connected to the largest volume in the deep zone (< -60 ft NGVD). The volume between -21 ft NGVD and -60 ft NGVD represents approximately 3 percent of the total mass of 780,000 mg/kg.

The calculated values for this threshold are summarized in the following table.

							Total
Area (sf)	109,166	10,198	8,588	2,822	1,430	559	132,763
Soil volume (cy)	47,307	2,531	1,319	226	159.8	21.6	51,564
Chemical mass (lbs)	82,479	2,503	777	67	53	6.7	85,886
Elevation at top of volume (ft NGVD)	7	5	-1	-2	-3	-5	-
Elevation at bottom of volume (ft NGVD)	-21	-13	-10	-8	-11	-8	-
Estimated Remediation Soil Volume (cy)	124,530	7,479	3,149	690	466	68	136,382

The shallow zone estimated remediation volume for the 100 mg/kg threshold is 136,382 cy.

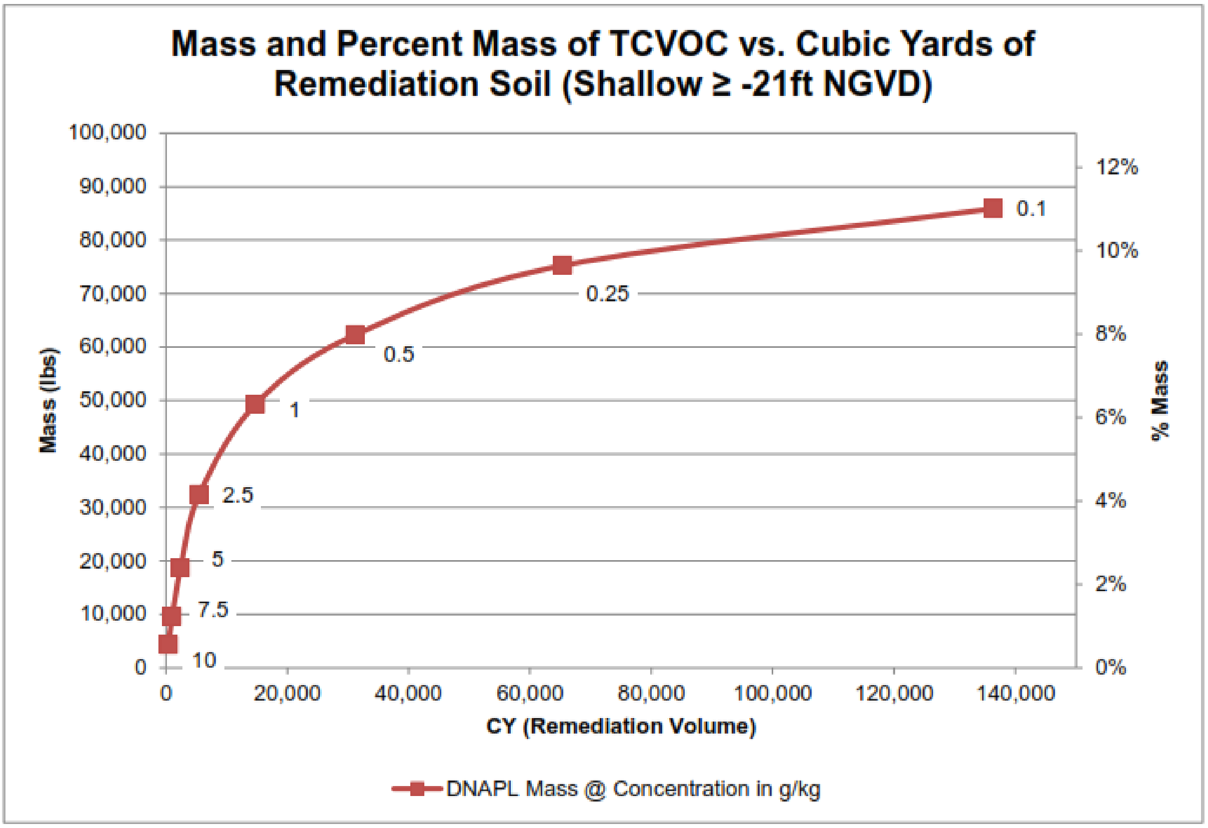
The following table summarizes the findings from the above analysis.

Potential Concentration Threshold (mg/kg)	DNAPL Mass from EVS (lbs)	Percent of Total DNAPL Mass	Soil Volume from EVS (cy)	Plan View Area (sf)	Estimated Remediation Volume (cy)
10,000	4,262	0.5%	138	1,390	396
7,500	9,551	1.2%	365	2,942	1,011
5,000	18,625	2.4%	918	6,492	2,405
2,500	32,395	4.2%	2,348	12,232	5,477
1,000	49,234	6.3%	6,401	27,097	14,744
500	62,266	8.0%	13,218	48,805	31,190
250	75,243	9.6%	26,666	75,715	65,445
100	85,886	11.0%	51,564	132,763	136,382

A review of the estimated remediation volumes for all the thresholds in comparison to the related soil volumes determined from the EVS software was completed. The comparison indicates that the average percent increase from the EVS volumes to the estimated remediation volumes is 254 percent, with a range of 230 to 287 percent.

Determining Concentration Threshold in the Shallow Zone

To evaluate the threshold of optimum remediation volume/mass ratio, total mass was plotted versus the estimated remediation volume for each of the potential concentration thresholds as shown below.



As shown on the graph, initially the mass of TCVOC in soil increases with minimum increases in the estimated remediation volume. The plotted line then begins to arc between the TCVOC ≥ 1,000 mg/kg and TCVOC ≥ 500 mg/kg concentration thresholds, indicating that the estimated remediation volumes are increasing more significantly with lower concentration thresholds. Between the TCVOC ≥ 500 mg/kg concentration threshold and the TCVOC ≥ 100 mg/kg concentration threshold, the graph becomes increasingly flat, indicating that the estimated remediation volumes are increasing at a greater rate than the masses.

The benefit of additional mass removal declines significantly at thresholds below 500 mg/kg. Therefore, the lower limit to identify DNAPL areas for potential remediation should be 500 mg/kg.

As discussed previously, at the TCVOC ≥ 500 mg/kg concentration threshold, there are three small areas between -21 and -60 ft NGVD as shown on Figure 9 that make up less than 0.01 percent of the total DNAPL mass of 780,000 mg/kg. The benefit of attempting to remove these masses is insignificant and not practical.

Deep Zone (< -60 ft NGVD)

The estimated remediation soil volumes for the deep zone were calculated using the average percent increase from the EVS volumes to the estimated remediation volumes for the shallow zone of 254 percent. This is based on the assumption that the procedure used for the shallow zone would yield similar results for the deep zone.

TCVOC ≥ 10,000 mg/kg Threshold

Three volumes were identified in the deep zone for TCVOC ≥ 10,000 mg/kg concentration threshold as shown in plan view on Figure 10.

The calculated values for this threshold are summarized in the following table.

				Total
Area (sf)	1,458	644	180	2,282
Soil volume (cy)	117.2	35.2	5.1	158
Chemical mass (lbs)	4,649	1,111.7	210.6	5,971
Elevation at top of volume (ft NGVD)	-125	-100	-125	-
Elevation at bottom of volume (ft NGVD)	-129	-103	-127	-
Estimated Remediation Soil Volume (cy)	297	89	13	400

The deep zone estimated remediation volume for the 10,000 mg/kg threshold is 400 cy.

TCVOC ≥ 7,500 mg/kg Threshold

Four volumes were identified in the deep zone for TCVOC ≥ 7,500 mg/kg concentration threshold as shown in plan view on Figure 11. The difference from the 10,000 mg/kg threshold is that one additional volume was identified.

The calculated values for this threshold are summarized in the following table.

					Total
Area (sf)	2,215	1,131	257	60	3,663
Soil volume (cy)	203	106	8.6	2	320
Chemical mass (lbs)	6,689	2,762	293	34	9,778
Elevation at top of volume (ft NGVD)	-125	-98	-125	-133	-
Elevation at bottom of volume (ft NGVD)	-129	-104	-127	-135	-
Estimated Remediation Soil Volume (cy)	516	269	22	5	812

The deep zone estimated remediation volume for the 7,500 mg/kg threshold is 812 cy.

TCVOC ≥ 5,000 mg/kg Threshold

Six volumes were identified in the deep zone for TCVOC ≥ 5,000 mg/kg concentration threshold as shown in plan view on Figure 12. The difference from the 7,500 mg/kg threshold is that additional volumes were identified.

The calculated values for this threshold are summarized in the following table.

							Total
Area (sf)	4,320	3,796	2,399	398	327	52	11,292
Soil volume (cy)	884	437	257	16.4	6.6	2.1	1,603
Chemical mass (lbs)	11,655	10,782	5,290	428	92	30	28,277
Elevation at top of volume (ft NGVD)	-130	-124	-98	-125	-132	-81	-
Elevation at bottom of volume (ft NGVD)	-140	-130	-104	-128	-134	-83	-
Estimated Remediation Soil Volume (cy)	2,245	1,110	653	42	17	5.3	4,072

The deep zone estimated remediation volume for the 5,000 mg/kg threshold is 4,072 cy.

TCVOC ≥ 2,500 mg/kg Threshold

Six volumes were identified in the deep zone for TCVOC ≥ 2,500 mg/kg concentration threshold as shown in plan view on Figure 13. The difference from the 5,000 mg/kg threshold is that two volumes combined and one additional volume was identified.

The calculated values for this threshold are summarized in the following table.

							Total
Area (sf)	35,150	9,687	4,896	877	658	346	51,614
Soil volume (cy)	12,449	1,585	747	37	65	18	14,901
Chemical mass (lbs)	116,370	21,281	9,962	627	597	141	148,978
Elevation at top of volume (ft NGVD)	-123	-124	-97	-125	-80	-98	-
Elevation at bottom of volume (ft NGVD)	-145	-131	-105	-128	-84	-101	-
Estimated Remediation Soil Volume (cy)	31,620	4,026	1,897	94	165	46	37,848

The deep zone estimated remediation volume for the 2,500 mg/kg threshold is 37,848 cy.

TCVOC ≥ 1,000 mg/kg Threshold

Six volumes were identified in the deep zone for TCVOC ≥ 1,000 mg/kg concentration threshold as shown in plan view on Figure 14. The difference from the 2,500 mg/kg threshold is that two volumes combined and one additional volume was identified.

The calculated values for this threshold are summarized in the following table.

							Total
Area (sf)	76,120	32,052	10,529	6,194	4,706	1,283	130,884
Soil volume (cy)	45,107	8,926	2,331	674.5	629	141	57,809
Chemical mass (lbs)	255,160	51,053	16,379	2,344	2,886	642	328,464
Elevation at top of volume (ft NGVD)	-117	-122	-95	-85	-78	-97	-
Elevation at bottom of volume (ft NGVD)	-152	-137	-108	-113	-90	-102	-
Estimated Remediation Soil Volume (cy)	114,572	22,672	5,921	1,713	1,598	358	146,834

The deep zone estimated remediation volume for the 1,000 mg/kg threshold is 146,834 cy.

TCVOC ≥ 500 mg/kg Threshold

Three volumes were identified in the deep zone for TCVOC ≥ 500 mg/kg concentration threshold as shown in plan view on Figure 15. The difference from the 1,000 mg/kg threshold is that some volumes combined.

The calculated values for this threshold are summarized in the following table.

				Total
Area (sf)	229,768	8,543	2,232	240,543
Soil volume (cy)	126,920	2,756	341	130,017
Chemical mass (lbs)	455,610	6,906	1,038	463,554
Elevation at top of volume (ft NGVD)	-94	-76	-96	-
Elevation at bottom of volume (ft NGVD)	-156	-92	-103	-
Estimated Remediation Soil Volume (cy)	322,377	7,000	866	330,243

The deep zone estimated remediation volume for the 500 mg/kg threshold is 330,243 cy.

TCVOC ≥ 250 mg/kg Threshold

Three volumes were identified in the deep zone for TCVOC ≥ 250 mg/kg concentration threshold as shown in plan view on Figure 16. The difference from the 500 mg/kg threshold is that two volumes combined and one additional volume was identified.

The calculated values for this threshold are summarized in the following table.

				Total
Area (sf)	330,617	3,532	2,304	336,453
Soil volume (cy)	242,611	756	281	243,648
Chemical mass (lbs)	571,030	1,444	230	572,704
Elevation at top of volume (ft NGVD)	-60	-95	-73	-
Elevation at bottom of volume (ft NGVD)	-156	-105	-78	-
Estimated Remediation Soil Volume (cy)	616,232	1,920	714	618,866

The deep zone estimated remediation volume for the 250 mg/kg threshold is 618,866 cy.

TCVOC ≥ 100 mg/kg Threshold

Four volumes were identified in the deep zone for TCVOC ≥ 100 mg/kg concentration threshold as shown in plan view on Figure 17. The difference from the 250 mg/kg threshold is that some volumes combined and additional volumes were identified.

The calculated values for this threshold are summarized in the following table.

					Total
Area (sf)	507,342	15,260	833	162	523,597
Soil volume (cy)	492,049	4,239.4	95	6	496,389
Chemical mass (lbs)	663,028	1,739	27.7	1.7	664,796
Elevation at top of volume (ft NGVD)	-60	-70	-66	-75	-
Elevation at bottom of volume (ft NGVD)	-156	-83	-72	-77	-
Estimated Remediation Soil Volume (cy)	1,249,805	10,768	241	15	1,260,829

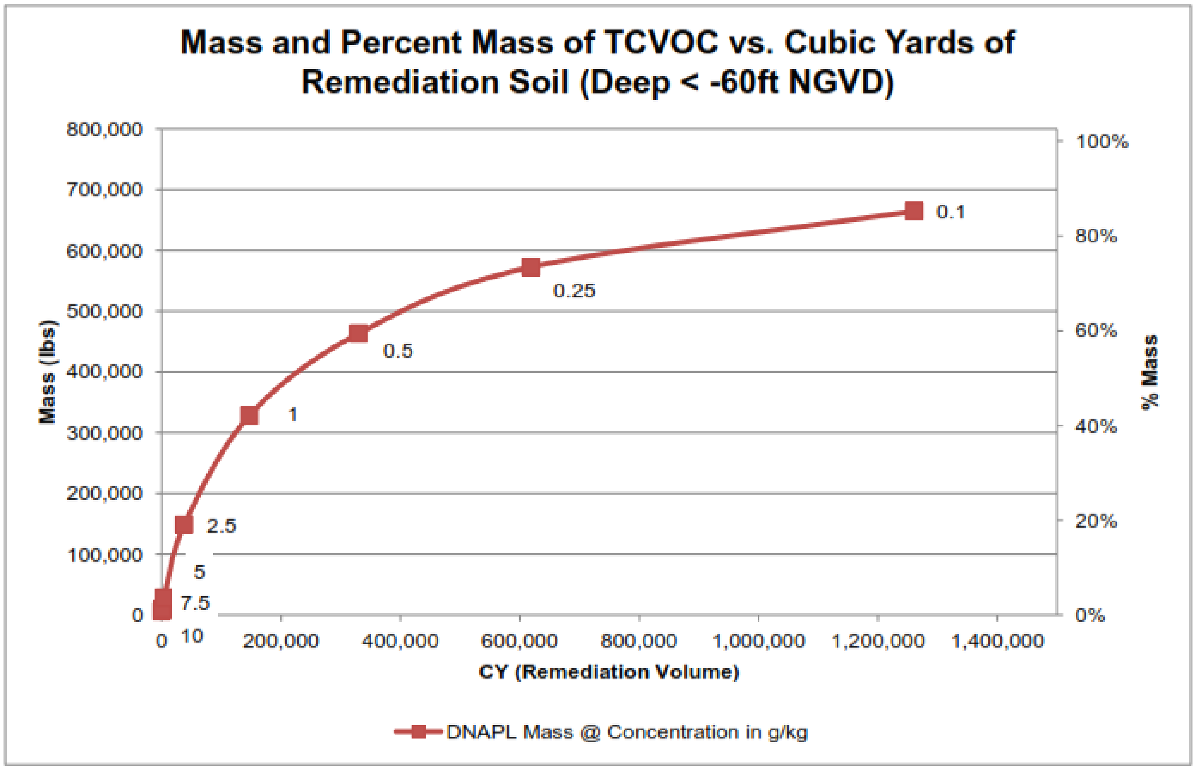
The deep zone estimated remediation volume for the 100 mg/kg threshold is 1,260,829 cy.

The following table summarizes the findings from the above analysis.

Potential Concentration Threshold (mg/kg)	DNAPL Mass from EVS (lbs)	Percent of Total DNAPL Mass	Soil Volume from EVS (cy)	Plan View Area (sf)	Estimated Remediation Volume (cy)
10,000	5,971	0.8%	158	2,282	400
7,500	9,778	1.3%	320	3,663	812
5,000	28,277	3.6%	1,603	11,292	4,072
2,500	148,978	19.1%	14,901	51,614	37,848
1,000	328,464	42.1%	57,809	130,884	146,834
500	463,554	59.4%	130,017	240,543	330,243
250	572,704	73.9%	243,648	336,453	618,866
100	664,796	85.2%	496,389	523,597	1,260,829

Determining Concentration Threshold in the Deep Zone

To evaluate the threshold of optimum remediation volume/mass ratio, total mass was plotted versus the estimated remediation volume for each of the potential concentration thresholds as shown below.



Similar to the shallow zone, initially the mass of TCVOC in soil increases with minimum increases in the estimated remediation volume. The plotted line then begins to arc between the TCVOC ≥ 1,000 mg/kg and TCVOC ≥ 500 mg/kg concentration thresholds, indicating that the estimated remediation volumes are increasing more significantly with lower concentration thresholds. Between the TCVOC ≥ 500 mg/kg concentration threshold and the TCVOC ≥ 100 mg/kg concentration threshold, the graph becomes increasingly flat, indicating that the estimated remediation volumes are increasing at a greater rate than the masses.

The benefit of additional mass removal declines significantly at thresholds below 500 mg/kg. Therefore, the lower limit to identify DNAPL areas for potential remediation should be 500 mg/kg.

Conclusion

The analysis presented herein determined that the lower limit to identify DNAPL areas for potential remediation should be 500 mg/kg. At this threshold concentration, the total masses targeted will be approximately 62,000 lbs in the shallow zone (-21 ft NGVD) and 464,000 lbs in the deep zone (< -60 ft NGVD). These masses represent approximately 8 percent and 59.4 percent of the total mass calculated at the 100 mg/kg concentration, respectively. The estimated remediation volumes containing these masses were calculated to be approximately 31,000 cy in the shallow zone and 330,000 cy in the deep zone.

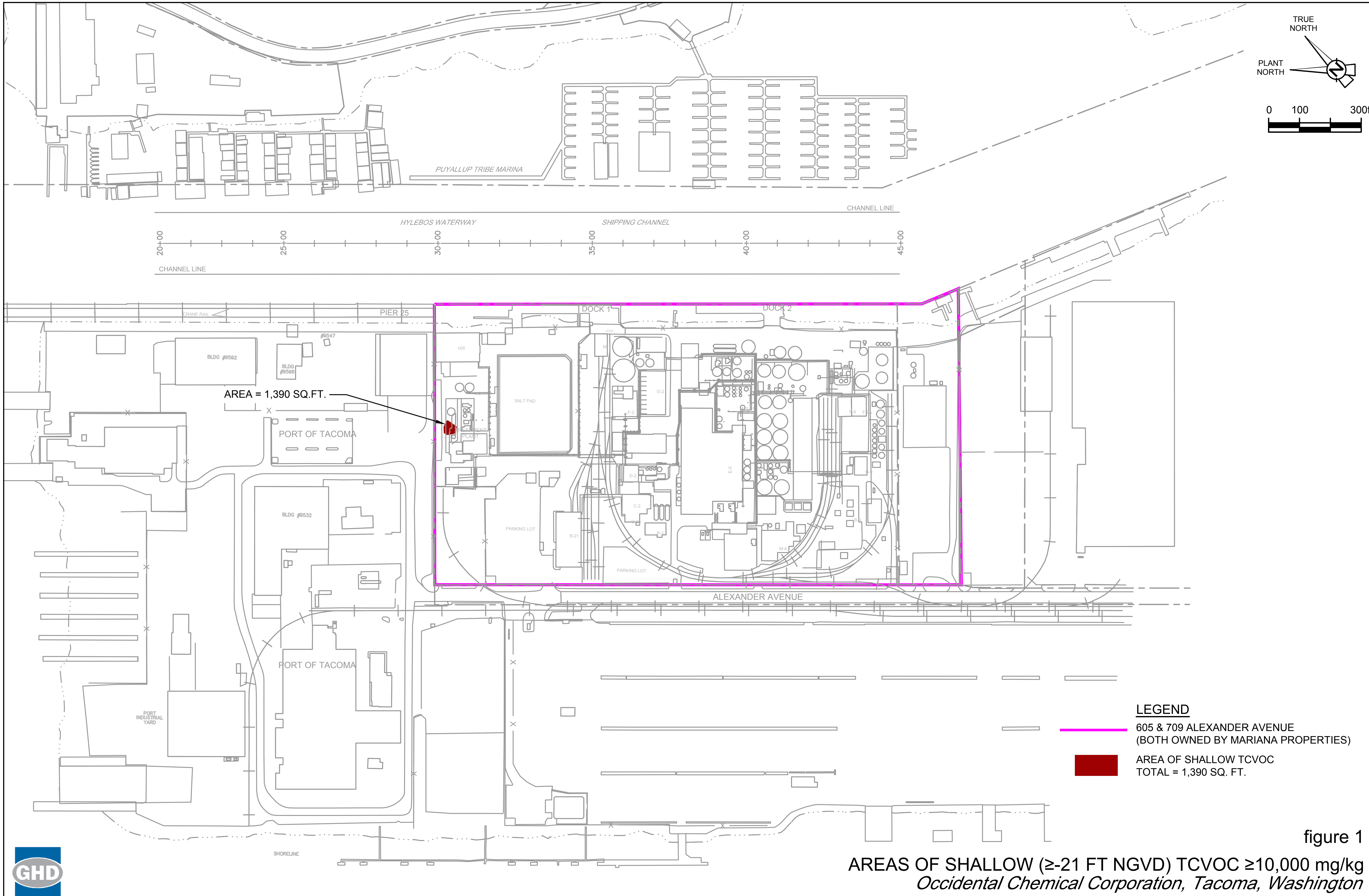


figure 1

AREAS OF SHALLOW (≥-21 FT NGVD) TCVOC ≥10,000 mg/kg

Occidental Chemical Corporation, Tacoma, Washington

07843-C2D2(MEMO079)GN-WA001 JUN 13, 2016

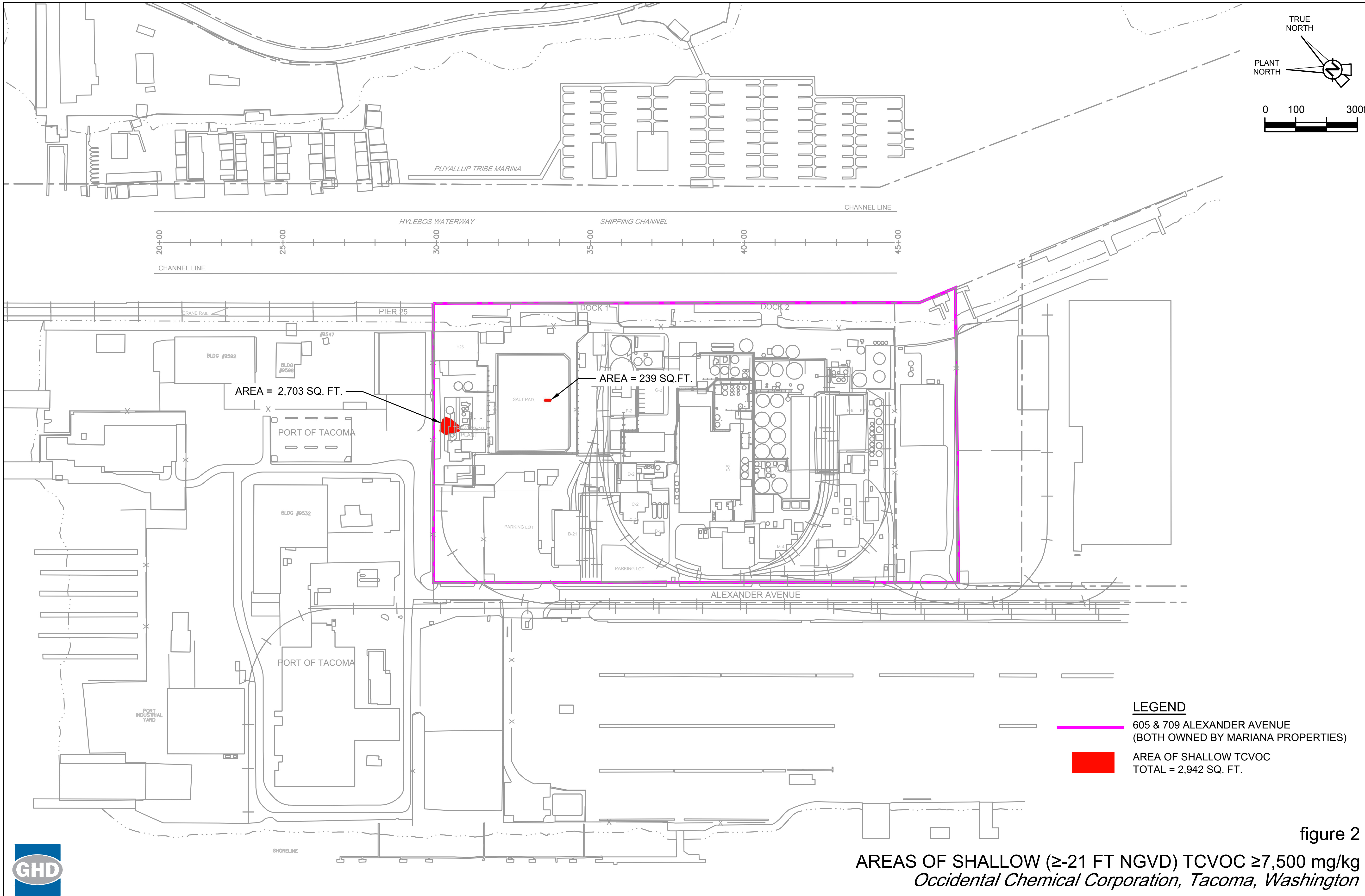


figure 2

AREAS OF SHALLOW (≥-21 FT NGVD) TCVOC ≥7,500 mg/kg

Occidental Chemical Corporation, Tacoma, Washington

07843-C2D2(MEMO079)GN-WA002 JUN 13, 2016

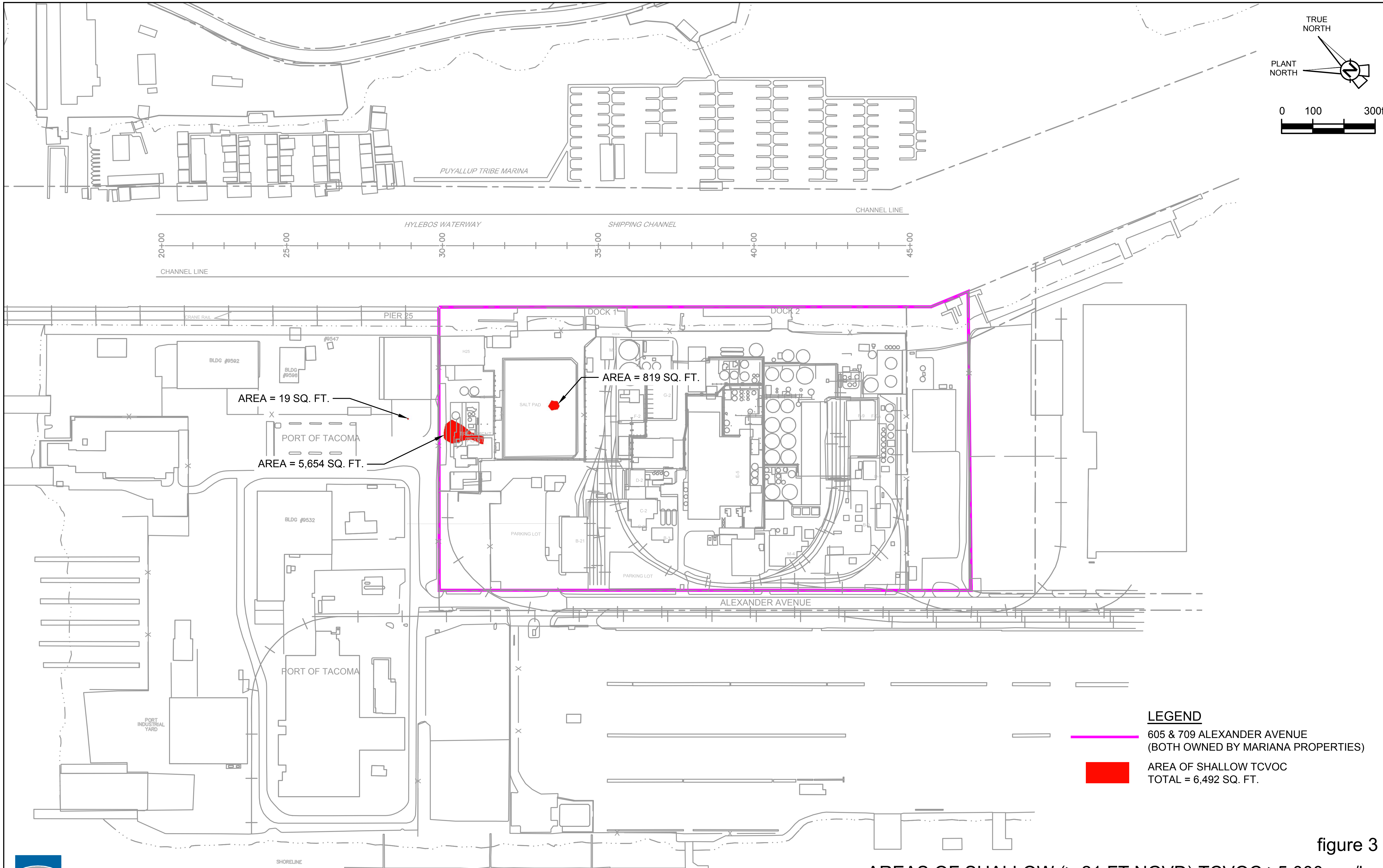


figure 3

AREAS OF SHALLOW (≥-21 FT NGVD) TCVOC ≥5,000 mg/kg

Occidental Chemical Corporation, Tacoma, Washington

GHD

07843-C2D2(MEMO079)GN-WA003 JUN 13, 2016

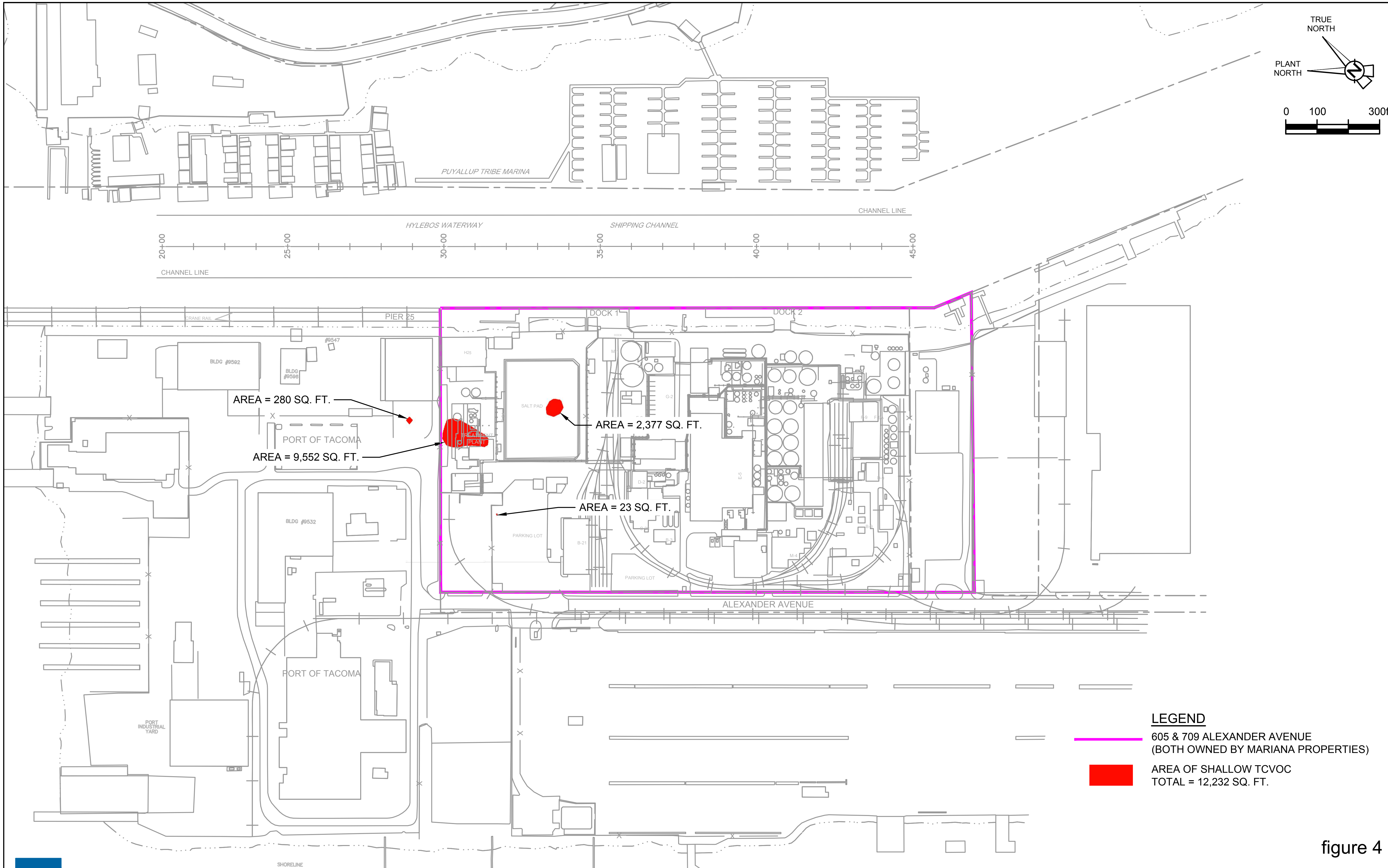


figure 4

AREAS OF SHALLOW (≥-21 FT NGVD) TCVOC ≥2,500 mg/kg

Occidental Chemical Corporation, Tacoma, Washington

07843-C2D2(MEMO079)GN-WA004 JUN 13, 2016

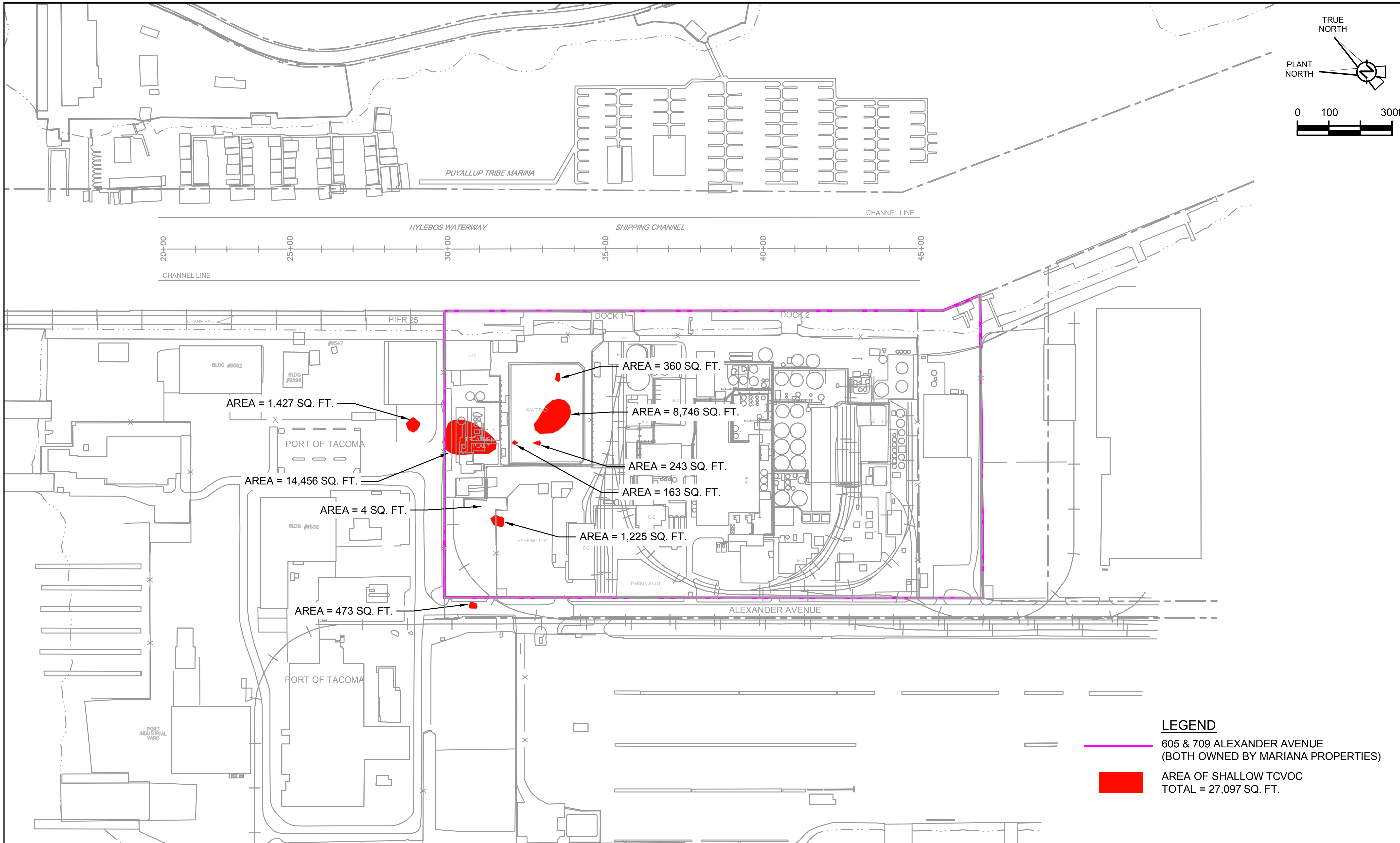


figure 5

AREAS OF SHALLOW (≥-21 FT NGVD) TCVOC ≥1,000 mg/kg

Occidental Chemical Corporation, Tacoma, Washington

07843-C2D2(MEMO079)GN-WA005 JUN 13, 2016

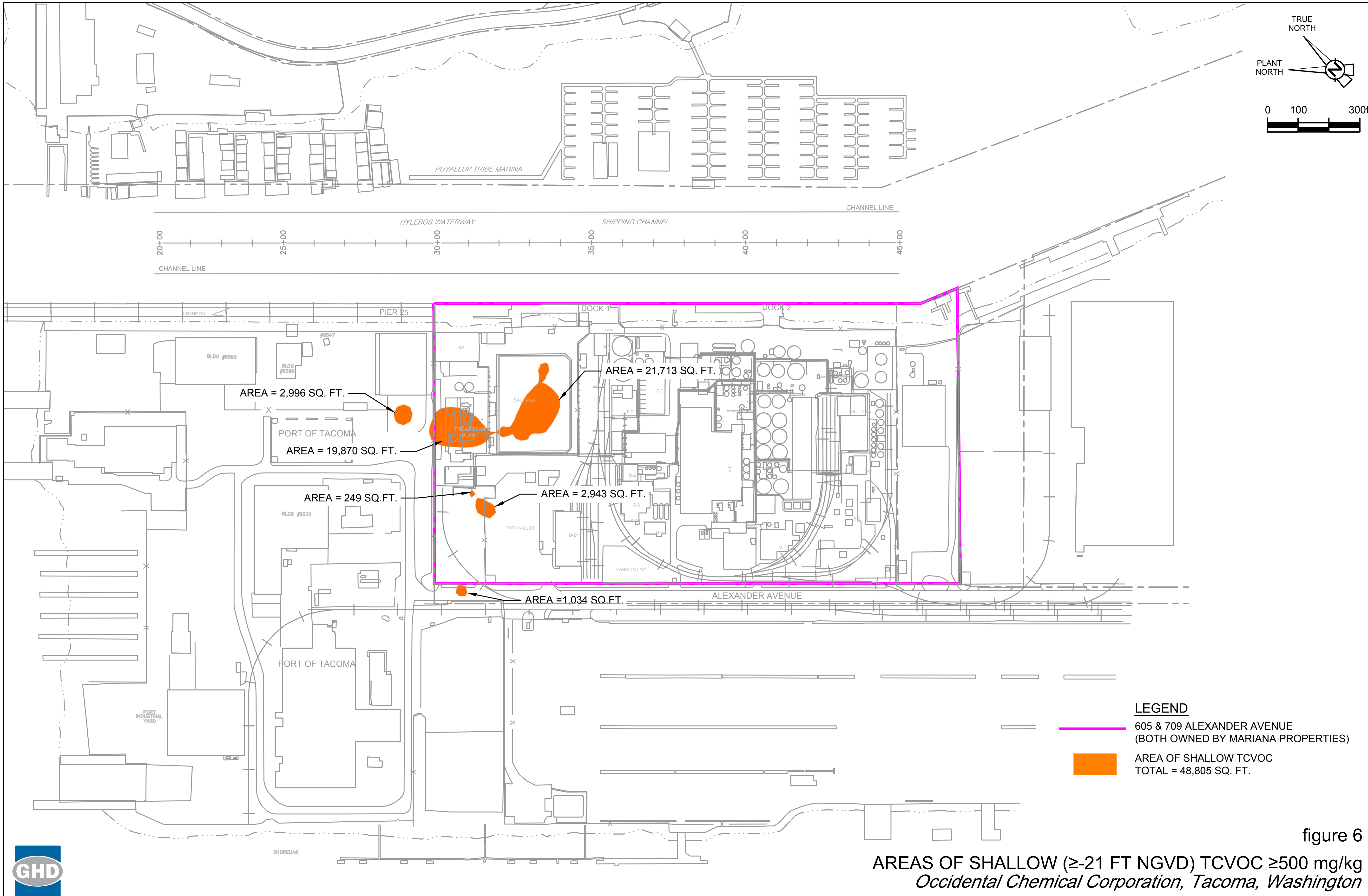


figure 6

AREAS OF SHALLOW (≥-21 FT NGVD) TCVOC ≥500 mg/kg

Occidental Chemical Corporation, Tacoma, Washington

07843-C2D2(MEMO079)GN-WA006 JUN 13, 2016

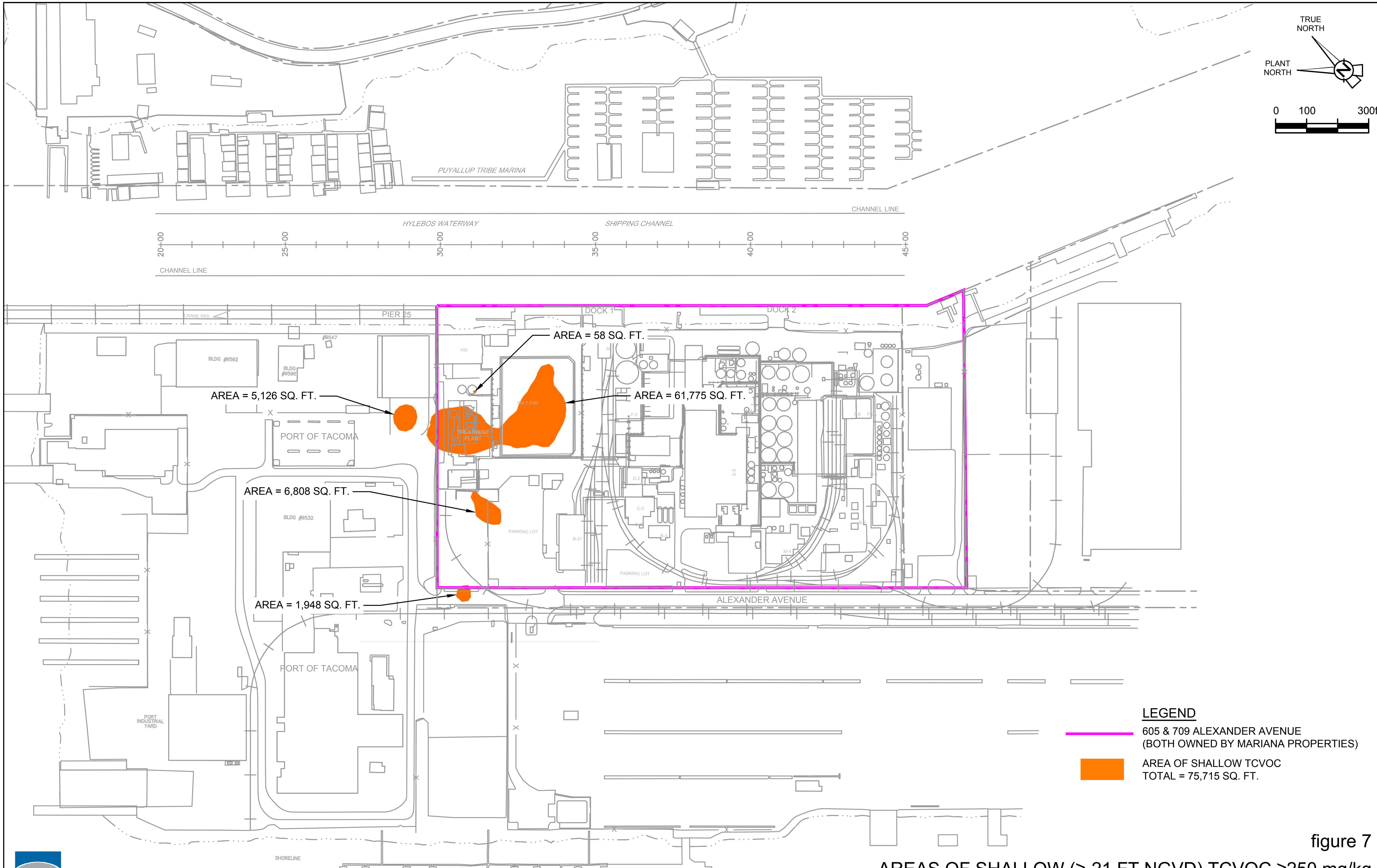


figure 7

AREAS OF SHALLOW (≥-21 FT NGVD) TCVOC ≥250 mg/kg

Occidental Chemical Corporation, Tacoma, Washington

07843-C2D2(MEMO079)GN-WA007 JUN 13, 2016

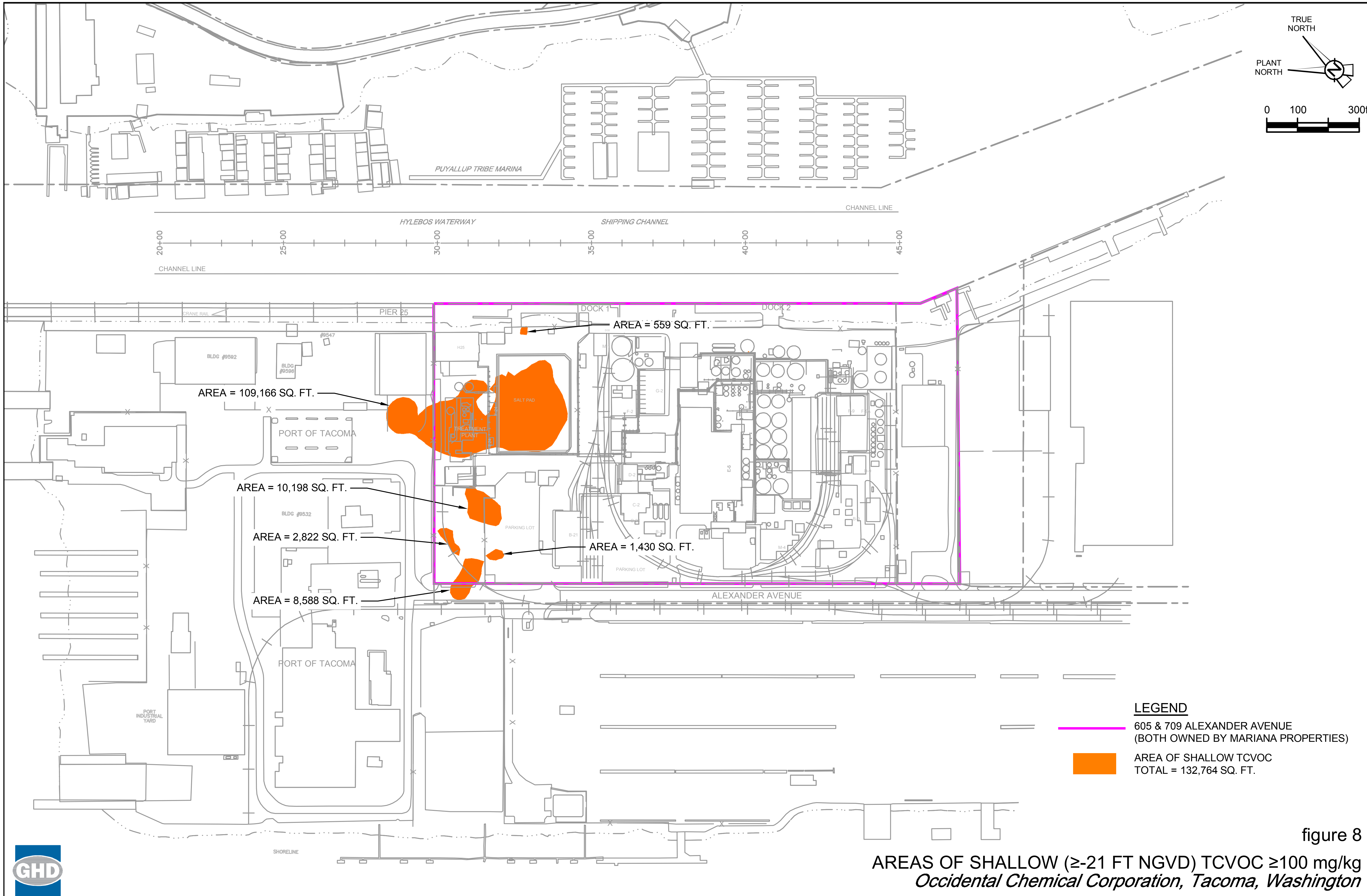


figure 8

AREAS OF SHALLOW (≥-21 FT NGVD) TCVOC ≥100 mg/kg

Occidental Chemical Corporation, Tacoma, Washington

07843-C2D2(MEMO079)GN-WA008 JUN 13, 2016

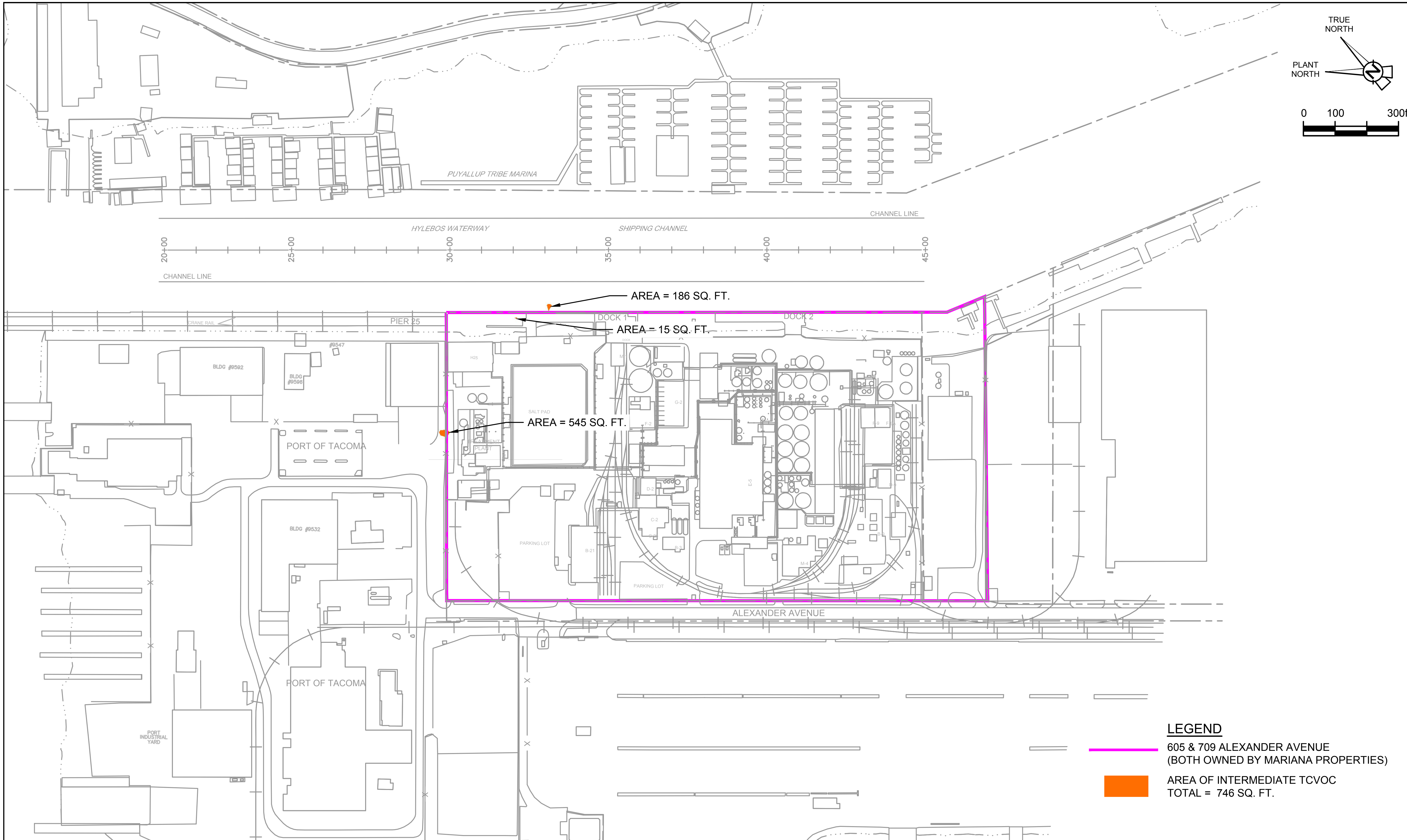
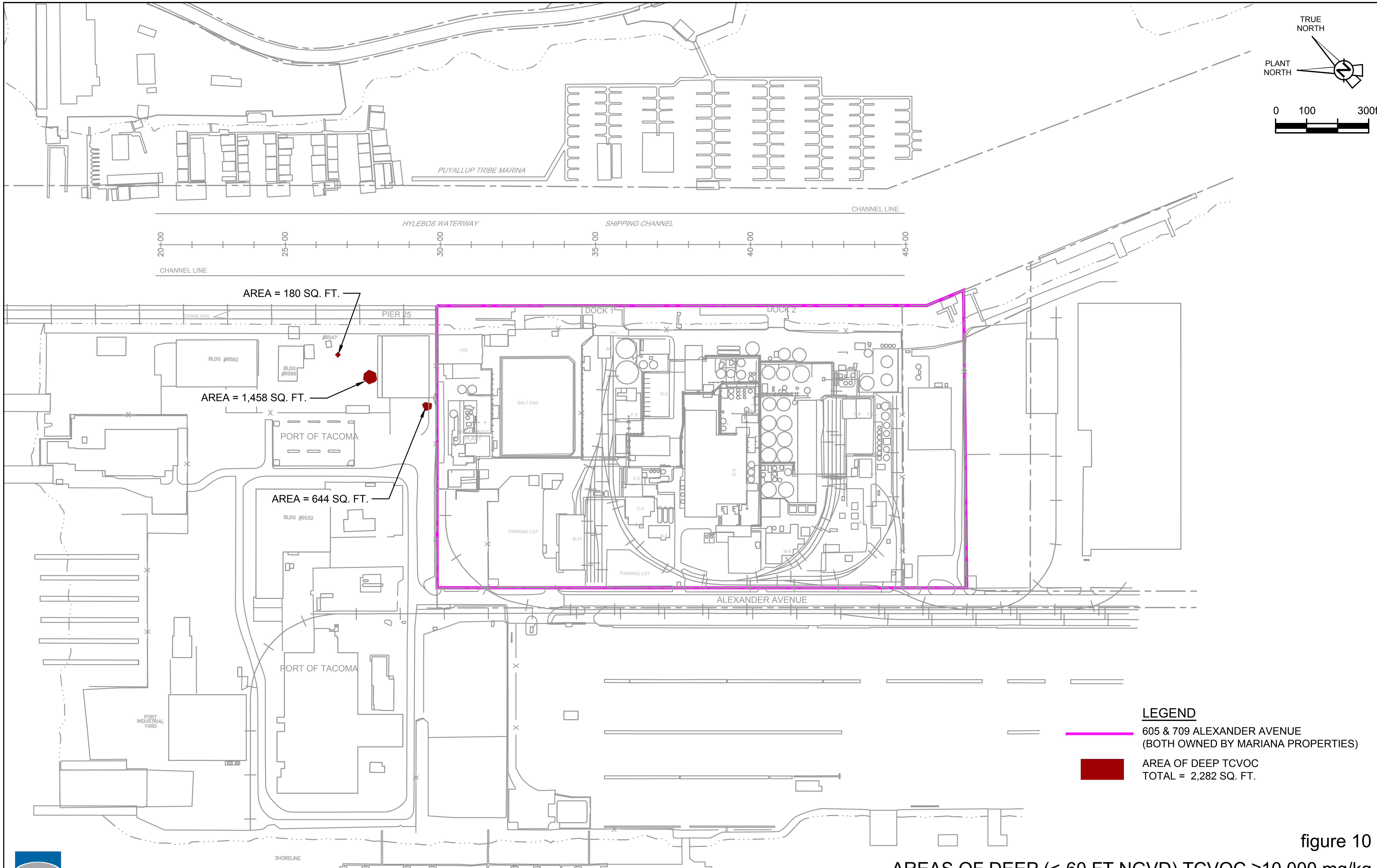


figure 9

AREAS OF INTERMEDIATE (-21 FT NGVD TO -60 FT NGVD) TCVOC ≥500 mg/kg

Occidental Chemical Corporation, Tacoma, Washington

07843-C2D2(MEMO079)GN-WA009 JUN 13, 2016



LEGEND

605 & 709 ALEXANDER AVENUE (BOTH OWNED BY MARIANA PROPERTIES)

AREA OF DEEP TCVOC TOTAL = 2,282 SQ. FT.

GHD

figure 10

AREAS OF DEEP (<-60 FT NGVD) TCVOC ≥10,000 mg/kg

Occidental Chemical Corporation, Tacoma, Washington

07843-C2D2(MEMO079)GN-WA010 JUN 13, 2016

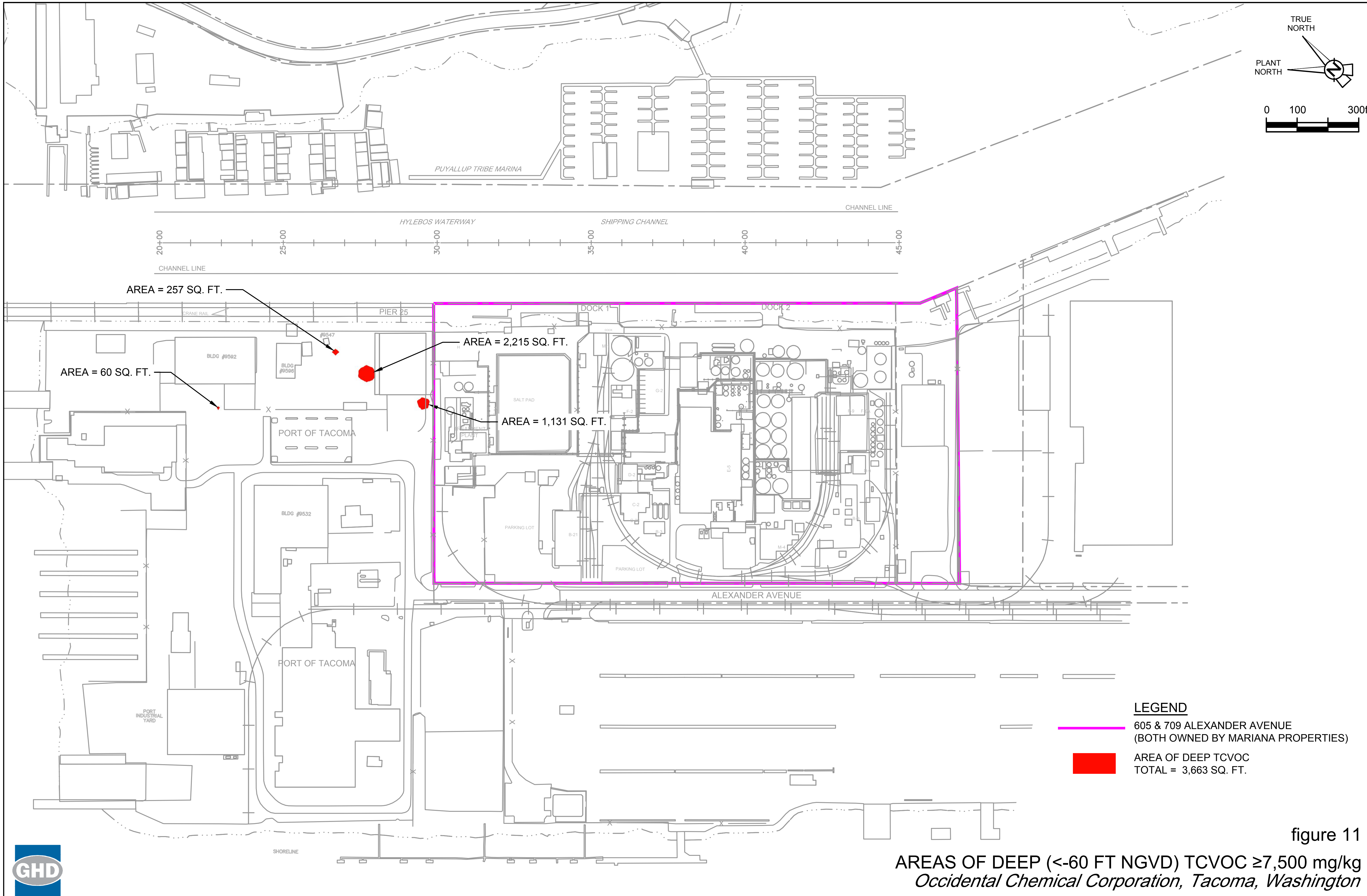


figure 11

AREAS OF DEEP (<-60 FT NGVD) TCVOC ≥7,500 mg/kg

Occidental Chemical Corporation, Tacoma, Washington

07843-C2D2(MEMO079)GN-WA011 JUN 13, 2016

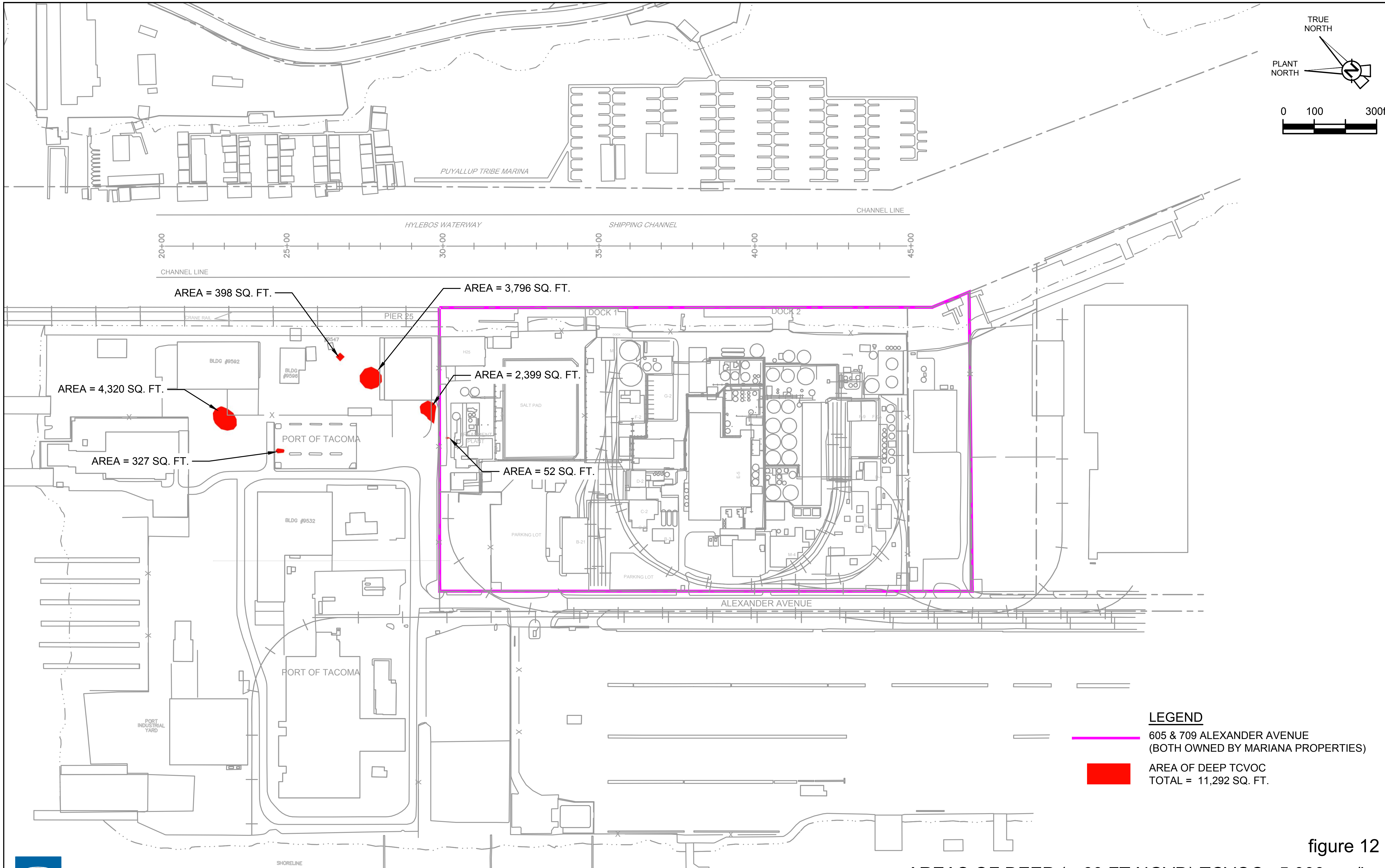


figure 12

AREAS OF DEEP (<-60 FT NGVD) TCVOC ≥5,000 mg/kg

Occidental Chemical Corporation, Tacoma, Washington

GHD

07843-C2D2(MEMO079)GN-WA012 JUN 13, 2016

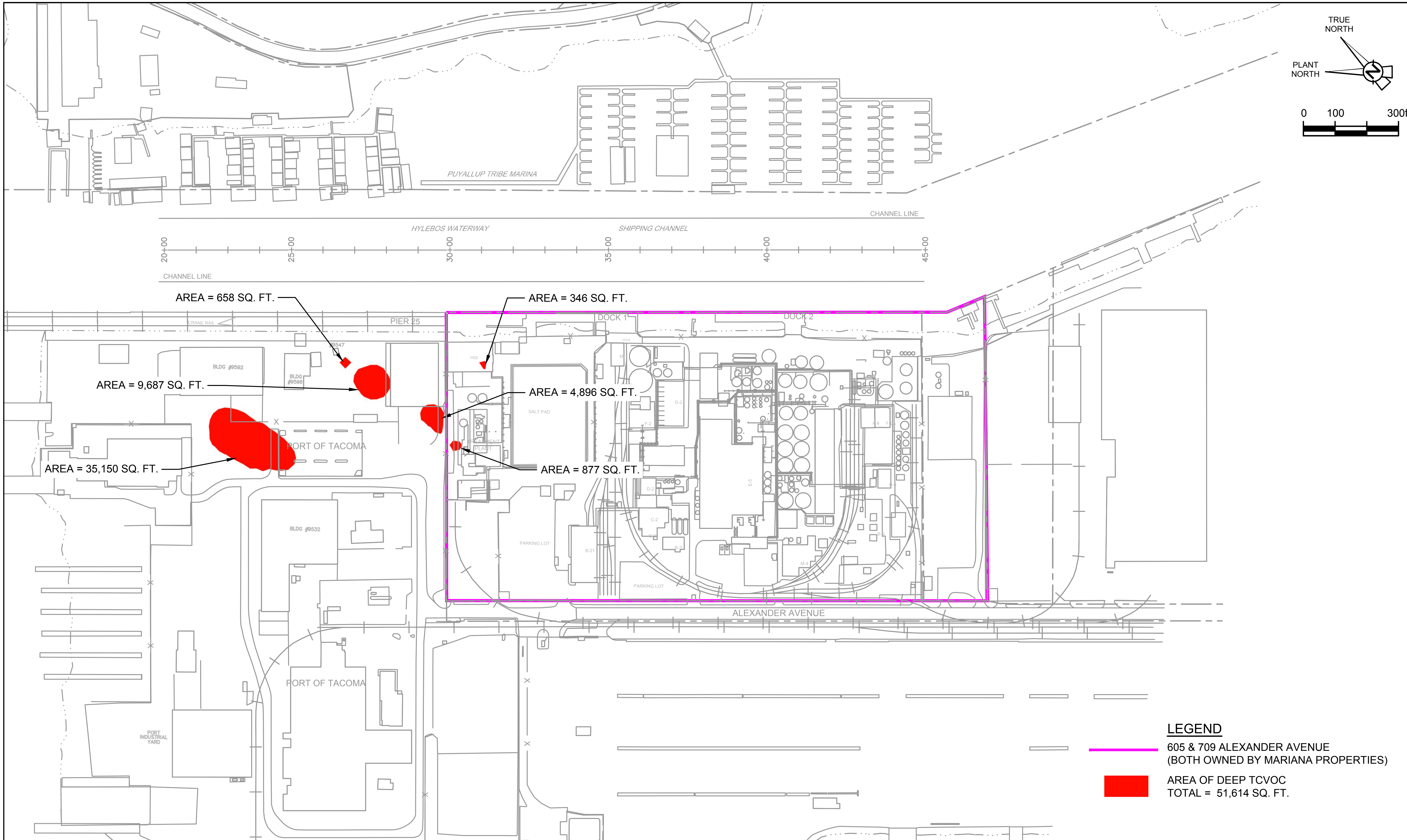


figure 13

AREAS OF DEEP (<-60 FT NGVD) TCVOC ≥2,500 mg/kg

Occidental Chemical Corporation, Tacoma, Washington

07843-C2D2(MEMO079)GN-WA013 JUN 13, 2016

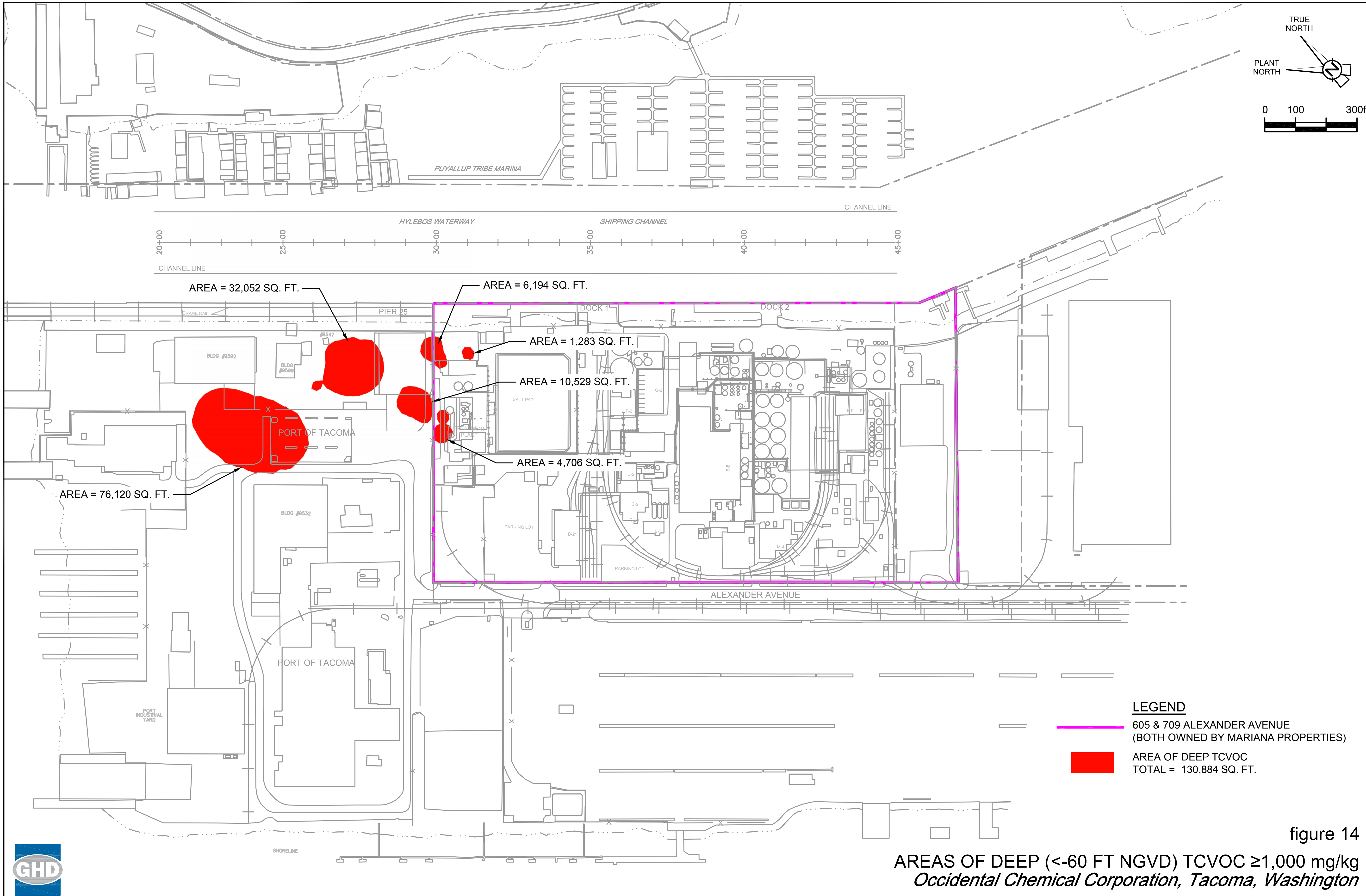


figure 14

AREAS OF DEEP (<-60 FT NGVD) TCVOC ≥1,000 mg/kg

Occidental Chemical Corporation, Tacoma, Washington

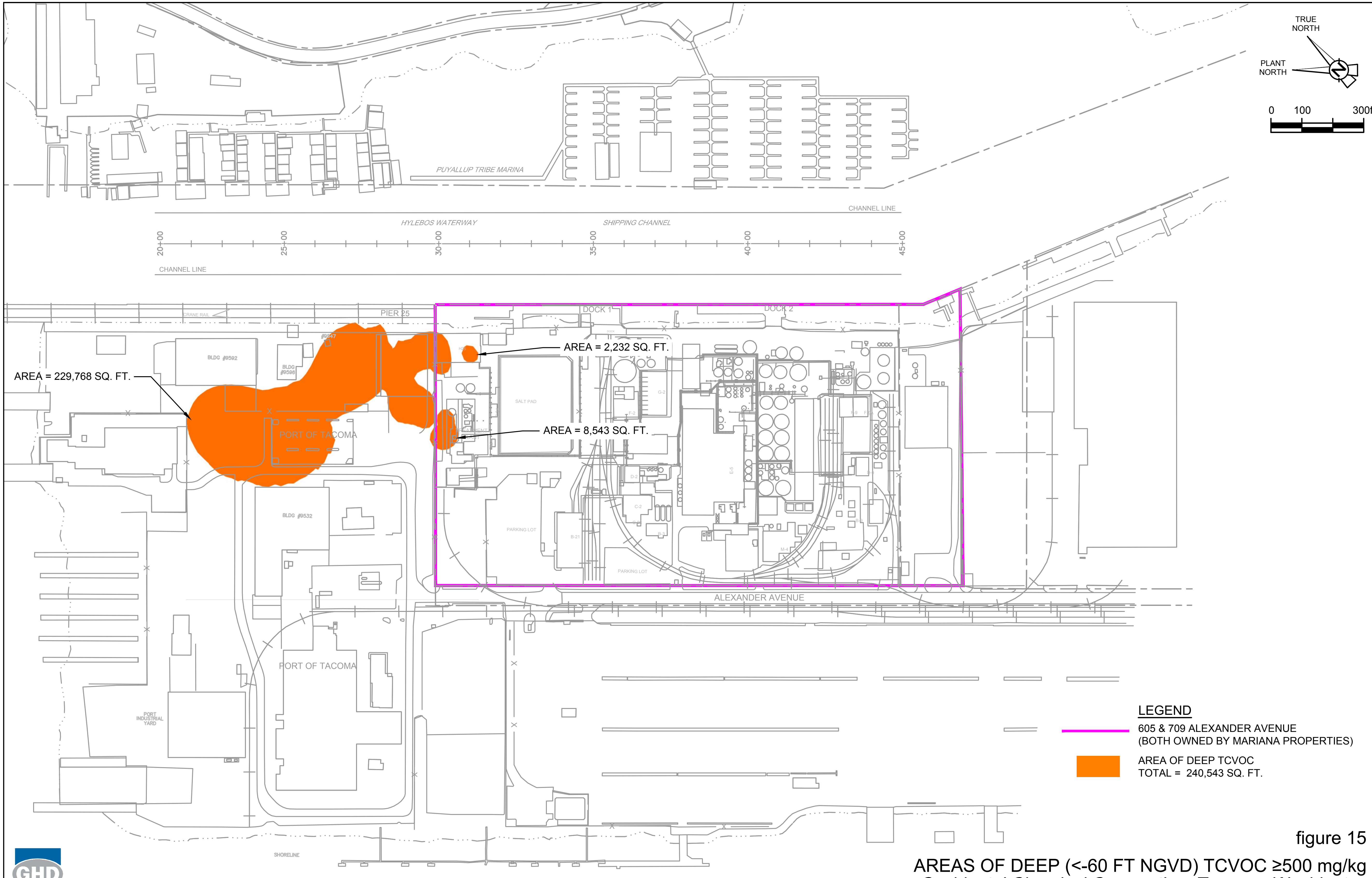


figure 15

AREAS OF DEEP (<-60 FT NGVD) TCVOC ≥500 mg/kg

Occidental Chemical Corporation, Tacoma, Washington

07843-C2D2(MEMO079)GN-WA015 JUN 13, 2016

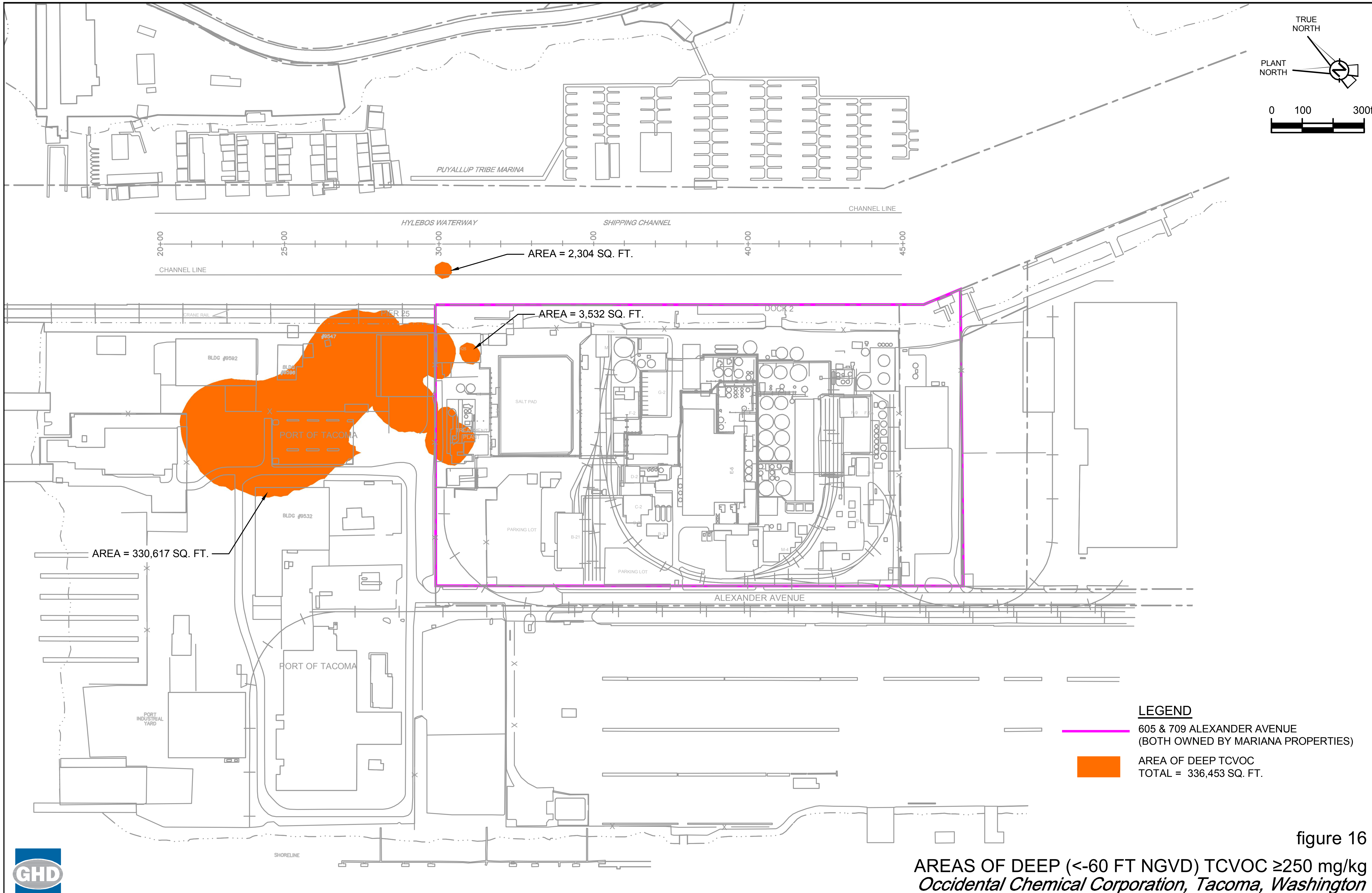


figure 16

AREAS OF DEEP (<-60 FT NGVD) TCVOC ≥250 mg/kg

Occidental Chemical Corporation, Tacoma, Washington

07843-C2D2(MEMO079)GN-WA016 JUN 13, 2016

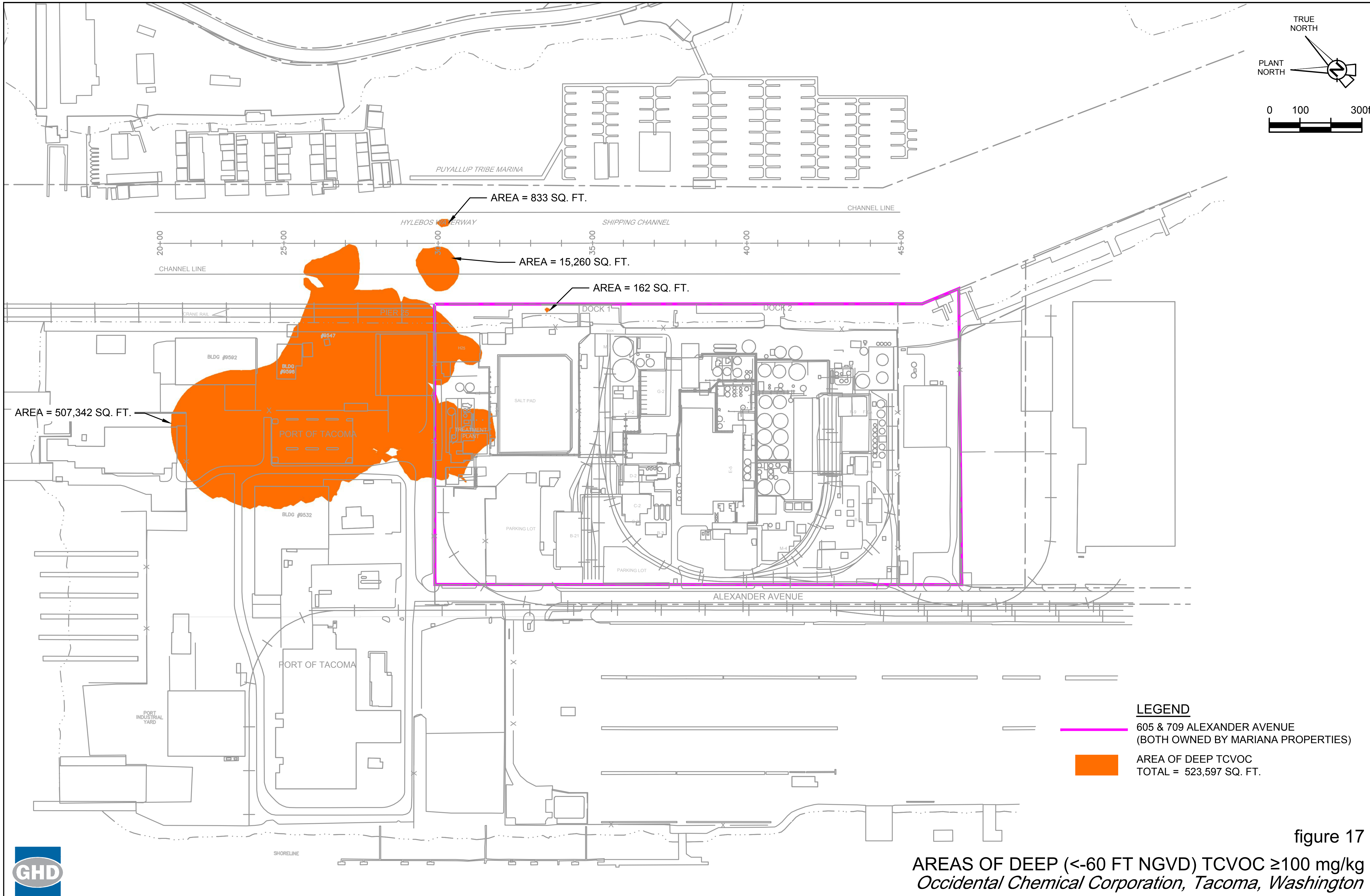


figure 17

AREAS OF DEEP (<-60 FT NGVD) TCVOC ≥100 mg/kg

Occidental Chemical Corporation, Tacoma, Washington

07843-C2D2(MEMO079)GN-WA017 JUN 13, 2016

Appendix E
Groundwater Flow Modeling for Remedial Alternatives that Incorporate Groundwater Extraction

Table of Contents

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Table Index

1. Introduction

This Appendix presents the evaluation of containment and mass reduction using the project's groundwater flow model as part of the Feasibility Study (FS) Report prepared on behalf of Occidental Chemical Corporation (OCC) at the "Occidental" Site associated in part with the former OCC facility located in Tacoma, Washington (Site). The groundwater modeling evaluation was conducted for the remedial alternatives considered in the FS that incorporate groundwater extraction.

A three-dimensional (3D) groundwater flow model was constructed and calibrated for the Site. The details of the calibrated groundwater model are presented in the *Draft Model Calibration Report* (MCR) (CRA, 2014a). The calibrated model was used to evaluate and compare the remedial alternatives that incorporate groundwater extraction using particle tracking methods. The modeling evaluation was conducted assuming the shut-down of the current groundwater extraction system. The groundwater extraction remedial alternatives include a sheet pile vertical barrier wall along the Site peninsula adjacent to the Hylebos Waterway (Waterway) and upland groundwater extraction wells as part of the containment system for the Site.

The modeling evaluation was conducted to evaluate levels of containment, migration, and mass reduction of the Total Chlorinated Volatile Organic Compounds (TCVOC) plume for the remedial alternatives that incorporate groundwater extraction. Reduction of the TCVOC plume was evaluated in terms of both reduction of aqueous phase TCVOC concentrations dissolved in groundwater (aqueous phase or dissolved TCVOC mass) and total TCVOC concentrations in soil (total TCVOC mass). The remedial alternatives evaluated using the calibrated model include:

- Containment Alternatives C100, C150, and C200
- VOC Mass Reduction Alternatives M100, M150, and M200
- VOC Mass Reduction Alternative MSP (Mass Reduction by Strategic Groundwater Pumping), referred to herein as ′VOC Mass Reduction Alternative MSP′

In general, the purpose and objectives of the modeling evaluation include:

- Evaluate the degree of hydraulic containment achieved by groundwater extraction for Containment Alternatives C100, C150, and C200, and VOC Mass Reduction Alternative MSP
- Evaluate potential discharge of TCVOC mass to the surface water bodies that surround the Site peninsula for Containment Alternatives C100, C150, and C200, and VOC Mass Reduction Alternative MSP
- Evaluate aqueous phase and total TCVOC mass reduction achieved by groundwater extraction for Containment Alternatives C100, C150, and C200, VOC Mass Reduction Alternatives M100, M150, and M200, and VOC Mass Reduction Alternative MSP

The simulated aqueous phase TCVOC mass reduction by groundwater extraction is calculated from TCVOC concentrations in groundwater above a threshold concentration of 2.4 µg/L (equal to approximately 157,000 pounds [lbs]). The simulated total TCVOC mass reduction is calculated from TCVOC concentrations in soil above a threshold soil concentration of 100 mg/kg (equal to approximately 787,000 lbs). The total TCVOC mass represents mass in the dissolved, sorbed, and dense non-aqueous phase liquid (DNAPL) phases.

In addition to having to meet Remedial Action Goals (RAGs) presented in Section 3.1 of the main report, the specific Model-Based Performance Objectives for the Containment Alternatives and VOC Mass Reduction Alternative MSP consist of:

1) Within the hydraulic control boundaries provided by the Agencies on March 30, 2016[1], there must be inward gradients and a target drawdown of at least 1 foot[2].

2) The containment system must result in an estimated TCVOC mass discharge of less than 0.2 percent of the current estimated total TCVOC mass in the aquifer (i.e., 0.2 percent of 787,000 lbs).

3) Groundwater flow beneath the Waterway must be directed to the plant-west toward the containment system.

The model also is used to predict and compare the amount of TCVOC mass reduction for the VOC Mass Reduction Alternatives independent of hydraulic containment.

This Appendix is organized as follows:

i) **Section 1 – Introduction:** provides the purpose and objectives of the modeling evaluation, and organization of this Appendix.

ii) **Section 2 – Modeling Approach**: presents the approach and methodology taken to complete the modeling evaluation.

iii) **Section 3 – Containment Alternatives**: presents the modeling results for the Containment Alternatives C100, C150, and C200.

iv) **Section 4 – VOC Mass Reduction Alternatives**: presents the modeling results for the VOC Mass Reduction Alternatives M100, M150, and M200 as well as VOC Mass Reduction Alternative MSP.

References cited in this Appendix are listed in Section 5.

2. Modeling Approach

The 3D groundwater flow model developed for the Site and presented in the MCR provides a useful tool to evaluate the effectiveness of potential groundwater extraction remedial alternatives that could be implemented to address the TCVOC groundwater plume at the Site. Refinements of extraction well locations, pumping rates, and remedial alternative performance can and would be completed during the detailed design. Section 2.1 describes the approaches taken to evaluate the performance of the remedial alternatives using the groundwater flow model. Section 2.2 describes the groundwater flow model set-up for the remedial alternatives.

---

1 The hydraulic control boundaries were provided by the Agencies for the 25-foot (ft), 50-ft, 75-ft, 100-ft, 130-ft, and 160-ft zone on Figures 1 to 6, respectively, of the Agencies' email correspondence to OCC dated March 30, 2016.

2 The target drawdown of 1 foot corresponds to lowering average groundwater elevations measured under pumping conditions by a minimum of 1 foot from the average groundwater elevations measured under non-pumping conditions.

2.1 Remedial Alternatives Evaluation Approach

The remedial alternatives were evaluated using the groundwater flow model based on the following two approaches:

a) Using simulated drawdown and groundwater flow directions to evaluate Model-Based Performance Objectives 1) and 3).

b) Using simulated aqueous phase TCVOC mass-weighted particle capture to evaluate Model-Based Performance Objective 2).

c) Using simulated total TCVOC mass-weighted particle capture to evaluate overall remedial alternative performance.

Simulated Drawdown and Groundwater Flow Direction

A field-based performance objective will be used to evaluate the remedial action once installed, which will entail measuring drawdown in the field to demonstrate actual remedial action performance. Since drawdown is equivalent to recovery, water levels would be measured, continuously at a selected time interval, at a select number of locations while the groundwater extraction and treatment system (GWETS) is running and during a temporarily shut-down of the GWETS. The temporary shut-down would take place following continuous GWETS operation for a time period sufficiently long to approach approximate steady-state groundwater flow conditions. The temporary shut-down would continue until approximate steady-state groundwater flow conditions were achieved. This would provide measurements of the groundwater level recovery occurring at select monitoring well locations on the Site peninsula and along the embankment adjacent to the Waterway after a temporary shut-down of the GWETS. The difference in the water levels (pre- and post-shut-down) in a well would be the measured drawdown at the well.

Consistent with the field-based evaluation of drawdown, simulated drawdown was determined using the following steps:

- Simulate the steady-state groundwater flow field under the operation of the remedial alternative, where the remedial action consists of extraction wells and a sheet pile vertical barrier wall along the embankment adjacent to the Waterway (pumping simulation).
- Simulate the steady-state groundwater flow field with the extraction wells shut-off and the sheet pile vertical barrier wall in place (non-pumping simulation).
- Determine the simulated drawdown by subtracting the fresh-water equivalent heads (FEHs) for the pumping simulation from the FEHs for the non-pumping simulation.

Simulated drawdown is used to evaluate Model-Based Performance Objective 1) by determining the ability of a remedial alternative to achieve simulated drawdown of least 1 foot within the hydraulic control boundaries on the Site peninsula, which typically correspond to where the groundwater TCVOC concentrations are greater than 1,000 µg/L.

In addition to simulated drawdown, simulated groundwater flow directions for each remedial alternative were determined by plotting groundwater flow velocity vectors predicted by the groundwater flow model under the influence of operating the remedial alternative. Model-Based Performance Objective 3) was further evaluated by determining whether groundwater flow under the Waterway is directed to the plant-west toward the containment system.

The two evaluation approaches are described below.

Simulated Mass-Weighted Particle Capture

Two approaches were used to simulate mass-weighted particle capture; one is based on aqueous phase TCVOC mass capture; and the other is based on total TCVOC mass capture. The simulated aqueous phase TCVOC mass-weighted particle capture approach released particles in each model cell with aqueous phase (i.e., groundwater) TCVOC concentrations above 2.4 µg/L, as presented in the *Draft Site Characterization Report* (SCR) (CRA, 2014b). The total TCVOC mass-weighted particle capture approach released particles in each model cell with soil TCVOC concentrations above 100 mg/kg.

The ability of the remedial alternatives to contain each particle was evaluated by simulating particle pathways forward-in-time within the groundwater flow field simulated under the influence of the remedial alternatives for a duration of 1,000 years. Particle pathways were simulated considering retarded advective migration using a retardation factor value of 5 based on TCVOC mass in the aquifer calculated from soil concentrations (that represent mass in the aqueous, sorbed, and DNAPL phases) and aqueous phase TCVOC mass calculated from groundwater concentrations. Specifically, the retardation factor is determined using the relationship:

$$R = 1 + \frac{M_{Total} - M_{Aqueous}}{M_{Aqueous}}$$

Where:

R = Retardation factor

M_{Total} = Total mass in aquifer calculated from soil TCVOC concentrations (above a threshold soil concentration of 100 mg/kg) equal to approximately 787,000 lbs

$M_{Aqueous}$ = Dissolved mass in aquifer calculated from groundwater TCVOC concentrations (above a threshold concentration of 2.4 µg/L) equal to approximately 157,000 lbs

Particle tracking represents how particles move through a simulated groundwater flow field by advective migration processes only (i.e., migration with the linear groundwater flow velocity). To represent retardation in the particle tracking simulations, the effective porosity used to calculate groundwater flow velocities is multiplied by the retardation factor value. In this way, the particle movement through the simulated groundwater flow field occurs at the retarded groundwater flow velocity. The retarded groundwater flow velocity represents how TCVOC migration in groundwater is slowed by TCVOC adsorption onto soil particles.

Aqueous phase and total TCVOC mass-weighted particle capture approaches were taken to evaluate the remedial alternatives. For the aqueous phase TCVOC mass-weighted particle capture approach, a TCVOC mass was determined for each particle based on the groundwater TCVOC concentration for the model cell where the particle was released and the volume of groundwater in the model cell. For the total TCVOC mass-weighted particle capture approach, a total TCVOC mass was determined for each particle based on the soil TCVOC concentration for the model cell where the particle was released and the volume of the model cell combined with the soil bulk density. The TCVOC concentrations per model cell were obtained from the 3D interpolated groundwater and soil TCVOC concentrations presented in the Draft SCR (CRA, 2014b).

The mass-weighted particle capture is used to evaluate Model-Based Performance Objective 2) by determining the ability of a remedial alternative to contain the TCVOC groundwater plume and limit the TCVOC mass-weighted particle discharge to the surface water bodies surrounding the Site peninsula to less than 0.2 percent of the estimated total TCVOC mass in the aquifer (i.e., 0.2 percent of 787,000 lbs).

Particle tracking does not account for the natural attenuation of the groundwater plumes (i.e., biodegradation, dispersion, dilution, etc.) that can reduce plume concentrations, particularly at the plume limits, and alleviate the need for containment. Consequently, the particle tracking method provides a conservative assessment of the TCVOC groundwater plume containment.

2.2 Remedial Alternatives Model Set-Up

The remedial alternatives were simulated using the Event 3A calibrated model presented in the MCR. Aqueous phase and total TCVOC mass-weighted particle capture was simulated under steady-state groundwater flow conditions for each alternative. Event 3A has an average Waterway surface water elevation of 0.71 feet (ft) National Geodetic Vertical Datum (NGVD), which was measured after dry conditions occurring from July to October 2012, and thus reflects a lower average surface water elevation in the Waterway. A lower average Waterway elevation increases hydraulic gradients towards, or groundwater discharge to, the Waterway, which increases the pumping required to achieve containment and is a conservative approach for evaluating containment. The groundwater pumping associated with the current groundwater extraction system implemented in the Event 3A calibrated model was turned off.

Further details regarding the model set-up applied for each remedial alternative are presented in the following sections.

3. Containment Alternatives

The modeling evaluation conducted for each of Containment Alternatives C100, C150, and C200 is presented in Sections 3.1, 3.2, and 3.3, respectively. Section 3.4 presents a summary of the modeling evaluation results for the Containment Alternatives.

3.1 Containment Alternative C100

Containment Alternative C100 represents a physical hydraulic sheet pile vertical barrier wall along the Site peninsula adjacent to the Waterway and upland groundwater extraction wells on the Site peninsula. The Event 3A calibrated model was used to determine the sheet pile vertical barrier wall alignment/depth and number of extraction wells (location and pumping rate) to provide containment of the upland TCVOC groundwater plume and prevent plume expansion. Containment Alternative C100 includes the existing inactive extraction well EXT-9. Potential reduced precipitation infiltration due to the capping component (physical direct contact exposure [PDCE] barrier) of Containment Alternative C100 (i.e., 605 & 709 Alexander Avenue Properties, N Landfill, and 709 Embankment Fill Area) was not implemented in the modeling evaluation as a conservative approach.

The sheet pile vertical barrier wall alignment/depth and number of extraction wells/pumping rates for Containment Alternative C100 were determined by making manual adjustments to the sheet pile vertical barrier wall and extraction wells combined with automatic optimization of extraction well locations. The Dynamically Dimensioned Search Algorithm (DDS) was selected to optimize well locations. DDS was selected because it has been shown to be an effective optimizer for computationally intensive models (Tolson and Shoemaker, 2007). DDS is also available as a discrete optimization algorithm which identifies well locations based on model cell row/column indices rather than Cartesian coordinates, which is advantageous when working with a row/column/layer based model such as SEAWAT (Langevin et al., 2008) used to develop the calibrated model for the Site. The Optimization Software Toolkit for Research Involving Computation Heuristics (OSTRICH) (Matott, 2005) was used to interface between the groundwater flow model and the optimization algorithm DDS.

Initially, the sheet pile vertical barrier wall length/depth and extraction well locations/pumping rates were manually adjusted to achieve containment of the upland TCVOC groundwater plume. The sheet pile vertical barrier wall alignment was set along the Waterway side of Docks 1 and 2. The sheet pile vertical barrier wall was represented in the model as a no-flow boundary condition consistent with constructing the sheet pile vertical barrier wall using steel sheet piling. Extraction well pumping rates were varied between 5 and 20 gallons per minute (gpm). A pumping rate of 5 gpm is approximately the average pumping for the existing active extraction wells after being redeveloped (i.e., Event 1), and a pumping rate of 20 gpm corresponds to the pumping rate sustained during the EXT-9 pumping test. An extraction well screen length of 20 ft was typically specified based on the 20 ft screen length installed for existing inactive extraction well EXT-9. Pumping rates specified for the extraction wells were weighted over the screen length based on the transmissivity of the model cells intersected by the well screens.

Manual adjustments to the sheet pile vertical barrier wall length/depth and extraction well locations were conducted initially to develop an understanding of sheet pile vertical barrier wall/extraction well interaction and key areas requiring wells for containment. The manual adjustments provided an indication of the sheet pile vertical barrier wall length/depth, number of extraction wells, extraction well pumping rates, and extraction well locations required for plume containment, which were used to inform a starting condition to apply for automated optimization of well locations.

For optimization, adjustment bounds were set around each extraction well based on the TCVOC plume location and containment results from manual adjustment. DDS was applied to optimize the horizontal locations (vertical locations and pumping rates were left as determined manually) within the adjustment bounds. For the optimization simulations, the sheet pile vertical barrier wall was left as determined using the manual adjustments. The objective of optimization was to maximize TCVOC groundwater plume containment while not placing extraction wells where the pH was greater than 10 standard units of pH (s.u.) (to minimize fouling of extraction wells). Following optimization, the extraction well locations were manually adjusted to a minimal degree to ensure that they were outside of building envelopes, and in some cases extraction wells were combined where the optimization resulted in extraction wells being placed adjacent to one another.

For Containment Alternative C100, the optimization of the manually located extraction wells resulted in eleven extraction wells (including existing inactive extraction well EXT-9) at a total pumping rate of 157.5 gpm. The sheet pile vertical barrier wall and extraction well layout for Containment Alternative C100 is presented on Figure 1. Table 1 summarizes the extraction well depths and pumping rates, as well as the initial chemistry at each extraction well in terms of groundwater TCVOC concentrations, soil TCVOC concentrations, and groundwater pH.

Figures 1 to 7 present the simulated drawdown and groundwater flow directions (groundwater flow direction indicates hydraulic gradient direction) for Containment Alternative C100 in the 15-ft, 25-ft, 50-ft, 75-ft, 100-ft, 130-ft, and 160-ft zones, respectively. Containment Alternative C100 achieves inward gradients and simulated drawdown of at least 1 foot where TCVOC concentrations are above 1,000 µg/L in the 15-ft zone (see Figure 1). Containment Alternative C100 achieves inward gradients and simulated drawdown of at least 1 foot within the majority of the hydraulic control boundaries for the 25-ft to 75-ft zones (see Figures 2 to 4), which essentially meets Model-Based Performance Objective 1). However, the simulated drawdown is less than 1 foot within a significant portion of the hydraulic control boundaries for the 100-ft and 130-ft zones (see Figures 5 and 6), and this does not meet Model-Based Performance Objective 1), although inward gradients are simulated for these zones. The majority of the 160-ft zone on the Site peninsula lies below the zone of apparent confining effect where lower permeability is represented in the groundwater flow model. Thus, simulating significant drawdown (i.e., 1 foot or more) within the hydraulic control boundary for the 160-ft zone is not expected (see Figure 7). For the portion of the 160-ft zone hydraulic control boundary that lies above the zone of apparent confining effect, Containment Alternative C100 achieves drawdown of greater than 0.5 ft and gradients are inward from Commencement Bay.

Table 2 and Table 3 summarize the simulated aqueous phase and total TCVOC mass-weighted particle capture, respectively, for Containment Alternative C100. Tables 2 and 3 are organized into two sections, as follows:

- Section I: presents the mass-weighted particle capture over all aquifer depths in terms of pounds of either aqueous phase TCVOC (Table 2) or total TCVOC (Table 3) mass removed
- Section II: presents mass-weighted particle capture over all aquifer depths in terms of percentage of either the total aqueous phase TCVOC mass based on groundwater concentrations (Table 2) or total TCVOC mass based on soil concentrations (Table 3).

Table 2 shows that Containment Alternative C100 achieves Model-Based Performance Objective 2). The TCVOC mass discharge to the surface water bodies surrounding the Site peninsula is approximately 0.02 percent of the total TCVOC mass in the aquifer (188 lbs) after the 1,000-year simulation duration.

Figures 4, 5, and 6 show that simulated groundwater flow directions under the Waterway in the 75-ft, 100-ft, and 130-ft zones, respectively, for Containment Alternative C100 are directed toward the Site peninsula and the groundwater extraction system, which meets Model-Based Performance Objective 3). The Waterway extends through the 15-ft to 50-ft zones (i.e., the Waterway consists of surface water for the 15-ft to 50-ft zones). As a result, groundwater flow directions are not simulated within the Waterway for these zones (see Figures 1 to 3). Under the Waterway, the 160-ft zone lies below the zone of apparent confining effect, which isolates this portion of the 160-ft zone from the overlying aquifer depth zones (see Figure 7).

3.2 Containment Alternative C150

Containment Alternative C150 is based on Containment Alternative C100 but with increased extraction rates. Containment Alternative C150 applies the same extraction wells as Containment Alternative C100, but with pumping rates increased by up to 50 percent from that applied in Containment Alternative C100. At some extraction well locations, the groundwater flow model would not sustain a 50 percent increase in pumping (i.e., the extraction well was simulated to go dry). This occurred at proposed extraction wells EXT-1(s) and EXT-5(s), and therefore, the maximum pumping rate that the model could sustain was applied for these extraction wells. Table 1 shows the pumping rates applied for Containment Alternative C150. The total pumping rate corresponds to 226.25 gpm, which is approximately 44 percent greater than Containment Alternative C100.

Figures 8 to 14 present the simulated drawdown and groundwater flow directions for Containment Alternative C150 in the 15-ft, 25-ft, 50-ft, 75-ft, 100-ft, 130-ft, and 160-ft zones, respectively. Containment Alternative C150 achieves inward gradients and simulated drawdown of at least 1 foot where TCVOC concentrations are above 1,000 µg/L in the 15-ft zone (see Figure 8). Containment Alternative C150 achieves inward gradients and simulated drawdown of at least 1 foot within the hydraulic control boundaries for the 25-ft and 50-ft zones (see Figures 9 and 10), which meets Model-Based Performance Objective 1). Containment Alternative C150 achieves inward gradients and simulated drawdown of at least 1 foot within the vast majority of the hydraulic control boundaries for the 75-ft to 130-ft zones (see Figures 11 to 13), which essentially meets Model-Based Performance Objective 1). The 1-foot simulated drawdown encompasses where TCVOC concentrations are above 1,000 µg/L in the 75-ft to 130-ft zones on the Site peninsula (see Figures 11 to 13). Also, expanding the simulated drawdown to 0.8 ft does encompass nearly all of the hydraulic control boundaries for the 75-ft to 130-ft zones. Simulating drawdown of 0.8 ft, or practically 1 foot of drawdown, to encompass the hydraulic control boundaries is within the level of uncertainty inherent in the groundwater flow model, and in combination with simulating inward gradients for the 75-ft to 130-ft zone hydraulic control boundaries, satisfies the intent of Model-Based Performance Objective 1). Simulating significant drawdown (i.e., 1 foot or more) in the 160-ft zone is not expected since the majority of this zone on the Site peninsula lies below the zone of apparent confining effect where lower permeability is represented in the groundwater flow model (see Figure 14). For the portion of the 160-ft zone hydraulic control boundary that lies above the zone of apparent confining effect, Containment Alternative C150 achieves drawdown of greater than 0.8 ft and gradients are inward from Commencement Bay.

Table 2 summarizes the simulated aqueous phase mass-weighted particle capture for Containment Alternative C150 and shows that it achieves Model-Based Performance Objective 2). The aqueous phase TCVOC mass discharge to the surface water bodies surrounding the Site peninsula is approximately 0.004 percent of the total TCVOC mass (35 lbs) in the aquifer after the 1,000-year simulation duration.

Figures 11, 12, and 13 show that simulated groundwater flow directions under the Waterway in the 75-ft, 100-ft, and 130-ft zones, respectively, for Containment Alternative C150 are directed toward the Site peninsula and the groundwater extraction system, which meets Model-Based Performance Objective 3). Under the Waterway, the 160-ft zone lies below the zone of apparent confining effect, which isolates this portion of the 160-ft zone from the overlying aquifer depth zones (see Figure 14).

3.3 Containment Alternative C200

Containment Alternative C200 is based on Containment Alternative C100 but with further increased extraction rates. Containment Alternative C200 applies the same extraction wells as Containment Alternative C100, but with pumping rates increased by up to 100 percent from that applied in Containment Alternative C100. At some extraction well locations, the groundwater flow model would not sustain a 100 percent increase in pumping (i.e., the extraction well was simulated to go dry). This occurred at proposed extraction wells EXT-1(s), EXT-5(s), EXT-15(s), EXT-18(s), and EXT-21(s). The maximum pumping rate that the model could sustain was applied for these extraction wells. For EXT-1(s), the increased pumping rate applied in Containment Alternative C150 had to be decreased to the pumping rate originally applied in Containment Alternative C100. Table 1 shows the pumping rates applied for Containment Alternative C200. The total pumping rate corresponds to 281.5 gpm, which is approximately 79 percent greater than Containment Alternative C100 and 24 percent greater than Containment Alternative C150.

Figures 15 to 21 present the simulated drawdown and groundwater flow directions for Containment Alternative C200 in the 15-ft, 25-ft, 50-ft, 75-ft, 100-ft, 130-ft, and 160-ft zones, respectively. Containment Alternative C200 achieves inward gradients and simulated drawdown of at least 1 foot where TCVOC concentrations are above 1,000 µg/L in the 15-ft zone (see Figure 15). Containment Alternative C200 achieves inward gradients and simulated drawdown of at least 1 foot within the hydraulic control boundaries for the 25-ft and 50-ft zones (see Figures 16 and 17), which meets Model-Based Performance Objective 1). Similar to Containment Alternative C150, Containment Alternative C200 achieves inward gradients and simulated drawdown of at least 1 foot within the vast majority of the hydraulic control boundaries for the 75-ft to 130-ft zones (see Figures 18 to 20), which essentially meets Model-Based Performance Objective 1). The 1-foot simulated drawdown encompasses where TCVOC concentrations are above 1,000 µg/L in the 75-ft to 130-ft zones on the Site peninsula (see Figures 18 to 20). The above in combination with simulating inward gradients for the 75-ft to 130-ft zone hydraulic control boundaries, satisfies the intent of Model-Based Performance Objective 1). Simulating significant drawdown (i.e., 1 foot or more) in the 160-ft zone is not expected since the majority of this zone on the Site peninsula lies below the zone of apparent confining effect where lower permeability is represented in the groundwater flow model (see Figure 21). For the portion of the 160-ft zone hydraulic control boundary that lies above the zone of apparent confining effect, Containment Alternative C200 achieves drawdown of greater than 1 foot and gradients are inward from Commencement Bay.

Table 2 summarizes the simulated aqueous phase mass-weighted particle capture for Containment Alternative C200. Table 2 shows that Containment Alternative C200 achieves Model-Based Performance Objective 2). The aqueous phase TCVOC mass discharge to the surface water bodies surrounding the Site peninsula is approximately 0.004 percent of the total TCVOC mass (30 lbs) in the aquifer after the 1,000-year simulation duration.

Figures 18, 19, and 20 show that simulated groundwater flow directions under the Waterway in the 75-ft, 100-ft, and 130-ft zones, respectively, for Containment Alternative C200 are directed toward the Site peninsula and the groundwater extraction system, which meets Model-Based Performance Objective 3). Under the Waterway, the 160-ft zone lies below the zone of apparent confining effect, which isolates this portion of the 160-ft zone from the overlying aquifer depth zones (see Figure 21).

3.4 Summary of Containment Alternatives Modeling Results

The modeling evaluation results show that both Containment Alternatives C150 and C200 meet the Model-Based Performance Objectives 2) and 3), and meet the intent of Model-Based Performance Objective 1), equivalently. Containment Alternative C150 meets the Model-Based Performance Objectives more economically since a lower total flow rate would result in lower operation and maintenance costs for treatment as presented in Subsection 5.2 of the main report. For example, less power consumption, less chemical usage for solids removal and pH adjustment, and less production of solids requiring off-Site disposal would be expected for Containment Alternative C150 compared to Containment Alternative C200. Additionally, as stated in Section 2, refinements of extraction well locations and pumping rates can and would be completed during the detailed design to further optimize the containment system with respect to the Model-Based Performance Objectives.

4. VOC Mass Reduction Alternatives

The modeling evaluation conducted for each of VOC Mass Reduction Alternatives M100, M150, and M200, as well as VOC Mass Reduction Alternative MSP, is presented in Sections 4.1, 4.2, 4.3, and 4.4 respectively. Section 4.5 presents a summary of the modeling evaluation results for the VOC mass reduction alternatives.

4.1 VOC Mass Reduction Alternative M100

VOC Mass Reduction Alternative M100 represents a physical hydraulic sheet pile vertical barrier wall along the Site peninsula adjacent to the Waterway and two upland groundwater extraction wells on the Site peninsula. Groundwater extraction for VOC mass reduction is represented only from areas of elevated concentrations in the shallow and deep TCVOC groundwater plume outside the areas of elevated/high pH (i.e., greater than 10 s.u.). Direct pumping from areas of high pH is avoided in order to prevent: potential fouling of the extraction and treatment system; the need for treatment of high pH water; and disposal of additional solids associated with this groundwater. Figure 22 shows the locations and depths of two proposed mass reduction extraction wells; one shallow and one deep. Table 1 summarizes the mass reduction extraction well depths and pumping rates, as well as the initial chemistry at each extraction well in terms of groundwater TCVOC concentrations, soil TCVOC concentrations, and groundwater pH. A total pumping rate of 35 gpm is applied for VOC Mass Reduction Alternative M100, which corresponds to specified pumping rates of 15 gpm for the proposed shallow extraction well and 20 gpm for the proposed deep extraction well. These well-specific pumping rates were determined by varying pumping at the wells between 5 and 20 gpm in the model to optimize capture assuming a containment system (i.e., C100) was operating, while avoiding capture of water with high pH. A pumping rate of 5 gpm is approximately the average pumping for the existing active extraction wells after being redeveloped (i.e., Event 1 applied for model calibration in the MCR), and a pumping rate of 20 gpm corresponds to the pumping rate sustained during the existing inactive extraction well EXT-9 pumping test.

VOC Mass Reduction Alternative M100 is not intended to provide complete containment of the TCVOC groundwater plume, and thus, is not evaluated against Model-Based Performance Objectives. Table 4 summarizes the simulated total TCVOC (dissolved, sorbed, and DNAPL phases) mass-weighted particle capture outside pH >10 s.u. for VOC Mass Reduction Alternative M100. After 20 years and 100 years, VOC Mass Reduction Alternative M100 achieves a total TCVOC mass-weighted particle capture of 35.0 percent (275,132 lbs) and 38.7 percent (304,597 lbs), respectively.

4.2 VOC Mass Reduction Alternative M150

VOC Mass Reduction Alternative M150 is based on VOC Mass Reduction Alternative M100 but with increased extraction rates. VOC Mass Reduction Alternative M150 applies the same extraction wells as VOC Mass Reduction Alternative M100, but with pumping rates increased by 50 percent from that applied in VOC Mass Reduction Alternative M100. Table 1 shows that a total pumping rate of 52.5 gpm is applied for VOC Mass Reduction Alternative M150.

Mass Reduction Alternative M150 is not evaluated against the Model-Based Performance Objectives since it is not intended to provide complete containment of the TCVOC groundwater plume. Table 4 summarizes the simulated total TCVOC mass-weighted particle capture outside pH >10 s.u. for VOC Mass Reduction Alternative M150. After 20 years and 100 years, VOC Mass Reduction Alternative M150 achieves a total TCVOC mass-weighted particle capture of 36.3 percent (285,394 lbs) and 40.2 percent (316,373 lbs), respectively.

4.3 VOC Mass Reduction Alternative M200

VOC Mass Reduction Alternative M200 is based on VOC Mass Reduction Alternative M100 but with further increased extraction rates. VOC Mass Reduction Alternative M200 applies the same extraction wells as VOC Mass Reduction Alternative M100, but with pumping rates increased by 100 percent from that applied in VOC Mass Reduction Alternative M100. Table 1 shows that a total pumping rate of 70 gpm is applied for VOC Mass Reduction Alternative M200.

Mass Reduction Alternative M200 is not evaluated against the Model-Based Performance Objectives since it is not intended to provide complete containment of the TCVOC groundwater plume. Table 4 summarizes the simulated total TCVOC mass-weighted particle capture outside pH >10 s.u. for VOC Mass Reduction Alternative M200. After 20 years and 100 years, VOC Mass Reduction Alternative M200 achieves a total TCVOC mass-weighted particle capture of 37.1 percent (291,648 lbs) and 41.4 percent (325,595 lbs), respectively.

4.4 VOC Mass Reduction Alternative MSP

To focus on total TCVOC reduction, VOC Mass Reduction Alternative MSP was developed to determine if total TCVOC could be further reduced and reduced more quickly in comparison to the reductions simulated for the other VOC Mass Reduction Alternatives (M100, M150, M200) by an alternative approach to extraction well placement. VOC Mass Reduction Alternative MSP is a combination of proposed extraction well placements by the Agencies provided to OCC in October 2016 as well as hand modified well placements (both in the horizontal and vertical in terms of screen depth and length) to maximize removal of total TCVOC mass. Like the Containment and other VOC Mass Reduction Alternatives, the VOC Mass Reduction Alternative MSP represents a physical hydraulic sheet pile vertical barrier wall along the Site peninsula adjacent to the Waterway and upland groundwater extraction wells on the Site peninsula. The location of the sheet pile vertical barrier wall determined through the optimization of the Containment Alternatives was applied to VOC Mass Reduction Alternative MSP and not further optimized.

Unlike the Containment Alternatives, which utilized DDS, optimization was completed manually to adjust the number of extraction wells/pumping rates to achieve optimum mass extraction from Site areas and depths containing the highest soil TCVOC concentrations while avoiding areas of high pH (pH >10 s.u.). Optimization through DDS was not utilized because there were few extraction well location possibilities that overlapped the highest soil TCVOC concentrations/lower pH areas and depths. Extraction rates were initially set to 20 gpm and reduced if portions of the well were simulated to go dry in the groundwater flow model. The extraction well screen length was set based on the depth of elevated soil TCVOC concentrations in a particular area. Table 1 presents the proposed extraction well rates, screen depths and lengths, along with the initial groundwater TCVOC concentrations, soil TCVOC concentrations, and groundwater pH at the proposed extraction well locations. By strategically positioning extraction wells in areas of elevated soil TCVOC concentrations both horizontally and vertically, mass reduction can be maximized. Pumping rates specified for the extraction wells were weighted over the screen length based on the transmissivity of the model cells intersected by the well screens.

As presented in Table 1, the manual optimization of proposed extraction well locations for VOC Mass Reduction Alternative MSP resulted in eleven extraction wells (optimized well locations do not include any existing wells or wells identified in the Containment Alternatives) at a total pumping rate of 210 gpm. Nine of the proposed extraction wells are in areas of elevated soil TCVOC concentrations and two of the wells are positioned to enhance containment of the VOC Mass Reduction Alternative MSP. The proposed sheet pile vertical barrier wall and extraction well layout for the VOC Mass Reduction Alternative MSP is presented on Figure 23.

Figures 23 to 29 present the simulated drawdown and groundwater flow directions for VOC Mass Reduction Alternative MSP in the 15-ft, 25-ft, 50-ft, 75-ft, 100-ft, 130-ft, and 160-ft zones, respectively. The VOC Mass Reduction Alternative MSP achieves inward gradients and simulated drawdown of at least 1 foot where TCVOC concentrations are above 1,000 µg/L in the 15-ft zone (see Figure 23). VOC Mass Reduction Alternative MSP achieves inward gradients and simulated drawdown of at least 1 foot within the hydraulic control boundaries for the 25-ft and 50-ft zones (see Figures 24 and 25), which meets Model-Based Performance Objective 1). The VOC Mass Reduction Alternative MSP achieves inward gradients and simulated drawdown of at least 1 foot within the vast majority of the hydraulic control boundaries for the 75-ft to 130-ft zones (see Figures 26 to 28), which essentially meets Model-Based Performance Objective 1). The 1-foot simulated drawdown encompasses where TCVOC concentrations are above 1,000 µg/L in the 75-ft to 130-ft zones on the Site peninsula (see Figures 26 to 28). Simulating significant drawdown (i.e., 1 foot or more) in the 160-ft zone is not expected since the majority of this zone on the Site peninsula lies below the zone of apparent confining effect where lower permeability is represented in the groundwater flow model (see Figure 29). For the portion of the 160-ft zone hydraulic control boundary that lies above the zone of apparent confining effect, VOC Mass Reduction Alternative MSP achieves drawdown of greater than 1 ft and gradients are inward from Commencement Bay.

Table 2 summarizes the simulated aqueous phase mass-weighted particle capture for VOC Mass Reduction Alternative MSP. Table 2 shows that VOC Mass Reduction Alternative MSP achieves Model-Based Performance Objective 2). The aqueous phase TCVOC mass discharge to the surface water bodies surrounding the Site peninsula is approximately 0.01 percent of the total TCVOC mass (22 lbs) in the aquifer after the 1,000-year simulation duration.

Figures 26, 27, and 28 show that simulated groundwater flow directions under the Waterway in the 75-ft, 100-ft, and 130-ft zones, respectively, for VOC Mass Reduction Alternative MSP are directed toward the Site peninsula and the groundwater extraction system, which meets Model-Based Performance Objective 3). Under the Waterway, the 160-ft zone lies below the zone of apparent confining effect, which isolates this portion of the 160-ft zone from the overlying aquifer depth zones (see Figure 29).

Table 4 summarizes the simulated total TCVOC mass-weighted particle capture outside pH >10 s.u. for VOC Mass Reduction Alternative MSP. After 20 years and 100 years, VOC Mass Reduction Alternative MSP achieves a total TCVOC mass-weighted particle capture of 41.2 percent (323,883 lbs) and 41.7 percent (328,540 lbs), respectively. In comparison to the other VOC mass reduction alternatives, the VOC Mass Reduction Alternative MSP reduces more overall total mass and the rate of reduction is greatest in the short term.

4.5 Summary of VOC Mass Reduction Alternatives

The modeling evaluation results show that VOC Mass Reduction Alternative MSP provides greater mass reduction of total TCVOC mass outside areas of high pH (pH >10 s.u.) and the rate of reduction is greatest in the short term when compared to the VOC Mass Reduction Alternatives M100, M150, and M200. Figures 30 shows the total TCVOC mass-weighted particle capture outside pH >10 s.u. over 100 years for VOC Mass Reduction Alternatives M100, M150, M200, and MSP. The significant improvement in the rate of total TCVOC mass removed in the short term provided by VOC Mass Reduction Alternative MSP is apparent on Figure 30.

As presented in Sections 6.2 and 8 of the main report, VOC Mass Reduction Alternative MSP is the preferred alternative based on the detailed evaluation performed. VOC Mass Reduction Alternative MSP provides both VOC mass reduction/removal by strategic groundwater pumping and pumps sufficient groundwater to achieve the Site Model-Based Performance Objectives for containment.

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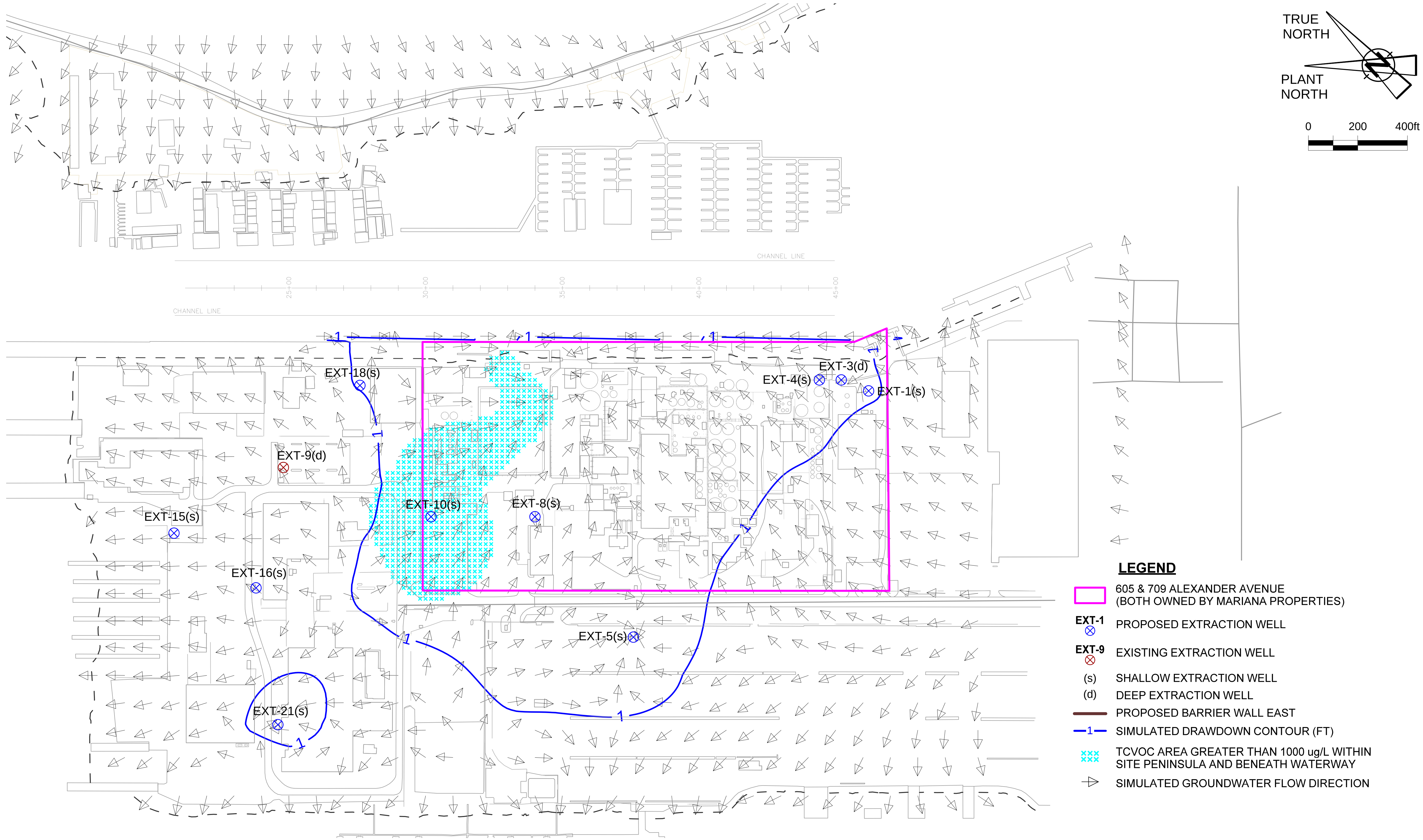

figure 1

SIMULATED DRAWDOWN AND GROUNDWATER FLOW DIRECTIONS
FOR CONTAINMENT ALTERNATIVE C100 - 15 FT ZONE
Occidental Chemical Corporation, Tacoma, Washington

GHD

007843-C2D2(RPT139) GN-WA-HYD (Z:\HEG\07843\RPT139\Appendix E\Jan2017-Rev\Figures\C100-DDN-15FT.srf) JAN 18/2017

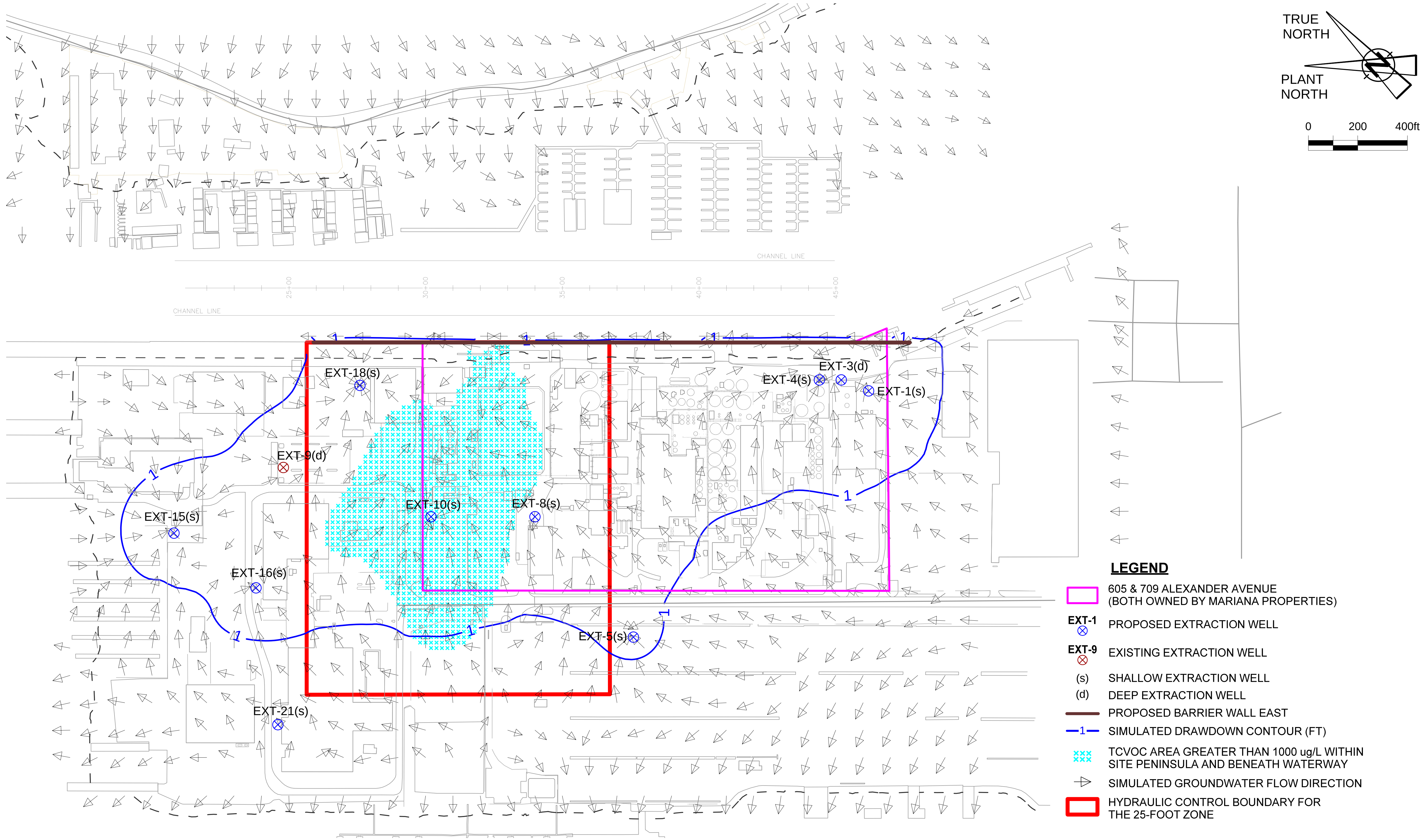

figure 2

SIMULATED DRAWDOWN AND GROUNDWATER FLOW DIRECTIONS
FOR CONTAINMENT ALTERNATIVE C100 - 25 FT ZONE
Occidental Chemical Corporation, Tacoma, Washington

GHD

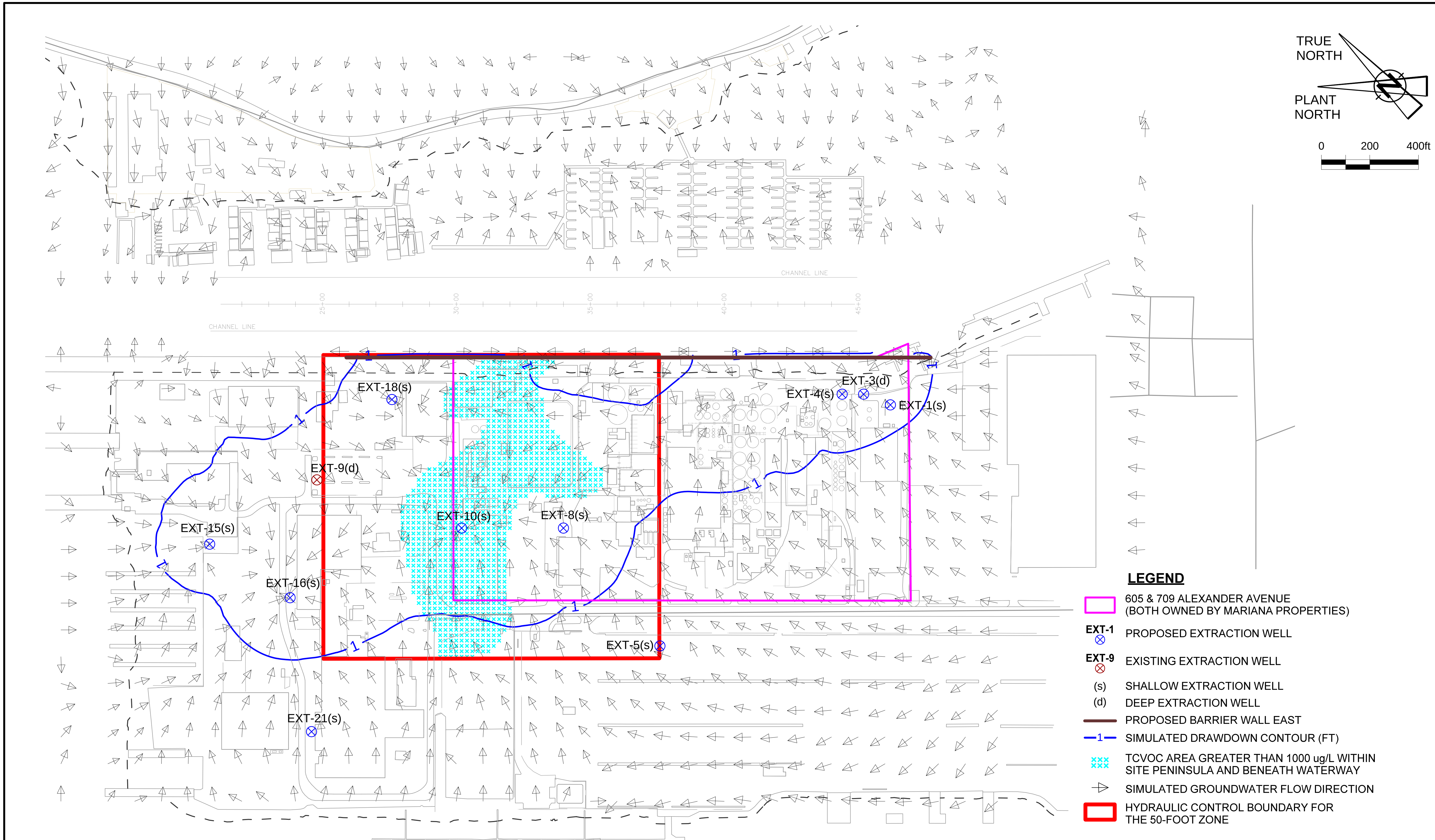

figure 3

SIMULATED DRAWDOWN AND GROUNDWATER FLOW DIRECTIONS
FOR CONTAINMENT ALTERNATIVE C100 - 50 FT ZONE
Occidental Chemical Corporation, Tacoma, Washington

GHD

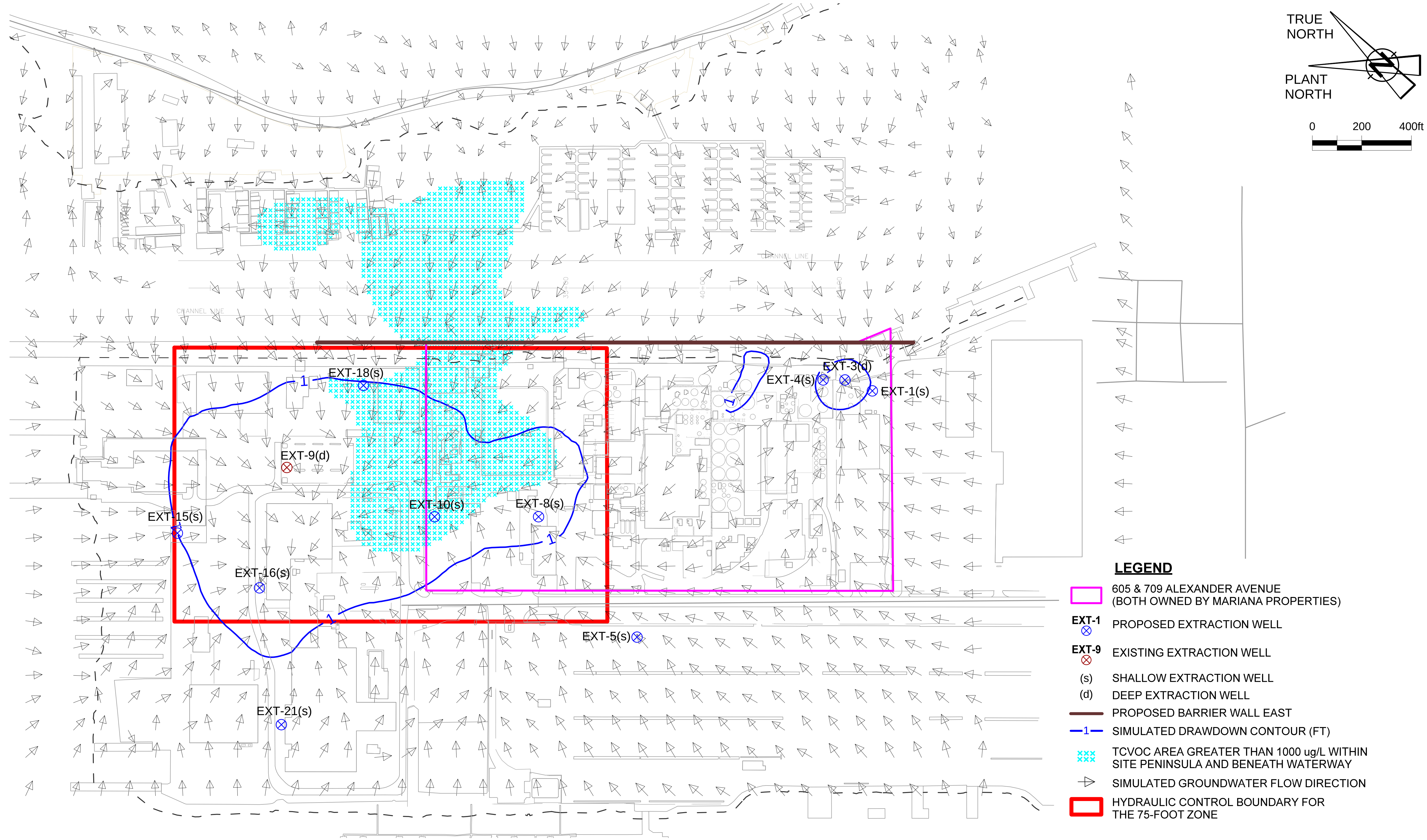

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figure 4

SIMULATED DRAWDOWN AND GROUNDWATER FLOW DIRECTIONS
FOR CONTAINMENT ALTERNATIVE C100 - 75 FT ZONE
Occidental Chemical Corporation, Tacoma, Washington

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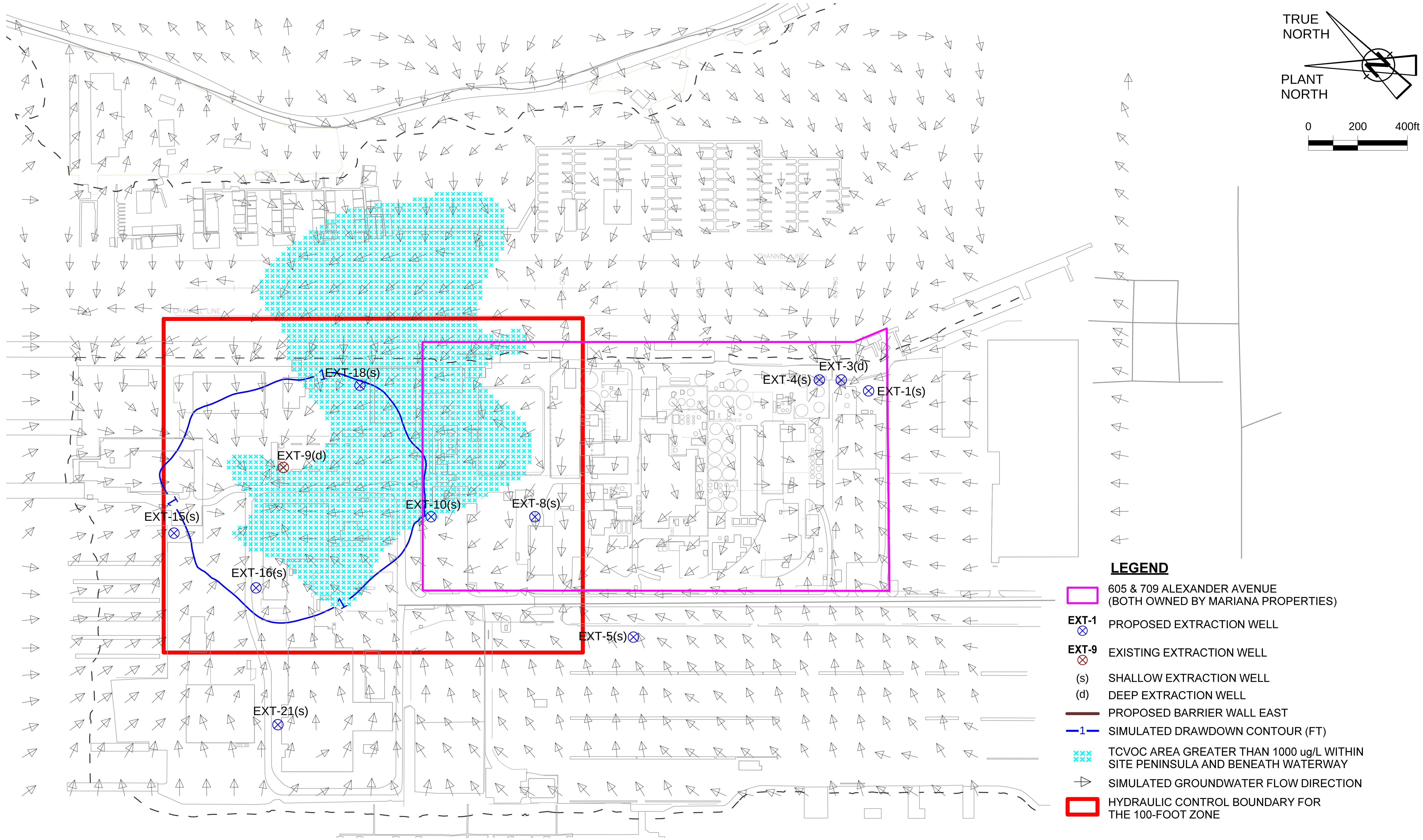

figure 5

SIMULATED DRAWDOWN AND GROUNDWATER FLOW DIRECTIONS
FOR CONTAINMENT ALTERNATIVE C100 - 100 FT ZONE
Occidental Chemical Corporation, Tacoma, Washington

GHD

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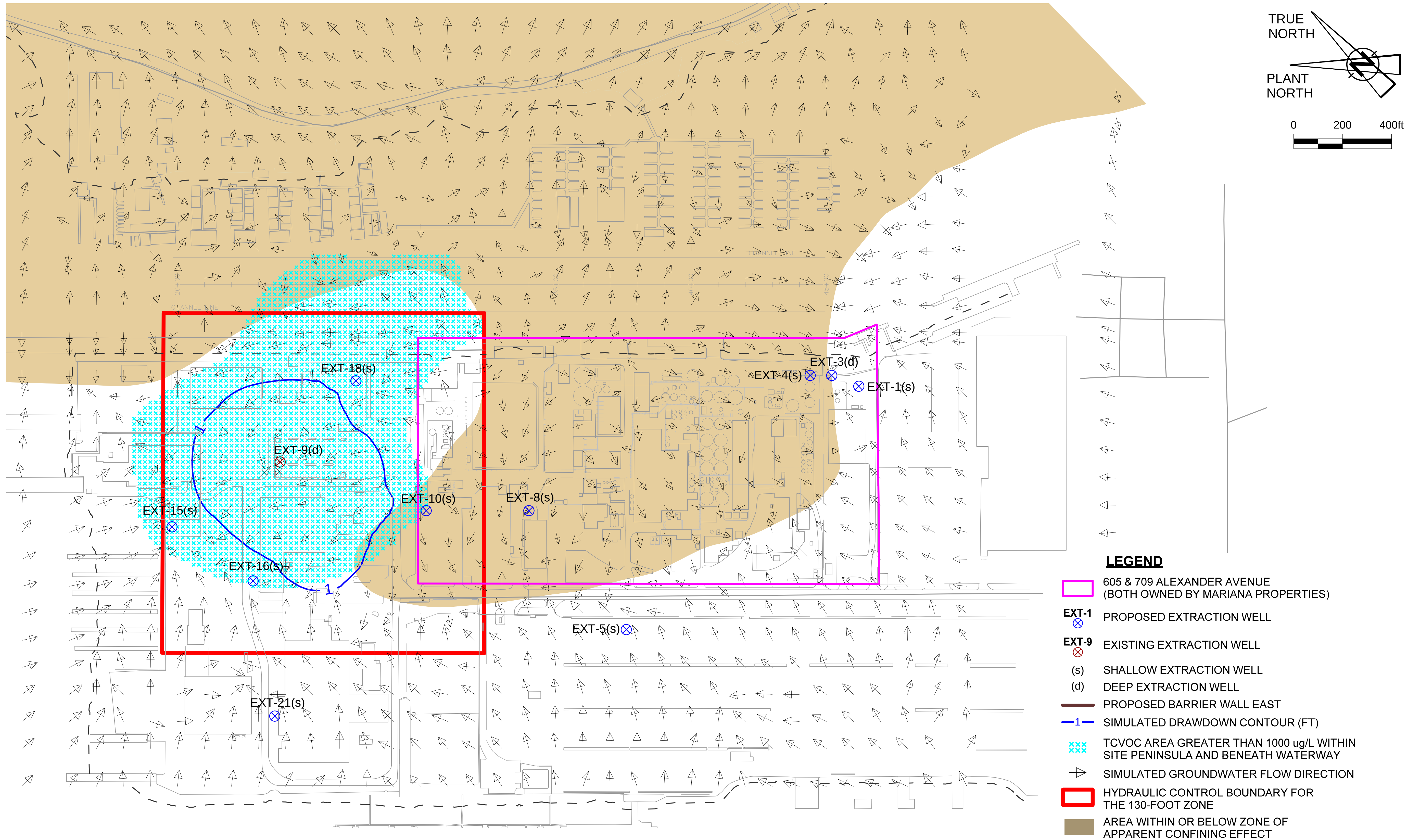

figure 6

SIMULATED DRAWDOWN AND GROUNDWATER FLOW DIRECTIONS
FOR CONTAINMENT ALTERNATIVE C100 - 130 FT ZONE
Occidental Chemical Corporation, Tacoma, Washington

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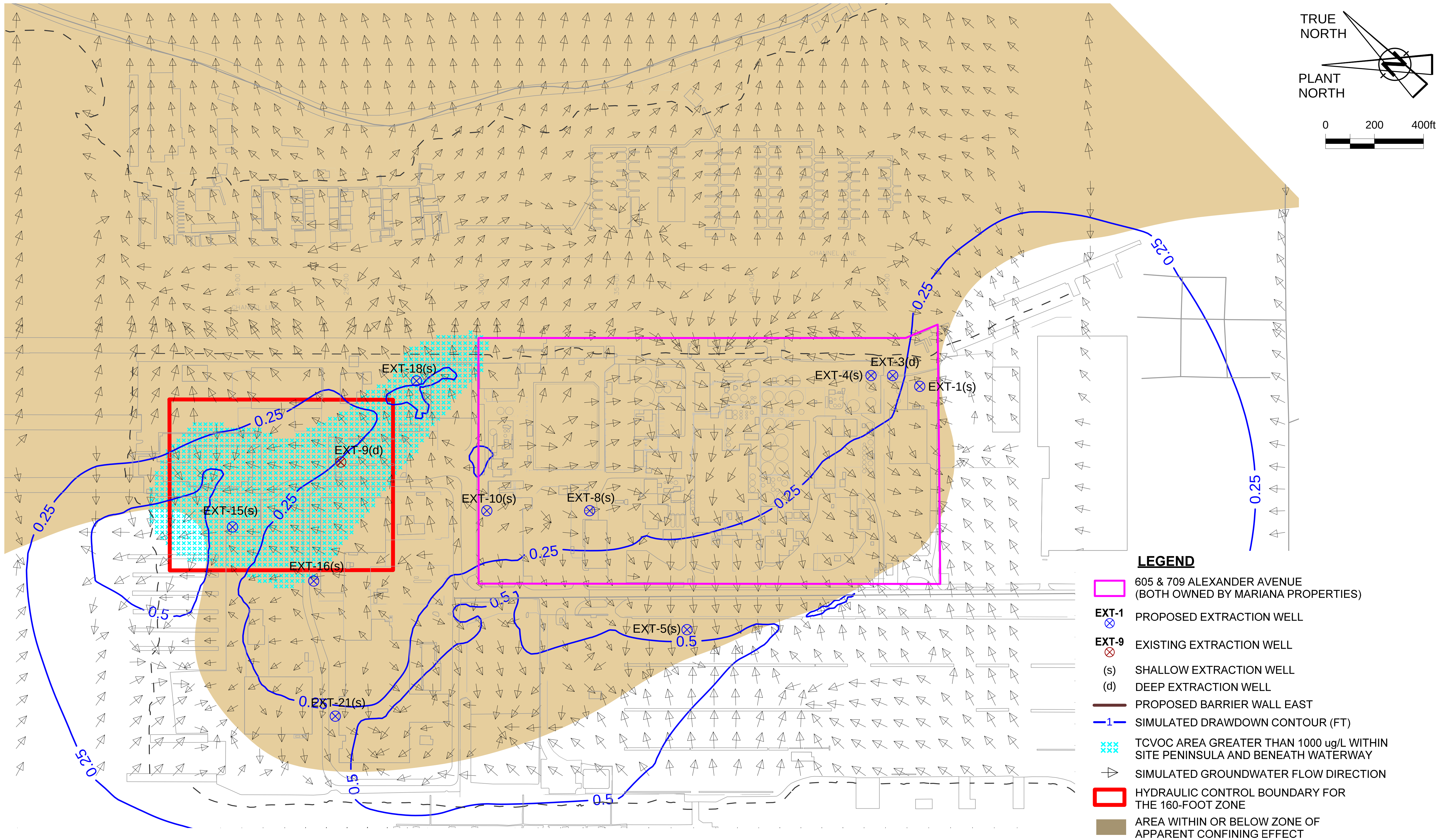

figure 7

SIMULATED DRAWDOWN AND GROUNDWATER FLOW DIRECTIONS
FOR CONTAINMENT ALTERNATIVE C100 - 160 FT ZONE

Occidental Chemical Corporation, Tacoma, Washington

GHD

007843-C2D2(RPT139) GN-WA-HYD (Z:\HEG\07843\RPT139\Appendix E\Jan2017-Rev\Figures\C100-DDN-160FT.srf) JAN 18/2017

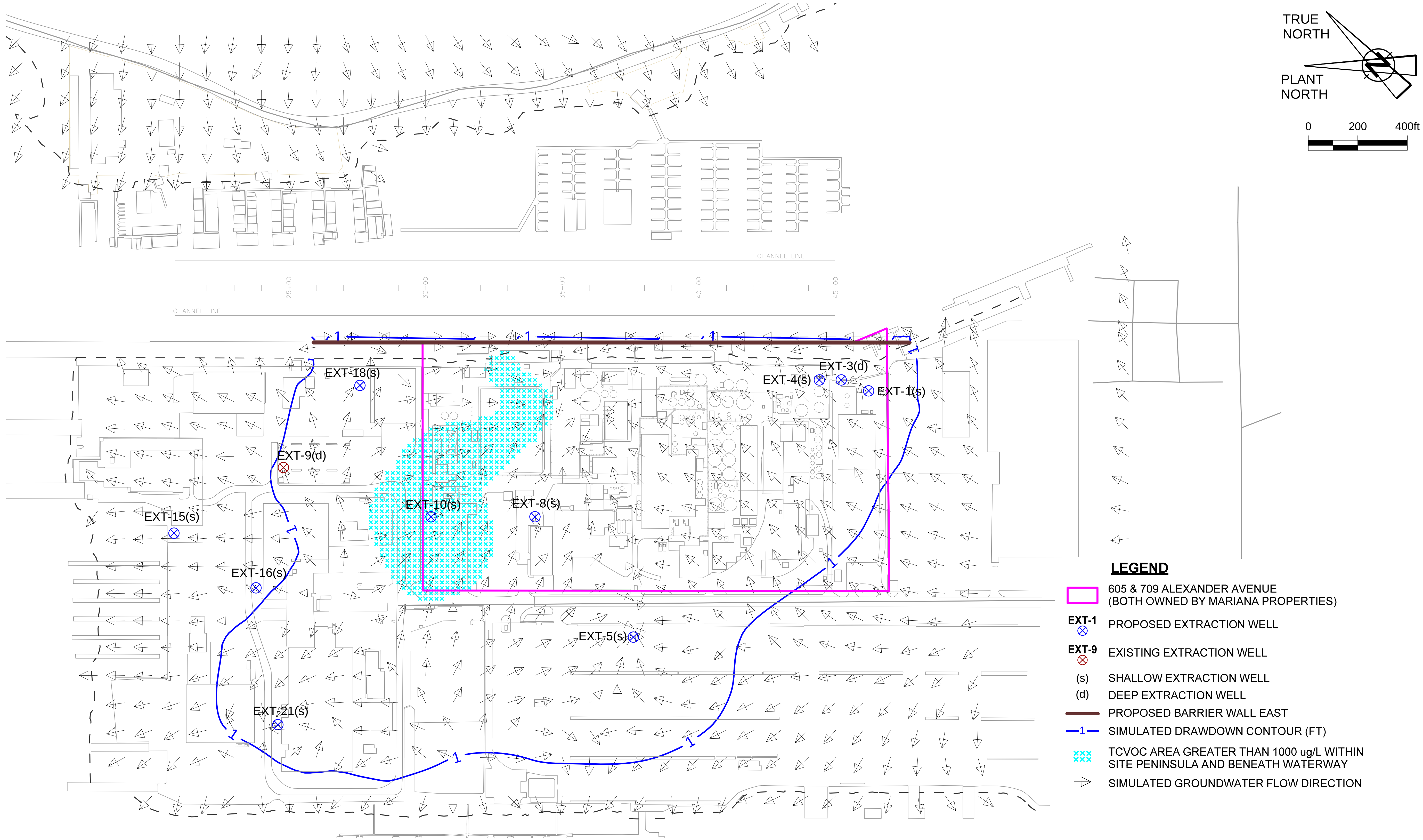

figure 8

SIMULATED DRAWDOWN AND GROUNDWATER FLOW DIRECTIONS
FOR CONTAINMENT ALTERNATIVE C150 - 15 FT ZONE
Occidental Chemical Corporation, Tacoma, Washington

GHD

007843-C2D2(RPT139) GN-WA-HYD (Z:\HEG\07843\RPT139\Appendix E\Jan2017-Rev\Figures\C150-DDN-15FT.srf) JAN 18/2017

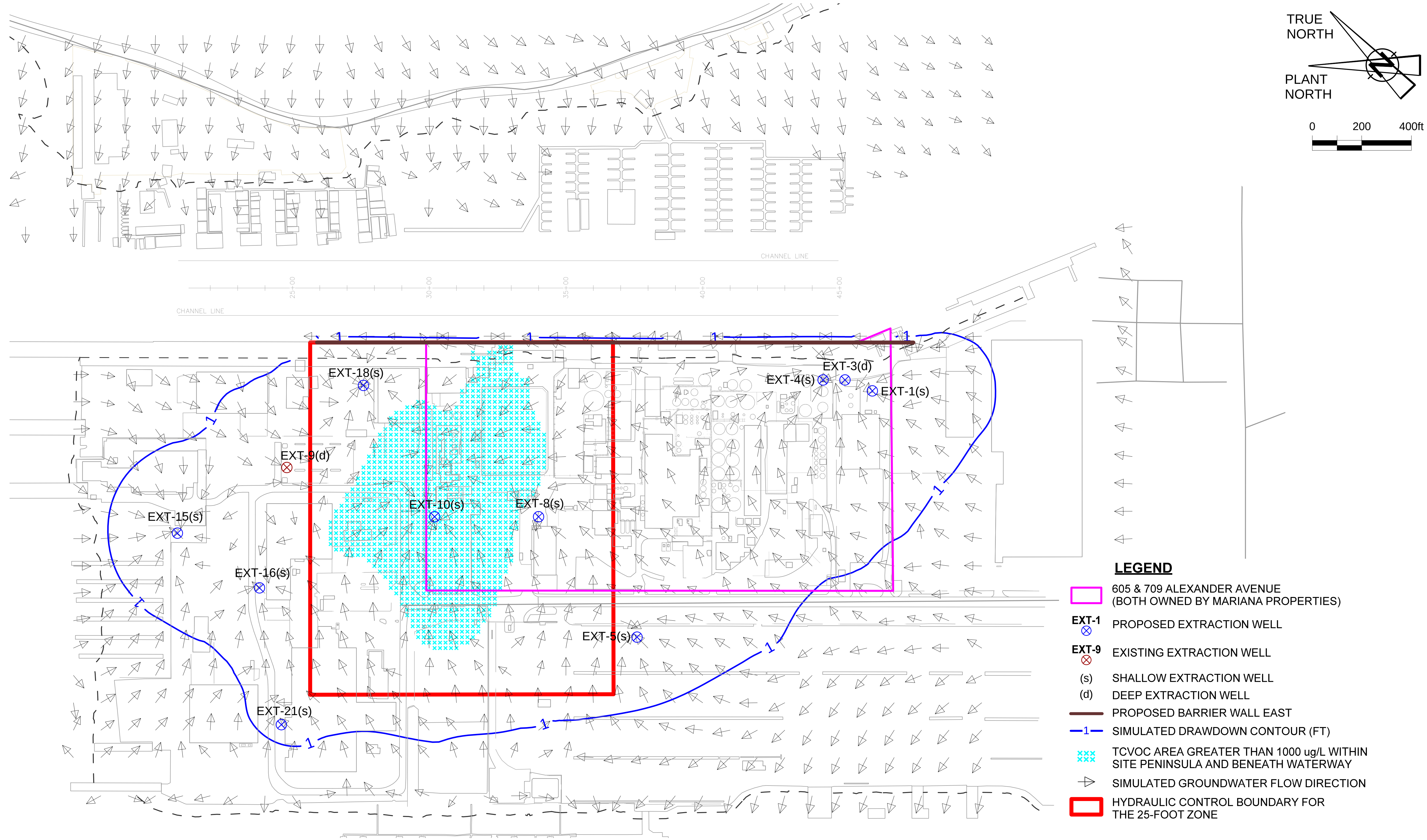

figure 9

SIMULATED DRAWDOWN AND GROUNDWATER FLOW DIRECTIONS
FOR CONTAINMENT ALTERNATIVE C150 - 25 FT ZONE
Occidental Chemical Corporation, Tacoma, Washington

GHD

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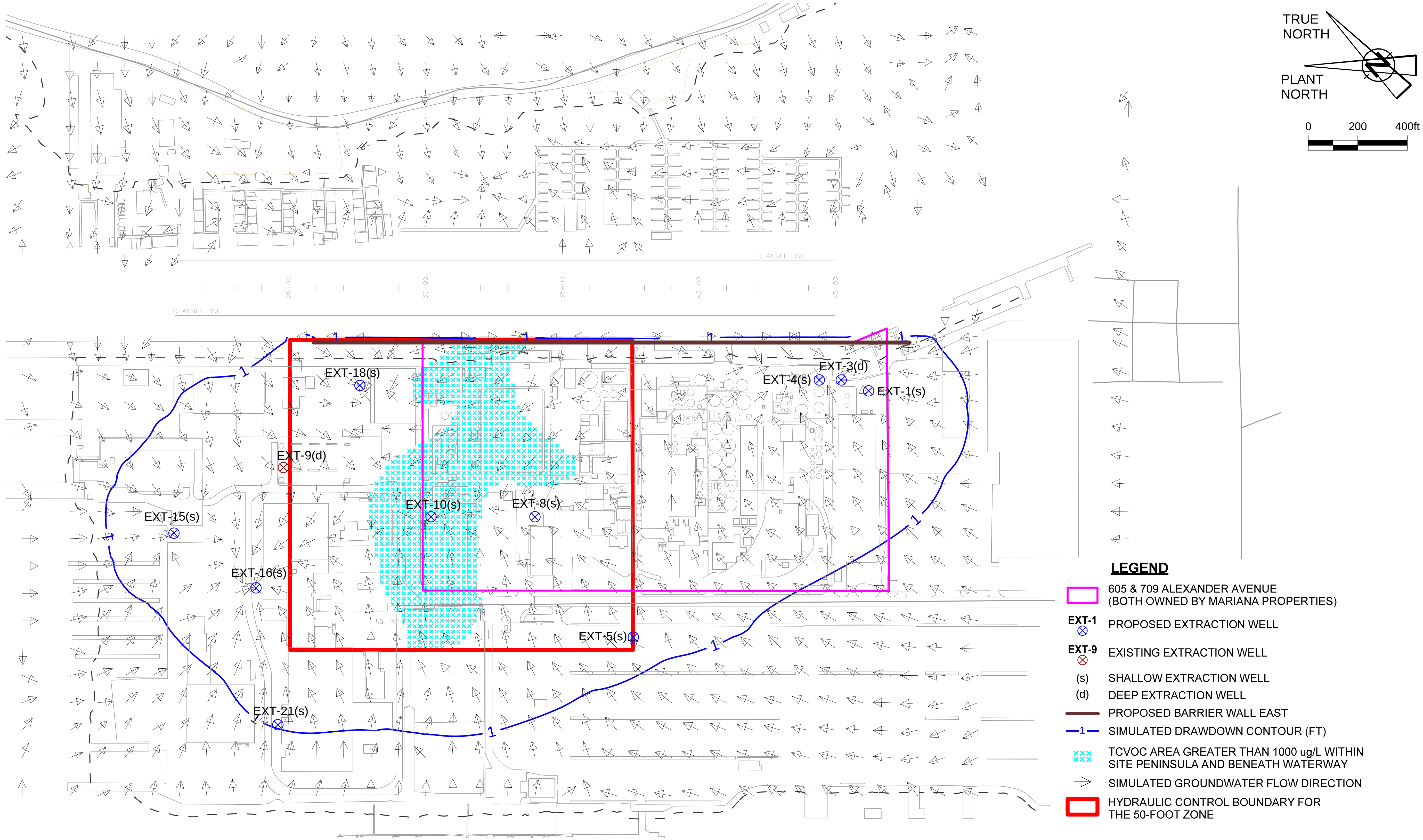

figure 10

SIMULATED DRAWDOWN AND GROUNDWATER FLOW DIRECTIONS
FOR CONTAINMENT ALTERNATIVE C150 - 50 FT ZONE
Occidental Chemical Corporation, Tacoma, Washington

GHD

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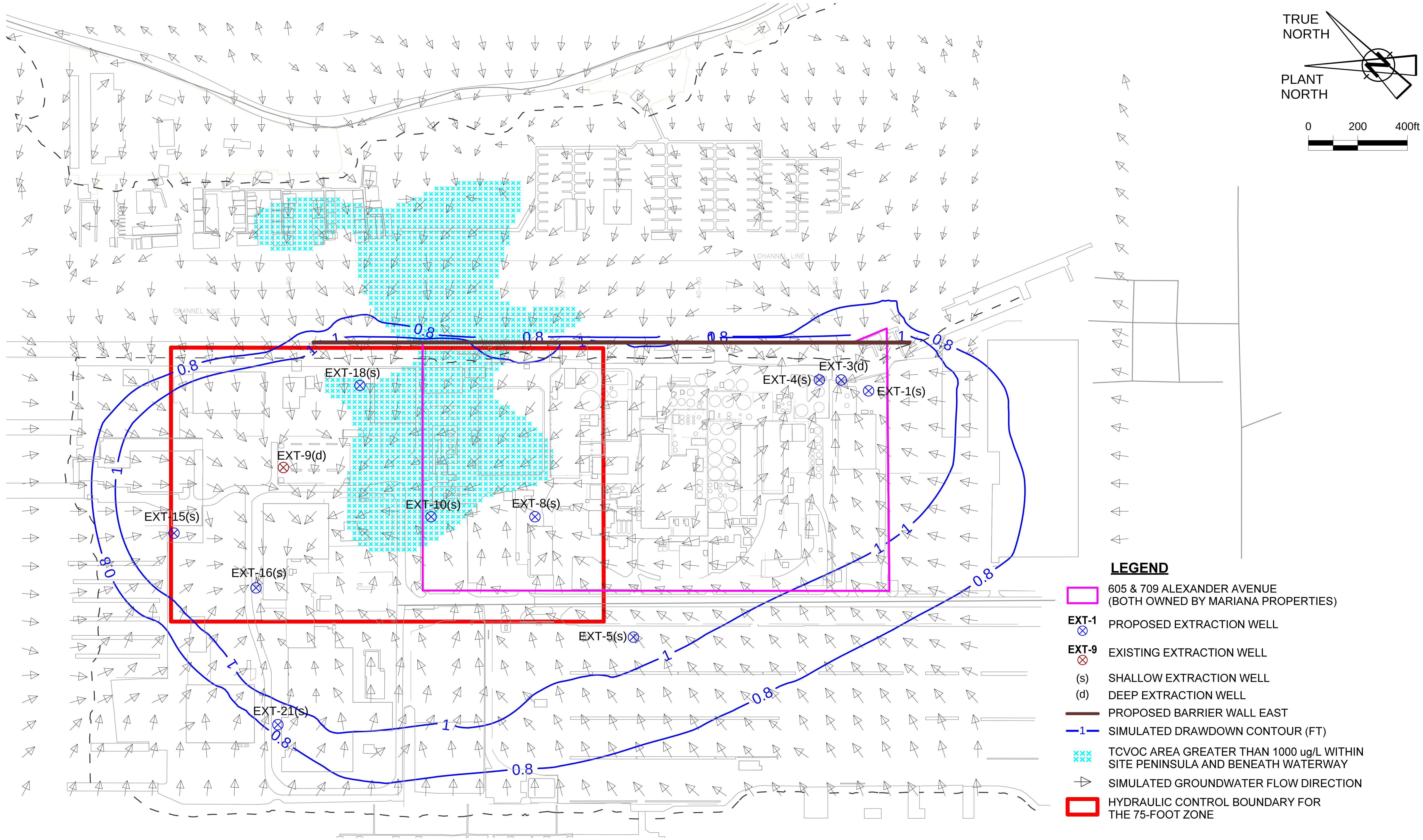

figure 11

SIMULATED DRAWDOWN AND GROUNDWATER FLOW DIRECTIONS
FOR CONTAINMENT ALTERNATIVE C150 - 75 FT ZONE
Occidental Chemical Corporation, Tacoma, Washington

GHD

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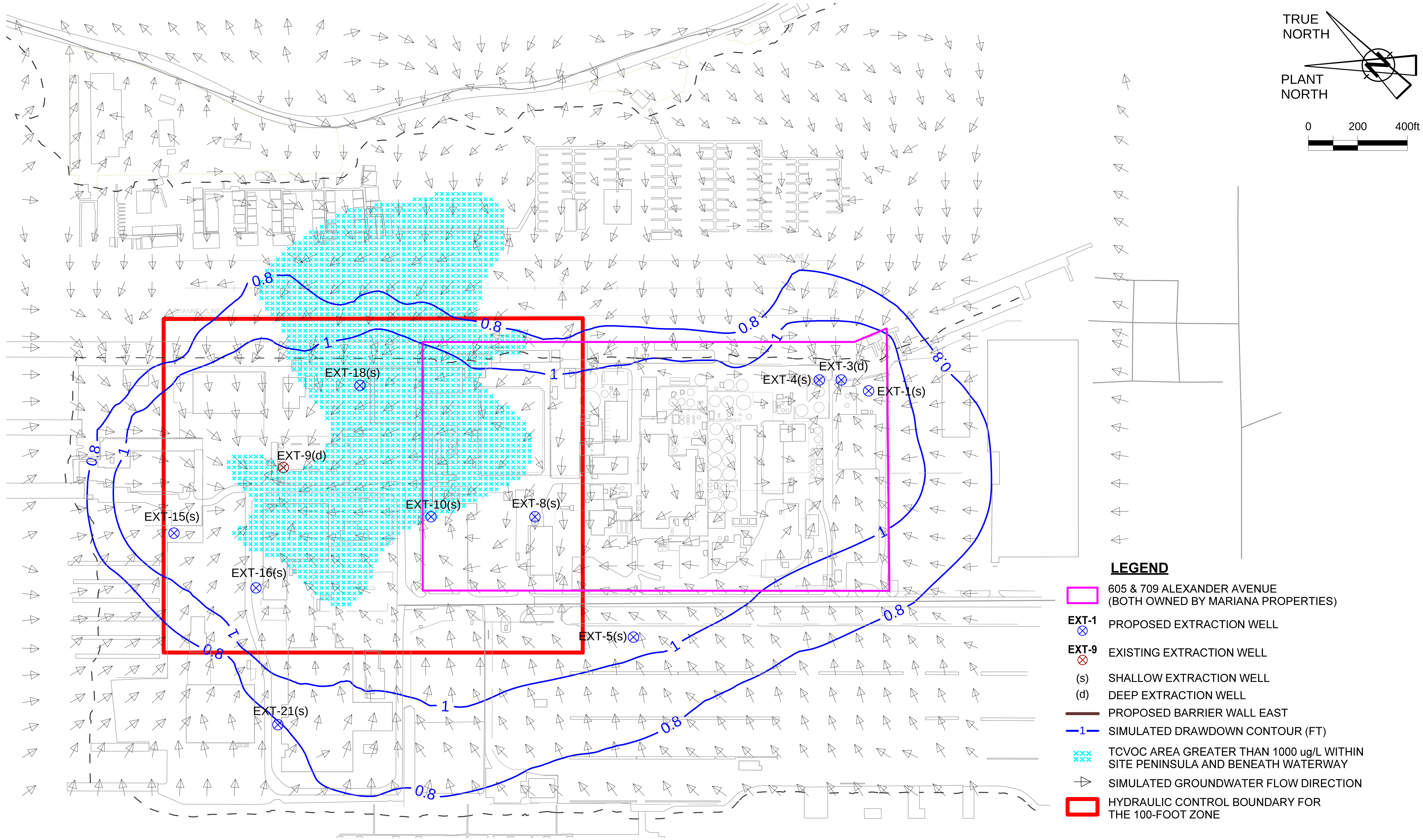

figure 12

SIMULATED DRAWDOWN AND GROUNDWATER FLOW DIRECTIONS
FOR CONTAINMENT ALTERNATIVE C150 - 100 FT ZONE
Occidental Chemical Corporation, Tacoma, Washington

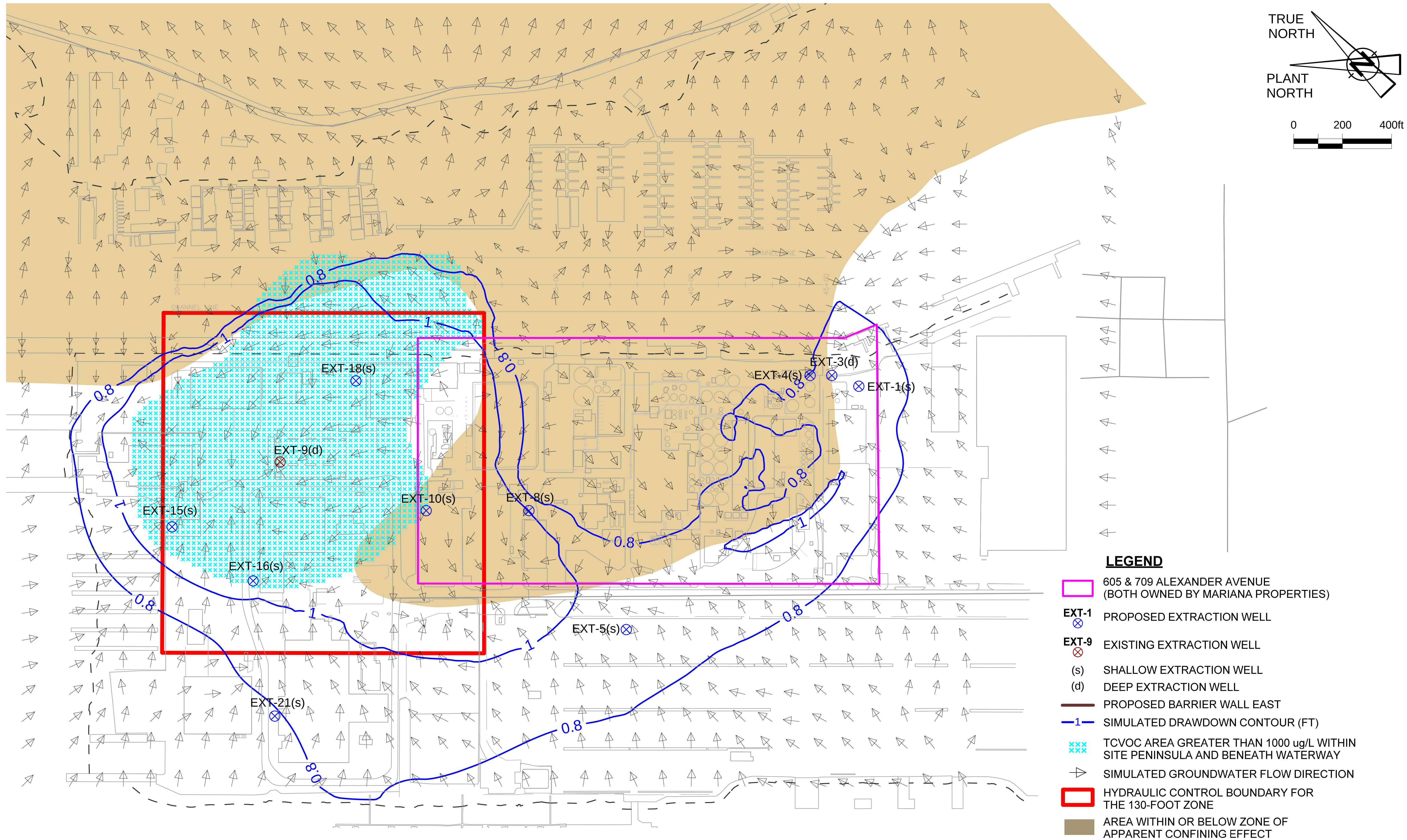

figure 13

SIMULATED DRAWDOWN AND GROUNDWATER FLOW DIRECTIONS
FOR CONTAINMENT ALTERNATIVE C150 - 130 FT ZONE
Occidental Chemical Corporation, Tacoma, Washington

007843-C2D2(RPT139) GN-WA-HYD (Z:\HEG\07843\RPT139\Appendix E\Jan2017-Rev\Figures\C150-DDN-130FT.srf) JAN 18/2017

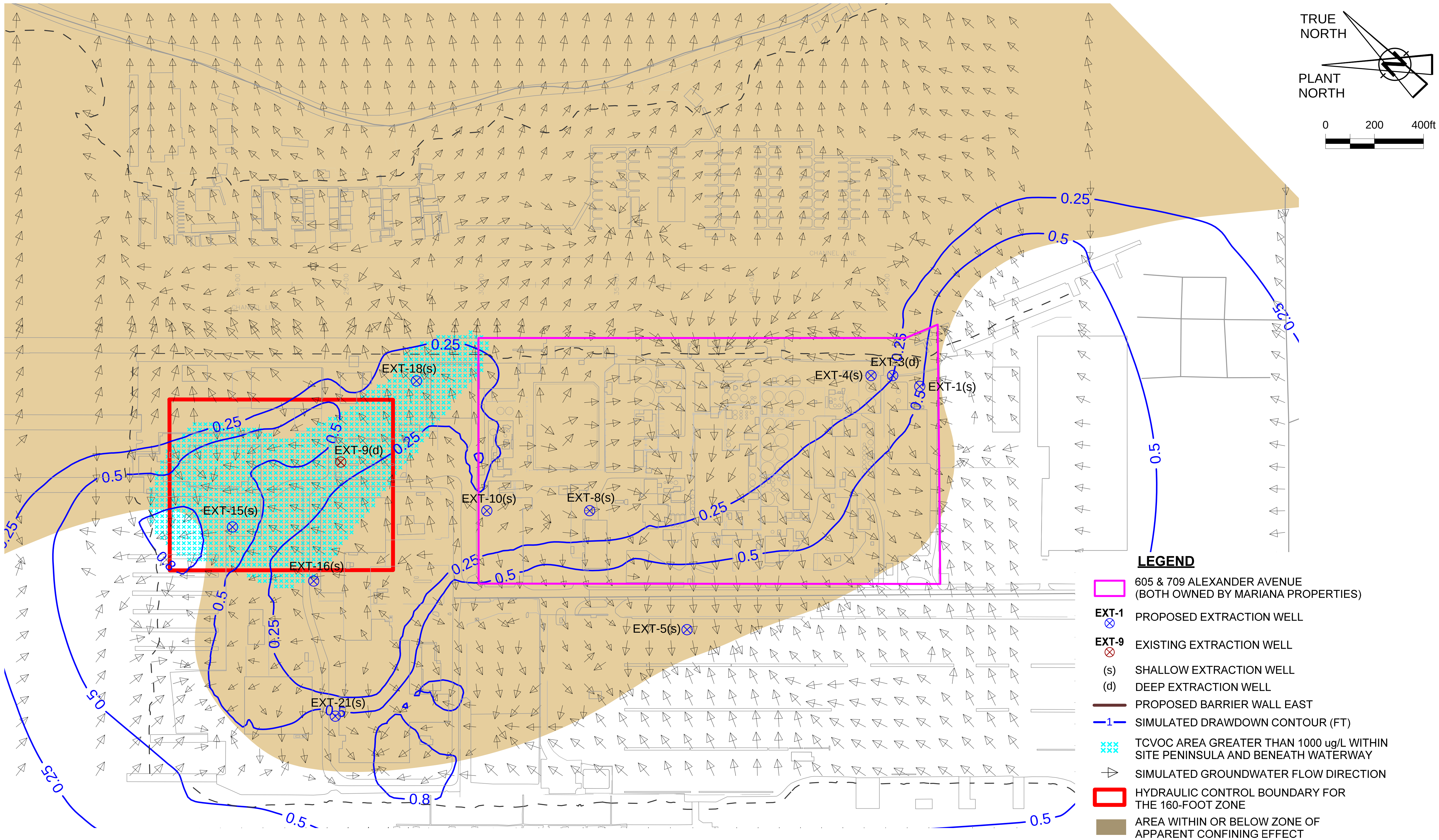

figure 14

SIMULATED DRAWDOWN AND GROUNDWATER FLOW DIRECTIONS
FOR CONTAINMENT ALTERNATIVE C150 - 160 FT ZONE
Occidental Chemical Corporation, Tacoma, Washington

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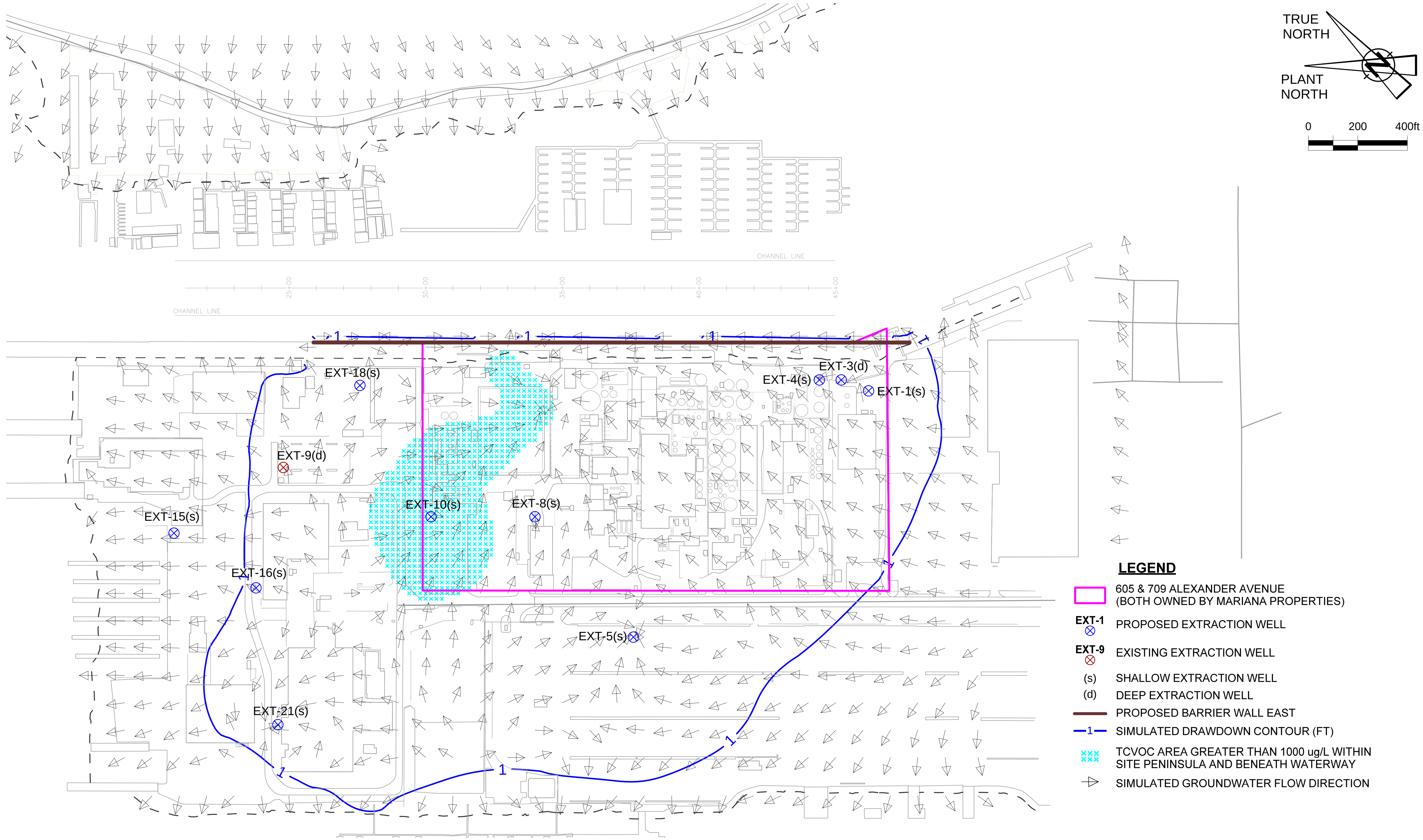


figure 15

SIMULATED DRAWDOWN AND GROUNDWATER FLOW DIRECTIONS
FOR CONTAINMENT ALTERNATIVE C200 - 15 FT ZONE
Occidental Chemical Corporation, Tacoma, Washington

007843-C2D2(RPT139) GN-WA-HYD (Z:\HEG\07843\RPT139\Appendix E\Jan2017-Rev\Figures\C200-DDN-15FT.srf) JAN 18/2017

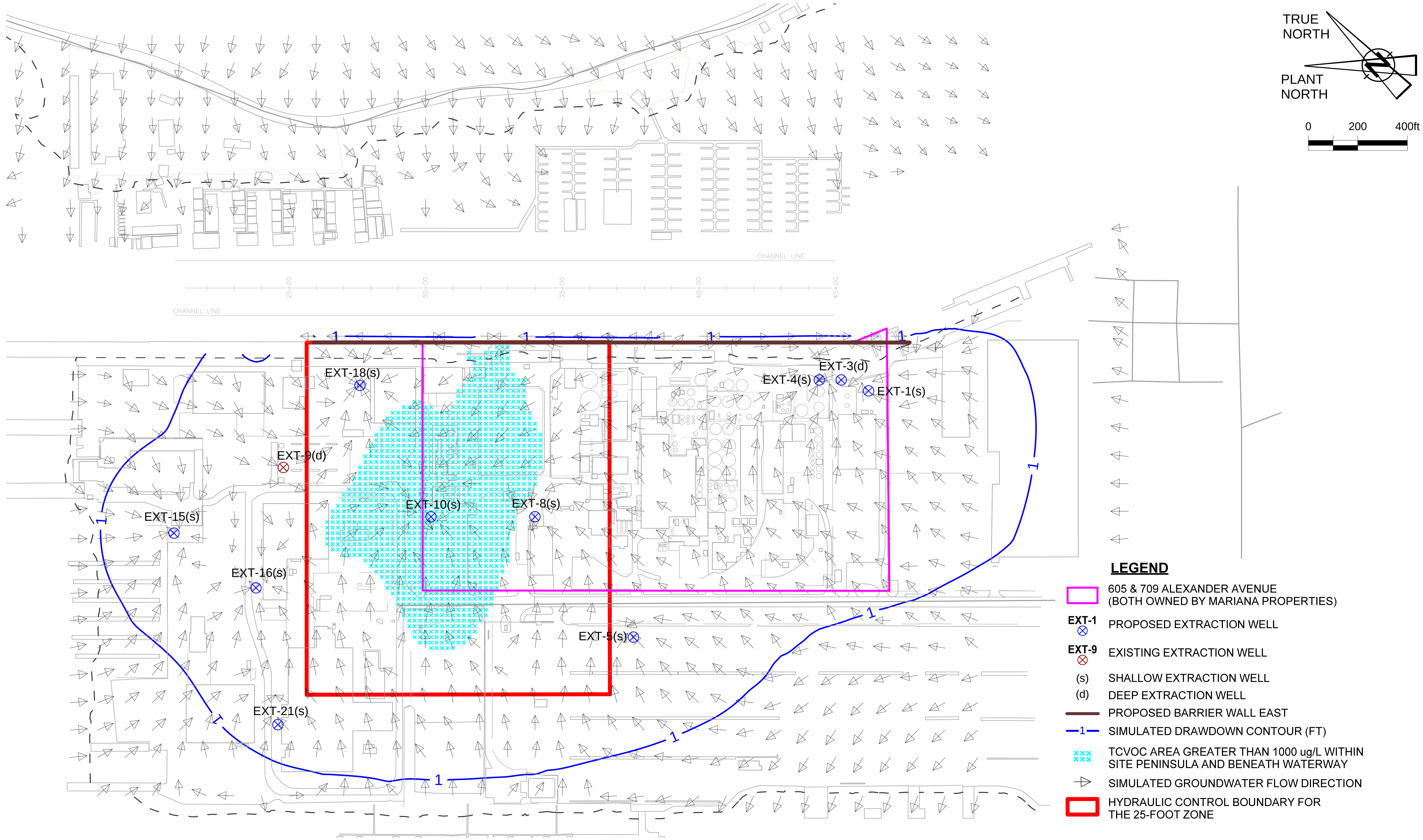


figure 16

SIMULATED DRAWDOWN AND GROUNDWATER FLOW DIRECTIONS
FOR CONTAINMENT ALTERNATIVE C200 - 25 FT ZONE

Occidental Chemical Corporation, Tacoma, Washington

GHD

007843-C2D2(RPT139) GN-WA-HYD (Z:\HEG\07843\RPT139\Appendix E\Jan2017-Rev\Figures\C200-DDN-25FT.srf) JAN 18/2017

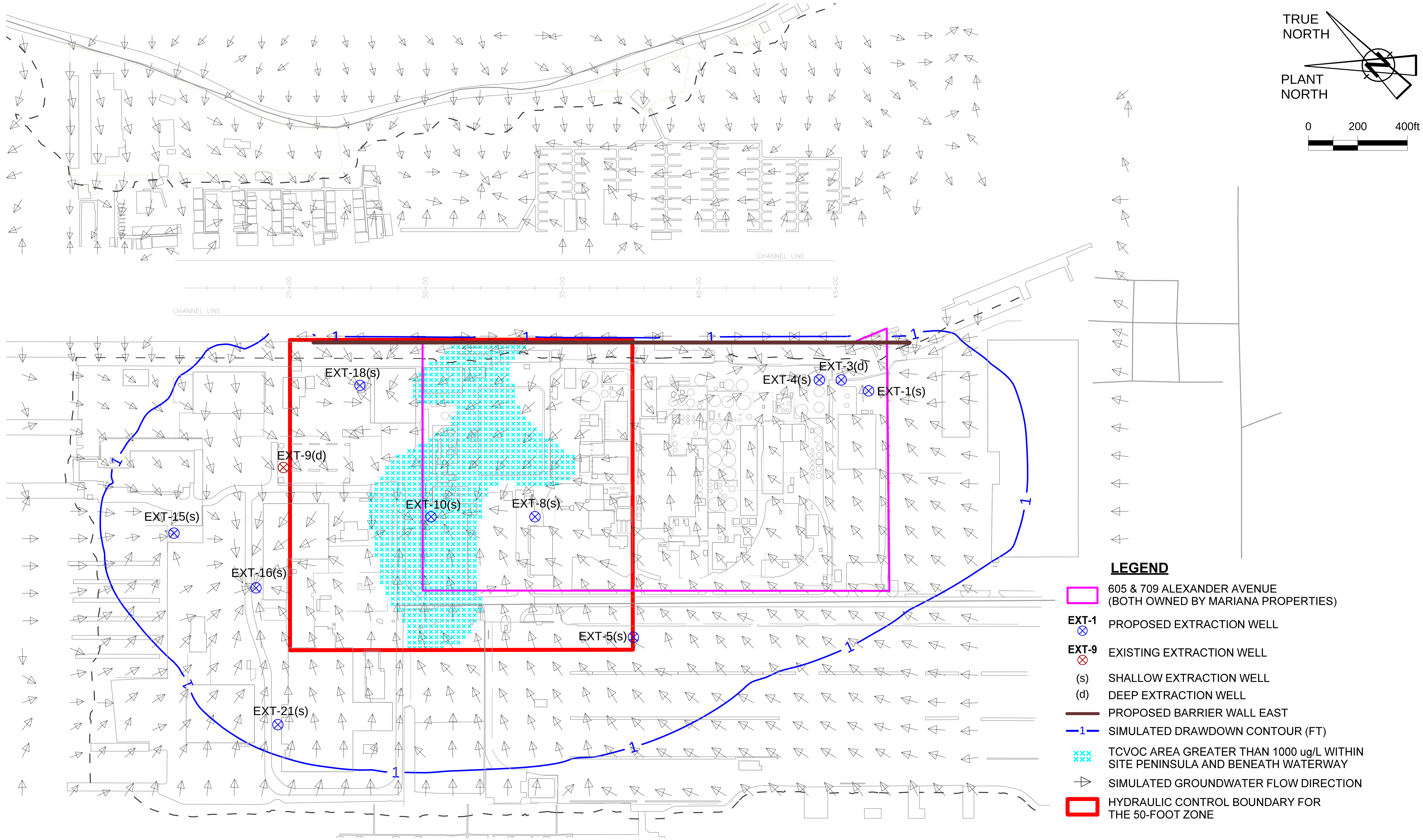


figure 17

SIMULATED DRAWDOWN AND GROUNDWATER FLOW DIRECTIONS
FOR CONTAINMENT ALTERNATIVE C200 - 50 FT ZONE
Occidental Chemical Corporation, Tacoma, Washington

007843-C2D2(RPT139) GN-WA-HYD (Z:\HEG\07843\RPT139\Appendix E\Jan2017-Rev\Figures\C200-DDN-50FT.srf) JAN 18/2017

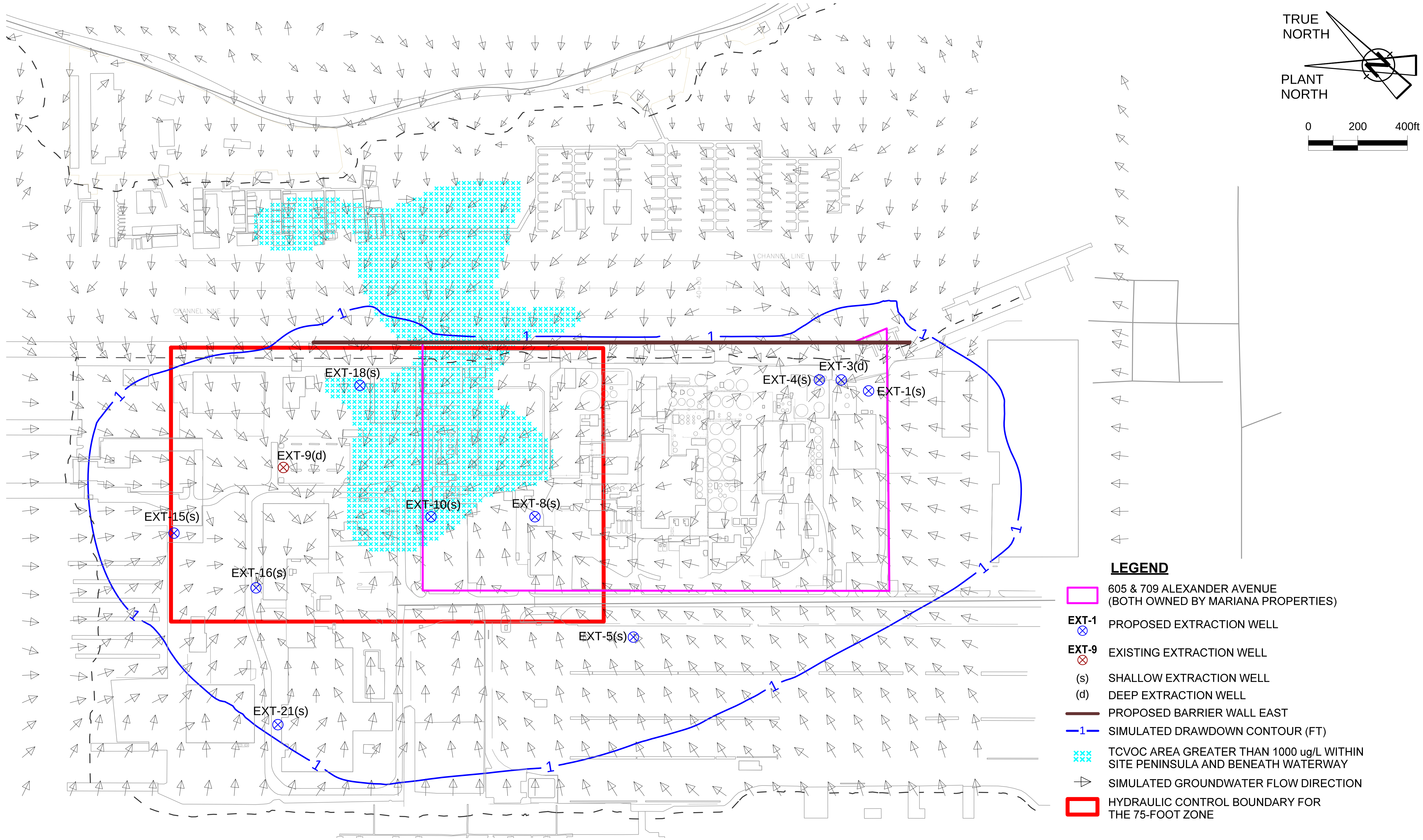


figure 18

SIMULATED DRAWDOWN AND GROUNDWATER FLOW DIRECTIONS
FOR CONTAINMENT ALTERNATIVE C200 - 75 FT ZONE

Occidental Chemical Corporation, Tacoma, Washington

GHD

007843-C2D2(RPT139) GN-WA-HYD (Z:\HEG\07843\RPT139\Appendix E\Jan2017-Rev\Figures\C200-DDN-75FT.srf) JAN 18/2017

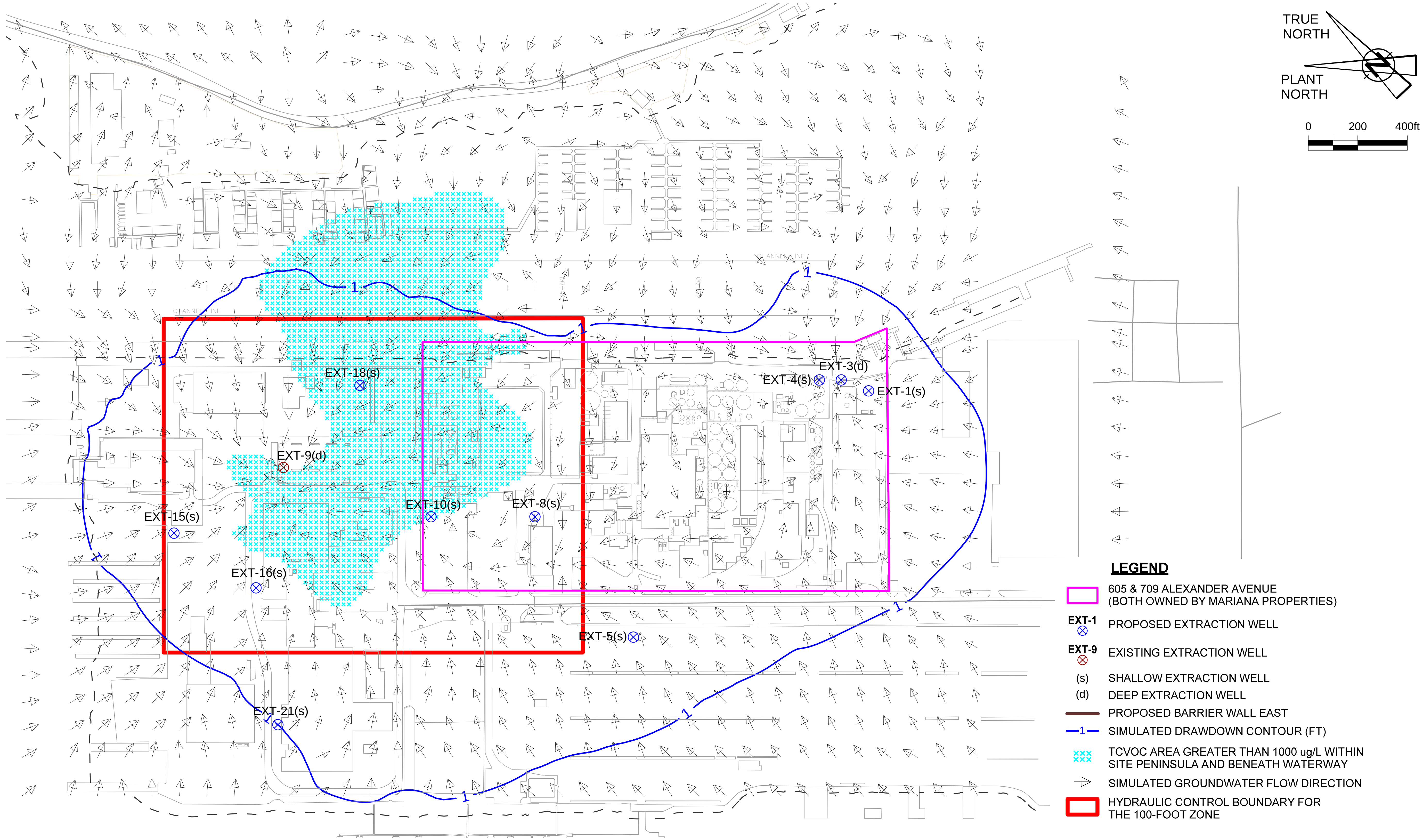


figure 19

SIMULATED DRAWDOWN AND GROUNDWATER FLOW DIRECTIONS
FOR CONTAINMENT ALTERNATIVE C200 - 100 FT ZONE
Occidental Chemical Corporation, Tacoma, Washington

007843-C2D2(RPT139) GN-WA-HYD (Z:\HEG\07843\RPT139\Appendix E\Jan2017-Rev\Figures\C200-DDN-100FT.srf) JAN 18/2017

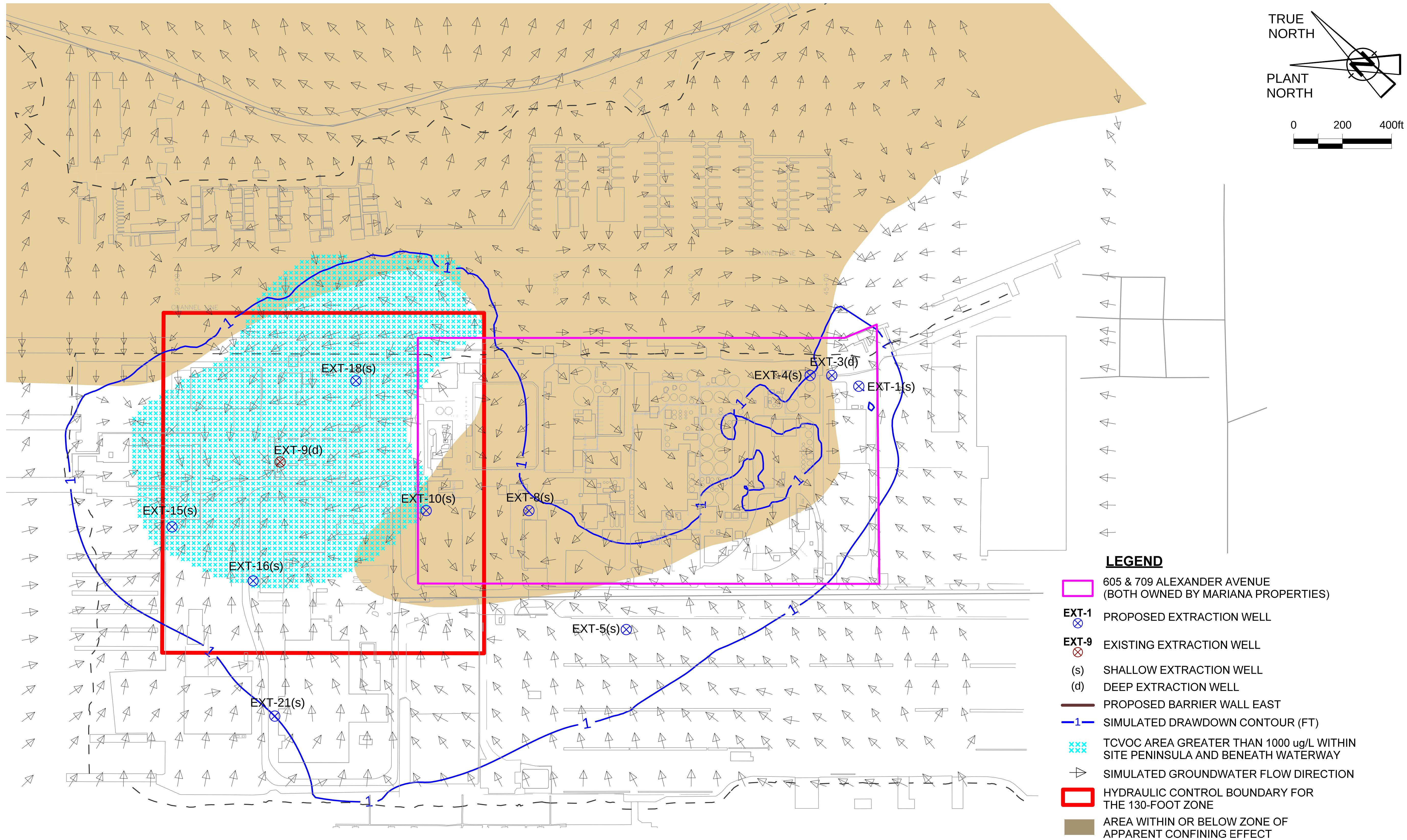


figure 20

SIMULATED DRAWDOWN AND GROUNDWATER FLOW DIRECTIONS FOR CONTAINMENT ALTERNATIVE C200 - 130 FT ZONE

Occidental Chemical Corporation, Tacoma, Washington

GHD

007843-C2D2(RPT139) GN-WA-HYD (Z:\HEG\07843\RPT139\Appendix E\Jan2017-Rev\Figures\C200-DDN-130FT.srf) JAN 18/2017

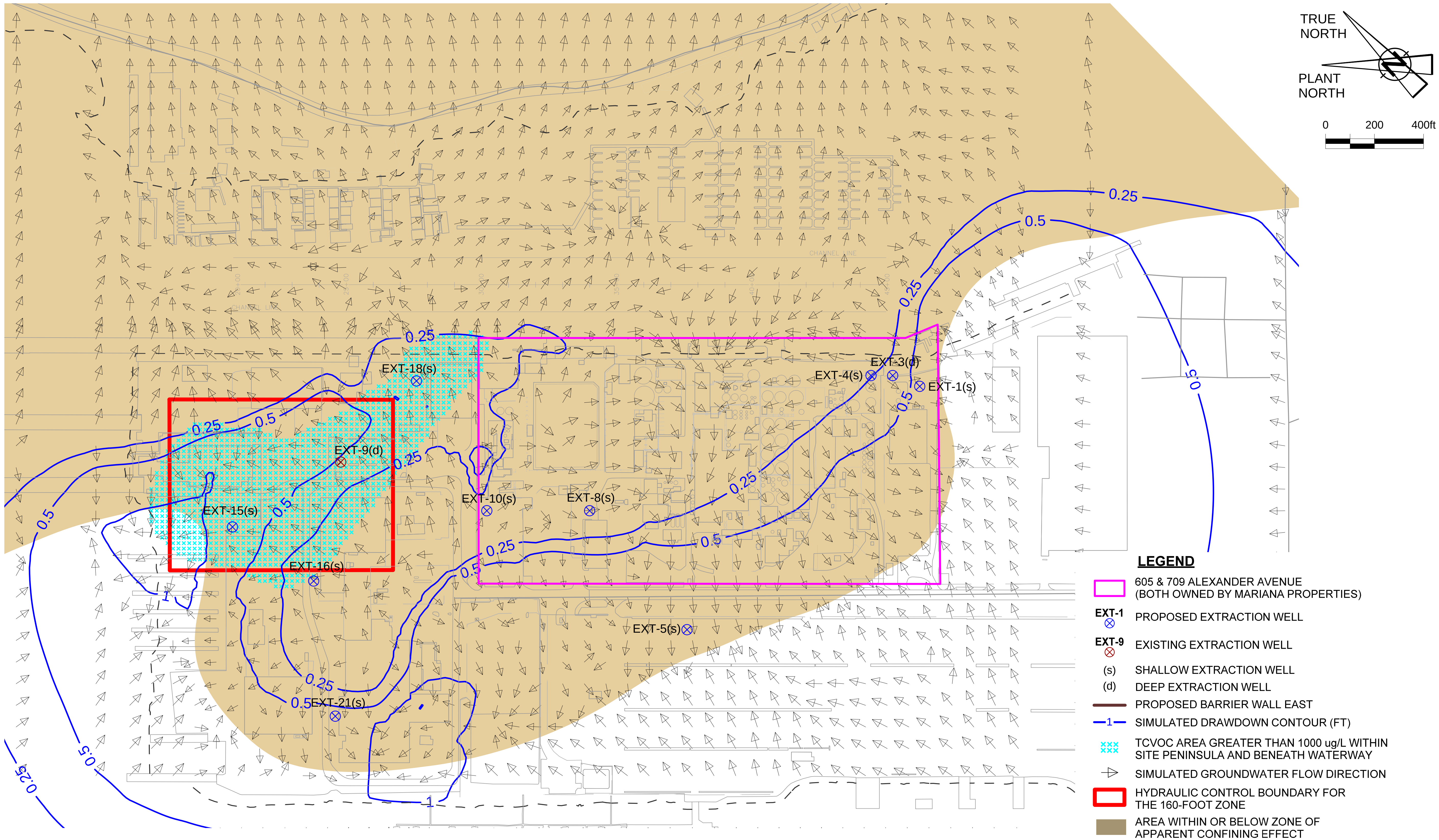


figure 21

SIMULATED DRAWDOWN AND GROUNDWATER FLOW DIRECTIONS
FOR CONTAINMENT ALTERNATIVE C200 - 160 FT ZONE

Occidental Chemical Corporation, Tacoma, Washington

GHD

007843-C2D2(RPT139) GN-WA-HYD (Z:\HEG\07843\RPT139\Appendix E\Jan2017-Rev\Figures\C200-DDN-160FT.srf) JAN 18/2017

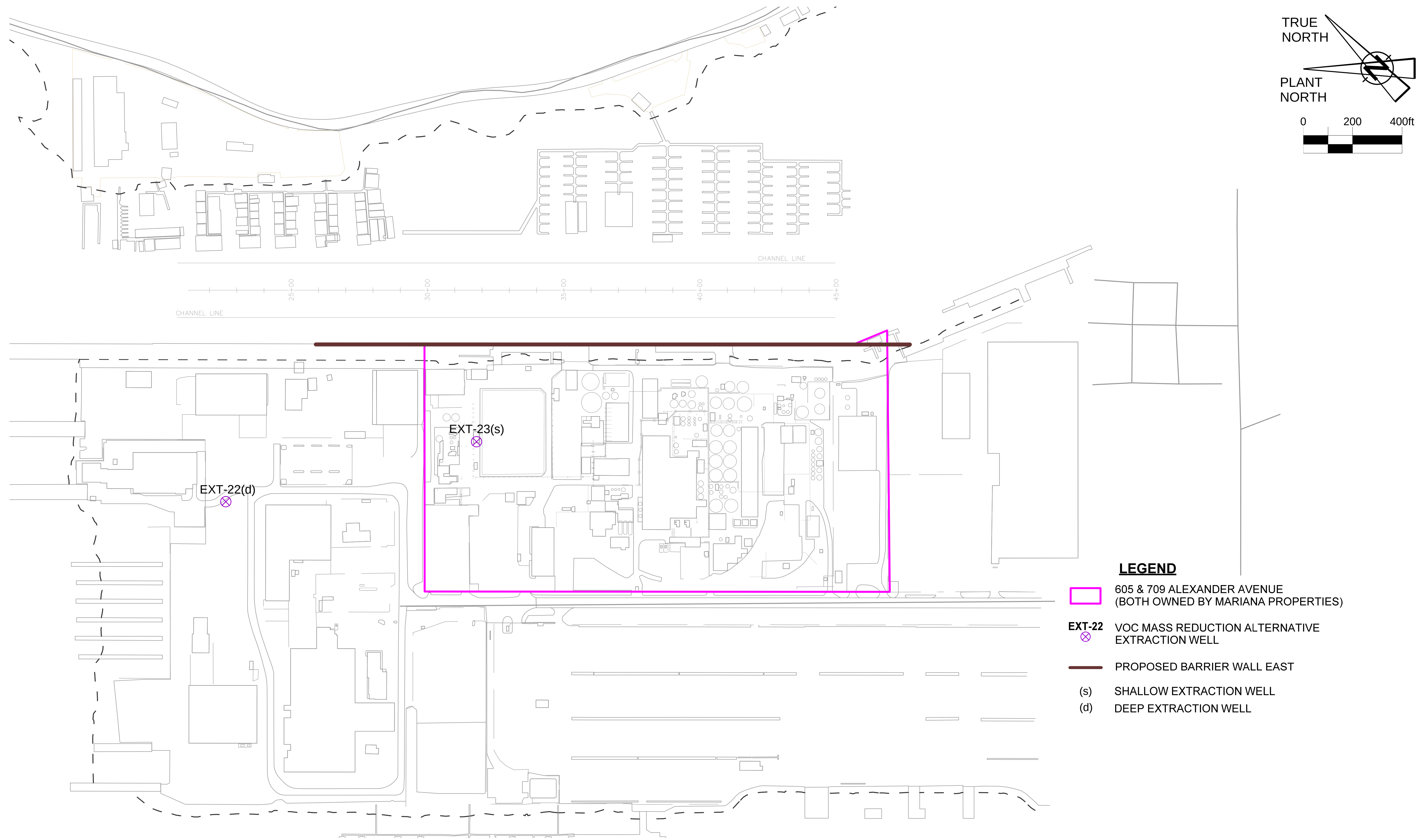


figure 22

EXTRACTION WELL LOCATIONS FOR VOC MASS REDUCTION ALTERNATIVES M100, M150, AND M200

Occidental Chemical Corporation, Tacoma, Washington

007843-C2D2(RPT139) GN-WA-HYD (Z:\HEG\07843\RPT139\Appendix E\Jan2017-Rev\Figures\F23-Ext22 and 23 Map.srf) JAN 18/2017

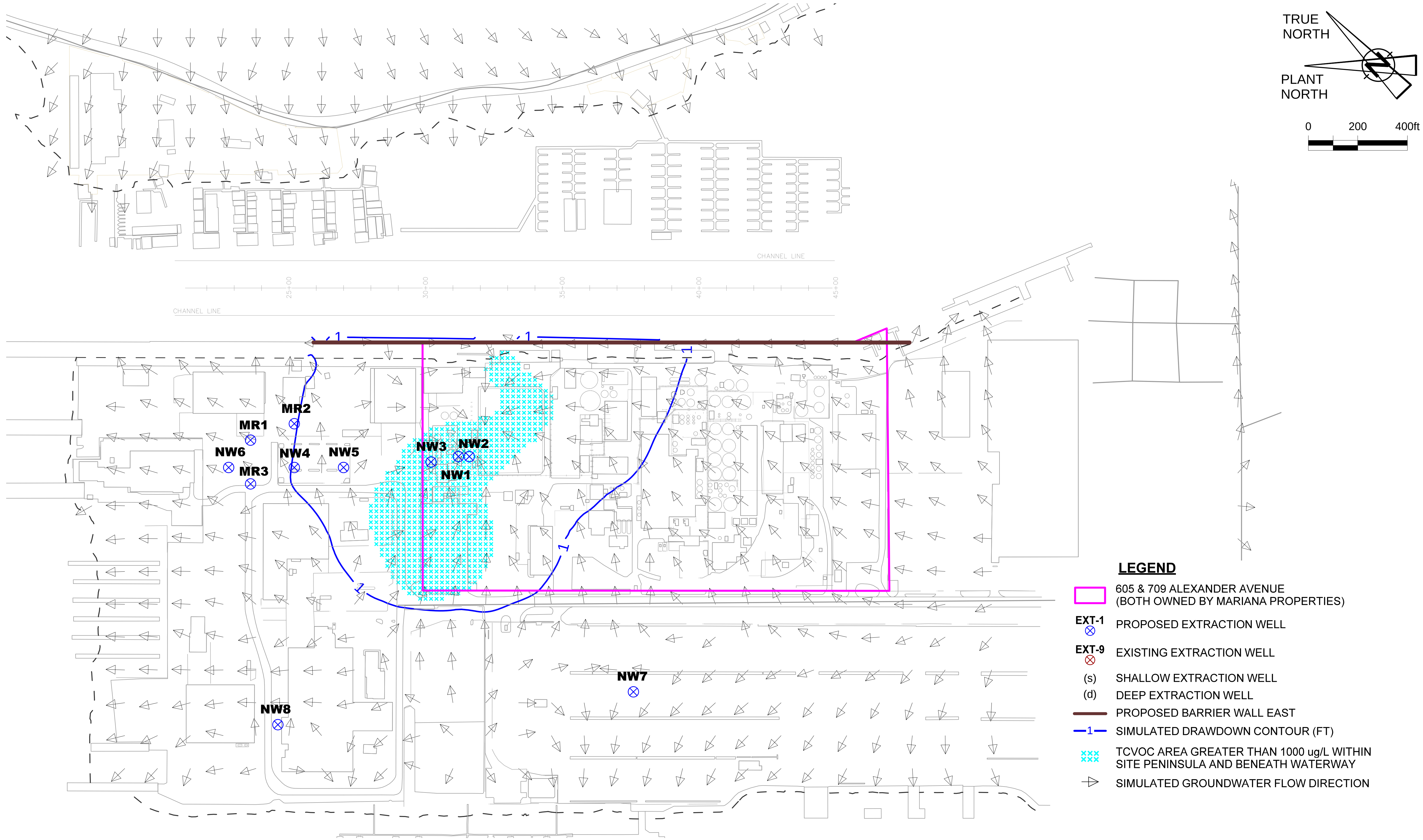


figure 23

SIMULATED DRAWDOWN AND GROUNDWATER FLOW DIRECTIONS
FOR VOC MASS REDUCTION ALTERNATIVE MSP - 15 FT ZONE

Occidental Chemical Corporation, Tacoma, Washington

007843-C2D2(RPT139) GN-WA-HYD (Z:\HEG\07843\RPT139\Appendix E\Jan2017-Rev\Figures\Opt5-DDN-15FT.srf) JAN 18/2017

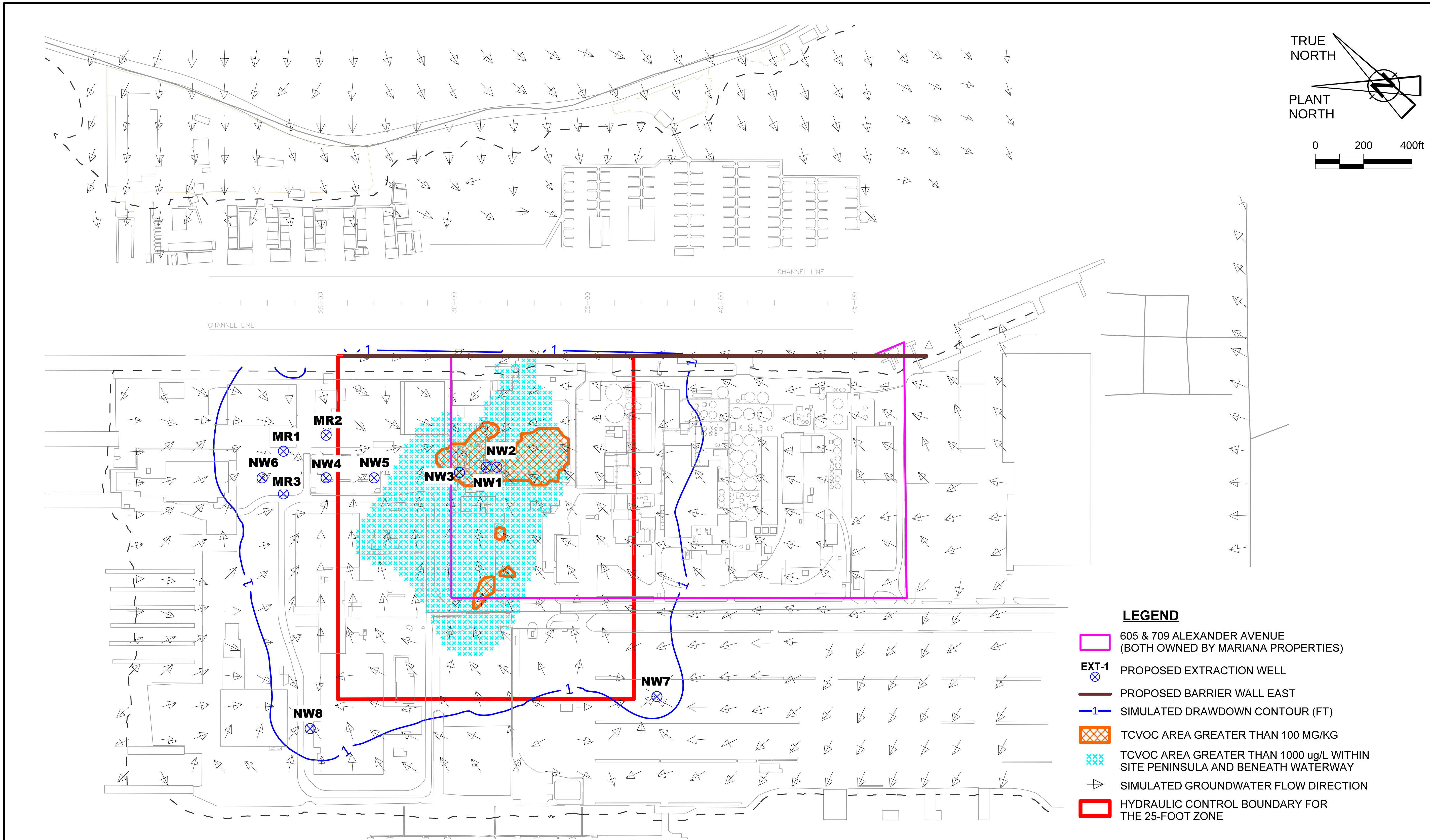


figure 24

SIMULATED DRAWDOWN AND GROUNDWATER FLOW DIRECTIONS
FOR VOC MASS REDUCTION ALTERNATIVE MSP - 25 FT ZONE
Occidental Chemical Corporation, Tacoma, Washington

007843-C2D2(RPT139) GN-WA-HYD (Z:\HEG\07843\RPT139\Appendix E\Jan2017-Rev\Figures\Opt5-DDN-25FT.srf) JAN 18/2017

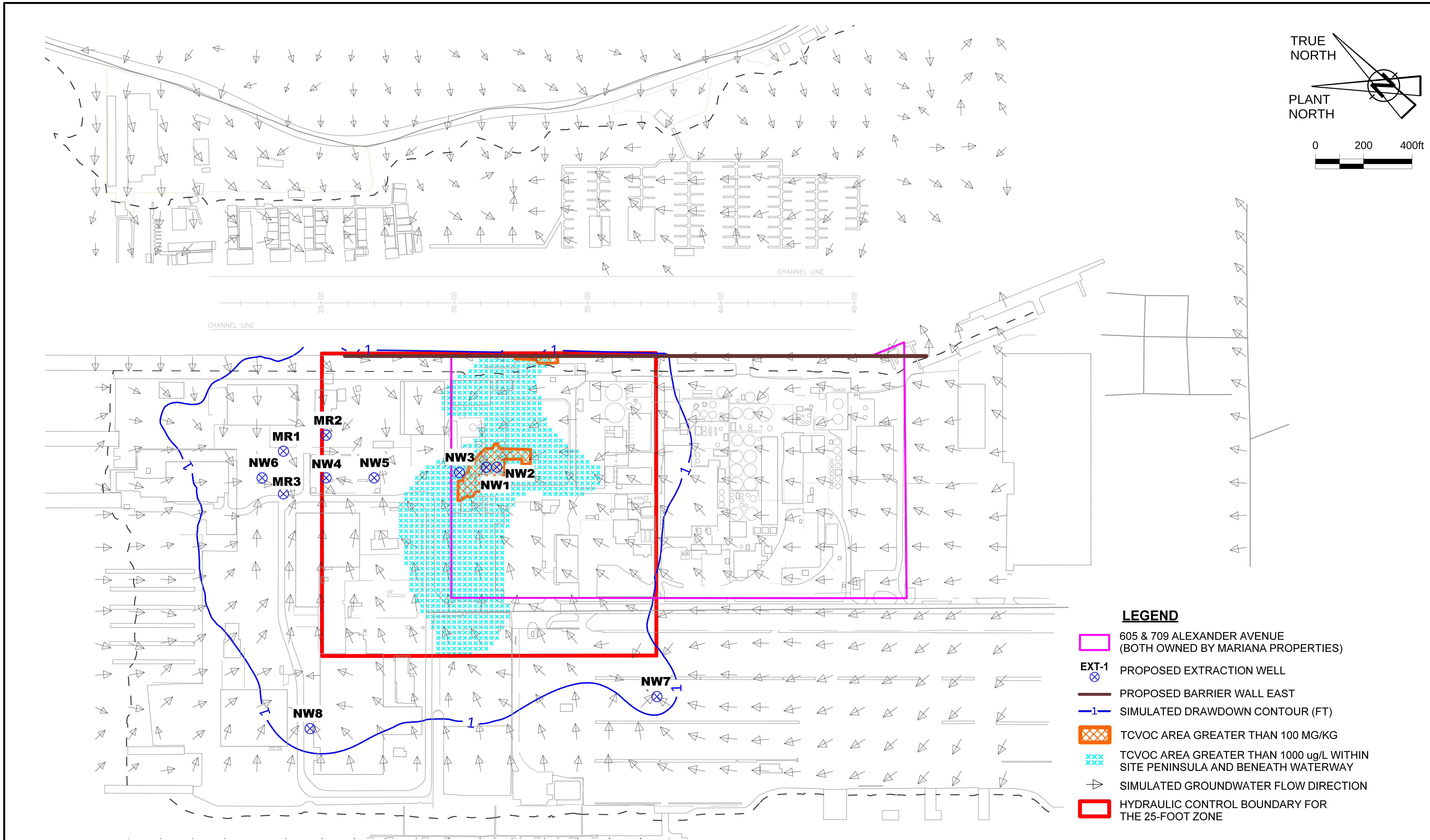


figure 25

SIMULATED DRAWDOWN AND GROUNDWATER FLOW DIRECTIONS
FOR VOC MASS REDUCTION ALTERNATIVE MSP - 50 FT ZONE
Occidental Chemical Corporation, Tacoma, Washington

007843-C2D2(RPT139) GN-WA-HYD (Z:\HEG\07843\RPT139\Appendix E\Jan2017-Rev\Figures\Opt5-DDN-50FT.srf) JAN 18/2017

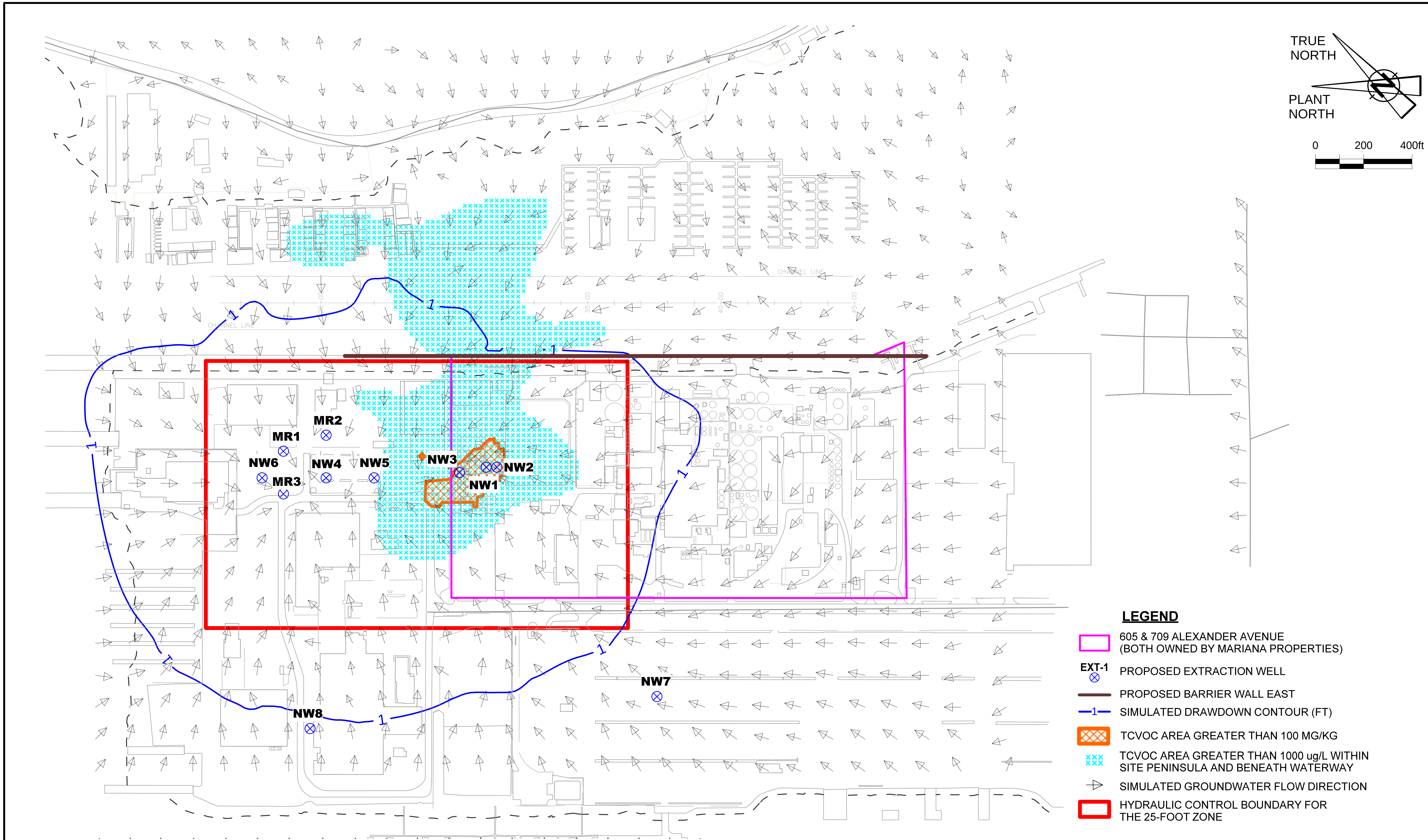


figure 26

SIMULATED DRAWDOWN AND GROUNDWATER FLOW DIRECTIONS
FOR VOC MASS REDUCTION ALTERNATIVE MSP - 75 FT ZONE

Occidental Chemical Corporation, Tacoma, Washington

007843-C2D2(RPT139) GN-WA-HYD (Z:\HEG\07843\RPT139\Appendix E\Jan2017-Rev\Figures\Opt5-DDN-75FT.srf) JAN 18/2017

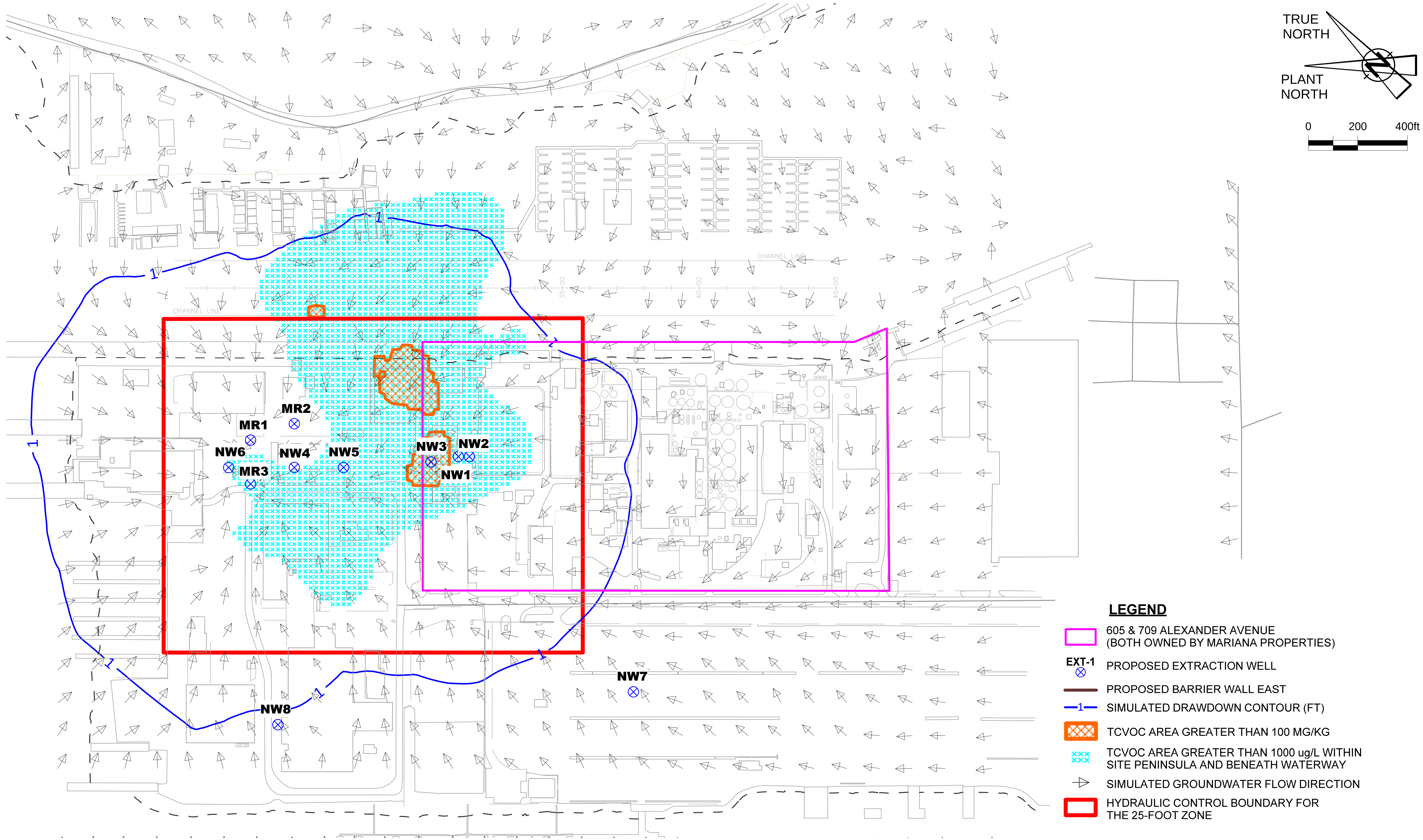


figure 27

SIMULATED DRAWDOWN AND GROUNDWATER FLOW DIRECTIONS
FOR VOC MASS REDUCTION ALTERNATIVE MSP - 100 FT ZONE

Occidental Chemical Corporation, Tacoma, Washington

007843-C2D2(RPT139) GN-WA-HYD (Z:\HEG\07843\RPT139\Appendix E\Jan2017-Rev\Figures\Opt5-DDN-100FT.srf) JAN 18/2017

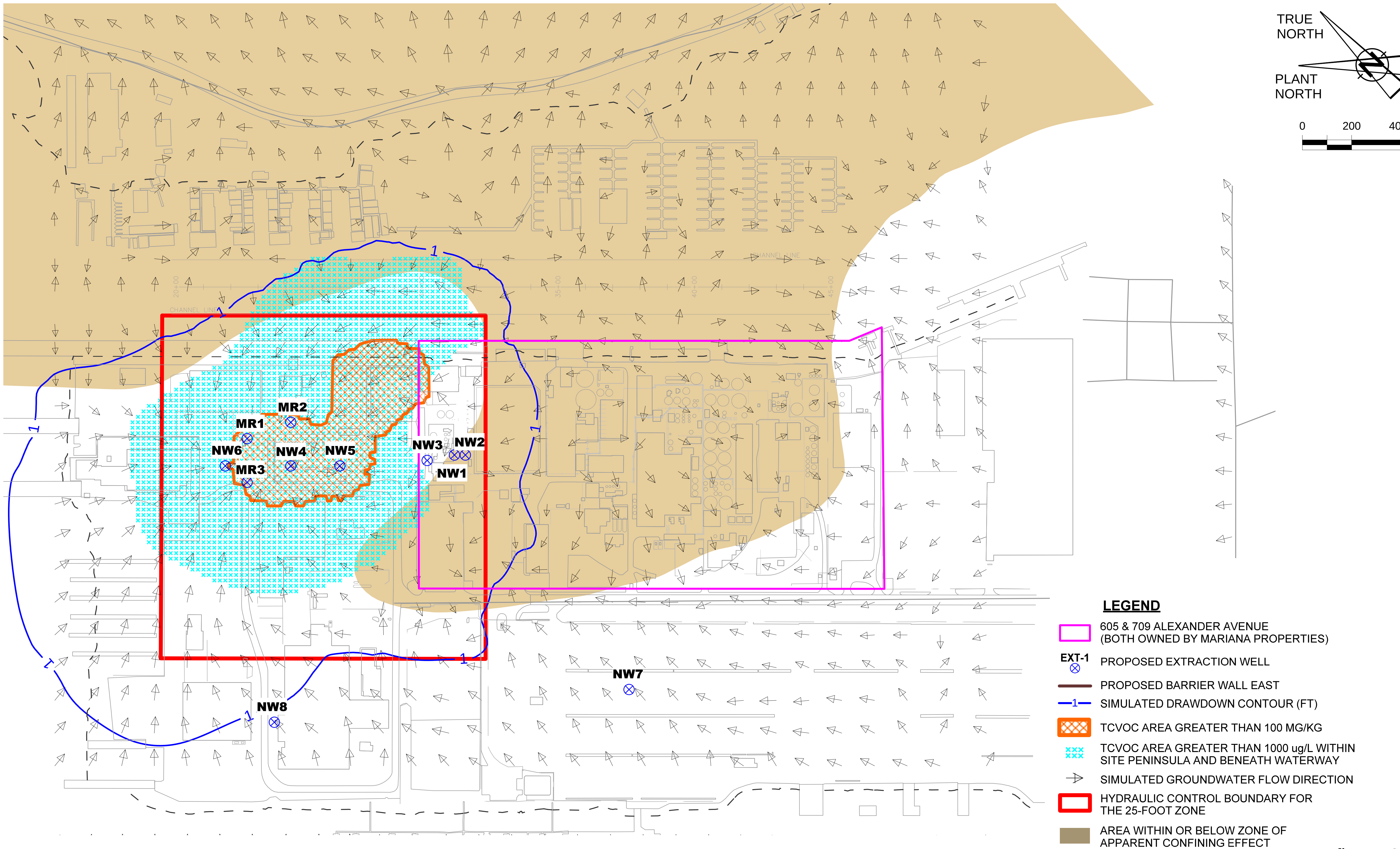


figure 28

SIMULATED DRAWDOWN AND GROUNDWATER FLOW DIRECTIONS
FOR VOC MASS REDUCTION ALTERNATIVE MSP - 130 FT ZONE
Occidental Chemical Corporation, Tacoma, Washington

007843-C2D2(RPT139) GN-WA-HYD (Z:\HEG\07843\RPT139\Appendix E\Jan2017-Rev\Figures\Opt5-DDN-130FT.srf) JAN 18/2017

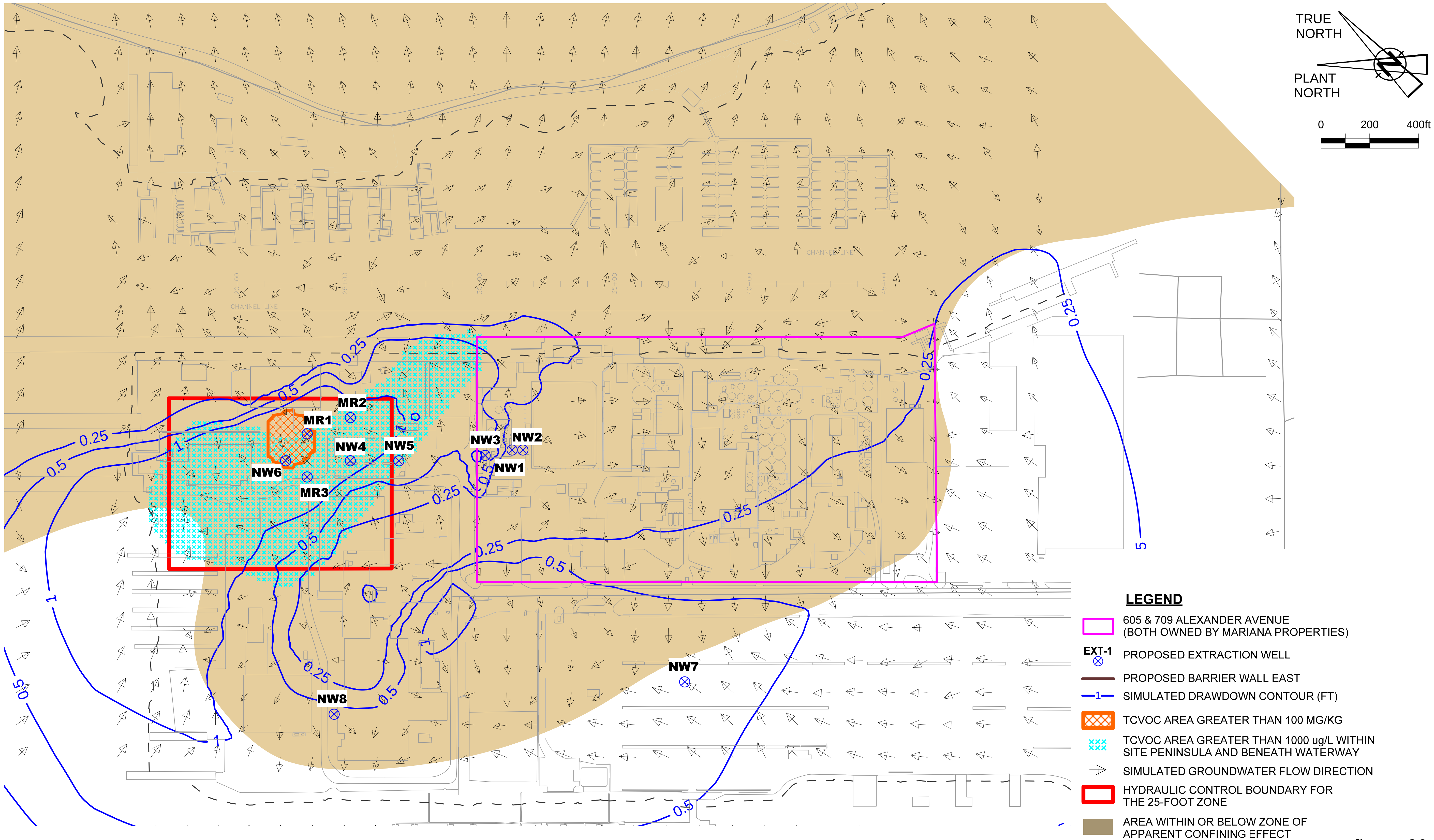


figure 29

SIMULATED DRAWDOWN AND GROUNDWATER FLOW DIRECTIONS
FOR VOC MASS REDUCTION ALTERNATIVE MSP - 160 FT ZONE
Occidental Chemical Corporation, Tacoma, Washington

007843-C2D2(RPT139) GN-WA-HYD (Z:\HEG\07843\RPT139\Appendix E\Jan2017-Rev\Figures\Opt5-DDN-160FT.srf) JAN 18/2017

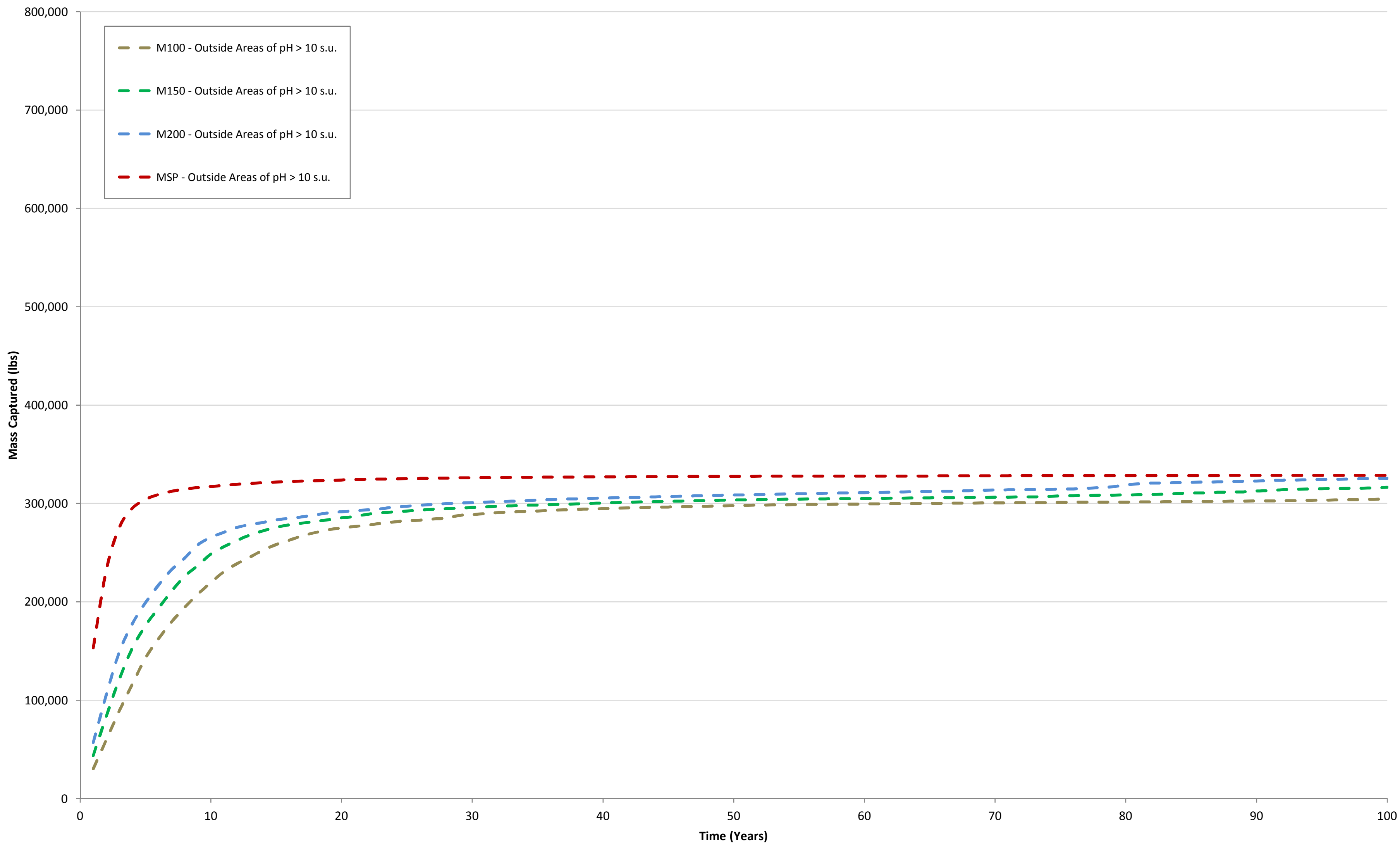


figure 30

CUMMULATIVE TOTAL TCVOC MASS-WEIGHTED PARTICLE CAPTURE OVER 100 YEARS

Occidental Chemical Corporation, Tacoma, Washington

Table 1

Remedial Alternative Summary and Initial Chemistry
Occidental Chemical Corporation
Tacoma, Washington

Well ID	Potential (P) or Installed (I)	Well Screen Interval (ft NGVD)		Screen Length	Containment Alternative C100[(1)]	Containment Alternative C150[(1)]		Containment Alternative C200[(1)]		VOC Mass Reduction Alternative M100[(1)]	VOC Mass Reduction Alternative M150[(1)]		VOC Mass Reduction Alternative M200[(1)]		Mass Reduction Alternative MSP[(1)]	Initial Groundwater TCVOC Concetration at Well Screen Midpoint	Initial Soil TCVOC Concetration at Well Screen Midpoint	Initial pH at Well Screen Midpoint
		Top	Bottom	(ft)	Modeled Extraction Rate (gpm)	Modeled Extraction Rate (gpm)	Factor Increase From C100	Modeled Extraction Rate (gpm)	Factor Increase From C100	Modeled Extraction Rate (gpm)	Modeled Extraction Rate (gpm)	Factor Increase From M100	Modeled Extraction Rate (gpm)	Factor Increase From M100	Modeled Extraction Rate (gpm)	(µg/L)	(ug/kg)	(s.u.)
EXT-1(s)	P	5	-15	20	15.0	16.5	1.1	15.0	1.0	-	-	-	-	-	-	121.8	41.8	8.9
EXT-3(d)	P	-50	-70	20	10.0	15.0	1.5	20.0	2.0	-	-	-	-	-	-	0.2	0.9	7.8
EXT-4(s)	P	-2.5	-22.5	20	20.0	30.0	1.5	40.0	2.0	-	-	-	-	-	-	2.3	1.9	9.0
EXT-5(s)	P	5.0	-15.0	20	15.0	18.5	1.2	17.5	1.2	-	-	-	-	-	-	0.2	2.7	8.1
EXT-8(s)	P	-2.5	-22.5	20	15.0	22.5	1.5	30.0	2.0	-	-	-	-	-	-	204	15.9	8.4
EXT-9(d)	I	-97.4	-117.4	20	20.0	30.0	1.5	40.0	2.0	-	-	-	-	-	-	274,200	171,841	7.3
EXT-10(s)	P	-2.5	-22.5	20	15.0	22.5	1.5	30.0	2.0	-	-	-	-	-	-	36,033	2,748	8.0
EXT-15(s)	P	-25.0	-45.0	20	7.5	11.25	1.5	12.0	1.6	-	-	-	-	-	-	18.3	2.6	7.7
EXT-16(s)	P	-25.0	-45.0	20	20.0	30.0	1.5	40.0	2.0	-	-	-	-	-	-	0.7	3.5	8.0
EXT-18(s)	P	-2.5	-22.5	20	15.0	22.5	1.5	29.0	1.9	-	-	-	-	-	-	3.6	16.1	7.3
EXT-21(s)	P	5.0	-15.0	20	5.0	7.5	1.5	8.0	1.6	-	-	-	-	-	-	0.2	1.7	8.6
EXT-22(d)	P	-136.0	-166.0	30	-	-	-	-	-	20.0	30.0	1.5	40.0	2.0	-	158,124	36,426	9.1
EXT-23(s)	P	-25	-45	20	-	-	-	-	-	15.0	22.5	1.5	30.0	2.0	-	141,351	71,524	8.6
MR1	P	-94	-120	26	-	-	-	-	-	-	-	-	-	-	20.0	100,461	63,856	7.4
MR2	P	-94	-120	26	-	-	-	-	-	-	-	-	-	-	20.0	157,144	72,412	7.3
MR3	P	-94	-120	26	-	-	-	-	-	-	-	-	-	-	20.0	73,696	57,947	7.1
NW1	P	-1.5	-18.75	17	-	-	-	-	-	-	-	-	-	-	20.0	77,014	1,851,321	8.7
NW2	P	-24	-38.75	15	-	-	-	-	-	-	-	-	-	-	20.0	75,408	243,136	9.0
NW3	P	-61.5	-76.25	15	-	-	-	-	-	-	-	-	-	-	20.0	108,108	420,986	8.9
NW4	P	-109	-141.25	32	-	-	-	-	-	-	-	-	-	-	20.0	77,811	1,828,853	7.9
NW5	P	-111.5	-123.75	12	-	-	-	-	-	-	-	-	-	-	20.0	26,654	311,899	9.4
NW6	P	-121.5	-153.75	32	-	-	-	-	-	-	-	-	-	-	20.0	213,482	1,863,691	9.8
NW7	P	-11.25	-36.25	25	-	-	-	-	-	-	-	-	-	-	20.0	0.5	0.1	9.1
NW8	P	-11.25	-36.25	25	-	-	-	-	-	-	-	-	-	-	10.0	0.1	1.7	8.8
		Total Extraction Flow (gpm):			**157.5**	**226.25**		**281.5**		**35.0**	**52.5**		**70.0**		**210.0**			
		Total Extraction Flow (ft^3/d):			**30,318.8**	**43,553.2**		**54,188.8**		**6,737.5**	**10,106.3**		**13,475.0**		**40,425.0**			

Note:
(1) Barrier wall applied in the model remediation alternative with the following properties:
Length: 2,180 ft
Width: 2.5 ft
Depth: 73.25 ft
(s) Shallow extraction well screened above the 75-ft zone (at -60 ft NGVD).
(d) Deep extraction well screened below the 75-ft zone (at -60 ft NGVD).

Table 2

Summary of Aqueous Phase TCVOC Mass-Weighted Particle Capture
Occidental Chemical Corporation
Tacoma, Washington

I. Aqueous Phase Mass-Weighted Particle Capture Summary - All Depths (lbs)

	Containment Alternative C100	Containment Alternative C150	Containment Alternative C200	VOC Mass Reduction Alternative MSP
Total Mass-Weighted Capture After 1000 years	145,632	147,073	148,013	153,356
Mass In System After 1000 Years	11,143	9,852	8,917	3,623
Mass Discharged to Surface Water After 1000 years	188	35	30	22
Captured Between 0 and 10 years	27,190	35,176	42,511	83,897
Captured Between 10 and 20 years	16,385	22,235	26,021	26,870
Captured Between 20 and 30 years	13,651	17,153	18,598	15,552
Total Mass-Weighted Capture After 30 Years	57,226	74,564	87,130	126,318
Captured Between 30 and 40 years	10,504	12,138	12,643	8,443
Captured Between 40 and 100 years	36,360	33,439	29,416	11,899
Total Mass-Weighted Capture After 100 Years	104,090	120,140	129,189	146,660
Captured Between 100 and 1000 years	41,541	26,933	18,824	6,655

II. Aqueous Phase Mass-Weighted Particle Capture Summary as Percentage of Total Dissolved TCVOC Mass in Groundwater(1) - All Depths (%)

	Containment Alternative C100	Containment Alternative C150	Containment Alternative C200	VOC Mass Reduction Alternative MSP
Total Mass-Weighted Capture After 1000 years	92.8	93.7	94.3	97.7
Mass In System After 1000 Years	7.1	6.3	5.7	2.3
Mass Discharged to Surface Water After 1000 years(2)	0.02	0.004	0.004	0.003
Captured Between 0 and 10 years	17.3	22.4	27.1	53.5
Captured Between 10 and 20 years	10.4	14.2	16.6	17.1
Captured Between 20 and 30 years	8.7	10.9	11.8	9.9
Total Mass-Weighted Capture After 30 Years	36.5	47.5	55.5	80.5
Captured Between 30 and 40 years	6.7	7.7	8.1	5.4
Captured Between 40 and 100 years	23.2	21.3	18.7	7.6
Total Mass-Weighted Capture After 100 Years	66.3	76.5	82.3	93.4
Captured Between 100 and 1000 years	26.5	17.2	12.0	4.2

Notes:

(1) Percent of dissolved TCVOC mass in groundwater is determined as the aqueous phase mass-weighted particle capture presented in Section I divided by the total dissolved phase mass in groundwater of approximately 157,000 lbs.
(2) Determined as percent of total TCVOC mass in aquifer based on the aqueous phase mass-weighted particle capture presented in Section I divided by the total TCVOC mass in the aquifer of approximately 787,000 lbs (calculated from soil concentrations).

Table 3

Summary of Total TCVOC Mass-Weighted Particle Capture
Occidental Chemical Corporation
Tacoma, Washington

I. Total Mass-Weighted Particle Capture Summary - All Depths (lbs)

	Containment Alternative C100	Containment Alternative C150	Containment Alternative C200	VOC Mass Reduction Alternative MSP
Total Mass-Weighted Capture After 1000 years	736,358	745,746	748,201	785,595
Mass In System After 1000 Years	50,559	41,172	38,716	1,322
Mass Discharged to Surface Water After 1000 years	0	0	0	0
Captured Between 0 and 10 years	67,218	120,855	178,276	656,140
Captured Between 10 and 20 years	77,905	122,877	154,204	62,717
Captured Between 20 and 30 years	54,573	80,352	78,424	18,556
Total Mass-Weighted Capture After 30 Years	199,696	324,084	410,905	737,412
Captured Between 30 and 40 years	45,161	51,590	45,696	8,640
Captured Between 40 and 100 years	122,649	136,884	132,194	20,782
Total Mass-Weighted Capture After 100 Years	367,506	512,559	588,795	766,835
Captured Between 100 and 1000 years	368,844	233,187	159,406	18,760

II. Total Mass-Weighted Particle Capture Summary as Percentage of Total TCVOC Mass in Aquifer[(1)] - All Depths (%)

	Containment Alternative C100	Containment Alternative C150	Containment Alternative C200	VOC Mass Reduction Alternative MSP
Total Mass-Weighted Capture After 1000 years	93.6	94.8	95.1	99.8
Mass In System After 1000 Years	6.4	5.2	4.9	0.2
Mass Discharged to Surface Water After 1000 years	0.00	0.00	0.00	0.00
Captured Between 0 and 10 years	8.5	15.4	22.7	83.4
Captured Between 10 and 20 years	9.9	15.6	19.6	8.0
Captured Between 20 and 30 years	6.9	10.2	10.0	2.4
Total Mass-Weighted Capture After 30 Years	25.4	41.2	52.2	93.7
Captured Between 30 and 40 years	5.7	6.6	5.8	1.1
Captured Between 40 and 100 years	15.6	17.4	16.8	2.6
Total Mass-Weighted Capture After 100 Years	46.7	65.1	74.8	97.4
Captured Between 100 and 1000 years	46.9	29.6	20.3	2.4

Notes:

(1) Percent of total mass is determined as the total mass-weighted particle capture presented in Section I divided by the total TCVOC mass in soil of approximately 787,000 lbs.

Table 4

Summary of Total TCVOC Mass-Weighted Particle Capture Outside pH >10 s.u.
Occidental Chemical Corporation
Tacoma, Washington

I. Total Mass-Weighted Particle Capture Summary - All Depths (lbs)

	VOC Mass Reduction Alternative M100	VOC Mass Reduction Alternative M150	VOC Mass Reduction Alternative M200	VOC Mass Reduction Alternative MSP
Captured at 2 years	59,644	83,650	105,419	232,271
Captured at 20 years	275,132	285,394	291,648	323,883
Captured at 100 years	304,597	316,373	325,595	328,540

Appendix F
Acid-Neutralizing Capacity (ANC) Evaluation

Appendix F Acid-Neutralizing Capacity (ANC) Evaluation Former Occidental Chemical Corporation Facility - Tacoma, Washington

This Appendix presents the evaluation of estimated acid-neutralizing capacity (ANC) in soil/groundwater at the "Occidental" Site associated in part with the former Occidental Chemical Corporation (OCC) facility located in Tacoma, Washington (Site). Portions of the Site contain soil and groundwater impacted by releases of caustic soda and have measured pH values greater than or equal to 12.5 s.u. (standard units of pH). The Site areas with elevated pH may be targeted for treatment or enhanced containment. The standard units of pH (i.e., the negative log of hydrogen ion concentration) are not a measure that can be used directly for determining a "quantity" or "mass" of pH in soil and groundwater. The Agencies requested that some metric analogous to mass per volume be used to evaluate remediation of Site areas with elevated pH. A metric provided by the Agencies was to estimate the ANC of the soil/groundwater with elevated pH.

The University of Washington study, "*Summary of K_D and Other Soil/Groundwater Characteristics*" (UofW, 2015; Figure 9[B]), provides a Site-specific method to convert the pH of soil/groundwater into ANC in the units of milliequivalents (meq) acid per gram of dry soil. This amount, or "quantity", of ANC then may be calculated for a volume of aquifer at a given pH value. The method permits quantifying areas of elevated pH (i.e., greater than or equal to 12.5 s.u.) that may be targeted for treatment or enhanced containment. The quantity of ANC per aquifer volume at a given pH then can be compared to the "total quantity" of ANC for all Site soil/groundwater equal to or above a pH of 7 s.u. (i.e., neutral pH). The calculation procedure used to determine the quantity of ANC per aquifer volume at pH values ranging from 9.5 to approximately 13 s.u. in increments of 0.5 s.u., as requested by the Agencies, is described below.

Table F.1 presents the calculation results for the quantity of ANC per aquifer volume at a given pH for both shallow (above -60 feet [ft] National Geodetic Vertical Datum [NGVD]) and deep (below -60 ft NGVD) zones as well as the total quantity of ANC for all Site soil/groundwater equal to or above a pH of 7 s.u. The values in Table F.1 were calculated as follows:

- A three-dimensional interpolation of the Site groundwater pH data was developed using the Mining Visualization System/Environmental Visualization System (MVS/EVS) software package, developed by C Tech Development Corporation (C Tech) (C Tech, 2007). MVS/EVS was used to calculate the volume of aquifer having pH values of 7 and from 9.5 to approximately 13 s.u. at increments of 0.5 s.u. The highest pH for the shallow zone (i.e., -60 ft NGVD and above) was 13.036 s.u., which represents the average pH above 12.5 s.u. in the shallow zone. The highest pH for the deep zone was 12.920 s.u., which represents the average pH above 12.5 s.u. in the deep zone. The Site groundwater pH data were used because they represent pH in the largest portion of the aquifer and measured values of elevated pH in soil are within the same volume (see Appendix B).
- The aquifer volume associated with each incremental pH value was calculated by determining the difference between the MVS/EVS calculated volumes for successive pH values. For example, the aquifer volume of a pH value of 12 s.u. was calculated as the MVS/EVS calculated volume for the pH value of 12 s.u. minus the MVS/EVS calculated volume for the pH value of 12.5 s.u.
- The mass of aquifer dry soil associated with each incremental pH value was calculated as the corresponding volume multiplied by the Site dry bulk density.
- Each incremental pH value was assumed to have uniform pH equal to increment value.

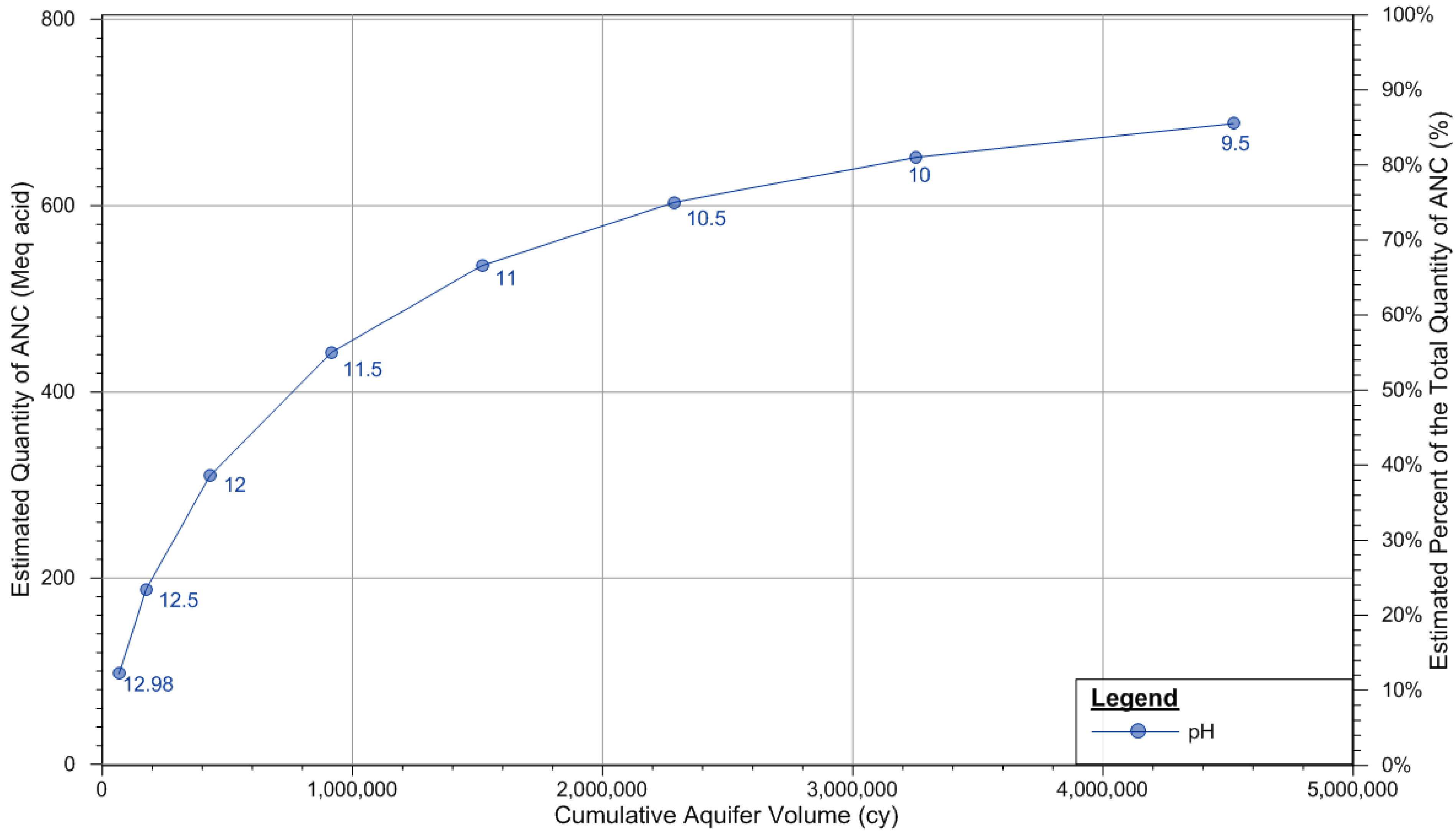
- For each incremental pH value, the regression line that UofW determined between soil/water pH and ANC ($y = 0.49x - 3.29$; where y = log of ANC, and x = pH) (UofW, 2015; Figure 9[B]) was used to calculate ANC in terms of milliequivalents (meq) acid per gram of aquifer dry soil (meq acid/g).
- The quantity of ANC (in meq acid) for each incremental pH value was calculated by multiplying the ANC in terms of meq acid/g by the mass of aquifer dry soil corresponding to the incremental pH value.
- The total quantity of ANC for all Site soil/groundwater equal to or above a pH of 7 s.u. was calculated by summing the quantity of ANC determined from successive incremental pH values, beginning at a pH of 7 s.u.
- The percentage of the total quantity of ANC associated with each incremental pH value was calculated by dividing the quantity of ANC for each incremental pH value by the total estimated quantity of ANC for a pH equal to or above 7 s.u.

Figure F.1 presents a graph of the cumulative aquifer volume versus the calculated quantities of ANC for each incremental pH value ranging from 9.5 to approximately 13 s.u. at increments of 0.5 s.u., as requested by the Agencies. A second vertical axis is provided on the right side of the graph to show the percent of the estimated total quantity of ANC associated with each incremental pH value. In the shallow zone (i.e., -60 ft NGVD and above), a pH greater than or equal to 12.5 s.u. represents approximately 11.2 percent of the total quantity of ANC in the aquifer. In the shallow and deep zones combined, a pH greater than or equal to 12.5 s.u. represents approximately 23.3 percent of the total quantity of ANC.

References

C Tech, 2007. MVS (Mining Visualization System)/EVS (Environmental Visualization System), Version 8.54, Kaneohe, Hawaii.

UofW, 2015. Summary of K_D and Other Soil/Groundwater Characteristics, Composite Mid-project Review (Composite_mid-project_summary_07-17-15.pdf), M. Benjamin, University of Washington, received via email on July 17, 2015.



OCCIDENTAL CHEMICAL CORPORATION
TACOMA, WA

ESTIMATED QUANTITY OF ACID-NEUTRALIZING CAPACITY (ANC) VS. AQUIFER VOLUME

JOB NUMBER	07843-C2D2
DATE	June 13, 2016

FIGURE F.1

Table F.1

Calculation of Estimated Acid-Neutralizing Capacity (ANC) in Aquifer
Occidental Chemical Corporation
Tacoma, Washington

MVS/EVS Model Parameters	Values
Soil Dry Bulk Density (g/cm^3)	1.61
Porosity	0.43

Zone	pH Values	Cumulative Soil Volume[3] (cy)	Soil Volume Associated with pH Increment (cy)	Soil Mass Associated with pH Increment (g)	Assumed pH Associated with Increment (s.u.)	ANC[4] Associated with Increment (meq acid/g of dry soil)	Amount of ANC In pH Increment (meq acid)	Cumulative Amount of ANC (meq)	Cumulative Quantity of ANC (Meq acid)	Percentage of Full Depth Total ANC (%)
Shallow zone[1]	~ 13 s.u.	35,528	35,528	43,732,619,748	13.036 (5)	1.25	54,757,737,311	54,757,737,311	55	6.8%
	>= 12.5 s.u.	78,006	42,478	52,287,610,383	12.50	0.68	35,760,105,749	90,517,843,060	91	11.2%
	>= 12 s.u.	155,750	77,744	95,697,725,448	12.00	0.39	37,230,735,473	127,748,578,533	128	15.9%
	>= 11.5 s.u.	299,470	143,720	176,909,820,712	11.50	0.22	39,151,818,829	166,900,397,362	167	20.7%
	>= 11 s.u.	548,490	249,020	306,527,160,824	11.00	0.13	38,589,483,217	205,489,880,579	205	25.5%
	>= 10.5 s.u.	909,290	360,800	444,120,952,636	10.50	0.07	31,805,429,357	237,295,309,936	237	29.5%
	>= 10 s.u.	1,387,600	478,310	588,767,995,718	10.00	0.04	23,985,246,966	261,280,556,902	261	32.5%
	>= 9.5 s.u.	1,963,800	576,200	709,264,115,601	9.50	0.02	16,436,448,669	277,717,005,571	278	34.5%
	>= 7 s.u.	17,374,000	15,410,200	18,968,937,650,522	7.00	0.00	26,184,423,049	303,901,428,620	304	37.8%
Deep zone[1]	~ 13 s.u.	31,627	31,627	38,930,746,588	12.920 (5)	1.10	42,765,419,095	42,765,419,095	43	5.3%
	>= 12.5 s.u.	96,374	64,747	79,699,277,495	12.50	0.68	54,507,264,159	97,272,683,254	97	12.1%
	>= 12 s.u.	273,500	177,126	218,030,398,716	12.00	0.39	84,823,668,081	182,096,351,336	182	22.6%
	>= 11.5 s.u.	618,410	344,910	424,561,412,898	11.50	0.22	93,959,461,679	276,055,813,014	276	34.3%
	>= 11 s.u.	970,410	352,000	433,288,734,279	11.00	0.13	54,547,819,823	330,603,632,837	331	41.1%
	>= 10.5 s.u.	1,377,210	406,800	500,743,912,229	10.50	0.07	35,860,445,295	366,464,078,132	366	45.5%
	>= 10 s.u.	1,866,000	488,790	601,668,183,035	10.00	0.04	24,510,775,155	390,974,853,287	391	48.6%
	>= 9.5 s.u.	2,557,900	691,900	851,683,168,317	9.50	0.02	19,736,860,177	410,711,713,464	411	51.0%
	>= 7 s.u.	55,750,000	53,192,100	65,475,959,325,662	7.00	0.00	90,381,983,963	501,093,697,427	501	62.3%
Full Depth[2]	~ 13 s.u.	67,155	67,155	82,663,366,337	12.981 (5)	1.18	97,315,941,958	97,315,941,958	97	12.1%
	>= 12.5 s.u.	174,380	107,225	131,986,887,878	12.50	0.68	90,267,369,908	187,583,311,866	188	23.3%
	>= 12 s.u.	429,250	254,870	313,728,124,164	12.00	0.39	122,054,403,554	309,637,715,420	310	38.5%
	>= 11.5 s.u.	917,880	488,630	601,471,233,610	11.50	0.22	133,111,280,508	442,748,995,929	443	55.0%
	>= 11 s.u.	1,518,900	601,020	739,815,895,103	11.00	0.13	93,137,303,039	535,886,298,968	536	66.6%
	>= 10.5 s.u.	2,286,500	767,600	944,864,864,865	10.50	0.07	67,665,874,651	603,552,173,620	604	75.0%
	>= 10 s.u.	3,253,600	967,100	1,190,436,178,753	10.00	0.04	48,496,022,121	652,048,195,740	652	81.0%
	>= 9.5 s.u.	4,521,700	1,268,100	1,560,947,283,918	9.50	0.02	36,173,308,846	688,221,504,587	688	85.5%
	>= 7 s.u.	73,124,000	68,602,300	84,444,896,976,184	7.00	0.00	116,566,407,012	804,787,911,599	805	100.0%

Notes:

(1) The shallow zone is between the water surface and -60 ft NGVD in MVS/EVS model. The deep zone is below -60 ft NGVD in MVS/EVS model
(2) The full depth zone is between the water surface and the bottom of MVS/EVS model
(3) Volumes calculated by MVS/EVS model
(4) Acid-neutralizing capacity (ANC) calculations based on The University of Washington study, "Summary of KD and Other Soil/Groundwater Characteristics" [UofW, 2015; Figure 9(B)], which provides a Site-specific method to convert the pH of soil/groundwater into ANC in the units of milliequivalents (meq) acid per gram of dry soil
(5) Average pH above 12.5 s.u. in the shallow zone, deep zone, and for full depth determined from MVS/EVS model

meq milliequivalents
Meq Megaequivalents = 10^9 x meq
g grams
cm^3 cubic centimeters
cy cubic yards
MVS/EVS model Mining Visualization System/Environmental Visualization System (MVS/EVS) software package, developed by C Tech Development Corporation (C Tech) (C Tech, 2007) model for the Site

Appendix G
Alternatives Cost Estimates

Appendix G-1
Containment Alternatives Cost Estimates

COMPARISON OF TOTAL COST OF CONTAINMENT ALTERNATIVES

Site: "Occidental" Site
Location: Tacoma, Washington
Phase: Feasibility Study (-30% to +50%)

Base Year: 2016
Date: December 6, 2016

DESCRIPTION	Alternative C1 No Action	Alternative C150 Groundwater Extraction Shallow and Deep Zones	Alternative C200 Groundwater Extraction Shallow and Deep Zones
Total Project Duration (Years)	0	30	30
Capital Cost	$0	$38,700,240	$38,700,240
Annual O&M Cost	$0	$1,180,644	$1,247,834
Total Periodic Cost	$0	$2,920,670	$2,920,670
Total Present Value of Alternative (7%)	$0	$54,356,480	$55,190,240
Total Present Value of Alternative (1.5%)	$0	$69,352,840	$70,966,460

Containment Alternative C150
GROUNDWATER EXTRACTION AND TREATMENT

COST ESTIMATE SUMMARY C150

Site: "Occidental" Site
Location: Tacoma, Washington
Phase: Feasibility Study (-30% to +50%) - 7%
Base Year: 2016
Date: December 6, 2016

Description: Containment Alternative C150 is designed to eliminate potentially complete exposure pathways and includes: institutional controls; groundwater monitoring; a Physical Direct Contact Exposure (PDCE) Barrier for 605 & 709 Alexander Avenue Properties, Navy Todd Dump, N Landfill, and 709 Embankment Fill Area; a sheet pile barrier wall adjacent to Hylebos; and hydraulic containment using a newly constructed GWETS. Capital Costs occur in Year 0. Annual O&M costs occur in Years 1-30. Periodic costs occur in years 5,10, 15, 20, and 25.

CAPITAL COSTS

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Mobilization/Demobilization					
Construction Equipment & Facilities	1	LS	$ 25,000	$ 25,000	Excavators, Loaders, etc.
Temporary facilities and Utilities	1	LS	$ 50,000	$ 50,000	Fence, roads, signs, trailers, etc.
H&S Plans and Submittals	1	LS	$ 15,000	$ 15,000	HASP, quality control, etc.
Design, Work Plans, Permits	1	LS	$ 100,000	$ 100,000	Barrier wall
Design, Work Plans, Permits	1	LS	$ 50,000	$ 50,000	Physical Direct Contact Exposure Barrier
Post-construction Submittals	1	LS	$ 150,000	$ 150,000	Report completed work
SUBTOTAL				$ 390,000	
Site Work					
Demolition of North Dock	1	LS	$ 446,000	$ 446,000	Quotation from vendor - See Cost Worksheet C-1
Demolition of South Dock	1	LS	$ 248,000	$ 248,000	Quotation from vendor - See Cost Worksheet C-2
Demolition of Existing Structures	1	LS	$ 250,000	$ 250,000	Treatment plant, office, misc. - Assumption
Construction Oversight	50	DAY	$ 1,920	$ 96,000	Assume 2 people
SUBTOTAL				$ 1,040,000	
Barrier Wall East Installation					
Mobilization/Demobilization	1	LS	$ 50,000	$ 50,000	2,180 ft long by 73.5 ft deep. Assuming barge installatior
Sheet Pile	4300	TN	$ 1,900	$ 8,170,000	Vendor quote (PZ-27 sheet)
Unload Sheet Pile	220	LS	$ 2,350	$ 517,000	Vendor quote
Install Perimeter SP Wall	160000	SF	$ 12	$ 1,920,000	Vendor quote (Adeka sealant; Anchor piles on 6' centers)
Fill along embankment behind wall	40370	CY	$ 18	$ 726,670	Avg. Depth 10 ft; 50 ft wide
Construction Oversight	130	DAY	$ 1,920	$ 249,600	Assume 2 people
Mitigation of Intertidal Areas	1	LS	$ 250,000	$ 250,000	Allowance
SUBTOTAL				$ 11,883,270	
Physical Direct Contact Exposure Barrier					
Mobilization/Demobilization	1	LS	$ 50,000	$ 50,000	
Preparation	1502820	SF	$ 0.6	$ 901,700	Remove debris and prepare surface. 34.5 acres.
Aggregate Base	27830	CY	$ 35	$ 974,050	6 inch base
Asphalt Cover (assume 4")	1502820	SF	$ 2	$ 3,005,640	Facility Construction Cost - RSMeans (2016)
Construction Oversight	130	DAY	$ 1,920	$ 249,600	Assume 2 personal
SUBTOTAL				$ 5,180,990	
Hydraulic Containment					
Mobilization/Demobilization	1	LS	$ 50,000	$ 50,000	
Groundwater Extraction System	1	LS	$ 927,470	$ 927,470	See Cost Worksheet C-3
Groundwater Treatment Equipment	1	LS	$ 2,544,230	$ 2,544,230	Assume 300 gpm System - See Cost Worksheet C-4
Groundwater Treatment Facility Building	1	LS	$ 2,145,820	$ 2,145,820	See Cost Worksheet C-5
High pH Treatment Additional Equipment	1	LS	$ 27,000	$ 27,000	Acid metering pump and equalization tank.
Construction Oversight	260	Day	$ 1,920	$ 499,200	
SUBTOTAL				$ 6,193,720	
Off-Site Treatment / Disposal					
Off-Site T&D of Soil Cuttings	20	CY	$ 394	$ 7,880	Vendor Quote
Off-Site T&D of Spoils	1250	CY	$ 394	$ 491,920	Vendor Quote
Off-Site T&D of Spoils - Hazardous	750	CY	$ 977	$ 732,780	Vendor Quote
SUBTOTAL				$ 1,232,580	
SUBTOTAL				$ 25,920,560	
Contingency		25%		$ 6,480,140	10% scope + 15% bid
SUBTOTAL				$ 32,400,700	
Project Management		5%		$ 1,620,040	
Remedial Design		8%		$ 2,592,060	
Construction Management		6%		$ 1,944,040	
Institutional Controls					
Institutional Controls Plan	1	LS	$ 13,000	$ 13,000	Description and implementation
Groundwater Use Restrictions	1	LS	$ 10,000	$ 10,000	Legal fees
Site Database	1	LS	$ 5,000	$ 5,000	Data management system
Documentation	1	LS	$ 20,000	$ 20,000	other submittals and documents
Perimeter fence	5300	FOOT	$ 18	$ 95,400	605 and 709 properties
SUBTOTAL				$ 143,400	
TOTAL CAPITAL COSTS				**$ 38,700,240**	

Containment Alternative C150
GROUNDWATER EXTRACTION AND TREATMENT

COST ESTIMATE SUMMARY C150

Site: "Occidental" Site
Location: Tacoma, Washington
Phase: Feasibility Study (-30% to +50%) - 7%
Base Year: 2016
Date: December 6, 2016

Description: Containment Alternative C150 is designed to eliminate potentially complete exposure pathways and includes: institutional controls; groundwater monitoring; a Physical Direct Contact Exposure (PDCE) Barrier for 605 & 709 Alexander Avenue Properties, Navy Todd Dump, N Landfill, and 709 Embankment Fill Area; a sheet pile barrier wall adjacent to Hylebos; and hydraulic containment using a newly constructed GWETS. Capital Costs occur in Year 0. Annual O&M costs occur in Years 1-30. Periodic costs occur in years 5,10, 15, 20, and 25.

ANNUAL O&M COSTS:

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Inspections					
Mobilization and Inspection	1	LS	$ 2,600	$ 2,600	Barriers and fencing
Reporting	1	LS	$ 5,200	$ 5,200	Inspection documentation
SUBTOTAL				$ 7,800	
Monitoring Groundwater					
Monitoring, sampling and reporting	1	LS	$ 297,000	$ 297,000	Will be in OMMP
Physical Direct Contact Exposure Barrier Maintenance					
Annual maintenance	1	LS	$ 10,000	$ 10,000	Allowance
Groundwater Treatment Plant					
Operation	1	year	$ 124,500	$ 124,500	GHD Quote
Carbon Consumption	6	EXCHANGE	$ 19,124	$ 114,744	GHD Quote
pH Adjustment	1	LS	$ 20,000	$ 20,000	GHD Quote
Equipment Allowance	1	LS	$ 6,000	$ 6,000	Allowance
Dilution Water	59460	$/1000 gals	$ 2.60	$ 154,600	Assume city water for dilution - quote
SUBTOTAL				$ 419,844	
Extraction Wells and Forcemains					
Annual maintenance	1	LS	$ 20,000	$ 20,000	Two weeks of work
Off-Site Treatment / Disposal					
Off-Site Transport/disposal of Solids	45	ton	$ 720	$ 32,400	Vendor Quote
SUBTOTAL				$ 787,044	
Contingency		30%		$ 236,120	10% scope + 20% bid
SUBTOTAL				$ 1,023,164	
Project Management		5%		$ 51,160	
Technical Support		10%		$ 102,320	
Site Info Database	1	LS	$ 4,000	$ 4,000	Update and maintain database
TOTAL ANNUAL O&M COSTS				**$ 1,180,644**	

PERIODIC COSTS:

DESCRIPTION	YEAR	QTY	UNIT	UNIT COST	TOTAL	NOTES
Five Year Review Report	5	1	EA	$ 75,000	$ 75,000	Report after 5 years
Equipment Replacement	5	1	LS	$ 19,100	$ 19,100	Equipment Replacement- See Cost Worksheet C-6
Update IC Plan	5	1	EA	$ 3,000	$ 3,000	Update Plan
SUBTOTAL					$ 97,100	
Five Year Review Report	10	1	EA	$ 50,000	$ 50,000	Report after 10 years
Equipment Replacement	10	1	LS	$ 19,100	$ 19,100	Equipment Replacement- See Cost Worksheet C-6
Update IC Plan	10	1	EA	$ 3,000	$ 3,000	Update Plan
SUBTOTAL					$ 72,100	
Five Year Review Report	15	1	EA	$ 40,000	$ 40,000	Report after 15 years
Cap Repair	15	1	LS	$ 300,570	$ 300,570	10 percent of asphalt
Equipment Replacement	15	1	LS	$ 1,503,910	$ 1,503,910	Equipment Replacement- See Cost Worksheet C-6
Update IC Plan	15	1	EA	$ 3,000	$ 3,000	Update Plan
Remedial Action Report	15	1	EA	$ 10,000	$ 10,000	
SUBTOTAL					$ 1,857,480	
Five Year Review Report	20	1	EA	$ 40,000	$ 40,000	Report after 20 years
Equipment Replacement	20	1	LS	$ 788,890	$ 788,890	Equipment Replacement- See Cost Worksheet C-6
Update IC Plan	20	1	EA	$ 3,000	$ 3,000	Update Plan
SUBTOTAL					$ 831,890	
Five Year Review Report	25	1	EA	$ 40,000	$ 40,000	Report after 25 years
Equipment Replacement	25	1	LS	$ 19,100	$ 19,100	Equipment Replacement- See Cost Worksheet C-6
Update IC Plan	25	1	EA	$ 3,000	$ 3,000	Update Plan
SUBTOTAL					$ 62,100	

Containment Alternative C150
GROUNDWATER EXTRACTION AND TREATMENT

COST ESTIMATE SUMMARY C150

Site: "Occidental" Site
Location: Tacoma, Washington
Phase: Feasibility Study (-30% to +50%) - 7%
Base Year: 2016
Date: December 6, 2016

Description: Containment Alternative C150 is designed to eliminate potentially complete exposure pathways and includes: institutional controls; groundwater monitoring; a Physical Direct Contact Exposure (PDCE) Barrier for 605 & 709 Alexander Avenue Properties, Navy Todd Dump, N Landfill, and 709 Embankment Fill Area; a sheet pile barrier wall adjacent to Hylebos; and hydraulic containment using a newly constructed GWETS. Capital Costs occur in Year 0. Annual O&M costs occur in Years 1-30. Periodic costs occur in years 5,10, 15, 20, and 25.

PRESENT VALUE ANALYSIS:

COST TYPE	YEAR	TOTAL COST	TOTAL COST PER YEAR	DISCOUNT FACTOR (1.5%)	PRESENT VALUE	NOTES
Capital Cost	0	$ 38,700,240	$ 38,700,240	1	$ 38,700,240	
Annual O&M Cost	1-30	$ 35,419,320	$ 1,180,644	12.41	$ 14,650,670	30 years
Periodic Cost	5	$ 97,100	$ 97,100	0.713	$ 69,240	5 year review, update plan, and Repair Costs
Periodic Cost	10	$ 72,100	$ 72,100	0.508	$ 36,660	5 year review, update plan, and Repair Costs
Periodic Cost	15	$ 1,857,480	$ 1,857,480	0.362	$ 673,240	5 year review, update plan, and Repair Costs
Periodic Cost	20	$ 831,890	$ 831,890	0.258	$ 214,980	5 year review, update plan, and Repair Costs
Periodic Cost	25	$ 62,100	$ 62,100	0.184	$ 11,450	5 year review, update plan, and Repair Costs
		$ 77,040,230			$ 54,356,480	

TOTAL PRESENT VALUE OF ALTERNATIVE **$ 54,356,480**

Containment Alternative C150
GROUNDWATER EXTRACTION AND TREATMENT

COST ESTIMATE SUMMARY C150

Site: "Occidental" Site
Location: Tacoma, Washington
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Date: December 6, 2016

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CAPITAL COSTS

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Mobilization/Demobilization					
Construction Equipment & Facilities	1	LS	$ 25,000	$ 25,000	Excavators, Loaders, etc.
Temporary facilities and Utilities	1	LS	$ 50,000	$ 50,000	Fence, roads, signs, trailers, etc.
H&S Plans and Submittals	1	LS	$ 15,000	$ 15,000	HASP, quality control, etc.
Design, Work Plans, Permits	1	LS	$ 100,000	$ 100,000	Barrier wall
Design, Work Plans, Permits	1	LS	$ 50,000	$ 50,000	Physical Direct Contact Exposure Barrier
Post-construction Submittals	1	LS	$ 150,000	$ 150,000	Report completed work
SUBTOTAL				$ 390,000	
Site Work					
Demolition of North Dock	1	LS	$ 446,000	$ 446,000	Quotation from vendor - See Cost Worksheet C-1
Demolition of South Dock	1	LS	$ 248,000	$ 248,000	Quotation from vendor - See Cost Worksheet C-2
Demolition of Existing Structures	1	LS	$ 250,000	$ 250,000	Treatment plant, office, misc. - Assumption
Construction Oversight	50	DAY	$ 1,920	$ 96,000	Assume 2 people
SUBTOTAL				$ 1,040,000	
Barrier Wall East Installation					
Mobilization/Demobilization	1	LS	$ 50,000	$ 50,000	2,180 ft long by 73.5 ft deep. Assuming barge installatior
Sheet Pile	4300	TN	$ 1,900	$ 8,170,000	Vendor quote (PZ-27 sheet)
Unload Sheet Pile	220	LS	$ 2,350	$ 517,000	Vendor quote
Install Perimeter SP Wall	160000	SF	$ 12	$ 1,920,000	Vendor quote (Adeka sealant; Anchor piles on 6' centers)
Fill along embankment behind wall	40370	CY	$ 18	$ 726,670	Avg. Depth 10 ft; 50 ft wide
Construction Oversight	130	DAY	$ 1,920	$ 249,600	Assume 2 people
Mitigation of Intertidal Areas	1	LS	$ 250,000	$ 250,000	Allowance
SUBTOTAL				$ 11,883,270	
Physical Direct Contact Exposure Barrier					
Mobilization/Demobilization	1	LS	$ 50,000	$ 50,000	
Preparation	1502820	SF	$ 0.6	$ 901,700	Remove debris and prepare surface. 34.5 acres.
Aggregate Base	27830	CY	$ 35	$ 974,050	6 inch base
Asphalt Cover (assume 4")	1502820	SF	$ 2	$ 3,005,640	Facility Construction Cost - RSMeans (2016)
Construction Oversight	130	DAY	$ 1,920	$ 249,600	Assume 2 personal
SUBTOTAL				$ 5,180,990	
Hydraulic Containment					
Mobilization/Demobilization	1	LS	$ 50,000	$ 50,000	
Groundwater Extraction System	1	LS	$ 927,470	$ 927,470	See Cost Worksheet C-3
Groundwater Treatment Equipment	1	LS	$ 2,544,230	$ 2,544,230	Assume 300 gpm System - See Cost Worksheet C-4
Groundwater Treatment Facility Building	1	LS	$ 2,145,820	$ 2,145,820	See Cost Worksheet C-5
High pH Treatment Additional Equipment	1	LS	$ 27,000	$ 27,000	Acid metering pump and equalization tank.
Construction Oversight	260	Day	$ 1,920	$ 499,200	
SUBTOTAL				$ 6,193,720	
Off-Site Treatment / Disposal					
Off-Site T&D of Soil Cuttings	20	CY	$ 394	$ 7,880	Vendor Quote
Off-Site T&D of Spoils	1250	CY	$ 394	$ 491,920	Vendor Quote
Off-Site T&D of Spoils - Hazardous	750	CY	$ 977	$ 732,780	Vendor Quote
SUBTOTAL				$ 1,232,580	
SUBTOTAL				$ 25,920,560	
Contingency		25%		$ 6,480,140	10% scope + 15% bid
SUBTOTAL				$ 32,400,700	
Project Management		5%		$ 1,620,040	
Remedial Design		8%		$ 2,592,060	
Construction Management		6%		$ 1,944,040	
Institutional Controls					
Institutional Controls Plan	1	LS	$ 13,000	$ 13,000	Description and implementation
Groundwater Use Restrictions	1	LS	$ 10,000	$ 10,000	Legal fees
Site Database	1	LS	$ 5,000	$ 5,000	Data management system
Documentation	1	LS	$ 20,000	$ 20,000	other submittals and documents
Perimeter fence	5300	FOOT	$ 18	$ 95,400	605 and 709 properties
SUBTOTAL				$ 143,400	
TOTAL CAPITAL COSTS				**$ 38,700,240**	

Containment Alternative C150
GROUNDWATER EXTRACTION AND TREATMENT

COST ESTIMATE SUMMARY C150

Site:	"Occidental" Site	Description:	Containment Alternative C150 is designed to eliminate potentially complete exposure pathways and includes: institutional controls; groundwater monitoring; a Physical Direct Contact Exposure (PDCE) Barrier for 605 & 709 Alexander Avenue Properties, Navy Todd Dump, N Landfill, and 709 Embankment Fill Area; a sheet pile barrier wall adjacent to Hylebos; and hydraulic containment using a newly constructed GWETS. Capital Costs occur in Year 0. Annual O&M costs occur in Years 1-30. Periodic costs occur in years 5,10, 15, 20, and 25.
Location:	Tacoma, Washington		
Phase:	Feasibility Study (-30% to +50%) - 1.5%		
Base Year:	2016		
Date:	December 6, 2016		

ANNUAL O&M COSTS:

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Inspections					
Mobilization and Inspection	1	LS	$ 2,600	$ 2,600	Barriers and fencing
Reporting	1	LS	$ 5,200	$ 5,200	Inspection documentation
SUBTOTAL				$ 7,800	
Monitoring Groundwater					
Monitoring, sampling and reporting	1	LS	$ 297,000	$ 297,000	Will be in OMMP
Physical Direct Contact Exposure Barrier Maintenance					
Annual maintenance	1	LS	$ 10,000	$ 10,000	Allowance
Groundwater Treatment Plant					
Operation	1	year	$ 124,500	$ 124,500	GHD Quote
Carbon Consumption	6	EXCHANGE	$ 19,124	$ 114,744	GHD Quote
pH Adjustment	1	LS	$ 20,000	$ 20,000	GHD Quote
Equipment Allowance	1	LS	$ 6,000	$ 6,000	Allowance
Dilution Water	59460	$/1000 gals	$ 2.60	$ 154,600	Assume city water for dilution - quote
SUBTOTAL				$ 419,844	
Extraction Wells and Forcemains					
Annual maintenance	1	LS	$ 20,000	$ 20,000	Two weeks of work
Off-Site Treatment / Disposal					
Off-Site Transport/disposal of Solids	45	ton	$ 720	$ 32,400	Vendor Quote
SUBTOTAL				$ 787,044	
Contingency		30%		$ 236,120	10% scope + 20% bid
SUBTOTAL				$ 1,023,164	
Project Management		5%		$ 51,160	
Technical Support		10%		$ 102,320	
Site Info Database	1	LS	$ 4,000	$ 4,000	Update and maintain database
TOTAL ANNUAL O&M COSTS				**$ 1,180,644**	

PERIODIC COSTS:

DESCRIPTION	YEAR	QTY	UNIT	UNIT COST	TOTAL	NOTES
Five Year Review Report	5	1	EA	$ 75,000	$ 75,000	Report after 5 years
Equipment Replacement	5	1	LS	$ 19,100	$ 19,100	Equipment Replacement- See Cost Worksheet C-6
Update IC Plan	5	1	EA	$ 3,000	$ 3,000	Update Plan
SUBTOTAL					$ 97,100	
Five Year Review Report	10	1	EA	$ 50,000	$ 50,000	Report after 10 years
Equipment Replacement	10	1	LS	$ 19,100	$ 19,100	Equipment Replacement- See Cost Worksheet C-6
Update IC Plan	10	1	EA	$ 3,000	$ 3,000	Update Plan
SUBTOTAL					$ 72,100	
Five Year Review Report	15	1	EA	$ 40,000	$ 40,000	Report after 15 years
Cap Repair	15	1	LS	$ 300,570	$ 300,570	10 percent of asphalt
Equipment Replacement	15	1	LS	$ 1,503,910	$ 1,503,910	Equipment Replacement- See Cost Worksheet C-6
Update IC Plan	15	1	EA	$ 3,000	$ 3,000	Update Plan
Remedial Action Report	15	1	EA	$ 10,000	$ 10,000	
SUBTOTAL					$ 1,857,480	
Five Year Review Report	20	1	EA	$ 40,000	$ 40,000	Report after 20 years
Equipment Replacement	20	1	LS	$ 788,890	$ 788,890	Equipment Replacement- See Cost Worksheet C-6
Update IC Plan	20	1	EA	$ 3,000	$ 3,000	Update Plan
SUBTOTAL					$ 831,890	
Five Year Review Report	25	1	EA	$ 40,000	$ 40,000	Report after 25 years
Equipment Replacement	25	1	LS	$ 19,100	$ 19,100	Equipment Replacement- See Cost Worksheet C-6
Update IC Plan	25	1	EA	$ 3,000	$ 3,000	Update Plan
SUBTOTAL					$ 62,100	

Containment Alternative C150
GROUNDWATER EXTRACTION AND TREATMENT

COST ESTIMATE SUMMARY C150

Site: "Occidental" Site
Location: Tacoma, Washington
Phase: Feasibility Study (-30% to +50%) - 1.5%
Base Year: 2016
Date: December 6, 2016

Description: Containment Alternative C150 is designed to eliminate potentially complete exposure pathways and includes: institutional controls; groundwater monitoring; a Physical Direct Contact Exposure (PDCE) Barrier for 605 & 709 Alexander Avenue Properties, Navy Todd Dump, N Landfill, and 709 Embankment Fill Area; a sheet pile barrier wall adjacent to Hylebos; and hydraulic containment using a newly constructed GWETS. Capital Costs occur in Year 0. Annual O&M costs occur in Years 1-30. Periodic costs occur in years 5,10, 15, 20, and 25.

PRESENT VALUE ANALYSIS:

COST TYPE	YEAR	TOTAL COST	TOTAL COST PER YEAR	DISCOUNT FACTOR (1.5%)	PRESENT VALUE	NOTES
Capital Cost	0	$ 38,700,240	$ 38,700,240	1	$ 38,700,240	
Annual O&M Cost	1-30	$ 35,419,320	$ 1,180,644	24.02	$ 28,354,160	30 years
Periodic Cost	5	$ 97,100	$ 97,100	0.928	$ 90,140	5 year review, update plan, and Repair Costs
Periodic Cost	10	$ 72,100	$ 72,100	0.862	$ 62,130	5 year review, update plan, and Repair Costs
Periodic Cost	15	$ 1,857,480	$ 1,857,480	0.800	$ 1,485,710	5 year review, update plan, and Repair Costs
Periodic Cost	20	$ 831,890	$ 831,890	0.742	$ 617,660	5 year review, update plan, and Repair Costs
Periodic Cost	25	$ 62,100	$ 62,100	0.689	$ 42,800	5 year review, update plan, and Repair Costs
		$ 77,040,230			$ 69,352,840	

TOTAL PRESENT VALUE OF ALTERNATIVE **$ 69,352,840**

Containment Alternative C200
GROUNDWATER EXTRACTION AND TREATMENT

COST ESTIMATE SUMMARY C200

Site: "Occidental" Site
Location: Tacoma, Washington
Phase: Feasibility Study (-30% to +50%) - 7%
Base Year: 2016
Date: December 6, 2016

Description: Containment Alternative C200 is designed to eliminate potentially complete exposure pathways and includes: institutional controls; groundwater monitoring; a Physical Direct Contact Exposure (PDCE) Barrier for 605 & 709 Alexander Avenue Properties, Navy Todd Dump, N Landfill, and 709 Embankment Fill Area; a sheet pile barrier wall adjacent to Hylebos; and hydraulic containment using a newly constructed GWETS. Capital Costs occur in Year 0. Annual O&M costs occur in Years 1-30. Periodic costs occur in years 5,10, 15, 20, and 25.

CAPITAL COSTS

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Mobilization/Demobilization					
Construction Equipment & Facilities	1	LS	$ 25,000	$ 25,000	Excavators, Loaders, etc.
Temporary facilities and Utilities	1	LS	$ 50,000	$ 50,000	Fence, roads, signs, trailers, etc.
H&S Plans and Submittals	1	LS	$ 15,000	$ 15,000	HASP, quality control, etc.
Design, Work Plans, Permits	1	LS	$ 100,000	$ 100,000	Barrier wall
Design, Work Plans, Permits	1	LS	$ 50,000	$ 50,000	Physical Direct Contact Exposure Barrier
Post-construction Submittals	1	LS	$ 150,000	$ 150,000	Report completed work
SUBTOTAL				$ 390,000	
Site Work					
Demolition of North Dock	1	LS	$ 446,000	$ 446,000	Quotation from vendor - See Cost Worksheet C-1
Demolition of South Dock	1	LS	$ 248,000	$ 248,000	Quotation from vendor - See Cost Worksheet C-2
Demolition of Existing Structures	1	LS	$ 250,000	$ 250,000	Treatment plant, office, misc. - Assumption
Construction Oversight	50	DAY	$ 1,920	$ 96,000	Assume 2 people
SUBTOTAL				$ 1,040,000	
Barrier Wall East Installation					
Mobilization/Demobilization	1	LS	$ 50,000	$ 50,000	2,180 ft long by 73.5 ft deep. Assuming barge installatior
Sheet Pile	4300	TN	$ 1,900	$ 8,170,000	Vendor quote (PZ-27 sheet)
Unload Sheet Pile	220	LS	$ 2,350	$ 517,000	Vendor quote
Install Perimeter SP Wall	160000	SF	$ 12	$ 1,920,000	Vendor quote (Adeka sealant; Anchor piles on 6' centers)
Fill along embankment behind wall	40370	CY	$ 18	$ 726,670	Avg. Depth 10 ft; 50 ft wide
Construction Oversight	130	DAY	$ 1,920	$ 249,600	Assume 2 people
Mitigation of Intertidal Areas	1	LS	$ 250,000	$ 250,000	Allowance
SUBTOTAL				$ 11,883,270	
Physical Direct Contact Exposure Barrier					
Mobilization/Demobilization	1	LS	$ 50,000	$ 50,000	
Preparation	1502820	SF	$ 0.6	$ 901,700	Remove debris and prepare surface. 34.5 acres.
Aggregate Base	27830	CY	$ 35	$ 974,050	6 inch base
Asphalt Cover (assume 4")	1502820	SF	$ 2	$ 3,005,640	Facility Construction Cost - RSMeans (2016)
Construction Oversight	130	DAY	$ 1,920	$ 249,600	Assume 2 personal
SUBTOTAL				$ 5,180,990	
Hydraulic Containment					
Mobilization/Demobilization	1	LS	$ 50,000	$ 50,000	
Groundwater Extraction System	1	LS	$ 927,470	$ 927,470	See Cost Worksheet C-3
Groundwater Treatment Equipment	1	LS	$ 2,544,230	$ 2,544,230	Assume 300 gpm System - See Cost Worksheet C-4
Groundwater Treatment Facility Building	1	LS	$ 2,145,820	$ 2,145,820	See Cost Worksheet C-5
High pH Treatment Additional Equipment	1	LS	$ 27,000	$ 27,000	Acid metering pump and equalization tank.
Construction Oversight	260	Day	$ 1,920	$ 499,200	
SUBTOTAL				$ 6,193,720	
Off-Site Treatment / Disposal					
Off-Site T&D of Soil Cuttings	20	CY	$ 394	$ 7,880	Vendor Quote
Off-Site T&D of Spoils	1250	CY	$ 394	$ 491,920	Vendor Quote
Off-Site T&D of Spoils - Hazardous	750	CY	$ 977	$ 732,780	Vendor Quote
SUBTOTAL				$ 1,232,580	
SUBTOTAL				$ 25,920,560	
Contingency		25%		$ 6,480,140	10% scope + 15% bid
SUBTOTAL				$ 32,400,700	
Project Management		5%		$ 1,620,040	
Remedial Design		8%		$ 2,592,060	
Construction Management		6%		$ 1,944,040	
Institutional Controls					
Institutional Controls Plan	1	LS	$ 13,000	$ 13,000	Description and implementation
Groundwater Use Restrictions	1	LS	$ 10,000	$ 10,000	Legal fees
Site Database	1	LS	$ 5,000	$ 5,000	Data management system
Documentation	1	LS	$ 20,000	$ 20,000	other submittals and documents
Perimeter fence	5300	FOOT	$ 18	$ 95,400	605 and 709 properties
SUBTOTAL				$ 143,400	
TOTAL CAPITAL COSTS				**$ 38,700,240**	

Containment Alternative C200
GROUNDWATER EXTRACTION AND TREATMENT

COST ESTIMATE SUMMARY C200

Site:	"Occidental" Site	Description:	Containment Alternative C200 is designed to eliminate potentially complete exposure pathways and includes: institutional controls; groundwater monitoring; a Physical Direct Contact Exposure (PDCE) Barrier for 605 & 709 Alexander Avenue Properties, Navy Todd Dump, N Landfill, and 709 Embankment Fill Area; a sheet pile barrier wall adjacent to Hylebos; and hydraulic containment using a newly constructed GWETS. Capital Costs occur in Year 0. Annual O&M costs occur in Years 1-30. Periodic costs occur in years 5,10, 15, 20, and 25.
Location:	Tacoma, Washington		
Phase:	Feasibility Study (-30% to +50%) - 7%		
Base Year:	2016		
Date:	December 6, 2016		

ANNUAL O&M COSTS:

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Inspections					
Mobilization and Inspection	1	LS	$ 2,600	$ 2,600	Barriers and fencing
Reporting	1	LS	$ 5,200	$ 5,200	Inspection documentation
SUBTOTAL				$ 7,800	
Monitoring Groundwater					
Monitoring, sampling and reporting	1	LS	$ 297,000	$ 297,000	Will be in OMMP
Physical Direct Contact Exposure Barrier Maintenance					
Annual maintenance	1	LS	$ 10,000	$ 10,000	Allowance
Groundwater Treatment Plant					
Operation	1	year	$ 124,500	$ 124,500	GHD Quote
Carbon Consumption	6	EXCHANGE	$ 19,124	$ 114,744	GHD Quote
pH Adjustment	1	LS	$ 20,000	$ 20,000	GHD Quote
Equipment Allowance	1	LS	$ 6,000	$ 6,000	Allowance
Dilution Water	73980	$/1000 gals	$ 2.60	$ 192,350	Assume city water for dilution - quote
SUBTOTAL				$ 457,594	
Extraction Wells and Forcemains					
Annual maintenance	1	LS	$ 20,000	$ 20,000	Two weeks of work
Off-Site Treatment / Disposal					
Off-Site Transport/disposal of Solids	55	ton	$ 720	$ 39,600	Vendor Quote
SUBTOTAL				$ 831,994	
Contingency		30%		$ 249,600	10% scope + 20% bid
SUBTOTAL				$ 1,081,594	
Project Management		5%		$ 54,080	
Technical Support		10%		$ 108,160	
Site Info Database	1	LS	$ 4,000	$ 4,000	Update and maintain database
TOTAL ANNUAL O&M COSTS				**$ 1,247,834**	

PERIODIC COSTS:

DESCRIPTION	YEAR	QTY	UNIT	UNIT COST	TOTAL	NOTES
Five Year Review Report	5	1	EA	$ 75,000	$ 75,000	Report after 5 years
Equipment Replacement	5	1	LS	$ 19,100	$ 19,100	Equipment Replacement- See Cost Worksheet C-6
Update IC Plan	5	1	EA	$ 3,000	$ 3,000	Update Plan
SUBTOTAL					$ 97,100	
Five Year Review Report	10	1	EA	$ 50,000	$ 50,000	Report after 10 years
Equipment Replacement	10	1	LS	$ 19,100	$ 19,100	Equipment Replacement- See Cost Worksheet C-6
Update IC Plan	10	1	EA	$ 3,000	$ 3,000	Update Plan
SUBTOTAL					$ 72,100	
Five Year Review Report	15	1	EA	$ 40,000	$ 40,000	Report after 15 years
Cap Repair	15	1	LS	$ 300,570	$ 300,570	10 percent of asphalt
Equipment Replacement	15	1	LS	$ 1,503,910	$ 1,503,910	Equipment Replacement- See Cost Worksheet C-6
Update IC Plan	15	1	EA	$ 3,000	$ 3,000	Update Plan
Remedial Action Report	15	1	EA	$ 10,000	$ 10,000	
SUBTOTAL					$ 1,857,480	
Five Year Review Report	20	1	EA	$ 40,000	$ 40,000	Report after 20 years
Equipment Replacement	20	1	LS	$ 788,890	$ 788,890	Equipment Replacement- See Cost Worksheet C-6
Update IC Plan	20	1	EA	$ 3,000	$ 3,000	Update Plan
SUBTOTAL					$ 831,890	
Five Year Review Report	25	1	EA	$ 40,000	$ 40,000	Report after 25 years
Equipment Replacement	25	1	LS	$ 19,100	$ 19,100	Equipment Replacement- See Cost Worksheet C-6
Update IC Plan	25	1	EA	$ 3,000	$ 3,000	Update Plan
SUBTOTAL					$ 62,100	

Containment Alternative C200
GROUNDWATER EXTRACTION AND TREATMENT

COST ESTIMATE SUMMARY C200

Site: "Occidental" Site
Location: Tacoma, Washington
Phase: Feasibility Study (-30% to +50%) - 7%
Base Year: 2016
Date: December 6, 2016

Description: Containment Alternative C200 is designed to eliminate potentially complete exposure pathways and includes: institutional controls; groundwater monitoring; a Physical Direct Contact Exposure (PDCE) Barrier for 605 & 709 Alexander Avenue Properties, Navy Todd Dump, N Landfill, and 709 Embankment Fill Area; a sheet pile barrier wall adjacent to Hylebos; and hydraulic containment using a newly constructed GWETS. Capital Costs occur in Year 0. Annual O&M costs occur in Years 1-30. Periodic costs occur in years 5,10, 15, 20, and 25.

PRESENT VALUE ANALYSIS:

COST TYPE	YEAR	TOTAL COST	TOTAL COST PER YEAR	DISCOUNT FACTOR (1.5%)	PRESENT VALUE	NOTES
Capital Cost	0	$ 38,700,240	$ 38,700,240	1	$ 38,700,240	
Annual O&M Cost	1-30	$ 37,435,020	$ 1,247,834	12.41	$ 15,484,430	30 years
Periodic Cost	5	$ 97,100	$ 97,100	0.713	$ 69,240	5 year review, update plan, and Repair Costs
Periodic Cost	10	$ 72,100	$ 72,100	0.508	$ 36,660	5 year review, update plan, and Repair Costs
Periodic Cost	15	$ 1,857,480	$ 1,857,480	0.362	$ 673,240	5 year review, update plan, and Repair Costs
Periodic Cost	20	$ 831,890	$ 831,890	0.258	$ 214,980	5 year review, update plan, and Repair Costs
Periodic Cost	25	$ 62,100	$ 62,100	0.184	$ 11,450	5 year review, update plan, and Repair Costs
		$ 79,055,930			$ 55,190,240	

TOTAL PRESENT VALUE OF ALTERNATIVE **$ 55,190,240**

Containment Alternative C200
GROUNDWATER EXTRACTION AND TREATMENT

COST ESTIMATE SUMMARY C200

Site: "Occidental" Site
Location: Tacoma, Washington
Phase: Feasibility Study (-30% to +50%) - 1.5%
Base Year: 2016
Date: December 6, 2016

Description: Containment Alternative C200 is designed to eliminate potentially complete exposure pathways and includes: institutional controls; groundwater monitoring; a Physical Direct Contact Exposure (PDCE) Barrier for 605 & 709 Alexander Avenue Properties, Navy Todd Dump, N Landfill, and 709 Embankment Fill Area; a sheet pile barrier wall adjacent to Hylebos; and hydraulic containment using a newly constructed GWETS. Capital Costs occur in Year 0. Annual O&M costs occur in Years 1-30. Periodic costs occur in years 5,10, 15, 20, and 25.

CAPITAL COSTS

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Mobilization/Demobilization					
Construction Equipment & Facilities	1	LS	$ 25,000	$ 25,000	Excavators, Loaders, etc.
Temporary facilities and Utilities	1	LS	$ 50,000	$ 50,000	Fence, roads, signs, trailers, etc.
H&S Plans and Submittals	1	LS	$ 15,000	$ 15,000	HASP, quality control, etc.
Design, Work Plans, Permits	1	LS	$ 100,000	$ 100,000	Barrier wall
Design, Work Plans, Permits	1	LS	$ 50,000	$ 50,000	Physical Direct Contact Exposure Barrier
Post-construction Submittals	1	LS	$ 150,000	$ 150,000	Report completed work
SUBTOTAL				$ 390,000	
Site Work					
Demolition of North Dock	1	LS	$ 446,000	$ 446,000	Quotation from vendor - See Cost Worksheet C-1
Demolition of South Dock	1	LS	$ 248,000	$ 248,000	Quotation from vendor - See Cost Worksheet C-2
Demolition of Existing Structures	1	LS	$ 250,000	$ 250,000	Treatment plant, office, misc. - Assumption
Construction Oversight	50	DAY	$ 1,920	$ 96,000	Assume 2 people
SUBTOTAL				$ 1,040,000	
Barrier Wall East Installation					
Mobilization/Demobilization	1	LS	$ 50,000	$ 50,000	2,180 ft long by 73.5 ft deep. Assuming barge installatior
Sheet Pile	4300	TN	$ 1,900	$ 8,170,000	Vendor quote (PZ-27 sheet)
Unload Sheet Pile	220	LS	$ 2,350	$ 517,000	Vendor quote
Install Perimeter SP Wall	160000	SF	$ 12	$ 1,920,000	Vendor quote (Adeka sealant; Anchor piles on 6' centers)
Fill along embankment behind wall	40370	CY	$ 18	$ 726,670	Avg. Depth 10 ft; 50 ft wide
Construction Oversight	130	DAY	$ 1,920	$ 249,600	Assume 2 people
Mitigation of Intertidal Areas	1	LS	$ 250,000	$ 250,000	Allowance
SUBTOTAL				$ 11,883,270	
Physical Direct Contact Exposure Barrier					
Mobilization/Demobilization	1	LS	$ 50,000	$ 50,000	
Preparation	1502820	SF	$ 0.6	$ 901,700	Remove debris and prepare surface. 34.5 acres.
Aggregate Base	27830	CY	$ 35	$ 974,050	6 inch base
Asphalt Cover (assume 4")	1502820	SF	$ 2	$ 3,005,640	Facility Construction Cost - RSMeans (2016)
Construction Oversight	130	DAY	$ 1,920	$ 249,600	Assume 2 personal
SUBTOTAL				$ 5,180,990	
Hydraulic Containment					
Mobilization/Demobilization	1	LS	$ 50,000	$ 50,000	
Groundwater Extraction System	1	LS	$ 927,470	$ 927,470	See Cost Worksheet C-3
Groundwater Treatment Equipment	1	LS	$ 2,544,230	$ 2,544,230	Assume 300 gpm System - See Cost Worksheet C-4
Groundwater Treatment Facility Building	1	LS	$ 2,145,820	$ 2,145,820	See Cost Worksheet C-5
High pH Treatment Additional Equipment	1	LS	$ 27,000	$ 27,000	Acid metering pump and equalization tank.
Construction Oversight	260	Day	$ 1,920	$ 499,200	
SUBTOTAL				$ 6,193,720	
Off-Site Treatment / Disposal					
Off-Site T&D of Soil Cuttings	20	CY	$ 394	$ 7,880	Vendor Quote
Off-Site T&D of Spoils	1250	CY	$ 394	$ 491,920	Vendor Quote
Off-Site T&D of Spoils - Hazardous	750	CY	$ 977	$ 732,780	Vendor Quote
SUBTOTAL				$ 1,232,580	
SUBTOTAL				$ 25,920,560	
Contingency		25%		$ 6,480,140	10% scope + 15% bid
SUBTOTAL				$ 32,400,700	
Project Management		5%		$ 1,620,040	
Remedial Design		8%		$ 2,592,060	
Construction Management		6%		$ 1,944,040	
Institutional Controls					
Institutional Controls Plan	1	LS	$ 13,000	$ 13,000	Description and implementation
Groundwater Use Restrictions	1	LS	$ 10,000	$ 10,000	Legal fees
Site Database	1	LS	$ 5,000	$ 5,000	Data management system
Documentation	1	LS	$ 20,000	$ 20,000	other submittals and documents
Perimeter fence	5300	FOOT	$ 18	$ 95,400	605 and 709 properties
SUBTOTAL				$ 143,400	
TOTAL CAPITAL COSTS				**$ 38,700,240**	

Containment Alternative C200
GROUNDWATER EXTRACTION AND TREATMENT

COST ESTIMATE SUMMARY C200

Site: "Occidental" Site
Location: Tacoma, Washington
Phase: Feasibility Study (-30% to +50%) - 1.5%
Base Year: 2016
Date: December 6, 2016

Description: Containment Alternative C200 is designed to eliminate potentially complete exposure pathways and includes: institutional controls; groundwater monitoring; a Physical Direct Contact Exposure (PDCE) Barrier for 605 & 709 Alexander Avenue Properties, Navy Todd Dump, N Landfill, and 709 Embankment Fill Area; a sheet pile barrier wall adjacent to Hylebos; and hydraulic containment using a newly constructed GWETS. Capital Costs occur in Year 0. Annual O&M costs occur in Years 1-30. Periodic costs occur in years 5,10, 15, 20, and 25.

ANNUAL O&M COSTS:

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Inspections					
Mobilization and Inspection	1	LS	$ 2,600	$ 2,600	Barriers and fencing
Reporting	1	LS	$ 5,200	$ 5,200	Inspection documentation
SUBTOTAL				$ 7,800	
Monitoring Groundwater					
Monitoring, sampling and reporting	1	LS	$ 297,000	$ 297,000	Will be in OMMP
Physical Direct Contact Exposure Barrier Maintenance					
Annual maintenance	1	LS	$ 10,000	$ 10,000	Allowance
Groundwater Treatment Plant					
Operation	1	year	$ 124,500	$ 124,500	GHD Quote
Carbon Consumption	6	EXCHANGE	$ 19,124	$ 114,744	GHD Quote
pH Adjustment	1	LS	$ 20,000	$ 20,000	GHD Quote
Equipment Allowance	1	LS	$ 6,000	$ 6,000	Allowance
Dilution Water	73980	$/1000 gals	$ 2.60	$ 192,350	Assume city water for dilution - quote
SUBTOTAL				$ 457,594	
Extraction Wells and Forcemains					
Annual maintenance	1	LS	$ 20,000	$ 20,000	Two weeks of work
Off-Site Treatment / Disposal					
Off-Site Transport/disposal of Solids	55	ton	$ 720	$ 39,600	Vendor Quote
SUBTOTAL				$ 831,994	
Contingency		30%		$ 249,600	10% scope + 20% bid
SUBTOTAL				$ 1,081,594	
Project Management		5%		$ 54,080	
Technical Support		10%		$ 108,160	
Site Info Database	1	LS	$ 4,000	$ 4,000	Update and maintain database
TOTAL ANNUAL O&M COSTS				**$ 1,247,834**	

PERIODIC COSTS:

DESCRIPTION	YEAR	QTY	UNIT	UNIT COST	TOTAL	NOTES
Five Year Review Report	5	1	EA	$ 75,000	$ 75,000	Report after 5 years
Equipment Replacement	5	1	LS	$ 19,100	$ 19,100	Equipment Replacement- See Cost Worksheet C-6
Update IC Plan	5	1	EA	$ 3,000	$ 3,000	Update Plan
SUBTOTAL					$ 97,100	
Five Year Review Report	10	1	EA	$ 50,000	$ 50,000	Report after 10 years
Equipment Replacement	10	1	LS	$ 19,100	$ 19,100	Equipment Replacement- See Cost Worksheet C-6
Update IC Plan	10	1	EA	$ 3,000	$ 3,000	Update Plan
SUBTOTAL					$ 72,100	
Five Year Review Report	15	1	EA	$ 40,000	$ 40,000	Report after 15 years
Cap Repair	15	1	LS	$ 300,570	$ 300,570	10 percent of asphalt
Equipment Replacement	15	1	LS	$ 1,503,910	$ 1,503,910	Equipment Replacement- See Cost Worksheet C-6
Update IC Plan	15	1	EA	$ 3,000	$ 3,000	Update Plan
Remedial Action Report	15	1	EA	$ 10,000	$ 10,000	
SUBTOTAL					$ 1,857,480	
Five Year Review Report	20	1	EA	$ 40,000	$ 40,000	Report after 20 years
Equipment Replacement	20	1	LS	$ 788,890	$ 788,890	Equipment Replacement- See Cost Worksheet C-6
Update IC Plan	20	1	EA	$ 3,000	$ 3,000	Update Plan
SUBTOTAL					$ 831,890	
Five Year Review Report	25	1	EA	$ 40,000	$ 40,000	Report after 25 years
Equipment Replacement	25	1	LS	$ 19,100	$ 19,100	Equipment Replacement- See Cost Worksheet C-6
Update IC Plan	25	1	EA	$ 3,000	$ 3,000	Update Plan
SUBTOTAL					$ 62,100	

Containment Alternative C200
GROUNDWATER EXTRACTION AND TREATMENT

COST ESTIMATE SUMMARY C200

Site:	"Occidental" Site	Description:	Containment Alternative C200 is designed to eliminate potentially complete exposure pathways and includes: institutional controls; groundwater monitoring; a Physical Direct Contact Exposure (PDCE) Barrier for 605 & 709 Alexander Avenue Properties, Navy Todd Dump, N Landfill, and 709 Embankment Fill Area; a sheet pile barrier wall adjacent to Hylebos; and hydraulic containment using a newly constructed GWETS. Capital Costs occur in Year 0. Annual O&M costs occur in Years 1-30. Periodic costs occur in years 5,10, 15, 20, and 25.
Location:	Tacoma, Washington		
Phase:	Feasibility Study (-30% to +50%) - 1.5%		
Base Year:	2016		
Date:	December 6, 2016		

PRESENT VALUE ANALYSIS:

COST TYPE	YEAR	TOTAL COST	TOTAL COST PER YEAR	DISCOUNT FACTOR (1.5%)	PRESENT VALUE	NOTES
Capital Cost	0	$ 38,700,240	$ 38,700,240	1	$ 38,700,240	
Annual O&M Cost	1-30	$ 37,435,020	$ 1,247,834	24.02	$ 29,967,780	30 years
Periodic Cost	5	$ 97,100	$ 97,100	0.928	$ 90,140	5 year review, update plan, and Repair Costs
Periodic Cost	10	$ 72,100	$ 72,100	0.862	$ 62,130	5 year review, update plan, and Repair Costs
Periodic Cost	15	$ 1,857,480	$ 1,857,480	0.800	$ 1,485,710	5 year review, update plan, and Repair Costs
Periodic Cost	20	$ 831,890	$ 831,890	0.742	$ 617,660	5 year review, update plan, and Repair Costs
Periodic Cost	25	$ 62,100	$ 62,100	0.689	$ 42,800	5 year review, update plan, and Repair Costs
		$ 79,055,930			$ 70,966,460	

TOTAL PRESENT VALUE OF ALTERNATIVE **$ 70,966,460**

Containment Alternatives C100, C150, C200
Capital Cost Sub-Element
NORTH DOCK DEMOLITION AND DISPOSAL

COST WORKSHEET C-1

Site: "Occidental" Site
Location: Tacoma, Washington
Phase: Feasibility Study (-30% to +50%)
Base Year: 2016

Prepared By: AW Date: 6/2/2016

Checked By: RJH Date: 12/6/2016

Work Statement:

The work includes the demolition and legal disposal of a approximately 18,430 square feet creosote timber dock from the water side of the dock structure. Material to be demolished includes, bull rail, water decking, joists, pile caps, and minimal cross bracing. Excludes timber pile removal.

Cost analysis:

Costs per demolition of 18,430 square feet dock.

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	UNIT TOTAL	TOTAL	
Dock Demolition and Removal	1	LS	-	-	-	350,000	350,000	Includes contractor profits
Construction Oversight (40 Days)	50	DAY	1,920	-	-	1,920	96,000	Engineer ($1200/day) to Supervisor ($720/day)
SUBTOTAL							446,000	
Prime Contractor Overhead						0%	-	
SUBTOTAL							446,000	
Prime Contractor Profit						0%	-	
TOTAL UNIT COST							$ 446,000	

Source of Cost Data:

December 17, 2013. From Nicolas Arvberger. American Construction Company. Oversight costs

Cost Adjustment Checklist:

	FACTOR:	NOTES:
☑	H&S Productivity	Quote is for Level D
☑	Escalation to Base Year	2016
☑	Area Cost Factor	Quotes is from local vendor
☑	Subcontractor Overhead and Profit	Included in unit pricing
☑	Prime Contractor Overhead and Profit	Included in unit pricing

Containment Alternatives C100, C150, C200
Capital Cost Sub-Element
SOUTH DOCK DEMOLITION AND DISPOSAL

COST WORKSHEET C-2

Site: "Occidental" Site
Location: Tacoma, Washington
Phase: Feasibility Study (-30% to +50%)
Base Year: 2016

Prepared By: AW Date: 6/2/2016

Checked By: RJH Date: 12/6/2016

Work Statement:

The work includes the demolition and legal disposal of a approximately 18,430 square feet creosote timber dock from the water side of the dock structure. Material to be demolished includes, bull rail, water decking, joists, pile caps, and minimal cross bracing. Excludes timber pile removal.

Cost analysis:

Costs per demolition of 18,430 square feet dock.

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	UNIT TOTAL	TOTAL	
Dock Demolition and Removal	1	LS	-	-	-	200,000	200,000	Includes contractor profits
Construction Oversight (40 Days)	25	DAY	1,920	-	-	1,920	48,000	Engineer ($1200/day) to Supervisor ($720/day)
SUBTOTAL							248,000	
Prime Contractor Overhead						0%	-	
SUBTOTAL							248,000	
Prime Contractor Profit						0%	-	
TOTAL UNIT COST							$ 248,000	

Source of Cost Data:

December 17, 2013. From Nicolas Arvberger. American Construction Company. Oversight costs

Cost Adjustment Checklist:

	FACTOR:	NOTES:
☑	H&S Productivity	Quote is for Level D
☑	Escalation to Base Year	2016
☑	Area Cost Factor	Quotes is from local vendor
☑	Subcontractor Overhead and Profit	Included in unit pricing
☑	Prime Contractor Overhead and Profit	Included in unit pricing

Containment Alternatives C100, C150, C200
Capital Cost Sub-Element
EXTRACTION WELLS AND CONVEYANCES

COST WORKSHEET C-3

Site: "Occidental" Site
Location: Tacoma, Washington
Phase: Feasibility Study (-30% to +50%)
Base Year: 2016

Prepared By: AW
Date: 6/2/2016

Checked By: RJH
Date: 12/6/2016

Work Statement:

The work includes groundwater extraction wells, pumps, well vaults, forcemains, electrical conduit, etc. to extract and convey groundwater to the treatment system.

Cost analysis:

Costs for equipment, preparation, and installation.

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	UNIT TOTAL	TOTAL	
Well Installation								
Mobilization/demobilization	1	LS	-	-	-	44,800	44,800	Driller Invoice
Wells Installation (-15 ft NGVD)	3	EA	incl.	26,600	incl.	26,600	79,800	6 inch well
Wells Installation (-22.5 ft NGVD)	4	EA	incl.	27,700	incl.	27,700	110,800	6 inch well
Wells Installation (-45 ft NGVD)	2	EA	incl.	30,900	incl.	30,900	61,800	6 inch well
Well Installation (-70 ft NGVD)	1	EA	incl.	34,500	incl.	34,500	34,500	6 inch well
Well Installation (EXT-9(d))	0	EA	-	-	-	-	-	Installed previously
Drilling Oversight	40	DAY	1,920	-	-	1,920	76,800	Two drill rigs operating
Surveyor	1	LS	20,000	-	-	20,000	20,000	
Pumps	11	EA	-	1,736	-	1,736	19,100	
Wiring	11	EA	-	1,800	-	1,800	19,800	
Well Development @ 8 hours each	88	HR	250	incl.	incl.	250	22,000	
Well Vaults (3' x 4' x 4') w/HD 20 Cover	11	EA	-	3,500	-	3,500	38,500	
Asphalt Removal (Assume 6")	1960	SY	10	-	-	10	18,620	
Asphalt Disposal	260	TN	incl.	incl.	-	-	-	
Excavation	3012	CY	9	incl.	-	9	25,602	
Sand Fill	1857	CY	30	incl.	incl.	30	55,246	
Aggregate Fill	1155	CY	35	incl.	incl.	35	40,425	
Asphalt Replacement	260	TN	105	incl.	incl.	105	27,300	
SUBTOTAL							695,090	
Piping/Electrical								
Electrical Power Allowance	1	LS	35,000	incl.	incl.	35,000	35,000	
Piping (HDPE)	5050	LF	incl.	incl.	4	4	20,200	
Electrical Conduit (2.0")	5050	LF	incl.	incl.	12	12	60,600	
Electrical Pull Boxes	17	EA	incl.	incl.	315	315	5,355	
Hydro-Test Piping	1	LS	2,500	incl.	-	2,500	2,500	
SUBTOTAL							123,660	
Prime Contractor Overhead						15%	61,538	
SUBTOTAL							880,288	
Prime Contractor Profit						10%	47,180	
TOTAL UNIT COST							$ 927,470	

Source of Cost Data:

Estimate from GHD Construction Division (April 27, 2016) and Drilling Contractor Previous Invoices for Site Work (2013)

Cost Adjustment Checklist:

	FACTOR:	NOTES:
☑	H&S Productivity	Assume Level D
☑	Escalation to Base Year	2016
☑	Area Cost Factor	Based on general pricing
☑	Subcontractor Overhead and Profit	Not included in unit prices except for well construction and oversight
☑	Prime Contractor Overhead and Profit	Not included in unit prices except for well construction and oversight

Containment Alternatives C100, C150, C200
Capital Cost Sub-Element
TREATMENT SYSTEM EQUIPMENT - 300 GPM SYSTEM

COST WORKSHEET C-4

Site: "Occidental" Site
Location: Tacoma, Washington
Phase: Feasibility Study (-30% to +50%)
Base Year: 2016

Prepared By: AW
Date: 6/2/2016

Checked By: RJH
Date: 12/6/2016

Work Statement:

The work includes system equipment necessary to treat extracted groundwater.

Cost analysis:

Costs for equipment, preparation, and installation.

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	UNIT TOTAL	TOTAL
Equipment:							
Inclined Plate Clarifier	1	LS	incl.	260,000	incl.	260,000	260,000
Filter Press	1	LS	incl.	208,000	incl.	208,000	208,000
Multimedia Filter Skid	1	LS	incl.	180,000	incl.	180,000	180,000
Air Stripper Blower	1	LS	incl.	83,440	incl.	83,440	83,440
Cartridge Filter Skid	1	LS	incl.	13,429	incl.	13,429	13,429
Carbon Filters (2 vessels)	1	LS	incl.	300,000	incl.	300,000	300,000
Regenerative Thermal Oxidizer Package	1	LS	incl.	900,200	incl.	900,200	900,200
Air Compressor	1	LS	incl.	14,600	incl.	14,600	14,600
Compressed Air Desiccant Dryer	1	LS	incl.	5,483	incl.	5,483	5,483
Freight and Tax	1	LS	-	-	-	277,000	277,000
SUBTOTAL							2,242,150
HVAC							
Treatment building heaters	4	EA	incl.	$ 1,423	incl.	1,423	5,692
Control room HVAC	1	LS	incl.	$ 3,718	incl.	3,718	3,718
Exhaust fans	4	EA	incl.	$ 806	incl.	806	3,222
SUBTOTAL							12,630
Pumps							
Clarifier Feed Pump	1	EA	incl.	18,280	incl.	18,280	18,280
Sand Filter Feed Pump	1	EA	incl.	22,356	incl.	22,356	22,356
Air Stripper Transfer Pump	1	EA	incl.	22,356	incl.	22,356	22,356
Sand Filter Backwash Pump	1	EA	incl.	24,243	incl.	24,243	24,243
Building Sump Pump	1	EA	incl.	2,563	incl.	2,563	2,563
Clarifier Bottoms Pump	1	EA	incl.	1,941	incl.	1,941	1,941
Filter Press Sludge Pump	1	EA	incl.	2,561	incl.	2,561	2,561
Dirty Backwash Recycle Pump	1	EA	incl.	1,941	incl.	1,941	1,941
SUBTOTAL							96,241
Metering Pumps							
Coagulant Metering Pump	1	LS	incl.	2,000	incl.	2,000	2,000
Polymer Metering / Blending Unit	1	LS	incl.	15,000	incl.	15,000	15,000
Sequestering Agent Metering Pump	1	LS	incl.	2,000	incl.	2,000	2,000
SUBTOTAL							19,000
Tanks							
Equalization Tank	1	EA	incl.	39,371	incl.	39,371	39,371
Clarifier Sludge Tank	1	EA	incl.	25,096	incl.	25,096	25,096
Filter Feed Tank	1	EA	incl.	19,200	incl.	19,200	19,200
Dirty Backwash Tank	1	EA	incl.	47,081	incl.	47,081	47,081
Effluent Tank	1	EA	incl.	16,469	incl.	16,469	16,469
Add metal tanks higher grade lining	1	LS	-	11,155	-	11,155	11,155
Add high seismic zone - extra 10%	10	%	-	158,372	-	158,372	15,837
SUBTOTAL							174,209
Prime Contractor Overhead						0%	-
SUBTOTAL							2,544,230
Prime Contractor Profit						0%	-
TOTAL UNIT COST							$2,544,230

Source of Cost Data:

Estimate from Gary Pritchard, GHD Process Engineer, April 29, 2016

Containment Alternatives C100, C150, C200
Capital Cost Sub-Element
TREATMENT SYSTEM EQUIPMENT - 300 GPM SYSTEM

COST WORKSHEET C-4

Site:	"Occidental" Site	Prepared By: AW	Checked By: RJH
Location:	Tacoma, Washington	Date: 6/2/2016	Date: 12/6/2016
Phase:	Feasibility Study (-30% to +50%)		
Base Year:	2016		

Cost Adjustment Checklist:

	FACTOR:	NOTES:
☑	H&S Productivity	Assume Level D
☑	Escalation to Base Year	2016
☑	Area Cost Factor	Based on general pricing
☑	Subcontractor Overhead and Profit	Included in unit pricing
☑	Prime Contractor Overhead and Profit	Included in unit pricing

Containment Alternatives C100, C150, C200
Capital Cost Sub-Element
TREATMENT SYSTEM BUILDING - 300 GPM SYSTEM

COST WORKSHEET C-5

Site: "Occidental" Site
Location: Tacoma, Washington
Phase: Feasibility Study (-30% to +50%)
Base Year: 2016

Prepared By: AW
Date: 6/2/2016

Checked By: RJH
Date: 12/6/2016

Work Statement:

The work includes construction of a building to house groundwater treatment equipment.

Cost analysis:

Costs for equipment, preparation, and installation.

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	UNIT TOTAL	TOTAL	
Building								
Building Pre-engineered Steel 115'x55'	1	LS	219,000	219,000	-	438,000	438,000	Vendor pricing
Building/Indoor Equipment Foundation	1	LS	232,000	232,000	-	464,000	464,000	GHD Estimate
Piping	1	LS	123,500	123,500	-	247,000	247,000	GHD Estimate
Instrumentation (plus wiring)	2	LS	122,385	122,385	-	244,770	489,540	GHD Estimate
Electrical	1	LS	166,641	166,641	-	333,282	333,282	GHD Estimate
Rigging	1	LS	93,000	-	-	93,000	93,000	GHD Estimate
Tax	1	LS	-	-	-	81,000	81,000	Vendor pricing
SUBTOTAL							2,145,820	
Prime Contractor Overhead						0%	-	
SUBTOTAL							2,145,820	
Prime Contractor Profit						0%	-	
TOTAL UNIT COST							$2,145,820	

Source of Cost Data:

Estimate from Gary Pritchard, GHD Process Engineer, April 29, 2016

Cost Adjustment Checklist:

	FACTOR:	NOTES:
☑	H&S Productivity	Assume Level D
☑	Escalation to Base Year	2016
☑	Area Cost Factor	Based on general pricing
☑	Subcontractor Overhead and Profit	Not included in unit prices except for well construction and oversight
☑	Prime Contractor Overhead and Profit	Not included in unit prices except for well construction and oversight

Containment Alternatives C100, C150, C200
O&M Sub-Element
TREATMENT SYSTEM EQUIPMENT - 300 GPM SYSTEM

COST WORKSHEET C-6

Site: "Occidental" Site
Location: Tacoma, Washington
Phase: Feasibility Study (-30% to +50%)
Base Year: 2016

Prepared By: AW
Date: 6/2/2016

Checked By: RJH
Date: 12/6/2016

Work Statement:

This work sheet includes equipment replacement costs based on typical product lives.

Cost analysis:

Costs for equipment, preparation, and installation.

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	UNIT TOTAL	TOTAL
5 Year Replacement							
EXT-1s Pump	1	EA	-	1,736	-	1,736	1,736
EXT-3d Pump	1	EA	-	1,736	-	1,736	1,736
EXT-4s Pump	1	EA	-	1,736	-	1,736	1,736
EXT-5s Pump	1	EA	-	1,736	-	1,736	1,736
EXT-8s Pump	1	EA	-	1,736	-	1,736	1,736
EXT-9d Pump	1	EA	-	1,736	-	1,736	1,736
EXT-10s Pump	1	EA	-	1,736	-	1,736	1,736
EXT-15s Pump	1	EA	-	1,736	-	1,736	1,736
EXT-16s Pump	1	EA	-	1,736	-	1,736	1,736
EXT-18s Pump	1	EA	-	1,736	-	1,736	1,736
EXT-21s Pump	1	EA	-	1,736	-	1,736	1,736
SUBTOTAL							19,100
15 Year Replacement							
Inclined Plate Clarifier	1	LS	incl.	260,000	incl.	260,000	260,000
Air Stripper Blower	1	LS	incl.	83,440	incl.	83,440	83,440
Regenerative Thermal Oxidizer Package	1	LS	incl.	900,200	incl.	900,200	900,200
Air Compressor	1	LS	incl.	14,600	incl.	14,600	14,600
Compressed Air Desiccant Dryer	1	LS	incl.	5,483	incl.	5,483	5,483
Clarifier Feed Pump	1	EA	incl.	18,280	incl.	18,280	18,280
Air Stripper Transfer Pump	1	EA	incl.	22,356	incl.	22,356	22,356
Building Sump Pump	1	EA	incl.	2,563	incl.	2,563	2,563
Clarifier Bottoms Pump	1	EA	incl.	1,941	incl.	1,941	1,941
Dirty Backwash Recycle Pump	1	EA	incl.	1,941	incl.	1,941	1,941
Coagulant Metering Pump	1	LS	incl.	2,000	incl.	2,000	2,000
Polymer Metering / Blending Unit	1	LS	incl.	15,000	incl.	15,000	15,000
Sequestering Agent Metering Pump	1	LS	incl.	2,000	incl.	2,000	2,000
Equalization Tank	1	EA	incl.	39,371	incl.	39,371	39,371
Clarifier Sludge Tank	1	EA	incl.	25,096	incl.	25,096	25,096
Dirty Backwash Tank	1	EA	incl.	47,081	incl.	47,081	47,081
Effluent Tank	1	EA	incl.	16,469	incl.	16,469	16,469
Add metal tanks higher grade lining	1	LS	-	11,155	-	11,155	11,155
Add tanks high seismic zone - extra 10%	10	%	-	158,372	-	158,372	15,837
SUBTOTAL							1,484,810
20 Year Replacement							
Filter Press	1	LS	incl.	208,000	incl.	208,000	208,000
Multimedia Filter Skid	1	LS	incl.	180,000	incl.	180,000	180,000
Cartridge Filter Skid	1	LS	incl.	13,429	incl.	13,429	13,429
Carbon Filters (2 vessels)	1	LS	incl.	300,000	incl.	300,000	300,000
Sand Filter Feed Pump	1	EA	incl.	22,356	incl.	22,356	22,356
Sand Filter Backwash Pump	1	EA	incl.	24,243	incl.	24,243	24,243
Filter Press Sludge Pump	1	EA	incl.	2,561	incl.	2,561	2,561
Filter Feed Tank	1	EA	incl.	19,200	incl.	19,200	19,200
SUBTOTAL							769,790
Prime Contractor Overhead						15%	2,865
SUBTOTAL							2,276,565
Prime Contractor Profit						10%	1,910
TOTAL UNIT COST							$2,278,480

Source of Cost Data:

Estimate from Gary Pritchard, GHD Process Engineer, April 29, 2016

Containment Alternatives C100, C150, C200
O&M Sub-Element
TREATMENT SYSTEM EQUIPMENT - 300 GPM SYSTEM

COST WORKSHEET C-6

Site:	"Occidental" Site	Prepared By: AW	Checked By: RJH
Location:	Tacoma, Washington	Date: 6/2/2016	Date: 12/6/2016
Phase:	Feasibility Study (-30% to +50%)		
Base Year:	2016		

Cost Adjustment Checklist:

	FACTOR:	NOTES:
☑	H&S Productivity	Assume Level D
☑	Escalation to Base Year	2016
☑	Area Cost Factor	Based on general pricing
☑	Subcontractor Overhead and Profit	Included in unit pricing except pumps
☑	Prime Contractor Overhead and Profit	Included in unit pricing except pumps

Containment Alternative C150
GROUNDWATER EXTRACTION AND TREATMENT

COST ESTIMATE SUMMARY C150

Site: "Occidental" Site
Location: Tacoma, Washington
Phase: Feasibility Study (-30% to +50%)
Base Year: 2016
Date: December 6, 2016

Description: 100-Year Cash Flow Projection at 7 percent

PRESENT VALUE ANALYSIS ***Base YR 2016*** 7.0% Discount Rate

Year	Cost Type	Cost	Discount Rate	Present Value	Notes
0	Capital Costs	$ 38,700,240	1.000	$ 38,700,240	
1	Annual O&M Costs	$ 1,180,644	0.935	$ 1,103,406	
2	Annual O&M Costs	$ 1,180,644	0.873	$ 1,031,220	
3	Annual O&M Costs	$ 1,180,644	0.816	$ 963,757	
4	Annual O&M Costs	$ 1,180,644	0.763	$ 900,708	
5	Annual O&M Costs	$ 1,180,644	0.713	$ 841,783	
5	Periodic Costs	$ 97,100	0.713	$ 69,231	5 year review, update plan, and Repair Costs
6	Annual O&M Costs	$ 1,180,644	0.666	$ 786,713	
7	Annual O&M Costs	$ 1,180,644	0.623	$ 735,246	
8	Annual O&M Costs	$ 1,180,644	0.582	$ 687,146	
9	Annual O&M Costs	$ 1,180,644	0.544	$ 642,192	
10	Annual O&M Costs	$ 1,180,644	0.508	$ 600,180	
10	Periodic Costs	$ 72,100	0.508	$ 36,652	5 year review, update plan, and Repair Costs
11	Annual O&M Costs	$ 1,180,644	0.475	$ 560,915	
12	Annual O&M Costs	$ 1,180,644	0.444	$ 524,220	
13	Annual O&M Costs	$ 1,180,644	0.415	$ 489,925	
14	Annual O&M Costs	$ 1,180,644	0.388	$ 457,874	
15	Annual O&M Costs	$ 1,180,644	0.362	$ 427,920	
15	Periodic Costs	$ 1,857,480	0.362	$ 673,236	5 year review, update plan, and Repair Costs
16	Annual O&M Costs	$ 1,180,644	0.339	$ 399,925	
17	Annual O&M Costs	$ 1,180,644	0.317	$ 373,762	
18	Annual O&M Costs	$ 1,180,644	0.296	$ 349,310	
19	Annual O&M Costs	$ 1,180,644	0.277	$ 326,458	
20	Annual O&M Costs	$ 1,180,644	0.258	$ 305,101	
20	Periodic Costs	$ 831,890	0.258	$ 214,976	5 year review, update plan, and Repair Costs
21	Annual O&M Costs	$ 1,180,644	0.242	$ 285,141	
22	Annual O&M Costs	$ 1,180,644	0.226	$ 266,487	
23	Annual O&M Costs	$ 1,180,644	0.211	$ 249,053	
24	Annual O&M Costs	$ 1,180,644	0.197	$ 232,760	
25	Annual O&M Costs	$ 1,180,644	0.184	$ 217,533	
25	Periodic Costs	$ 62,100	0.184	$ 11,442	5 year review, update plan, and Repair Costs
26	Annual O&M Costs	$ 1,180,644	0.172	$ 203,302	
27	Annual O&M Costs	$ 1,180,644	0.161	$ 190,001	
28	Annual O&M Costs	$ 1,180,644	0.150	$ 177,571	
29	Annual O&M Costs	$ 1,180,644	0.141	$ 165,955	
30	Annual O&M Costs	$ 1,180,644	0.131	$ 155,098	
30	Periodic Costs	$ 1,857,480	0.131	$ 244,012	5 year review, update plan, and Repair Costs
31	Annual O&M Costs	$ 1,180,644	0.123	$ 144,951	
32	Annual O&M Costs	$ 1,180,644	0.115	$ 135,468	
33	Annual O&M Costs	$ 1,180,644	0.107	$ 126,606	
34	Annual O&M Costs	$ 1,180,644	0.100	$ 118,323	
35	Annual O&M Costs	$ 1,180,644	0.094	$ 110,583	
35	Periodic Costs	$ 62,100	0.094	$ 5,816	5 year review, update plan, and Repair Costs
36	Annual O&M Costs	$ 1,180,644	0.088	$ 103,348	
37	Annual O&M Costs	$ 1,180,644	0.082	$ 96,587	
38	Annual O&M Costs	$ 1,180,644	0.076	$ 90,268	
39	Annual O&M Costs	$ 1,180,644	0.071	$ 84,363	
40	Annual O&M Costs	$ 1,180,644	0.067	$ 78,844	
40	Periodic Costs	$ 831,890	0.067	$ 55,554	5 year review, update plan, and Repair Costs
41	Annual O&M Costs	$ 1,180,644	0.062	$ 73,686	
42	Annual O&M Costs	$ 1,180,644	0.058	$ 68,865	
43	Annual O&M Costs	$ 1,180,644	0.055	$ 64,360	
44	Annual O&M Costs	$ 1,180,644	0.051	$ 60,150	
45	Annual O&M Costs	$ 1,180,644	0.048	$ 56,215	
45	Periodic Costs	$ 1,857,480	0.048	$ 88,441	5 year review, update plan, and Repair Costs
46	Annual O&M Costs	$ 1,180,644	0.044	$ 52,537	
47	Annual O&M Costs	$ 1,180,644	0.042	$ 49,100	
48	Annual O&M Costs	$ 1,180,644	0.039	$ 45,888	
49	Annual O&M Costs	$ 1,180,644	0.036	$ 42,886	
50	Annual O&M Costs	$ 1,180,644	0.034	$ 40,080	
50	Periodic Costs	$ 62,100	0.034	$ 2,108	5 year review, update plan, and Repair Costs
50	Periodic Costs	$ 5,453,300	0.034	$ 185,127	Repair sheet pile wall (50 percent of full install)
51	Annual O&M Costs	$ 1,180,644	0.032	$ 37,458	
52	Annual O&M Costs	$ 1,180,644	0.030	$ 35,008	
53	Annual O&M Costs	$ 1,180,644	0.028	$ 32,717	
54	Annual O&M Costs	$ 1,180,644	0.026	$ 30,577	
55	Annual O&M Costs	$ 1,180,644	0.024	$ 28,577	
55	Periodic Costs	$ 62,100	0.024	$ 1,503	5 year review, update plan, and Repair Costs
56	Annual O&M Costs	$ 1,180,644	0.023	$ 26,707	
57	Annual O&M Costs	$ 1,180,644	0.021	$ 24,960	
58	Annual O&M Costs	$ 1,180,644	0.020	$ 23,327	
59	Annual O&M Costs	$ 1,180,644	0.018	$ 21,801	
60	Annual O&M Costs	$ 1,180,644	0.017	$ 20,375	
60	Periodic Costs	$ 831,890	0.017	$ 14,356	5 year review, update plan, and Repair Costs
61	Annual O&M Costs	$ 1,180,644	0.016	$ 19,042	
62	Annual O&M Costs	$ 1,180,644	0.015	$ 17,796	
63	Annual O&M Costs	$ 1,180,644	0.014	$ 16,632	
64	Annual O&M Costs	$ 1,180,644	0.013	$ 15,544	
65	Annual O&M Costs	$ 1,180,644	0.012	$ 14,527	
65	Periodic Costs	$ 62,100	0.012	$ 764	5 year review, update plan, and Repair Costs
66	Annual O&M Costs	$ 1,180,644	0.011	$ 13,577	
67	Annual O&M Costs	$ 1,180,644	0.011	$ 12,688	
68	Annual O&M Costs	$ 1,180,644	0.010	$ 11,858	
69	Annual O&M Costs	$ 1,180,644	0.009	$ 11,083	
70	Annual O&M Costs	$ 1,180,644	0.009	$ 10,357	
70	Periodic Costs	$ 62,100	0.009	$ 545	5 year review, update plan, and Repair Costs

Containment Alternative C150
GROUNDWATER EXTRACTION AND TREATMENT

COST ESTIMATE SUMMARY C150

Site: "Occidental" Site
Location: Tacoma, Washington
Phase: Feasibility Study (-30% to +50%)
Base Year: 2016
Date: December 6, 2016

Description: 100-Year Cash Flow Projection at 7 percent

PRESENT VALUE ANALYSIS ***Base YR 2016*** 7.0% Discount Rate

Year	Cost Type	Cost	Discount Rate	Present Value	Notes
71	Annual O&M Costs	$ 1,180,644	0.008	$ 9,680	
72	Annual O&M Costs	$ 1,180,644	0.008	$ 9,047	
73	Annual O&M Costs	$ 1,180,644	0.007	$ 8,455	
74	Annual O&M Costs	$ 1,180,644	0.007	$ 7,902	
75	Annual O&M Costs	$ 1,180,644	0.006	$ 7,385	
75	Periodic Costs	$ 1,857,480	0.006	$ 11,618	5 year review, update plan, and Repair Costs
76	Annual O&M Costs	$ 1,180,644	0.006	$ 6,902	
77	Annual O&M Costs	$ 1,180,644	0.005	$ 6,450	
78	Annual O&M Costs	$ 1,180,644	0.005	$ 6,028	
79	Annual O&M Costs	$ 1,180,644	0.005	$ 5,634	
80	Annual O&M Costs	$ 1,180,644	0.004	$ 5,265	
80	Periodic Costs	$ 831,890	0.004	$ 3,710	5 year review, update plan, and Repair Costs
81	Annual O&M Costs	$ 1,180,644	0.004	$ 4,921	
82	Annual O&M Costs	$ 1,180,644	0.004	$ 4,599	
83	Annual O&M Costs	$ 1,180,644	0.004	$ 4,298	
84	Annual O&M Costs	$ 1,180,644	0.003	$ 4,017	
85	Annual O&M Costs	$ 1,180,644	0.003	$ 3,754	
85	Periodic Costs	$ 62,100	0.003	$ 197	5 year review, update plan, and Repair Costs
86	Annual O&M Costs	$ 1,180,644	0.003	$ 3,508	
87	Annual O&M Costs	$ 1,180,644	0.003	$ 3,279	
88	Annual O&M Costs	$ 1,180,644	0.003	$ 3,064	
89	Annual O&M Costs	$ 1,180,644	0.002	$ 2,864	
90	Annual O&M Costs	$ 1,180,644	0.002	$ 2,677	
90	Periodic Costs	$ 1,857,480	0.002	$ 4,211	5 year review, update plan, and Repair Costs
91	Annual O&M Costs	$ 1,180,644	0.002	$ 2,501	
92	Annual O&M Costs	$ 1,180,644	0.002	$ 2,338	
93	Annual O&M Costs	$ 1,180,644	0.002	$ 2,185	
94	Annual O&M Costs	$ 1,180,644	0.002	$ 2,042	
95	Annual O&M Costs	$ 1,180,644	0.002	$ 1,908	
95	Periodic Costs	$ 62,100	0.002	$ 100	5 year review, update plan, and Repair Costs
96	Annual O&M Costs	$ 1,180,644	0.002	$ 1,784	
97	Annual O&M Costs	$ 1,180,644	0.001	$ 1,667	
98	Annual O&M Costs	$ 1,180,644	0.001	$ 1,558	
99	Annual O&M Costs	$ 1,180,644	0.001	$ 1,456	
100	Annual O&M Costs	$ 1,180,644	0.001	$ 1,361	
100	GWTP Demolition	$ 1,000,000	0.001	$ 1,152	
100	Final Completion Report	$ 100,000	0.001	$ 115	
		$ 176,600,000		**$ 57,170,000**	

TOTAL PRESENT VALUE OF ALTERNATIVE **$ 57,170,000**

Containment Alternative C150
GROUNDWATER EXTRACTION AND TREATMENT

COST ESTIMATE SUMMARY C150

Site: "Occidental" Site
Location: Tacoma, Washington
Phase: Feasibility Study (-30% to +50%)
Base Year: 2016
Date: December 6, 2016

Description: 100-Year Cash Flow Projection at 1.5 percent

PRESENT VALUE ANALYSIS ***Base YR 2016*** 1.5% Discount Rate

Year	Cost Type	Cost	Discount Rate	Present Value	Notes
0	Capital Costs	$ 38,700,240	1.000	$ 38,700,240	
1	Annual O&M Costs	$ 1,180,644	0.985	$ 1,163,196	
2	Annual O&M Costs	$ 1,180,644	0.971	$ 1,146,006	
3	Annual O&M Costs	$ 1,180,644	0.956	$ 1,129,070	
4	Annual O&M Costs	$ 1,180,644	0.942	$ 1,112,384	
5	Annual O&M Costs	$ 1,180,644	0.928	$ 1,095,945	
5	Periodic Costs	$ 97,100	0.928	$ 90,134	5 year review, update plan, and Repair Costs
6	Annual O&M Costs	$ 1,180,644	0.915	$ 1,079,749	
7	Annual O&M Costs	$ 1,180,644	0.901	$ 1,063,792	
8	Annual O&M Costs	$ 1,180,644	0.888	$ 1,048,071	
9	Annual O&M Costs	$ 1,180,644	0.875	$ 1,032,582	
10	Annual O&M Costs	$ 1,180,644	0.862	$ 1,017,322	
10	Periodic Costs	$ 72,100	0.862	$ 62,126	5 year review, update plan, and Repair Costs
11	Annual O&M Costs	$ 1,180,644	0.849	$ 1,002,288	
12	Annual O&M Costs	$ 1,180,644	0.836	$ 987,476	
13	Annual O&M Costs	$ 1,180,644	0.824	$ 972,883	
14	Annual O&M Costs	$ 1,180,644	0.812	$ 958,505	
15	Annual O&M Costs	$ 1,180,644	0.800	$ 944,340	
15	Periodic Costs	$ 1,857,480	0.800	$ 1,485,708	5 year review, update plan, and Repair Costs
16	Annual O&M Costs	$ 1,180,644	0.788	$ 930,384	
17	Annual O&M Costs	$ 1,180,644	0.776	$ 916,635	
18	Annual O&M Costs	$ 1,180,644	0.765	$ 903,088	
19	Annual O&M Costs	$ 1,180,644	0.754	$ 889,742	
20	Annual O&M Costs	$ 1,180,644	0.742	$ 876,593	
20	Periodic Costs	$ 831,890	0.742	$ 617,654	5 year review, update plan, and Repair Costs
21	Annual O&M Costs	$ 1,180,644	0.731	$ 863,639	
22	Annual O&M Costs	$ 1,180,644	0.721	$ 850,876	
23	Annual O&M Costs	$ 1,180,644	0.710	$ 838,301	
24	Annual O&M Costs	$ 1,180,644	0.700	$ 825,912	
25	Annual O&M Costs	$ 1,180,644	0.689	$ 813,707	
25	Periodic Costs	$ 62,100	0.689	$ 42,800	5 year review, update plan, and Repair Costs
26	Annual O&M Costs	$ 1,180,644	0.679	$ 801,682	
27	Annual O&M Costs	$ 1,180,644	0.669	$ 789,834	
28	Annual O&M Costs	$ 1,180,644	0.659	$ 778,162	
29	Annual O&M Costs	$ 1,180,644	0.649	$ 766,662	
30	Annual O&M Costs	$ 1,180,644	0.640	$ 755,332	
30	Periodic Costs	$ 1,857,480	0.640	$ 1,188,346	5 year review, update plan, and Repair Costs
31	Annual O&M Costs	$ 1,180,644	0.630	$ 744,169	
32	Annual O&M Costs	$ 1,180,644	0.621	$ 733,172	
33	Annual O&M Costs	$ 1,180,644	0.612	$ 722,337	
34	Annual O&M Costs	$ 1,180,644	0.603	$ 711,662	
35	Annual O&M Costs	$ 1,180,644	0.594	$ 701,144	
35	Periodic Costs	$ 62,100	0.594	$ 36,879	5 year review, update plan, and Repair Costs
36	Annual O&M Costs	$ 1,180,644	0.585	$ 690,783	
37	Annual O&M Costs	$ 1,180,644	0.576	$ 680,574	
38	Annual O&M Costs	$ 1,180,644	0.568	$ 670,516	
39	Annual O&M Costs	$ 1,180,644	0.560	$ 660,607	
40	Annual O&M Costs	$ 1,180,644	0.551	$ 650,845	
40	Periodic Costs	$ 831,890	0.551	$ 458,590	5 year review, update plan, and Repair Costs
41	Annual O&M Costs	$ 1,180,644	0.543	$ 641,226	
42	Annual O&M Costs	$ 1,180,644	0.535	$ 631,750	
43	Annual O&M Costs	$ 1,180,644	0.527	$ 622,414	
44	Annual O&M Costs	$ 1,180,644	0.519	$ 613,215	
45	Annual O&M Costs	$ 1,180,644	0.512	$ 604,153	
45	Periodic Costs	$ 1,857,480	0.512	$ 950,500	5 year review, update plan, and Repair Costs
46	Annual O&M Costs	$ 1,180,644	0.504	$ 595,225	
47	Annual O&M Costs	$ 1,180,644	0.497	$ 586,428	
48	Annual O&M Costs	$ 1,180,644	0.489	$ 577,762	
49	Annual O&M Costs	$ 1,180,644	0.482	$ 569,224	
50	Annual O&M Costs	$ 1,180,644	0.475	$ 560,811	
50	Periodic Costs	$ 62,100	0.475	$ 29,498	5 year review, update plan, and Repair Costs
50	Periodic Costs	$ 5,453,300	0.475	$ 2,590,343	Repair sheet pile wall (50 percent of full install)
51	Annual O&M Costs	$ 1,180,644	0.468	$ 552,524	
52	Annual O&M Costs	$ 1,180,644	0.461	$ 544,358	
53	Annual O&M Costs	$ 1,180,644	0.454	$ 536,313	
54	Annual O&M Costs	$ 1,180,644	0.448	$ 528,388	
55	Annual O&M Costs	$ 1,180,644	0.441	$ 520,579	
55	Periodic Costs	$ 62,100	0.441	$ 27,382	5 year review, update plan, and Repair Costs
56	Annual O&M Costs	$ 1,180,644	0.434	$ 512,886	
57	Annual O&M Costs	$ 1,180,644	0.428	$ 505,306	
58	Annual O&M Costs	$ 1,180,644	0.422	$ 497,839	
59	Annual O&M Costs	$ 1,180,644	0.415	$ 490,481	
60	Annual O&M Costs	$ 1,180,644	0.409	$ 483,233	
60	Periodic Costs	$ 831,890	0.409	$ 340,489	5 year review, update plan, and Repair Costs
61	Annual O&M Costs	$ 1,180,644	0.403	$ 476,091	
62	Annual O&M Costs	$ 1,180,644	0.397	$ 469,056	
63	Annual O&M Costs	$ 1,180,644	0.391	$ 462,124	
64	Annual O&M Costs	$ 1,180,644	0.386	$ 455,294	
65	Annual O&M Costs	$ 1,180,644	0.380	$ 448,566	
65	Periodic Costs	$ 62,100	0.380	$ 23,594	5 year review, update plan, and Repair Costs
66	Annual O&M Costs	$ 1,180,644	0.374	$ 441,937	
67	Annual O&M Costs	$ 1,180,644	0.369	$ 435,406	
68	Annual O&M Costs	$ 1,180,644	0.363	$ 428,971	
69	Annual O&M Costs	$ 1,180,644	0.358	$ 422,632	
70	Annual O&M Costs	$ 1,180,644	0.353	$ 416,386	
70	Periodic Costs	$ 62,100	0.353	$ 21,901	5 year review, update plan, and Repair Costs

Containment Alternative C150
GROUNDWATER EXTRACTION AND TREATMENT

COST ESTIMATE SUMMARY C150

Site: "Occidental" Site
Location: Tacoma, Washington
Phase: Feasibility Study (-30% to +50%)
Base Year: 2016
Date: December 6, 2016

Description: 100-Year Cash Flow Projection at 1.5 percent

PRESENT VALUE ANALYSIS ***Base YR 2016*** 1.5% Discount Rate

Year	Cost Type	Cost	Discount Rate	Present Value	Notes
71	Annual O&M Costs	$ 1,180,644	0.347	$ 410,232	
72	Annual O&M Costs	$ 1,180,644	0.342	$ 404,170	
73	Annual O&M Costs	$ 1,180,644	0.337	$ 398,197	
74	Annual O&M Costs	$ 1,180,644	0.332	$ 392,312	
75	Annual O&M Costs	$ 1,180,644	0.327	$ 386,515	
75	Periodic Costs	$ 1,857,480	0.327	$ 608,094	5 year review, update plan, and Repair Costs
76	Annual O&M Costs	$ 1,180,644	0.323	$ 380,802	
77	Annual O&M Costs	$ 1,180,644	0.318	$ 375,175	
78	Annual O&M Costs	$ 1,180,644	0.313	$ 369,630	
79	Annual O&M Costs	$ 1,180,644	0.308	$ 364,168	
80	Annual O&M Costs	$ 1,180,644	0.304	$ 358,786	
80	Periodic Costs	$ 831,890	0.304	$ 252,803	5 year review, update plan, and Repair Costs
81	Annual O&M Costs	$ 1,180,644	0.299	$ 353,484	
82	Annual O&M Costs	$ 1,180,644	0.295	$ 348,260	
83	Annual O&M Costs	$ 1,180,644	0.291	$ 343,113	
84	Annual O&M Costs	$ 1,180,644	0.286	$ 338,043	
85	Annual O&M Costs	$ 1,180,644	0.282	$ 333,047	
85	Periodic Costs	$ 62,100	0.282	$ 17,518	5 year review, update plan, and Repair Costs
86	Annual O&M Costs	$ 1,180,644	0.278	$ 328,125	
87	Annual O&M Costs	$ 1,180,644	0.274	$ 323,276	
88	Annual O&M Costs	$ 1,180,644	0.270	$ 318,498	
89	Annual O&M Costs	$ 1,180,644	0.266	$ 313,792	
90	Annual O&M Costs	$ 1,180,644	0.262	$ 309,154	
90	Periodic Costs	$ 1,857,480	0.262	$ 486,385	5 year review, update plan, and Repair Costs
91	Annual O&M Costs	$ 1,180,644	0.258	$ 304,585	
92	Annual O&M Costs	$ 1,180,644	0.254	$ 300,084	
93	Annual O&M Costs	$ 1,180,644	0.250	$ 295,649	
94	Annual O&M Costs	$ 1,180,644	0.247	$ 291,280	
95	Annual O&M Costs	$ 1,180,644	0.243	$ 286,976	
95	Periodic Costs	$ 62,100	0.243	$ 15,094	5 year review, update plan, and Repair Costs
96	Annual O&M Costs	$ 1,180,644	0.239	$ 282,735	
97	Annual O&M Costs	$ 1,180,644	0.236	$ 278,556	
98	Annual O&M Costs	$ 1,180,644	0.232	$ 274,440	
99	Annual O&M Costs	$ 1,180,644	0.229	$ 270,384	
100	Annual O&M Costs	$ 1,180,644	0.226	$ 266,388	
100	GWTP Demolition	$ 1,000,000	0.226	$ 225,629	
100	Final Completion Report	$ 100,000	0.226	$ 22,563	
		$ 176,600,000		**$ 109,240,000**	

TOTAL PRESENT VALUE OF ALTERNATIVE **$ 109,240,000**

Containment Alternative C200
GROUNDWATER EXTRACTION AND TREATMENT

COST ESTIMATE SUMMARY C200

Site:	"Occidental" Site	Description:	100-Year Cash Flow Projection at 7 percent
Location:	Tacoma, Washington		
Phase:	Feasibility Study (-30% to +50%)		
Base Year:	2016		
Date:	December 6, 2016		

PRESENT VALUE ANALYSIS ***Base YR 2016*** 7.0% Discount Rate

Year	Cost Type	Cost	Discount Rate	Present Value	Notes
0	Capital Costs	$ 38,700,240	1.000	$ 38,700,240	
1	Annual O&M Costs	$ 1,247,834	0.935	$ 1,166,200	
2	Annual O&M Costs	$ 1,247,834	0.873	$ 1,089,907	
3	Annual O&M Costs	$ 1,247,834	0.816	$ 1,018,604	
4	Annual O&M Costs	$ 1,247,834	0.763	$ 951,967	
5	Annual O&M Costs	$ 1,247,834	0.713	$ 889,688	
5	Periodic Costs	$ 97,100	0.713	$ 69,231	5 year review, update plan, and Repair Costs
6	Annual O&M Costs	$ 1,247,834	0.666	$ 831,484	
7	Annual O&M Costs	$ 1,247,834	0.623	$ 777,088	
8	Annual O&M Costs	$ 1,247,834	0.582	$ 726,251	
9	Annual O&M Costs	$ 1,247,834	0.544	$ 678,739	
10	Annual O&M Costs	$ 1,247,834	0.508	$ 634,336	
10	Periodic Costs	$ 72,100	0.508	$ 36,652	5 year review, update plan, and Repair Costs
11	Annual O&M Costs	$ 1,247,834	0.475	$ 592,837	
12	Annual O&M Costs	$ 1,247,834	0.444	$ 554,053	
13	Annual O&M Costs	$ 1,247,834	0.415	$ 517,807	
14	Annual O&M Costs	$ 1,247,834	0.388	$ 483,932	
15	Annual O&M Costs	$ 1,247,834	0.362	$ 452,272	
15	Periodic Costs	$ 1,857,480	0.362	$ 673,236	5 year review, update plan, and Repair Costs
16	Annual O&M Costs	$ 1,247,834	0.339	$ 422,685	
17	Annual O&M Costs	$ 1,247,834	0.317	$ 395,032	
18	Annual O&M Costs	$ 1,247,834	0.296	$ 369,189	
19	Annual O&M Costs	$ 1,247,834	0.277	$ 345,036	
20	Annual O&M Costs	$ 1,247,834	0.258	$ 322,464	
20	Periodic Costs	$ 831,890	0.258	$ 214,976	5 year review, update plan, and Repair Costs
21	Annual O&M Costs	$ 1,247,834	0.242	$ 301,368	
22	Annual O&M Costs	$ 1,247,834	0.226	$ 281,653	
23	Annual O&M Costs	$ 1,247,834	0.211	$ 263,227	
24	Annual O&M Costs	$ 1,247,834	0.197	$ 246,006	
25	Annual O&M Costs	$ 1,247,834	0.184	$ 229,912	
25	Periodic Costs	$ 62,100	0.184	$ 11,442	5 year review, update plan, and Repair Costs
26	Annual O&M Costs	$ 1,247,834	0.172	$ 214,871	
27	Annual O&M Costs	$ 1,247,834	0.161	$ 200,814	
28	Annual O&M Costs	$ 1,247,834	0.150	$ 187,677	
29	Annual O&M Costs	$ 1,247,834	0.141	$ 175,399	
30	Annual O&M Costs	$ 1,247,834	0.131	$ 163,924	
30	Periodic Costs	$ 1,857,480	0.131	$ 244,012	5 year review, update plan, and Repair Costs
31	Annual O&M Costs	$ 1,247,834	0.123	$ 153,200	
32	Annual O&M Costs	$ 1,247,834	0.115	$ 143,178	
33	Annual O&M Costs	$ 1,247,834	0.107	$ 133,811	
34	Annual O&M Costs	$ 1,247,834	0.100	$ 125,057	
35	Annual O&M Costs	$ 1,247,834	0.094	$ 116,876	
35	Periodic Costs	$ 62,100	0.094	$ 5,816	5 year review, update plan, and Repair Costs
36	Annual O&M Costs	$ 1,247,834	0.088	$ 109,230	
37	Annual O&M Costs	$ 1,247,834	0.082	$ 102,084	
38	Annual O&M Costs	$ 1,247,834	0.076	$ 95,405	
39	Annual O&M Costs	$ 1,247,834	0.071	$ 89,164	
40	Annual O&M Costs	$ 1,247,834	0.067	$ 83,331	
40	Periodic Costs	$ 831,890	0.067	$ 55,554	5 year review, update plan, and Repair Costs
41	Annual O&M Costs	$ 1,247,834	0.062	$ 77,879	
42	Annual O&M Costs	$ 1,247,834	0.058	$ 72,784	
43	Annual O&M Costs	$ 1,247,834	0.055	$ 68,023	
44	Annual O&M Costs	$ 1,247,834	0.051	$ 63,573	
45	Annual O&M Costs	$ 1,247,834	0.048	$ 59,414	
45	Periodic Costs	$ 1,857,480	0.048	$ 88,441	5 year review, update plan, and Repair Costs
46	Annual O&M Costs	$ 1,247,834	0.044	$ 55,527	
47	Annual O&M Costs	$ 1,247,834	0.042	$ 51,894	
48	Annual O&M Costs	$ 1,247,834	0.039	$ 48,499	
49	Annual O&M Costs	$ 1,247,834	0.036	$ 45,326	
50	Annual O&M Costs	$ 1,247,834	0.034	$ 42,361	
50	Periodic Costs	$ 62,100	0.034	$ 2,108	5 year review, update plan, and Repair Costs
50	Periodic Costs	$ 5,453,300	0.034	$ 185,127	Repair sheet pile wall (50 percent of full install)
51	Annual O&M Costs	$ 1,247,834	0.032	$ 39,590	
52	Annual O&M Costs	$ 1,247,834	0.030	$ 37,000	
53	Annual O&M Costs	$ 1,247,834	0.028	$ 34,579	
54	Annual O&M Costs	$ 1,247,834	0.026	$ 32,317	
55	Annual O&M Costs	$ 1,247,834	0.024	$ 30,203	
55	Periodic Costs	$ 62,100	0.024	$ 1,503	5 year review, update plan, and Repair Costs
56	Annual O&M Costs	$ 1,247,834	0.023	$ 28,227	
57	Annual O&M Costs	$ 1,247,834	0.021	$ 26,380	
58	Annual O&M Costs	$ 1,247,834	0.020	$ 24,655	
59	Annual O&M Costs	$ 1,247,834	0.018	$ 23,042	
60	Annual O&M Costs	$ 1,247,834	0.017	$ 21,534	
60	Periodic Costs	$ 831,890	0.017	$ 14,356	5 year review, update plan, and Repair Costs
61	Annual O&M Costs	$ 1,247,834	0.016	$ 20,125	
62	Annual O&M Costs	$ 1,247,834	0.015	$ 18,809	
63	Annual O&M Costs	$ 1,247,834	0.014	$ 17,578	
64	Annual O&M Costs	$ 1,247,834	0.013	$ 16,428	
65	Annual O&M Costs	$ 1,247,834	0.012	$ 15,354	
65	Periodic Costs	$ 62,100	0.012	$ 764	5 year review, update plan, and Repair Costs
66	Annual O&M Costs	$ 1,247,834	0.011	$ 14,349	
67	Annual O&M Costs	$ 1,247,834	0.011	$ 13,410	
68	Annual O&M Costs	$ 1,247,834	0.010	$ 12,533	
69	Annual O&M Costs	$ 1,247,834	0.009	$ 11,713	
70	Annual O&M Costs	$ 1,247,834	0.009	$ 10,947	
70	Periodic Costs	$ 62,100	0.009	$ 545	5 year review, update plan, and Repair Costs

Containment Alternative C200
GROUNDWATER EXTRACTION AND TREATMENT

COST ESTIMATE SUMMARY C200

Site: "Occidental" Site
Location: Tacoma, Washington
Phase: Feasibility Study (-30% to +50%)
Base Year: 2016
Date: December 6, 2016

Description: 100-Year Cash Flow Projection at 7 percent

PRESENT VALUE ANALYSIS ***Base YR 2016*** 7.0% Discount Rate

Year	Cost Type	Cost	Discount Rate	Present Value	Notes
71	Annual O&M Costs	$ 1,247,834	0.008	$ 10,231	
72	Annual O&M Costs	$ 1,247,834	0.008	$ 9,561	
73	Annual O&M Costs	$ 1,247,834	0.007	$ 8,936	
74	Annual O&M Costs	$ 1,247,834	0.007	$ 8,351	
75	Annual O&M Costs	$ 1,247,834	0.006	$ 7,805	
75	Periodic Costs	$ 1,857,480	0.006	$ 11,618	5 year review, update plan, and Repair Costs
76	Annual O&M Costs	$ 1,247,834	0.006	$ 7,294	
77	Annual O&M Costs	$ 1,247,834	0.005	$ 6,817	
78	Annual O&M Costs	$ 1,247,834	0.005	$ 6,371	
79	Annual O&M Costs	$ 1,247,834	0.005	$ 5,954	
80	Annual O&M Costs	$ 1,247,834	0.004	$ 5,565	
80	Periodic Costs	$ 831,890	0.004	$ 3,710	5 year review, update plan, and Repair Costs
81	Annual O&M Costs	$ 1,247,834	0.004	$ 5,201	
82	Annual O&M Costs	$ 1,247,834	0.004	$ 4,861	
83	Annual O&M Costs	$ 1,247,834	0.004	$ 4,543	
84	Annual O&M Costs	$ 1,247,834	0.003	$ 4,245	
85	Annual O&M Costs	$ 1,247,834	0.003	$ 3,968	
85	Periodic Costs	$ 62,100	0.003	$ 197	5 year review, update plan, and Repair Costs
86	Annual O&M Costs	$ 1,247,834	0.003	$ 3,708	
87	Annual O&M Costs	$ 1,247,834	0.003	$ 3,466	
88	Annual O&M Costs	$ 1,247,834	0.003	$ 3,239	
89	Annual O&M Costs	$ 1,247,834	0.002	$ 3,027	
90	Annual O&M Costs	$ 1,247,834	0.002	$ 2,829	
90	Periodic Costs	$ 1,857,480	0.002	$ 4,211	5 year review, update plan, and Repair Costs
91	Annual O&M Costs	$ 1,247,834	0.002	$ 2,644	
92	Annual O&M Costs	$ 1,247,834	0.002	$ 2,471	
93	Annual O&M Costs	$ 1,247,834	0.002	$ 2,309	
94	Annual O&M Costs	$ 1,247,834	0.002	$ 2,158	
95	Annual O&M Costs	$ 1,247,834	0.002	$ 2,017	
95	Periodic Costs	$ 62,100	0.002	$ 100	5 year review, update plan, and Repair Costs
96	Annual O&M Costs	$ 1,247,834	0.002	$ 1,885	
97	Annual O&M Costs	$ 1,247,834	0.001	$ 1,762	
98	Annual O&M Costs	$ 1,247,834	0.001	$ 1,646	
99	Annual O&M Costs	$ 1,247,834	0.001	$ 1,539	
100	Annual O&M Costs	$ 1,247,834	0.001	$ 1,438	
100	GWTP Demolition	$ 1,000,000	0.001	$ 1,152	
100	Final Completion Report	$ 100,000	0.001	$ 115	
		$ 183,320,000		**$ 58,130,000**	

TOTAL PRESENT VALUE OF ALTERNATIVE **$ 58,130,000**

Containment Alternative C200
GROUNDWATER EXTRACTION AND TREATMENT

COST ESTIMATE SUMMARY C200

Site: "Occidental" Site
Location: Tacoma, Washington
Phase: Feasibility Study (-30% to +50%)
Base Year: 2016
Date: December 6, 2016

Description: 100-Year Cash Flow Projection at 1.5 percent

PRESENT VALUE ANALYSIS ***Base YR 2016*** 1.5% Discount Rate

Year	Cost Type	Cost	Discount Rate	Present Value	Notes
0	Capital Costs	$ 38,700,240	1.000	$ 38,700,240	
1	Annual O&M Costs	$ 1,247,834	0.985	$ 1,229,393	
2	Annual O&M Costs	$ 1,247,834	0.971	$ 1,211,225	
3	Annual O&M Costs	$ 1,247,834	0.956	$ 1,193,325	
4	Annual O&M Costs	$ 1,247,834	0.942	$ 1,175,690	
5	Annual O&M Costs	$ 1,247,834	0.928	$ 1,158,315	
5	Periodic Costs	$ 97,100	0.928	$ 90,134	5 year review, update plan, and Repair Costs
6	Annual O&M Costs	$ 1,247,834	0.915	$ 1,141,197	
7	Annual O&M Costs	$ 1,247,834	0.901	$ 1,124,332	
8	Annual O&M Costs	$ 1,247,834	0.888	$ 1,107,716	
9	Annual O&M Costs	$ 1,247,834	0.875	$ 1,091,346	
10	Annual O&M Costs	$ 1,247,834	0.862	$ 1,075,218	
10	Periodic Costs	$ 72,100	0.862	$ 62,126	5 year review, update plan, and Repair Costs
11	Annual O&M Costs	$ 1,247,834	0.849	$ 1,059,328	
12	Annual O&M Costs	$ 1,247,834	0.836	$ 1,043,673	
13	Annual O&M Costs	$ 1,247,834	0.824	$ 1,028,249	
14	Annual O&M Costs	$ 1,247,834	0.812	$ 1,013,053	
15	Annual O&M Costs	$ 1,247,834	0.800	$ 998,082	
15	Periodic Costs	$ 1,857,480	0.800	$ 1,485,708	5 year review, update plan, and Repair Costs
16	Annual O&M Costs	$ 1,247,834	0.788	$ 983,332	
17	Annual O&M Costs	$ 1,247,834	0.776	$ 968,800	
18	Annual O&M Costs	$ 1,247,834	0.765	$ 954,483	
19	Annual O&M Costs	$ 1,247,834	0.754	$ 940,377	
20	Annual O&M Costs	$ 1,247,834	0.742	$ 926,480	
20	Periodic Costs	$ 831,890	0.742	$ 617,654	5 year review, update plan, and Repair Costs
21	Annual O&M Costs	$ 1,247,834	0.731	$ 912,788	
22	Annual O&M Costs	$ 1,247,834	0.721	$ 899,299	
23	Annual O&M Costs	$ 1,247,834	0.710	$ 886,008	
24	Annual O&M Costs	$ 1,247,834	0.700	$ 872,915	
25	Annual O&M Costs	$ 1,247,834	0.689	$ 860,014	
25	Periodic Costs	$ 62,100	0.689	$ 42,800	5 year review, update plan, and Repair Costs
26	Annual O&M Costs	$ 1,247,834	0.679	$ 847,305	
27	Annual O&M Costs	$ 1,247,834	0.669	$ 834,783	
28	Annual O&M Costs	$ 1,247,834	0.659	$ 822,446	
29	Annual O&M Costs	$ 1,247,834	0.649	$ 810,292	
30	Annual O&M Costs	$ 1,247,834	0.640	$ 798,317	
30	Periodic Costs	$ 1,857,480	0.640	$ 1,188,346	5 year review, update plan, and Repair Costs
31	Annual O&M Costs	$ 1,247,834	0.630	$ 786,520	
32	Annual O&M Costs	$ 1,247,834	0.621	$ 774,896	
33	Annual O&M Costs	$ 1,247,834	0.612	$ 763,444	
34	Annual O&M Costs	$ 1,247,834	0.603	$ 752,162	
35	Annual O&M Costs	$ 1,247,834	0.594	$ 741,046	
35	Periodic Costs	$ 62,100	0.594	$ 36,879	5 year review, update plan, and Repair Costs
36	Annual O&M Costs	$ 1,247,834	0.585	$ 730,095	
37	Annual O&M Costs	$ 1,247,834	0.576	$ 719,305	
38	Annual O&M Costs	$ 1,247,834	0.568	$ 708,675	
39	Annual O&M Costs	$ 1,247,834	0.560	$ 698,202	
40	Annual O&M Costs	$ 1,247,834	0.551	$ 687,884	
40	Periodic Costs	$ 831,890	0.551	$ 458,590	5 year review, update plan, and Repair Costs
41	Annual O&M Costs	$ 1,247,834	0.543	$ 677,718	
42	Annual O&M Costs	$ 1,247,834	0.535	$ 667,703	
43	Annual O&M Costs	$ 1,247,834	0.527	$ 657,835	
44	Annual O&M Costs	$ 1,247,834	0.519	$ 648,113	
45	Annual O&M Costs	$ 1,247,834	0.512	$ 638,535	
45	Periodic Costs	$ 1,857,480	0.512	$ 950,500	5 year review, update plan, and Repair Costs
46	Annual O&M Costs	$ 1,247,834	0.504	$ 629,099	
47	Annual O&M Costs	$ 1,247,834	0.497	$ 619,802	
48	Annual O&M Costs	$ 1,247,834	0.489	$ 610,642	
49	Annual O&M Costs	$ 1,247,834	0.482	$ 601,618	
50	Annual O&M Costs	$ 1,247,834	0.475	$ 592,727	
50	Periodic Costs	$ 62,100	0.475	$ 29,498	5 year review, update plan, and Repair Costs
50	Periodic Costs	$ 5,453,300	0.475	$ 2,590,343	Repair sheet pile wall (50 percent of full install)
51	Annual O&M Costs	$ 1,247,834	0.468	$ 583,967	
52	Annual O&M Costs	$ 1,247,834	0.461	$ 575,337	
53	Annual O&M Costs	$ 1,247,834	0.454	$ 566,835	
54	Annual O&M Costs	$ 1,247,834	0.448	$ 558,458	
55	Annual O&M Costs	$ 1,247,834	0.441	$ 550,205	
55	Periodic Costs	$ 62,100	0.441	$ 27,382	5 year review, update plan, and Repair Costs
56	Annual O&M Costs	$ 1,247,834	0.434	$ 542,074	
57	Annual O&M Costs	$ 1,247,834	0.428	$ 534,063	
58	Annual O&M Costs	$ 1,247,834	0.422	$ 526,170	
59	Annual O&M Costs	$ 1,247,834	0.415	$ 518,394	
60	Annual O&M Costs	$ 1,247,834	0.409	$ 510,733	
60	Periodic Costs	$ 831,890	0.409	$ 340,489	5 year review, update plan, and Repair Costs
61	Annual O&M Costs	$ 1,247,834	0.403	$ 503,186	
62	Annual O&M Costs	$ 1,247,834	0.397	$ 495,749	
63	Annual O&M Costs	$ 1,247,834	0.391	$ 488,423	
64	Annual O&M Costs	$ 1,247,834	0.386	$ 481,205	
65	Annual O&M Costs	$ 1,247,834	0.380	$ 474,094	
65	Periodic Costs	$ 62,100	0.380	$ 23,594	5 year review, update plan, and Repair Costs
66	Annual O&M Costs	$ 1,247,834	0.374	$ 467,087	
67	Annual O&M Costs	$ 1,247,834	0.369	$ 460,184	
68	Annual O&M Costs	$ 1,247,834	0.363	$ 453,384	
69	Annual O&M Costs	$ 1,247,834	0.358	$ 446,683	
70	Annual O&M Costs	$ 1,247,834	0.353	$ 440,082	
70	Periodic Costs	$ 62,100	0.353	$ 21,901	5 year review, update plan, and Repair Costs

Containment Alternative C200
GROUNDWATER EXTRACTION AND TREATMENT

COST ESTIMATE SUMMARY C200

Site:	"Occidental" Site	Description:	100-Year Cash Flow Projection at 1.5 percent
Location:	Tacoma, Washington		
Phase:	Feasibility Study (-30% to +50%)		
Base Year:	2016		
Date:	December 6, 2016		

PRESENT VALUE ANALYSIS ***Base YR 2016*** 1.5% Discount Rate

Year	Cost Type	Cost	Discount Rate	Present Value	Notes
71	Annual O&M Costs	$ 1,247,834	0.347	$ 433,579	
72	Annual O&M Costs	$ 1,247,834	0.342	$ 427,171	
73	Annual O&M Costs	$ 1,247,834	0.337	$ 420,858	
74	Annual O&M Costs	$ 1,247,834	0.332	$ 414,639	
75	Annual O&M Costs	$ 1,247,834	0.327	$ 408,511	
75	Periodic Costs	$ 1,857,480	0.327	$ 608,094	5 year review, update plan, and Repair Costs
76	Annual O&M Costs	$ 1,247,834	0.323	$ 402,474	
77	Annual O&M Costs	$ 1,247,834	0.318	$ 396,526	
78	Annual O&M Costs	$ 1,247,834	0.313	$ 390,666	
79	Annual O&M Costs	$ 1,247,834	0.308	$ 384,893	
80	Annual O&M Costs	$ 1,247,834	0.304	$ 379,204	
80	Periodic Costs	$ 831,890	0.304	$ 252,803	5 year review, update plan, and Repair Costs
81	Annual O&M Costs	$ 1,247,834	0.299	$ 373,600	
82	Annual O&M Costs	$ 1,247,834	0.295	$ 368,079	
83	Annual O&M Costs	$ 1,247,834	0.291	$ 362,640	
84	Annual O&M Costs	$ 1,247,834	0.286	$ 357,280	
85	Annual O&M Costs	$ 1,247,834	0.282	$ 352,000	
85	Periodic Costs	$ 62,100	0.282	$ 17,518	5 year review, update plan, and Repair Costs
86	Annual O&M Costs	$ 1,247,834	0.278	$ 346,798	
87	Annual O&M Costs	$ 1,247,834	0.274	$ 341,673	
88	Annual O&M Costs	$ 1,247,834	0.270	$ 336,624	
89	Annual O&M Costs	$ 1,247,834	0.266	$ 331,649	
90	Annual O&M Costs	$ 1,247,834	0.262	$ 326,748	
90	Periodic Costs	$ 1,857,480	0.262	$ 486,385	5 year review, update plan, and Repair Costs
91	Annual O&M Costs	$ 1,247,834	0.258	$ 321,919	
92	Annual O&M Costs	$ 1,247,834	0.254	$ 317,162	
93	Annual O&M Costs	$ 1,247,834	0.250	$ 312,475	
94	Annual O&M Costs	$ 1,247,834	0.247	$ 307,857	
95	Annual O&M Costs	$ 1,247,834	0.243	$ 303,307	
95	Periodic Costs	$ 62,100	0.243	$ 15,094	5 year review, update plan, and Repair Costs
96	Annual O&M Costs	$ 1,247,834	0.239	$ 298,825	
97	Annual O&M Costs	$ 1,247,834	0.236	$ 294,409	
98	Annual O&M Costs	$ 1,247,834	0.232	$ 290,058	
99	Annual O&M Costs	$ 1,247,834	0.229	$ 285,771	
100	Annual O&M Costs	$ 1,247,834	0.226	$ 281,548	
100	GWTP Demolition	$ 1,000,000	0.226	$ 225,629	
100	Final Completion Report	$ 100,000	0.226	$ 22,563	
		$ 183,320,000		**$ 112,710,000**	

TOTAL PRESENT VALUE OF ALTERNATIVE	**$ 112,710,000**

Appendix G-2
VOC Mass Alternatives Cost Estimates

COMPARISON OF TOTAL COST OF VOC MASS REMEDIAL ALTERNATIVES

Site: "Occidental" Site
Location: Tacoma, Washington
Phase: Feasibility Study (-30% to +50%)

Base Year: 2016
Date: January 11, 2017

DESCRIPTION	Alternative M1 No Additional Action	Alternative M100 Groundwater Extraction Shallow and Deep Zones	Alternative M150 Groundwater Extraction Shallow and Deep Zones	Alternative M200 Groundwater Extraction Shallow and Deep Zones	Alternative MSP Strategic Groundwater Pumping Shallow and Deep Zones	Alternative M3 Soil Excavation And On-Site Treatment Shallow Zone	Alternative M5 ERH/SVE Shallow Zone	Alternative M6 Soil Excavation And On-Site Treatment And ERH/SVE Shallow Zone	Alternative M8 ERH/SVE And ISCO/ISB Shallow Zone	Alternative M9 ERH/SVE And ISCO/ISB Shallow and Deep Zones
Total Project Duration without C150 (Years)	0	30	30	30	30	1	1.5	2	19	19
Total Project Duration with C150 (Years)	30	30	30	30	30	30	30	30	30	30
Capital Cost	$38,700,240	$38,903,190	$38,903,190	$38,903,190	$38,854,780	$41,366,240	$50,712,040	$52,488,140	$114,264,240	$354,880,940
Annual O&M Cost	$1,180,644	$1,250,644	$1,282,584	$1,314,324	$1,210,180	$1,180,644	$1,180,644	$1,180,644	$1,189,644	$1,195,644
Total Periodic Cost	$2,920,670	$2,956,070	$2,956,070	$2,956,070	$2,920,670	$2,920,670	$2,920,670	$2,920,670	$29,796,220	$71,578,970
Total Present Value of Alternative (7%)	$54,356,480	$55,442,430	$55,838,770	$56,232,640	$54,877,530	$57,022,480	$66,368,280	$68,144,380	$142,006,010	$401,254,360
Total Present Value of Alternative (1.5%)	$69,352,840	$71,265,400	$72,032,470	$72,794,730	$70,216,710	$72,018,840	$81,364,640	$83,140,740	$167,471,640	$442,991,030

Note:
Costs for Alternative C150 (Containment) are added to all VOC mass remedial alternatives except Alternative MSP, which includes cost for containment already.

VOC Mass Reduction Alternative M100
GROUNDWATER EXTRACTION

COST ESTIMATE SUMMARY M100

Site: "Occidental" Site
Location: Tacoma, Washington
Phase: Feasibility Study (-30% to +50%) - 7%
Base Year: 2016
Date: December 8, 2016

Description: Mass Reduction Alternative M100 was designed to extract shallow and deep groundwater with high concentrations of VOC outside the areas of high pH. The pumping rate is estimated to be 35 gpm. Assume soil cuttings and trench spoils are placed under PDCE Barrier.

CAPITAL COSTS

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Installation of Extraction Wells and Conveyance				$ 136,250	See Cost Worksheet M-1
SUBTOTAL				$ 136,250	
Contingency		25%		$34,100	10% scope + 15% bid
SUBTOTAL				$170,350	
Project Management		5%		$8,600	
Remedial Design		8%		$13,700	
Construction Management		6%		$10,300	
TOTAL CAPITAL COSTS				**$202,950**	

ANNUAL O&M COSTS:

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Inspection	1	LS	$ 500	$ 500	
Monitoring Groundwater					
Monitoring, Sampling, and Reporting	0	LS	$ -	$ -	Included in containment alternative
Groundwater Treatment (Assumes GWETS for Containment Alternative)					
Carbon Consumption	0.7	EXCHANGE	$ 19,124	$ 13,387	GHD Quote
pH Adjustment	1	LS	$ 2,333	$ 2,333	GHD Quote
Dilution Water	9198	$/1000 gals	$ 2.60	$ 23,918	Assume city water for dilution - quote
SUBTOTAL				$ 39,600	
Extraction Wells and Forcemains					
Annual maintenance	1	LS	$ 3,000	$ 3,000	1.5 days
Off-Site Treatment / Disposal					
Off-Site Transport/disposal of Solids	5	ton	$ 720	$ 3,600	Vendor Quote
SUBTOTAL				$ 46,700	
Contingency		30%		$ 14,100	10% scope + 20% bid
SUBTOTAL				$ 60,800	
Project Management		5%		$ 3,100	
Technical Support		10%		$ 6,100	
TOTAL ANNUAL O&M COSTS				**$ 70,000**	

PERIODIC COSTS:

DESCRIPTION	YEAR	QTY	UNIT	UNIT COST	TOTAL	NOTES
Pump Replacement	5	1	EA	$ 7,080	$ 7,080	See Cost Worksheet M-2
Pump Replacement	10	1	EA	$ 7,080	$ 7,080	See Cost Worksheet M-2
Pump Replacement	15	1	EA	$ 7,080	$ 7,080	See Cost Worksheet M-2
Pump Replacement	20	1	EA	$ 7,080	$ 7,080	See Cost Worksheet M-2
Pump Replacement	25	1	EA	$ 7,080	$ 7,080	See Cost Worksheet M-2

PRESENT VALUE ANALYSIS:

COST TYPE	YEAR	TOTAL COST	TOTAL COST PER YEAR	DISCOUNT FACTOR (7%)	PRESENT VALUE	NOTES
Capital Cost	0	$ 202,950	$ 202,950	1	$ 202,950	
Annual O&M Cost	1-30	$ 2,100,000	$ 70,000	12.41	$ 868,640	30 years
Periodic Cost	5	$ 7,080	$ 7,080	0.713	$ 5,050	Equipment replacement
Periodic Cost	10	$ 7,080	$ 7,080	0.508	$ 3,600	Equipment replacement
Periodic Cost	15	$ 7,080	$ 7,080	0.362	$ 2,570	Equipment replacement
Periodic Cost	20	$ 7,080	$ 7,080	0.258	$ 1,830	Equipment replacement
Periodic Cost	25	$ 7,080	$ 7,080	0.184	$ 1,310	Equipment replacement
		$ 2,338,350			$ 1,085,950	
TOTAL PRESENT VALUE OF ALTERNATIVE					**$ 1,085,950**	

VOC Mass Reduction Alternative M100
GROUNDWATER EXTRACTION

COST ESTIMATE SUMMARY M100

Site:	"Occidental" Site	Description:	Mass Reduction Alternative M100 was designed to extract shallow and deep groundwater with high concentrations of VOC outside the areas of high pH. The pumping rate is estimated to be 35 gpm. Assume soil cuttings and trench spoils are placed under PDCE Barrier.
Location:	Tacoma, Washington		
Phase:	Feasibility Study (-30% to +50%) - 1.5%		
Base Year:	2016		
Date:	December 8, 2016		

CAPITAL COSTS

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Installation of Extraction Wells and Conveyance				$ 136,250	See Cost Worksheet M-1
SUBTOTAL				$ 136,250	
Contingency		25%		$34,100	10% scope + 15% bid
SUBTOTAL				$170,350	
Project Management		5%		$8,600	
Remedial Design		8%		$13,700	
Construction Management		6%		$10,300	
TOTAL CAPITAL COSTS				**$202,950**	

ANNUAL O&M COSTS:

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Inspection	1	LS	$ 500	$ 500	
Monitoring Groundwater					
Monitoring, Sampling, and Reporting	0	LS	$ -	$ -	Included in containment alternative
Groundwater Treatment (Assumes GWETS for Containment Alternative)					
Carbon Consumption	0.7	EXCHANGE	$ 19,124	$ 13,387	GHD Quote
pH Adjustment	1	LS	$ 2,333	$ 2,333	GHD Quote
Dilution Water	9198	$/1000 gals	$ 2.60	$ 23,918	Assume city water for dilution - quote
SUBTOTAL				$ 39,600	
Extraction Wells and Forcemains					
Annual maintenance	1	LS	$ 3,000	$ 3,000	1.5 days
Off-Site Treatment / Disposal					
Off-Site Transport/disposal of Solids	5	ton	$ 720	$ 3,600	Vendor Quote
SUBTOTAL				$ 46,700	
Contingency		30%		$ 14,100	10% scope + 20% bid
SUBTOTAL				$ 60,800	
Project Management		5%		$ 3,100	
Technical Support		10%		$ 6,100	
TOTAL ANNUAL O&M COSTS				**$ 70,000**	

PERIODIC COSTS:

DESCRIPTION	YEAR	QTY	UNIT	UNIT COST	TOTAL	NOTES
Pump Replacement	5	1	EA	$ 7,080	$ 7,080	See Cost Worksheet M-2
Pump Replacement	10	1	EA	$ 7,080	$ 7,080	See Cost Worksheet M-2
Pump Replacement	15	1	EA	$ 7,080	$ 7,080	See Cost Worksheet M-2
Pump Replacement	20	1	EA	$ 7,080	$ 7,080	See Cost Worksheet M-2
Pump Replacement	25	1	EA	$ 7,080	$ 7,080	See Cost Worksheet M-2

PRESENT VALUE ANALYSIS:

COST TYPE	YEAR	TOTAL COST	TOTAL COST PER YEAR	DISCOUNT FACTOR (1.5%)	PRESENT VALUE	NOTES
Capital Cost	0	$ 202,950	$ 202,950	1	$ 202,950	
Annual O&M Cost	1-30	$ 2,100,000	$ 70,000	24.02	$ 1,681,110	30 years
Periodic Cost	5	$ 7,080	$ 7,080	0.928	$ 6,580	Equipment replacement
Periodic Cost	10	$ 7,080	$ 7,080	0.862	$ 6,110	Equipment replacement
Periodic Cost	15	$ 7,080	$ 7,080	0.800	$ 5,670	Equipment replacement
Periodic Cost	20	$ 7,080	$ 7,080	0.742	$ 5,260	Equipment replacement
Periodic Cost	25	$ 7,080	$ 7,080	0.689	$ 4,880	Equipment replacement
		$ 2,338,350			$ 1,912,560	

TOTAL PRESENT VALUE OF ALTERNATIVE **$ 1,912,560**

VOC Mass Reduction Alternative M150
GROUNDWATER EXTRACTION

COST ESTIMATE SUMMARY M150

Site: "Occidental" Site
Location: Tacoma, Washington
Phase: Feasibility Study (-30% to +50%) - 7%
Base Year: 2016
Date: December 8, 2016

Description: Mass Reduction Alternative M150 was designed to extract shallow and deep groundwater with high concentrations of VOC outside the areas of high pH. The pumping rate is estimated to be 52.5 gpm. Assume soil cuttings and trench spoils are placed under PDCE Barrier.

CAPITAL COSTS

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Installation of Extraction Wells and Conveyance				$ 136,250	See Cost Worksheet M-1
SUBTOTAL				$ 136,250	
Contingency		25%		$34,100	10% scope + 15% bid
SUBTOTAL				$170,350	
Project Management		5%		$8,600	
Remedial Design		8%		$13,700	
Construction Management		6%		$10,300	
TOTAL CAPITAL COSTS				**$202,950**	

ANNUAL O&M COSTS:

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Inspection	1	LS	$ 500	$ 500	
Monitoring Groundwater					
Monitoring, Sampling, and Reporting	0	LS	$ -	$ -	Included in containment alternative
Groundwater Treatment (Assumes GWETS for Containment Alternative)					
Carbon Consumption	1.05	EXCHANGE	$ 19,124	$ 20,080	GHD Quote
pH Adjustment	1	LS	$ 3,500	$ 3,500	GHD Quote
Dilution Water	13797	$/1000 gals	$ 2.60	$ 35,877	Assume city water for dilution - quote
SUBTOTAL				$ 59,500	
Extraction Wells and Forcemains					
Annual maintenance	1	LS	$ 3,000	$ 3,000	1.5 days
Off-Site Treatment / Disposal					
Off-Site Transport/disposal of Solids	7	ton	$ 720	$ 5,040	Vendor Quote
SUBTOTAL				$ 68,040	
Contingency		30%		$ 20,500	10% scope + 20% bid
SUBTOTAL				$ 88,540	
Project Management		5%		$ 4,500	
Technical Support		10%		$ 8,900	
TOTAL ANNUAL O&M COSTS				**$ 101,940**	

PERIODIC COSTS:

DESCRIPTION	YEAR	QTY	UNIT	UNIT COST	TOTAL	NOTES
Pump Replacement	5	1	EA	$ 7,080	$ 7,080	See Cost Worksheet M-2
Pump Replacement	10	1	EA	$ 7,080	$ 7,080	See Cost Worksheet M-2
Pump Replacement	15	1	EA	$ 7,080	$ 7,080	See Cost Worksheet M-2
Pump Replacement	20	1	EA	$ 7,080	$ 7,080	See Cost Worksheet M-2
Pump Replacement	25	1	EA	$ 7,080	$ 7,080	See Cost Worksheet M-2

PRESENT VALUE ANALYSIS:

COST TYPE	YEAR	TOTAL COST	TOTAL COST PER YEAR	DISCOUNT FACTOR (7%)	PRESENT VALUE	NOTES
Capital Cost	0	$ 202,950	$ 202,950	1	$ 202,950	
Annual O&M Cost	1-30	$ 3,058,200	$ 101,940	12.41	$ 1,264,980	30 years
Periodic Cost	5	$ 7,080	$ 7,080	0.713	$ 5,050	Equipment replacement
Periodic Cost	10	$ 7,080	$ 7,080	0.508	$ 3,600	Equipment replacement
Periodic Cost	15	$ 7,080	$ 7,080	0.362	$ 2,570	Equipment replacement
Periodic Cost	20	$ 7,080	$ 7,080	0.258	$ 1,830	Equipment replacement
Periodic Cost	25	$ 7,080	$ 7,080	0.184	$ 1,310	Equipment replacement
		$ 3,296,550			$ 1,482,290	

TOTAL PRESENT VALUE OF ALTERNATIVE **$ 1,482,290**

VOC Mass Reduction Alternative M150
GROUNDWATER EXTRACTION

COST ESTIMATE SUMMARY M150

Site: "Occidental" Site
Location: Tacoma, Washington
Phase: Feasibility Study (-30% to +50%) - 1.5%
Base Year: 2016
Date: December 8, 2016

Description: Mass Reduction Alternative M150 was designed to extract shallow and deep groundwater with high concentrations of VOC outside the areas of high pH. The pumping rate is estimated to be 52.5 gpm. Assume soil cuttings and trench spoils are placed under PDCE Barrier.

CAPITAL COSTS

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Installation of Extraction Wells and Conveyance				$ 136,250	See Cost Worksheet M-1
SUBTOTAL				$ 136,250	
Contingency		25%		$34,100	10% scope + 15% bid
SUBTOTAL				$170,350	
Project Management		5%		$8,600	
Remedial Design		8%		$13,700	
Construction Management		6%		$10,300	
TOTAL CAPITAL COSTS				**$202,950**	

ANNUAL O&M COSTS:

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Inspection	1	LS	$ 500	$ 500	
Monitoring Groundwater					
Monitoring, Sampling, and Reporting	0	LS	$ -	$ -	Included in containment alternative
Groundwater Treatment (Assumes GWETS for Containment Alternative)					
Carbon Consumption	1.05	EXCHANGE	$ 19,124	$ 20,080	GHD Quote
pH Adjustment	1	LS	$ 3,500	$ 3,500	GHD Quote
Dilution Water	13797	$/1000 gals	$ 2.60	$ 35,877	Assume city water for dilution - quote
SUBTOTAL				$ 59,500	
Extraction Wells and Forcemains					
Annual maintenance	1	LS	$ 3,000	$ 3,000	1.5 days
Off-Site Treatment / Disposal					
Off-Site Transport/disposal of Solids	7	ton	$ 720	$ 5,040	Vendor Quote
SUBTOTAL				$ 68,040	
Contingency		30%		$ 20,500	10% scope + 20% bid
SUBTOTAL				$ 88,540	
Project Management		5%		$ 4,500	
Technical Support		10%		$ 8,900	
TOTAL ANNUAL O&M COSTS				**$ 101,940**	

PERIODIC COSTS:

DESCRIPTION	YEAR	QTY	UNIT	UNIT COST	TOTAL	NOTES
Pump Replacement	5	1	EA	$ 7,080	$ 7,080	See Cost Worksheet M-2
Pump Replacement	10	1	EA	$ 7,080	$ 7,080	See Cost Worksheet M-2
Pump Replacement	15	1	EA	$ 7,080	$ 7,080	See Cost Worksheet M-2
Pump Replacement	20	1	EA	$ 7,080	$ 7,080	See Cost Worksheet M-2
Pump Replacement	25	1	EA	$ 7,080	$ 7,080	See Cost Worksheet M-2

PRESENT VALUE ANALYSIS:

COST TYPE	YEAR	TOTAL COST	TOTAL COST PER YEAR	DISCOUNT FACTOR (1.5%)	PRESENT VALUE	NOTES
Capital Cost	0	$ 202,950	$ 202,950	1	$ 202,950	
Annual O&M Cost	1-30	$ 3,058,200	$ 101,940	24.02	$ 2,448,180	30 years
Periodic Cost	5	$ 7,080	$ 7,080	0.928	$ 6,580	Equipment replacement
Periodic Cost	10	$ 7,080	$ 7,080	0.862	$ 6,110	Equipment replacement
Periodic Cost	15	$ 7,080	$ 7,080	0.800	$ 5,670	Equipment replacement
Periodic Cost	20	$ 7,080	$ 7,080	0.742	$ 5,260	Equipment replacement
Periodic Cost	25	$ 7,080	$ 7,080	0.689	$ 4,880	Equipment replacement
		$ 3,296,550			$ 2,679,630	

TOTAL PRESENT VALUE OF ALTERNATIVE **$ 2,679,630**

VOC Mass Reduction Alternative M200
GROUNDWATER EXTRACTION

COST ESTIMATE SUMMARY M200

Site: "Occidental" Site
Location: Tacoma, Washington
Phase: Feasibility Study (-30% to +50%) - 7%
Base Year: 2016
Date: December 8, 2016

Description: Mass Reduction Alternative M200 was designed to extract shallow and deep groundwater with high concentrations of VOC outside the areas of high pH. The pumping rate is estimated to be 70 gpm. Assume soil cuttings and trench spoils are placed under PDCE Barrier.

CAPITAL COSTS

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Installation of Extraction Wells and Conveyance				$ 136,250	See Cost Worksheet M-1
SUBTOTAL				$ 136,250	
Contingency		25%		$34,100	10% scope + 15% bid
SUBTOTAL				$170,350	
Project Management		5%		$8,600	
Remedial Design		8%		$13,700	
Construction Management		6%		$10,300	
TOTAL CAPITAL COSTS				**$202,950**	

ANNUAL O&M COSTS:

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Inspection	1	LS	$ 500	$ 500	
Monitoring Groundwater					
Monitoring, Sampling, and Reporting	0	LS	$ -	$ -	Included in containment alternative
Groundwater Treatment (Assumes GWETS for Containment Alternative)					
Carbon Consumption	1.4	EXCHANGE	$ 19,124	$ 26,774	GHD Quote
pH Adjustment	1	LS	$ 4,667	$ 4,667	GHD Quote
Dilution Water	18396	$/1000 gals	$ 2.60	$ 47,836	Assume city water for dilution - quote
SUBTOTAL				$ 79,300	
Extraction Wells and Forcemains					
Annual maintenance	1	LS	$ 3,000	$ 3,000	1.5 days
Off-Site Treatment / Disposal					
Off-Site Transport/disposal of Solids	9	ton	$ 720	$ 6,480	Vendor Quote
SUBTOTAL				$ 89,280	
Contingency		30%		$ 26,800	10% scope + 20% bid
SUBTOTAL				$ 116,080	
Project Management		5%		$ 5,900	
Technical Support		10%		$ 11,700	
TOTAL ANNUAL O&M COSTS				**$ 133,680**	

PERIODIC COSTS:

DESCRIPTION	YEAR	QTY	UNIT	UNIT COST	TOTAL	NOTES
Pump Replacement	5	1	EA	$ 7,080	$ 7,080	See Cost Worksheet M-2
Pump Replacement	10	1	EA	$ 7,080	$ 7,080	See Cost Worksheet M-2
Pump Replacement	15	1	EA	$ 7,080	$ 7,080	See Cost Worksheet M-2
Pump Replacement	20	1	EA	$ 7,080	$ 7,080	See Cost Worksheet M-2
Pump Replacement	25	1	EA	$ 7,080	$ 7,080	See Cost Worksheet M-2

PRESENT VALUE ANALYSIS:

COST TYPE	YEAR	TOTAL COST	TOTAL COST PER YEAR	DISCOUNT FACTOR (7%)	PRESENT VALUE	NOTES
Capital Cost	0	$ 202,950	$ 202,950	1	$ 202,950	
Annual O&M Cost	1-30	$ 4,010,400	$ 133,680	12.41	$ 1,658,850	30 years
Periodic Cost	5	$ 7,080	$ 7,080	0.713	$ 5,050	Equipment replacement
Periodic Cost	10	$ 7,080	$ 7,080	0.508	$ 3,600	Equipment replacement
Periodic Cost	15	$ 7,080	$ 7,080	0.362	$ 2,570	Equipment replacement
Periodic Cost	20	$ 7,080	$ 7,080	0.258	$ 1,830	Equipment replacement
Periodic Cost	25	$ 7,080	$ 7,080	0.184	$ 1,310	Equipment replacement
		$ 4,248,750			$ 1,876,160	

TOTAL PRESENT VALUE OF ALTERNATIVE **$ 1,876,160**

VOC Mass Reduction Alternative M200
GROUNDWATER EXTRACTION

COST ESTIMATE SUMMARY M200

Site: "Occidental" Site
Location: Tacoma, Washington
Phase: Feasibility Study (-30% to +50%) - 1.5%
Base Year: 2016
Date: December 8, 2016

Description: Mass Reduction Alternative M200 was designed to extract shallow and deep groundwater with high concentrations of VOC outside the areas of high pH. The pumping rate is estimated to be 70 gpm. Assume soil cuttings and trench spoils are placed under PDCE Barrier.

CAPITAL COSTS

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Installation of Extraction Wells and Conveyance				$ 136,250	See Cost Worksheet M-1
SUBTOTAL				$ 136,250	
Contingency		25%		$34,100	10% scope + 15% bid
SUBTOTAL				$170,350	
Project Management		5%		$8,600	
Remedial Design		8%		$13,700	
Construction Management		6%		$10,300	
TOTAL CAPITAL COSTS				**$202,950**	

ANNUAL O&M COSTS:

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Inspection	1	LS	$ 500	$ 500	
Monitoring Groundwater					
Monitoring, Sampling, and Reporting	0	LS	$ -	$ -	Included in containment alternative
Groundwater Treatment (Assumes GWETS for Containment Alternative)					
Carbon Consumption	1.4	EXCHANGE	$ 19,124	$ 26,774	GHD Quote
pH Adjustment	1	LS	$ 4,667	$ 4,667	GHD Quote
Dilution Water	18396	$/1000 gals	$ 2.60	$ 47,836	Assume city water for dilution - quote
SUBTOTAL				$ 79,300	
Extraction Wells and Forcemains					
Annual maintenance	1	LS	$ 3,000	$ 3,000	1.5 days
Off-Site Treatment / Disposal					
Off-Site Transport/disposal of Solids	9	ton	$ 720	$ 6,480	Vendor Quote
SUBTOTAL				$ 89,280	
Contingency		30%		$ 26,800	10% scope + 20% bid
SUBTOTAL				$ 116,080	
Project Management		5%		$ 5,900	
Technical Support		10%		$ 11,700	
TOTAL ANNUAL O&M COSTS				**$ 133,680**	

PERIODIC COSTS:

DESCRIPTION	YEAR	QTY	UNIT	UNIT COST	TOTAL	NOTES
Pump Replacement	5	1	EA	$ 7,080	$ 7,080	See Cost Worksheet M-2
Pump Replacement	10	1	EA	$ 7,080	$ 7,080	See Cost Worksheet M-2
Pump Replacement	15	1	EA	$ 7,080	$ 7,080	See Cost Worksheet M-2
Pump Replacement	20	1	EA	$ 7,080	$ 7,080	See Cost Worksheet M-2
Pump Replacement	25	1	EA	$ 7,080	$ 7,080	See Cost Worksheet M-2

PRESENT VALUE ANALYSIS:

COST TYPE	YEAR	TOTAL COST	TOTAL COST PER YEAR	DISCOUNT FACTOR (1.5%)	PRESENT VALUE	NOTES
Capital Cost	0	$ 202,950	$ 202,950	1	$ 202,950	
Annual O&M Cost	1-30	$ 4,010,400	$ 133,680	24.02	$ 3,210,440	30 years
Periodic Cost	5	$ 7,080	$ 7,080	0.928	$ 6,580	Equipment replacement
Periodic Cost	10	$ 7,080	$ 7,080	0.862	$ 6,110	Equipment replacement
Periodic Cost	15	$ 7,080	$ 7,080	0.800	$ 5,670	Equipment replacement
Periodic Cost	20	$ 7,080	$ 7,080	0.742	$ 5,260	Equipment replacement
Periodic Cost	25	$ 7,080	$ 7,080	0.689	$ 4,880	Equipment replacement
		$ 4,248,750			$ 3,441,890	
TOTAL PRESENT VALUE OF ALTERNATIVE					**$ 3,441,890**	

VOC Mass Reduction Alternative MSP
GROUNDWATER EXTRACTION AND TREATMENT

COST ESTIMATE SUMMARY MSP

Site: "Occidental" Site
Location: Tacoma, Washington
Phase: Feasibility Study (-30% to +50%) - 7%
Base Year: 2016
Date: December 8, 2016

Description: Mass Reduction Alternative MSP is designed to reduce VOC mass and eliminate potentially complete exposure pathways, and includes: extraction of shallow and deep groundwater with high concentrations of VOC outside the areas of high pH; institutional controls; groundwater monitoring; a Physical Direct Contact Exposure (PDCE) Barrier for 605 & 709 Alexander Avenue Properties, Navy Todd Dump, N Landfill, and 709 Embankment Fill Area; a sheet pile barrier wall adjacent to Hylebos; and hydraulic containment using a newly constructed GWETS. The pumping rate is estimated to be 210 gpm. Assume soil cuttings and trench spoils are placed under PDCE Barrier. Capital Costs occur in Year 0. Annual O&M costs occur in Years 1-30. Periodic costs occur in years 5,10, 15, 20, and 25.

CAPITAL COSTS

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Mobilization/Demobilization					
Construction Equipment & Facilities	1	LS	$ 25,000	$ 25,000	Excavators, Loaders, etc.
Temporary facilities and Utilities	1	LS	$ 50,000	$ 50,000	Fence, roads, signs, trailers, etc.
H&S Plans and Submittals	1	LS	$ 15,000	$ 15,000	HASP, quality control, etc.
Design, Work Plans, Permits	1	LS	$ 100,000	$ 100,000	Barrier wall
Design, Work Plans, Permits	1	LS	$ 50,000	$ 50,000	Physical Direct Contact Exposure Barrier
Post-construction Submittals	1	LS	$ 150,000	$ 150,000	Report completed work
SUBTOTAL				$ 390,000	
Site Work					
Demolition of North Dock	1	LS	$ 446,000	$ 446,000	Quotation from vendor - See Cost Worksheet C-1
Demolition of South Dock	1	LS	$ 248,000	$ 248,000	Quotation from vendor - See Cost Worksheet C-2
Demolition of Existing Structures	1	LS	$ 250,000	$ 250,000	Treatment plant, office, misc. - Assumption
Construction Oversight	50	DAY	$ 1,920	$ 96,000	Assume 2 people
SUBTOTAL				$ 1,040,000	
Barrier Wall East Installation					
Mobilization/Demobilization	1	LS	$ 50,000	$ 50,000	2,180 ft long by 73.5 ft deep. Assuming barge installation
Sheet Pile	4300	TN	$ 1,900	$ 8,170,000	Vendor quote (PZ-27 sheet)
Unload Sheet Pile	220	LS	$ 2,350	$ 517,000	Vendor quote
Install Perimeter SP Wall	160000	SF	$ 12	$ 1,920,000	Vendor quote (Adeka sealant; Anchor piles on 6' centers)
Fill along embankment behind wall	40370	CY	$ 18	$ 726,670	Avg. Depth 10 ft; 50 ft wide
Construction Oversight	130	DAY	$ 1,920	$ 249,600	Assume 2 people
Mitigation of Intertidal Areas	1	LS	$ 250,000	$ 250,000	Allowance
SUBTOTAL				$ 11,883,270	
Physical Direct Contact Exposure Barrier					
Mobilization/Demobilization	1	LS	$ 50,000	$ 50,000	
Preparation	1502820	SF	$ 0.6	$ 901,700	Remove debris and prepare surface. 34.5 acres.
Aggregate Base	27830	CY	$ 35	$ 974,050	6 inch base
Asphalt Cover (assume 4")	1502820	SF	$ 2	$ 3,005,640	Facility Construction Cost - RSMeans (2016)
Construction Oversight	130	DAY	$ 1,920	$ 249,600	Assume 2 personal
SUBTOTAL				$ 5,180,990	
VOC Mass Extraction and Hydraulic Containment					
Mobilization/Demobilization	1	LS	$ 50,000	$ 50,000	
Groundwater Extraction System	1	LS	$ 1,031,360	$ 1,031,360	See Cost Worksheet M-13
Groundwater Treatment Equipment	1	LS	$ 2,544,230	$ 2,544,230	Assume 300 gpm System - See Cost Worksheet C-4
Groundwater Treatment Facility Building	1	LS	$ 2,145,820	$ 2,145,820	See Cost Worksheet C-5
High pH Treatment Additional Equipment	1	LS	$ 27,000	$ 27,000	Acid metering pump and equalization tank.
Construction Oversight	260	Day	$ 1,920	$ 499,200	
SUBTOTAL				$ 6,297,610	
Off-Site Treatment / Disposal					
Off-Site T&D of Soil Cuttings	20	CY	$ 394	$ 7,880	Vendor Quote
Off-Site T&D of Spoils	1250	CY	$ 394	$ 491,920	Vendor Quote
Off-Site T&D of Spoils - Hazardous	750	CY	$ 977	$ 732,780	Vendor Quote
SUBTOTAL				$ 1,232,580	
SUBTOTAL				$ 26,024,450	
Contingency		25%		$ 6,506,110	10% scope + 15% bid
SUBTOTAL				$ 32,530,560	
Project Management		5%		$ 1,626,530	
Remedial Design		8%		$ 2,602,450	
Construction Management		6%		$ 1,951,840	
Institutional Controls					
Institutional Controls Plan	1	LS	$ 13,000	$ 13,000	Description and implementation
Groundwater Use Restrictions	1	LS	$ 10,000	$ 10,000	Legal fees
Site Database	1	LS	$ 5,000	$ 5,000	Data management system
Documentation	1	LS	$ 20,000	$ 20,000	other submittals and documents
Perimeter fence	5300	FOOT	$ 18	$ 95,400	605 and 709 properties
SUBTOTAL				$ 143,400	
TOTAL CAPITAL COSTS				**$ 38,854,780**	

VOC Mass Reduction Alternative MSP
GROUNDWATER EXTRACTION AND TREATMENT

COST ESTIMATE SUMMARY MSP

Site: "Occidental" Site
Location: Tacoma, Washington
Phase: Feasibility Study (-30% to +50%) - 7%
Base Year: 2016
Date: December 8, 2016

Description: Mass Reduction Alternative MSP is designed to reduce VOC mass and eliminate potentially complete exposure pathways, and includes: extraction of shallow and deep groundwater with high concentrations of VOC outside the areas of high pH; institutional controls; groundwater monitoring; a Physical Direct Contact Exposure (PDCE) Barrier for 605 & 709 Alexander Avenue Properties, Navy Todd Dump, N Landfill, and 709 Embankment Fill Area; a sheet pile barrier wall adjacent to Hylebos; and hydraulic containment using a newly constructed GWETS. The pumping rate is estimated to be 210 gpm. Assume soil cuttings and trench spoils are placed under PDCE Barrier. Capital Costs occur in Year 0. Annual O&M costs occur in Years 1-30. Periodic costs occur in years 5,10, 15, 20, and 25.

ANNUAL O&M COSTS:

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Inspections					
Mobilization and Inspection	1	LS	$ 2,600	$ 2,600	Barriers and fencing
Reporting	1	LS	$ 5,200	$ 5,200	Inspection documentation
SUBTOTAL				$ 7,800	
Monitoring Groundwater					
Monitoring, sampling and reporting	1	LS	$ 297,000	$ 297,000	Will be in OMMP
Physical Direct Contact Exposure Barrier Maintenance					
Annual maintenance	1	LS	$ 10,000	$ 10,000	Allowance
Groundwater Treatment Plant					
Operation	1	year	$ 124,500	$ 124,500	GHD Quote
Carbon Consumption	7.5	EXCHANGE	$ 19,124	$ 143,430	GHD Quote
pH Adjustment	1	LS	$ 25,000	$ 25,000	GHD Quote
Equipment Allowance	1	LS	$ 6,000	$ 6,000	Allowance
Dilution Water	55190	$/1000 gals	$ 2.60	$ 143,500	Assume city water for dilution - quote
SUBTOTAL				$ 442,430	
Extraction Wells and Forcemains					
Annual maintenance	1	LS	$ 20,000	$ 20,000	Two weeks of work
Off-Site Treatment / Disposal					
Off-Site Transport/disposal of Solids	41	ton	$ 720	$ 29,520	Vendor Quote
SUBTOTAL				$ 806,750	
Contingency		30%		$ 242,030	10% scope + 20% bid
SUBTOTAL				$ 1,048,780	
Project Management		5%		$ 52,500	
Technical Support		10%		$ 104,900	
Site Info Database	1	LS	$ 4,000	$ 4,000	Update and maintain database
TOTAL ANNUAL O&M COSTS				**$ 1,210,180**	

PERIODIC COSTS:

DESCRIPTION	YEAR	QTY	UNIT	UNIT COST	TOTAL	NOTES
Five Year Review Report	5	1	EA	$ 75,000	$ 75,000	Report after 5 years
Equipment Replacement	5	1	LS	$ 19,100	$ 19,100	Equipment Replacement- See Cost Worksheet M-14
Update IC Plan	5	1	EA	$ 3,000	$ 3,000	Update Plan
SUBTOTAL					$ 97,100	
Five Year Review Report	10	1	EA	$ 50,000	$ 50,000	Report after 10 years
Equipment Replacement	5	1	LS	$ 19,100	$ 19,100	Equipment Replacement- See Cost Worksheet M-14
Update IC Plan	10	1	EA	$ 3,000	$ 3,000	Update Plan
SUBTOTAL					$ 72,100	
Five Year Review Report	15	1	EA	$ 40,000	$ 40,000	Report after 15 years
Cap Repair	15	1	LS	$ 300,570	$ 300,570	10 percent of asphalt
Equipment Replacement	15	1	LS	$ 1,503,910	$ 1,503,910	Equipment Replacement- See Cost Worksheet M-14
Update IC Plan	15	1	EA	$ 3,000	$ 3,000	Update Plan
Remedial Action Report	15	1	EA	$ 10,000	$ 10,000	
SUBTOTAL					$ 1,857,480	
Five Year Review Report	20	1	EA	$ 40,000	$ 40,000	Report after 20 years
Equipment Replacement	20	1	LS	$ 788,890	$ 788,890	Equipment Replacement- See Cost Worksheet M-14
Update IC Plan	20	1	EA	$ 3,000	$ 3,000	Update Plan
SUBTOTAL					$ 831,890	
Five Year Review Report	25	1	EA	$ 40,000	$ 40,000	Report after 25 years
Equipment Replacement	25	1	LS	$ 19,100	$ 19,100	Equipment Replacement- See Cost Worksheet M-14
Update IC Plan	25	1	EA	$ 3,000	$ 3,000	Update Plan
SUBTOTAL					$ 62,100	

VOC Mass Reduction Alternative MSP
GROUNDWATER EXTRACTION AND TREATMENT

COST ESTIMATE SUMMARY MSP

Site: "Occidental" Site
Location: Tacoma, Washington
Phase: Feasibility Study (-30% to +50%) - 7%
Base Year: 2016
Date: December 8, 2016

Description: Mass Reduction Alternative MSP is designed to reduce VOC mass and eliminate potentially complete exposure pathways, and includes: extraction of shallow and deep groundwater with high concentrations of VOC outside the areas of high pH; institutional controls; groundwater monitoring; a Physical Direct Contact Exposure (PDCE) Barrier for 605 & 709 Alexander Avenue Properties, Navy Todd Dump, N Landfill, and 709 Embankment Fill Area; a sheet pile barrier wall adjacent to Hylebos; and hydraulic containment using a newly constructed GWETS. The pumping rate is estimated to be 210 gpm. Assume soil cuttings and trench spoils are placed under PDCE Barrier. Capital Costs occur in Year 0. Annual O&M costs occur in Years 1-30. Periodic costs occur in years 5,10, 15, 20, and 25.

PRESENT VALUE ANALYSIS:

COST TYPE	YEAR	TOTAL COST	TOTAL COST PER YEAR	DISCOUNT FACTOR (1.5%)	PRESENT VALUE	NOTES
Capital Cost	0	$ 38,854,780	$ 38,854,780	1	$ 38,854,780	
Annual O&M Cost	1-30	$ 36,305,400	$ 1,210,180	12.41	$ 15,017,180	30 years
Periodic Cost	5	$ 97,100	$ 97,100	0.713	$ 69,240	5 year review, update plan, and Repair Costs
Periodic Cost	10	$ 72,100	$ 72,100	0.508	$ 36,660	5 year review, update plan, and Repair Costs
Periodic Cost	15	$ 1,857,480	$ 1,857,480	0.362	$ 673,240	5 year review, update plan, and Repair Costs
Periodic Cost	20	$ 831,890	$ 831,890	0.258	$ 214,980	5 year review, update plan, and Repair Costs
Periodic Cost	25	$ 62,100	$ 62,100	0.184	$ 11,450	5 year review, update plan, and Repair Costs
		$ 78,080,850			$ 54,877,530	

TOTAL PRESENT VALUE OF ALTERNATIVE **$ 54,877,530**

VOC Mass Reduction Alternative MSP
GROUNDWATER EXTRACTION AND TREATMENT

COST ESTIMATE SUMMARY MSP

Site: "Occidental" Site
Location: Tacoma, Washington
Phase: Feasibility Study (-30% to +50%) - 1.5%
Base Year: 2016
Date: December 8, 2016

Description: Mass Reduction Alternative MSP is designed to reduce VOC mass and eliminate potentially complete exposure pathways, and includes: extraction of shallow and deep groundwater with high concentrations of VOC outside the areas of high pH; institutional controls; groundwater monitoring; a Physical Direct Contact Exposure (PDCE) Barrier for 605 & 709 Alexander Avenue Properties, Navy Todd Dump, N Landfill, and 709 Embankment Fill Area; a sheet pile barrier wall adjacent to Hylebos; and hydraulic containment using a newly constructed GWETS. The pumping rate is estimated to be 210 gpm. Assume soil cuttings and trench spoils are placed under PDCE Barrier. Capital Costs occur in Year 0. Annual O&M costs occur in Years 1-30. Periodic costs occur in years 5,10, 15, 20, and 25.

CAPITAL COSTS

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Mobilization/Demobilization					
Construction Equipment & Facilities	1	LS	$ 25,000	$ 25,000	Excavators, Loaders, etc.
Temporary facilities and Utilities	1	LS	$ 50,000	$ 50,000	Fence, roads, signs, trailers, etc.
H&S Plans and Submittals	1	LS	$ 15,000	$ 15,000	HASP, quality control, etc.
Design, Work Plans, Permits	1	LS	$ 100,000	$ 100,000	Barrier wall
Design, Work Plans, Permits	1	LS	$ 50,000	$ 50,000	Physical Direct Contact Exposure Barrier
Post-construction Submittals	1	LS	$ 150,000	$ 150,000	Report completed work
SUBTOTAL				$ 390,000	
Site Work					
Demolition of North Dock	1	LS	$ 446,000	$ 446,000	Quotation from vendor - See Cost Worksheet C-1
Demolition of South Dock	1	LS	$ 248,000	$ 248,000	Quotation from vendor - See Cost Worksheet C-2
Demolition of Existing Structures	1	LS	$ 250,000	$ 250,000	Treatment plant, office, misc. - Assumption
Construction Oversight	50	DAY	$ 1,920	$ 96,000	Assume 2 people
SUBTOTAL				$ 1,040,000	
Barrier Wall East Installation					
Mobilization/Demobilization	1	LS	$ 50,000	$ 50,000	2,180 ft long by 73.5 ft deep. Assuming barge installatior
Sheet Pile	4300	TN	$ 1,900	$ 8,170,000	Vendor quote (PZ-27 sheet)
Unload Sheet Pile	220	LS	$ 2,350	$ 517,000	Vendor quote
Install Perimeter SP Wall	160000	SF	$ 12	$ 1,920,000	Vendor quote (Adeka sealant; Anchor piles on 6' centers)
Fill along embankment behind wall	40370	CY	$ 18	$ 726,670	Avg. Depth 10 ft; 50 ft wide
Construction Oversight	130	DAY	$ 1,920	$ 249,600	Assume 2 people
Mitigation of Intertidal Areas	1	LS	$ 250,000	$ 250,000	Allowance
SUBTOTAL				$ 11,883,270	
Physical Direct Contact Exposure Barrier					
Mobilization/Demobilization	1	LS	$ 50,000	$ 50,000	
Preparation	1502820	SF	$ 0.6	$ 901,700	Remove debris and prepare surface. 34.5 acres.
Aggregate Base	27830	CY	$ 35	$ 974,050	6 inch base
Asphalt Cover (assume 4")	1502820	SF	$ 2	$ 3,005,640	Facility Construction Cost - RSMeans (2016)
Construction Oversight	130	DAY	$ 1,920	$ 249,600	Assume 2 personal
SUBTOTAL				$ 5,180,990	
VOC Mass Extraction and Hydraulic Containment					
Mobilization/Demobilization	1	LS	$ 50,000	$ 50,000	
Groundwater Extraction System	1	LS	$ 1,031,360	$ 1,031,360	See Cost Worksheet M-13
Groundwater Treatment Equipment	1	LS	$ 2,544,230	$ 2,544,230	Assume 300 gpm System - See Cost Worksheet C-4
Groundwater Treatment Facility Building	1	LS	$ 2,145,820	$ 2,145,820	See Cost Worksheet C-5
High pH Treatment Additional Equipment	1	LS	$ 27,000	$ 27,000	Acid metering pump and equalization tank.
Construction Oversight	260	Day	$ 1,920	$ 499,200	
SUBTOTAL				$ 6,297,610	
Off-Site Treatment / Disposal					
Off-Site T&D of Soil Cuttings	20	CY	$ 394	$ 7,880	Vendor Quote
Off-Site T&D of Spoils	1250	CY	$ 394	$ 491,920	Vendor Quote
Off-Site T&D of Spoils - Hazardous	750	CY	$ 977	$ 732,780	Vendor Quote
SUBTOTAL				$ 1,232,580	
SUBTOTAL				$ 26,024,450	
Contingency		25%		$ 6,506,110	10% scope + 15% bid
SUBTOTAL				$ 32,530,560	
Project Management		5%		$ 1,626,530	
Remedial Design		8%		$ 2,602,450	
Construction Management		6%		$ 1,951,840	
Institutional Controls					
Institutional Controls Plan	1	LS	$ 13,000	$ 13,000	Description and implementation
Groundwater Use Restrictions	1	LS	$ 10,000	$ 10,000	Legal fees
Site Database	1	LS	$ 5,000	$ 5,000	Data management system
Documentation	1	LS	$ 20,000	$ 20,000	other submittals and documents
Perimeter fence	5300	FOOT	$ 18	$ 95,400	605 and 709 properties
SUBTOTAL				$ 143,400	
TOTAL CAPITAL COSTS				**$ 38,854,780**	

VOC Mass Reduction Alternative MSP
GROUNDWATER EXTRACTION AND TREATMENT

COST ESTIMATE SUMMARY MSP

Site: "Occidental" Site
Location: Tacoma, Washington
Phase: Feasibility Study (-30% to +50%) - 1.5%
Base Year: 2016
Date: December 8, 2016

Description: Mass Reduction Alternative MSP is designed to reduce VOC mass and eliminate potentially complete exposure pathways, and includes: extraction of shallow and deep groundwater with high concentrations of VOC outside the areas of high pH; institutional controls; groundwater monitoring; a Physical Direct Contact Exposure (PDCE) Barrier for 605 & 709 Alexander Avenue Properties, Navy Todd Dump, N Landfill, and 709 Embankment Fill Area; a sheet pile barrier wall adjacent to Hylebos; and hydraulic containment using a newly constructed GWETS. The pumping rate is estimated to be 210 gpm. Assume soil cuttings and trench spoils are placed under PDCE Barrier. Capital Costs occur in Year 0. Annual O&M costs occur in Years 1-30. Periodic costs occur in years 5,10, 15, 20, and 25.

ANNUAL O&M COSTS:

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Inspections					
Mobilization and Inspection	1	LS	$ 2,600	$ 2,600	Barriers and fencing
Reporting	1	LS	$ 5,200	$ 5,200	Inspection documentation
SUBTOTAL				$ 7,800	
Monitoring Groundwater					
Monitoring, sampling and reporting	1	LS	$ 297,000	$ 297,000	Will be in OMMP
Physical Direct Contact Exposure Barrier Maintenance					
Annual maintenance	1	LS	$ 10,000	$ 10,000	Allowance
Groundwater Treatment Plant					
Operation	1	year	$ 124,500	$ 124,500	GHD Quote
Carbon Consumption	7.5	EXCHANGE	$ 19,124	$ 143,430	GHD Quote
pH Adjustment	1	LS	$ 25,000	$ 25,000	GHD Quote
Equipment Allowance	1	LS	$ 6,000	$ 6,000	Allowance
Dilution Water	55190	$/1000 gals	$ 2.60	$ 143,500	Assume city water for dilution - quote
SUBTOTAL				$ 442,430	
Extraction Wells and Forcemains					
Annual maintenance	1	LS	$ 20,000	$ 20,000	Two weeks of work
Off-Site Treatment / Disposal					
Off-Site Transport/disposal of Solids	41	ton	$ 720	$ 29,520	Vendor Quote
SUBTOTAL				$ 806,750	
Contingency		30%		$ 242,030	10% scope + 20% bid
SUBTOTAL				$ 1,048,780	
Project Management		5%		$ 52,500	
Technical Support		10%		$ 104,900	
Site Info Database	1	LS	$ 4,000	$ 4,000	Update and maintain database
TOTAL ANNUAL O&M COSTS				**$ 1,210,180**	

PERIODIC COSTS:

DESCRIPTION	YEAR	QTY	UNIT	UNIT COST	TOTAL	NOTES
Five Year Review Report	5	1	EA	$ 75,000	$ 75,000	Report after 5 years
Equipment Replacement	5	1	LS	$ 19,100	$ 19,100	Equipment Replacement- See Cost Worksheet M-14
Update IC Plan	5	1	EA	$ 3,000	$ 3,000	Update Plan
SUBTOTAL					$ 97,100	
Five Year Review Report	10	1	EA	$ 50,000	$ 50,000	Report after 10 years
Equipment Replacement	5	1	LS	$ 19,100	$ 19,100	Equipment Replacement- See Cost Worksheet M-14
Update IC Plan	10	1	EA	$ 3,000	$ 3,000	Update Plan
SUBTOTAL					$ 72,100	
Five Year Review Report	15	1	EA	$ 40,000	$ 40,000	Report after 15 years
Cap Repair	15	1	LS	$ 300,570	$ 300,570	10 percent of asphalt
Equipment Replacement	15	1	LS	$ 1,503,910	$ 1,503,910	Equipment Replacement- See Cost Worksheet M-14
Update IC Plan	15	1	EA	$ 3,000	$ 3,000	Update Plan
Remedial Action Report	15	1	EA	$ 10,000	$ 10,000	
SUBTOTAL					$ 1,857,480	
Five Year Review Report	20	1	EA	$ 40,000	$ 40,000	Report after 20 years
Equipment Replacement	20	1	LS	$ 788,890	$ 788,890	Equipment Replacement- See Cost Worksheet M-14
Update IC Plan	20	1	EA	$ 3,000	$ 3,000	Update Plan
SUBTOTAL					$ 831,890	
Five Year Review Report	25	1	EA	$ 40,000	$ 40,000	Report after 25 years
Equipment Replacement	25	1	LS	$ 19,100	$ 19,100	Equipment Replacement- See Cost Worksheet M-14
Update IC Plan	25	1	EA	$ 3,000	$ 3,000	Update Plan
SUBTOTAL					$ 62,100	

VOC Mass Reduction Alternative MSP
GROUNDWATER EXTRACTION AND TREATMENT

COST ESTIMATE SUMMARY MSP

Site: "Occidental" Site
Location: Tacoma, Washington
Phase: Feasibility Study (-30% to +50%) - 1.5%
Base Year: 2016
Date: December 8, 2016

Description: Mass Reduction Alternative MSP is designed to reduce VOC mass and eliminate potentially complete exposure pathways, and includes: extraction of shallow and deep groundwater with high concentrations of VOC outside the areas of high pH; institutional controls; groundwater monitoring; a Physical Direct Contact Exposure (PDCE) Barrier for 605 & 709 Alexander Avenue Properties, Navy Todd Dump, N Landfill, and 709 Embankment Fill Area; a sheet pile barrier wall adjacent to Hylebos; and hydraulic containment using a newly constructed GWETS. The pumping rate is estimated to be 210 gpm. Assume soil cuttings and trench spoils are placed under PDCE Barrier. Capital Costs occur in Year 0. Annual O&M costs occur in Years 1-30. Periodic costs occur in years 5,10, 15, 20, and 25.

PRESENT VALUE ANALYSIS:

COST TYPE	YEAR	TOTAL COST	TOTAL COST PER YEAR	DISCOUNT FACTOR (1.5%)	PRESENT VALUE	NOTES
Capital Cost	0	$ 38,854,780	$ 38,854,780	1	$ 38,854,780	
Annual O&M Cost	1-30	$ 36,305,400	$ 1,210,180	24.02	$ 29,063,490	30 years
Periodic Cost	5	$ 97,100	$ 97,100	0.928	$ 90,140	5 year review, update plan, and Repair Costs
Periodic Cost	10	$ 72,100	$ 72,100	0.862	$ 62,130	5 year review, update plan, and Repair Costs
Periodic Cost	15	$ 1,857,480	$ 1,857,480	0.800	$ 1,485,710	5 year review, update plan, and Repair Costs
Periodic Cost	20	$ 831,890	$ 831,890	0.742	$ 617,660	5 year review, update plan, and Repair Costs
Periodic Cost	25	$ 62,100	$ 62,100	0.689	$ 42,800	5 year review, update plan, and Repair Costs
		$ 78,080,850			$ 70,216,710	

TOTAL PRESENT VALUE OF ALTERNATIVE **$ 70,216,710**

VOC Mass Removal Alternative M3
SHALLOW SOIL EXCAVATION WITH ON-SITE TREATMENT

COST ESTIMATE SUMMARY M3

Site: "Occidental" Site
Location: Tacoma, Washington
Phase: Feasibility Study (-30% to +50%)
Base Year: 2016
Date: December 8, 2016

Description: Mass Removal Alternative M3 was designed to remove near surface soil potentially containing DNAPL (PTW) that could be a future source of contamination in soil and groundwater. The M3 alternative includes the following elements: Excavation of shallow soil above -4 ft NGVD containing TCVOC concentrations greater than 100 mg/kg; Removal of VOC from the excavated soil by on-Site treatment; Backfill on Site of treated excavated soil. Capital costs occur in Year 0. No annual O&M costs. No Periodic costs.

CAPITAL COSTS

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Mobilization/Demobilization					
Construction Equipment & Facilities	1	LS	$ 25,000	$ 25,000	Excavators, Loaders, etc.
Temporary facilities and Utilities	1	LS	$ 25,000	$ 25,000	Fence, roads, signs, trailers, etc.
H&S Plans and Submittals	1	LS	$ 15,000	$ 15,000	HASP, quality control, etc.
Demobilization	1	LS	$ 10,000	$ 10,000	
SUBTOTAL				$ 75,000	
Soil Excavation Above -4ft NGVD					
Excavate Dry Soil over Impacted Zone	18,800	CY	$ 8	$ 150,400	Stockpiled
Excavate Dry Impacted Soil	2,820	CY	$ 8	$ 22,560	Staged for Ex Situ SVE
Excavate Wet Soil over Impacted Zone	12,870	CY	$ 8	$ 102,960	Stockpiled and drained
Excavate Wet Impacted Soil	7,910	CY	$ 8	$ 63,280	Staged for Ex Situ SVE
Backfill With Soil Not Being Treated	31,670	CY	$ 6	$ 190,020	
Backfill With Imported Fill	10,730	CY	$ 23	$ 246,790	
Grade Treated Soil	10,730	CY	$ 6	$ 64,380	Treated soils backfilled on 605 property
Asphalt cover (assume 4" thickness)	25710	SF	$ 2	$ 51,420	Off 605 Property; RSMeans (2016)
SUBTOTAL				$ 891,800	
Ex Situ Soil Vapor Extraction (SVE)					
Preparation and Setup	1	LS	$ 20,000	$ 20,000	GDH Construction Division Estimate
Electrical	1	LS	$ 20,000	$ 20,000	GDH Construction Division Estimate
Portable Air Treatment Equipment	1	LS	$ 400,000	$ 400,000	Vendor quote
Establish Unsaturated Treatment Pile	2,820	CY	$ 10.75	$ 30,315	GDH Construction Division Estimate
Establish Saturated Treatment Pile	7,910	CY	$ 10.25	$ 81,078	GDH Construction Division Estimate
VE Piping for Piles	2050	LF	$ 4.25	$ 8,713	4 inch - Vendor quote
VE Header Piping	400	LF	$ 15	$ 6,000	GDH Construction Division Estimate
System Testing and Startup	1	LS	$ 18,000	$ 18,000	GDH Construction Division Estimate
Operation	9	Months	$ 15,000	$ 135,000	GDH Construction Division Estimate
Consumables	9	Months	$ 10,000	$ 90,000	GDH Construction Division Estimate
SUBTOTAL				$ 809,100	
Sampling and Analysis					
Field Sampling and Analysis	1	LS	$ 16,200	$ 16,200	Estimate
SUBTOTAL				$ 16,200	
SUBTOTAL				$ 1,792,100	
Contingency		25%		$448,000	10% scope + 15% bid
SUBTOTAL				$2,240,100	
Project Management		5%		$112,100	
Remedial Design		8%		$179,300	
Construction Management		6%		$134,500	
TOTAL CAPITAL COSTS				$2,666,000	

ANNUAL O&M COSTS:
No annual O&M costs

PERIODIC COSTS:
No periodic costs

PRESENT VALUE ANALYSIS:

COST TYPE	YEAR	TOTAL COST	TOTAL COST PER YEAR	DISCOUNT FACTOR (7%)	PRESENT VALUE	NOTES
Capital Cost	0	$2,666,000	$2,666,000	1.000	$2,666,000	
Annual O&M Cost	-	$0	$0	-	$0	No annual O&M
Periodic Cost	-	$0	$0	-	$0	No periodic costs
		$2,666,000			$2,666,000	

TOTAL PRESENT VALUE OF ALTERNATIVE $2,666,000

VOC Mass Removal Alternative M5
SHALLOW SOIL TREATMENT BY ERH/SVE

COST ESTIMATE SUMMARY M5

Site: "Occidental" Site
Location: Tacoma, Washington
Phase: Feasibility Study (-30% to +50%)
Base Year: 2016
Date: December 8, 2016

Description: Mass Reduction Alternative M5 was designed to further reduce, by in situ treatment, TCVOC concentrations in a greater quantity of shallow soil, compared to M3 alternative, potentially containing DNAPL (PTW) that could be a future source of contamination in soil and groundwater. The M5 alternative includes the following elements: Treatment using in situ electrical resistance heating (ERH) of shallow saturated soil below 2.5 ft NGVD and above -21 ft NGVD containing TCVOC concentrations greater than 500 mg/kg; Treatment using in situ SVE of shallow unsaturated (vadose zone) soil above 2.5 ft NGVD containing TCVOC concentrations greater than 500 mg/kg. Assume soil cuttings are placed under PDCE Barrier. Capital costs occur in Year 0. No annual O&M costs. No Periodic costs.

CAPITAL COSTS:

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Mobilization/Demobilization					
Design, Work Plans, Permits	1	LS	$ 233,000	$ 233,000	Vendor Quote
Materials Mobilization	1	LS	$ 1,681,000	$ 1,681,000	Vendor Quote
Electrical Permit and Connection	1	LS	$ 120,000	$ 120,000	Vendor Quote
Demobilization and Final Report	1	LS	$ 128,000	$ 128,000	Vendor Quote
SUBTOTAL				$ 2,162,000	
ERH and SVE					
Subsurface Installation - Drill	1	LS	$ 1,181,818	$ 1,181,818	Vendor Quote
Subsurface Installation - Install	1	LS	$ 118,182	$ 118,182	Vendor Quote
Surface Installation and Start-up					
Month 8	1	LS	$ 407,182	$ 407,182	Vendor Quote
Month 9	1	LS	$ 452,424	$ 452,424	Vendor Quote
Month 10	1	LS	$ 452,424	$ 452,424	Vendor Quote
Month 11	1	LS	$ 180,970	$ 180,970	Vendor Quote
Remediation System Operation					
Month 11	1	LS	$ 283,600	$ 283,600	Vendor Quote
Month 12	1	LS	$ 472,667	$ 472,667	Vendor Quote
Month 13	1	LS	$ 472,667	$ 472,667	Vendor Quote
Month 14	1	LS	$ 472,667	$ 472,667	Vendor Quote
Month 15	1	LS	$ 425,400	$ 425,400	Vendor Quote
Electrical Energy Usage					
Month 11	1	LS	$ 106,267	$ 106,267	Vendor Quote
Month 12	1	LS	$ 177,111	$ 177,111	Vendor Quote
Month 13	1	LS	$ 177,111	$ 177,111	Vendor Quote
Month 14	1	LS	$ 177,111	$ 177,111	Vendor Quote
Month 15	1	LS	$ 159,400	$ 159,400	Vendor Quote
Carbon Regeneration	1	LS	$ 4,000	$ 4,000	Vendor Quote
Misc. Operational Cost	1	LS	$ 92,000	$ 92,000	Vendor Quote
SUBTOTAL				$ 5,813,000	
Monitoring					
Shallow Stainless Steel Wells	10	EA	$ 5,800	$ 58,000	Previous Drilling Invoice
Sampling	6	EA	$ 7,000	$ 42,000	Estimated
SUBTOTAL				$ 100,000	
SUBTOTAL				$ 8,075,000	
Contingency		25%		$ 2,018,800	10% scope + 15% bid
SUBTOTAL				$ 10,093,800	
Project Management		5%		$ 504,700	
Remedial Design		8%		$ 807,600	
Construction Management		6%		$ 605,700	
TOTAL CAPITAL COSTS				**$ 12,011,800**	

ANNUAL O&M COSTS:
No annual O&M costs

PERIODIC COSTS:
No periodic costs

PRESENT VALUE ANALYSIS:

COST TYPE	YEAR	TOTAL COST	TOTAL COST PER YEAR	DISCOUNT FACTOR (7%)	PRESENT VALUE	NOTES
Capital Cost	0	$12,011,800	$12,011,800	1.000	$12,011,800	
Annual O&M Cost	-	$0	$0	-	$0	No annual O&M
Periodic Cost	-	$0	$0	-	$0	No periodic costs
		$12,011,800			$12,011,800	

TOTAL PRESENT VALUE OF ALTERNATIVE **$12,011,800**

VOC Mass Removal Alternative M6
SHALLOW SOIL EXCAVATION WITH ON-SITE TREATMENT AND SHALLOW SOIL TREATMENT BY ERH/SVE

COST ESTIMATE SUMMARY M6

Site: "Occidental" Site
Location: Tacoma, Washington
Phase: Feasibility Study (-30% to +50%)
Base Year: 2016
Date: December 8, 2016

Description: The M6 alternative is a combination of the excavation and ERH treatment elements from the M3 and M5 alternatives. The total area/volume for ERH is approximately 7 percent less. Assume soil cuttings are placed under PDCE Barrier. Capital costs occur in Year 0. No annual O&M costs. No Periodic costs.

CAPITAL COSTS:

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
VOC Mass Removal Alternative M3				$ 1,792,100	See Cost Estimate Summary M3
VOC Mass Removal Alternative M5				$ 7,476,852	See Cost Estimate Summary M5; Adjusted for smaller volume
SUBTOTAL				$ 9,269,000	
Contingency		25%		$ 2,317,300	10% scope + 15% bid
SUBTOTAL				$ 11,586,300	
Project Management		5%		$ 579,400	
Remedial Design		8%		$ 927,000	
Construction Management		6%		$ 695,200	
TOTAL CAPITAL COSTS				**$ 13,787,900**	

ANNUAL O&M COSTS:
No annual O&M costs

PERIODIC COSTS:
No periodic costs

PRESENT VALUE ANALYSIS:

COST TYPE	YEAR	TOTAL COST	TOTAL COST PER YEAR	DISCOUNT FACTOR (7%)	PRESENT VALUE	NOTES
Capital Cost	0	$13,787,900	$13,787,900	1.000	$13,787,900	
Annual O&M Cost	-	$0	$0	-	$0	No annual O&M
Periodic Cost	-	$0	$0	-	$0	No periodic costs
		$13,787,900			$13,787,900	

TOTAL PRESENT VALUE OF ALTERNATIVE **$13,787,900**

VOC Mass Removal Alternative M8
SHALLOW SOIL TREATMENT BY ERH/SVE AND SHALLOW GROUNDWATER/SOIL TREATMENT BY ISCO/ISB

COST ESTIMATE SUMMARY M8

Site: "Occidental" Site
Location: Tacoma, Washington
Phase: Feasibility Study (-30% to +50%) - 7%
Base Year: 2016
Date: December 8, 2016

Description: Mass Reduction Alternative M8 was designed to further reduce, by in situ treatment, TCVOC concentrations in shallow groundwater and in shallow soil potentially containing DNAPL (PTW) that could be a future source of contamination in soil and groundwater. The M8 alternative includes the M5 alternative (ERH and SVE) plus elements for treatment of shallow groundwater as follows: Treatment using in situ chemical oxidation (ISCO) of shallow groundwater above -60 ft NGVD containing TCVOC concentrations greater than 10 mg/L within the zone where pH is between 10 s.u. and 12.5 s.u.; Treatment using enhanced in situ bioremediation (ISB) of shallow groundwater above -60 ft NGVD containing TCVOC concentrations greater than 10 mg/L within the zone where pH is less than 10 s.u. Assume soil cuttings are placed under PDCE Barrier. Capital costs occur in Year 0. No annual O&M costs. No Periodic costs.

CAPITAL COSTS:

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
VOC Mass Removal Alternative M5				$ 8,075,000	See Cost Estimate Summary M5
In Situ Chemical Oxidation (ISCO)					
Installation of Shallow Injection Wells	340	EA	$ 8,075	$ 2,745,500	See Cost Worksheet M-3; 10-foot radius
Injection Event 1	1	LS	$ 1,936,370	$ 1,936,370	See Cost Worksheet M-5
Injection Event 2	1	LS	$ 1,936,370	$ 1,936,370	See Cost Worksheet M-5
Injection Event 3	1	LS	$ 1,936,370	$ 1,936,370	See Cost Worksheet M-5
Injection Event 4	1	LS	$ 1,936,370	$ 1,936,370	See Cost Worksheet M-5
Well Abandonment	1	LS	$ 170,000	$ 170,000	Estimate
SUBTOTAL				$ 10,661,000	
Enhanced In Situ Bioremediation (ISB)					
Installation of Shallow Injection Wells	280	EA	$ 8,075	$ 2,261,000	See Cost Worksheet M-3; 10-foot radius, 150-foot spacing
Injection Event 1	1	LS	$ 9,934,060	$ 9,934,060	See Cost Worksheet M-6
Injection Event 2	1	LS	$ 9,934,060	$ 9,934,060	See Cost Worksheet M-6
Injection Event 3	1	LS	$ 9,934,060	$ 9,934,060	See Cost Worksheet M-6
SUBTOTAL				$ 32,063,200	
Monitoring, Sampling, Testing, Analysis				$ -	Included in containment alternative
SUBTOTAL				$ 50,799,200	
Contingency		25%		$ 12,699,800	10% scope + 15% bid
SUBTOTAL				$ 63,499,000	
Project Management		5%		$ 3,175,000	
Remedial Design		8%		$ 5,080,000	
Construction Management		6%		$ 3,810,000	
TOTAL CAPITAL COSTS				**$ 75,564,000**	

ANNUAL O&M COSTS:

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Inspection	1	LS	$ 6,000	$ 6,000	3 days
Monitoring Groundwater					
Monitoring, Sampling, and Reporting	0	LS	$ -	$ -	Included in containment alternative
SUBTOTAL				$ 6,000	
Contingency		30%		$ 1,800	10% scope + 20% bid
SUBTOTAL				$ 7,800	
Project Management		5%		$ 400	
Technical Support		10%		$ 800	
TOTAL ANNUAL O&M COSTS				**$ 9,000**	

PERIODIC COSTS:

DESCRIPTION	YEAR	QTY	UNIT	UNIT COST	TOTAL	NOTES
Enhanced In Situ Bioremediation (ISB)						
Injection Event 4	8	1	EA	$ 5,551,560	$ 5,551,560	See Cost Worksheet M-7
Injection Event 5	10	1	EA	$ 5,551,560	$ 5,551,560	See Cost Worksheet M-7
Injection Event 6	12	1	EA	$ 5,551,560	$ 5,551,560	See Cost Worksheet M-7
Injection Event 7	14	1	EA	$ 3,360,290	$ 3,360,290	See Cost Worksheet M-8
Injection Event 8	16	1	EA	$ 3,360,290	$ 3,360,290	See Cost Worksheet M-8
Injection Event 9	18	1	EA	$ 3,360,290	$ 3,360,290	See Cost Worksheet M-8
Well Abandonment	19	1	EA	$ 140,000	$ 140,000	Estimate

VOC Mass Removal Alternative M8
SHALLOW SOIL TREATMENT BY ERH/SVE
AND SHALLOW GROUNDWATER/SOIL
TREATMENT BY ISCO/ISB

COST ESTIMATE SUMMARY M8

Site: "Occidental" Site
Location: Tacoma, Washington
Phase: Feasibility Study (-30% to +50%) - 7%
Base Year: 2016
Date: December 8, 2016

Description: Mass Reduction Alternative M8 was designed to further reduce, by in situ treatment, TCVOC concentrations in shallow groundwater and in shallow soil potentially containing DNAPL (PTW) that could be a future source of contamination in soil and groundwater. The M8 alternative includes the M5 alternative (ERH and SVE) plus elements for treatment of shallow groundwater as follows: Treatment using in situ chemical oxidation (ISCO) of shallow groundwater above -60 ft NGVD containing TCVOC concentrations greater than 10 mg/L within the zone where pH is between 10 s.u. and 12.5 s.u.; Treatment using enhanced in situ bioremediation (ISB) of shallow groundwater above -60 ft NGVD containing TCVOC concentrations greater than 10 mg/L within the zone where pH is less than 10 s.u. Assume soil cuttings are placed under PDCE Barrier. Capital costs occur in Year 0. No annual O&M costs. No Periodic costs.

PRESENT VALUE ANALYSIS:

COST TYPE	YEAR	TOTAL COST	TOTAL COST PER YEAR	DISCOUNT FACTOR (7%)	PRESENT VALUE	NOTES
Capital Cost	0	$ 75,564,000	$ 75,564,000	1	$ 75,564,000	
Annual O&M Cost	1-19	$ 171,000	$ 9,000	10.34	$ 93,030	19 Years
Periodic Cost	8	$ 5,551,560	$ 5,551,560	0.582	$ 3,231,060	Injection Event for ISB
Periodic Cost	10	$ 5,551,560	$ 5,551,560	0.508	$ 2,822,140	Injection Event for ISB
Periodic Cost	12	$ 5,551,560	$ 5,551,560	0.444	$ 2,464,960	Injection Event for ISB
Periodic Cost	14	$ 3,360,290	$ 3,360,290	0.388	$ 1,303,180	Injection Event for ISB
Periodic Cost	16	$ 3,360,290	$ 3,360,290	0.339	$ 1,138,250	Injection Event for ISB
Periodic Cost	18	$ 3,360,290	$ 3,360,290	0.296	$ 994,190	Injection Event for ISB
Periodic Cost	19	$ 140,000	$ 140,000	0.277	$ 38,720	Injection Event for ISB
		$102,610,550			$ 87,649,530	

TOTAL PRESENT VALUE OF ALTERNATIVE **$ 87,649,530**

VOC Mass Removal Alternative M8
SHALLOW SOIL TREATMENT BY ERH/SVE AND SHALLOW GROUNDWATER/SOIL TREATMENT BY ISCO/ISB

COST ESTIMATE SUMMARY M8

Site: "Occidental" Site
Location: Tacoma, Washington
Phase: Feasibility Study (-30% to +50%) - 1.5%
Base Year: 2016
Date: December 8, 2016

Description: Mass Reduction Alternative M8 was designed to further reduce, by in situ treatment, TCVOC concentrations in shallow groundwater and in shallow soil potentially containing DNAPL (PTW) that could be a future source of contamination in soil and groundwater. The M8 alternative includes the M5 alternative (ERH and SVE) plus elements for treatment of shallow groundwater as follows: Treatment using in situ chemical oxidation (ISCO) of shallow groundwater above -60 ft NGVD containing TCVOC concentrations greater than 10 mg/L within the zone where pH is between 10 s.u. and 12.5 s.u.; Treatment using enhanced in situ bioremediation (ISB) of shallow groundwater above -60 ft NGVD containing TCVOC concentrations greater than 10 mg/L within the zone where pH is less than 10 s.u. Assume soil cuttings are placed under PDCE Barrier. Capital costs occur in Year 0. No annual O&M costs. No Periodic costs.

CAPITAL COSTS:

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
VOC Mass Removal Alternative M5				$ 8,075,000	See Cost Estimate Summary M5
In Situ Chemical Oxidation (ISCO)					
Installation of Shallow Injection Wells	340	EA	$ 8,075	$ 2,745,500	See Cost Worksheet M-3; 10-foot radius
Injection Event 1	1	LS	$ 1,936,370	$ 1,936,370	See Cost Worksheet M-5
Injection Event 2	1	LS	$ 1,936,370	$ 1,936,370	See Cost Worksheet M-5
Injection Event 3	1	LS	$ 1,936,370	$ 1,936,370	See Cost Worksheet M-5
Injection Event 4	1	LS	$ 1,936,370	$ 1,936,370	See Cost Worksheet M-5
Well Abandonment	1	LS	$ 170,000	$ 170,000	Estimate
SUBTOTAL				$ 10,661,000	
Enhanced In Situ Bioremediation (ISB)					
Installation of Shallow Injection Wells	280	EA	$ 8,075	$ 2,261,000	See Cost Worksheet M-3; 10-foot radius, 150-foot spacing
Injection Event 1	1	LS	$ 9,934,060	$ 9,934,060	See Cost Worksheet M-6
Injection Event 2	1	LS	$ 9,934,060	$ 9,934,060	See Cost Worksheet M-6
Injection Event 3	1	LS	$ 9,934,060	$ 9,934,060	See Cost Worksheet M-6
SUBTOTAL				$ 32,063,200	
Monitoring, Sampling, Testing, Analysis				$ -	Included in containment alternative
SUBTOTAL				$ 50,799,200	
Contingency		25%		$ 12,699,800	10% scope + 15% bid
SUBTOTAL				$ 63,499,000	
Project Management		5%		$ 3,175,000	
Remedial Design		8%		$ 5,080,000	
Construction Management		6%		$ 3,810,000	
TOTAL CAPITAL COSTS				**$ 75,564,000**	

ANNUAL O&M COSTS:

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Inspection	1	LS	$ 6,000	$ 6,000	3 days
Monitoring Groundwater					
Monitoring, Sampling, and Reporting	0	LS	$ -	$ -	Included in containment alternative
SUBTOTAL				$ 6,000	
Contingency		30%		$ 1,800	10% scope + 20% bid
SUBTOTAL				$ 7,800	
Project Management		5%		$ 400	
Technical Support		10%		$ 800	
TOTAL ANNUAL O&M COSTS				**$ 9,000**	

PERIODIC COSTS:

DESCRIPTION	YEAR	QTY	UNIT	UNIT COST	TOTAL	NOTES
Enhanced In Situ Bioremediation (ISB)						
Injection Event 4	8	1	EA	$ 5,551,560	$ 5,551,560	See Cost Worksheet M-7
Injection Event 5	10	1	EA	$ 5,551,560	$ 5,551,560	See Cost Worksheet M-7
Injection Event 6	12	1	EA	$ 5,551,560	$ 5,551,560	See Cost Worksheet M-7
Injection Event 7	14	1	EA	$ 3,360,290	$ 3,360,290	See Cost Worksheet M-8
Injection Event 8	16	1	EA	$ 3,360,290	$ 3,360,290	See Cost Worksheet M-8
Injection Event 9	18	1	EA	$ 3,360,290	$ 3,360,290	See Cost Worksheet M-8
Well Abandonment	19	1	EA	$ 140,000	$ 140,000	Estimate

VOC Mass Removal Alternative M8
SHALLOW SOIL TREATMENT BY ERH/SVE
AND SHALLOW GROUNDWATER/SOIL
TREATMENT BY ISCO/ISB

COST ESTIMATE SUMMARY M8

Site: "Occidental" Site
Location: Tacoma, Washington
Phase: Feasibility Study (-30% to +50%) - 1.5%
Base Year: 2016
Date: December 8, 2016

Description: Mass Reduction Alternative M8 was designed to further reduce, by in situ treatment, TCVOC concentrations in shallow groundwater and in shallow soil potentially containing DNAPL (PTW) that could be a future source of contamination in soil and groundwater. The M8 alternative includes the M5 alternative (ERH and SVE) plus elements for treatment of shallow groundwater as follows: Treatment using in situ chemical oxidation (ISCO) of shallow groundwater above -60 ft NGVD containing TCVOC concentrations greater than 10 mg/L within the zone where pH is between 10 s.u. and 12.5 s.u.; Treatment using enhanced in situ bioremediation (ISB) of shallow groundwater above -60 ft NGVD containing TCVOC concentrations greater than 10 mg/L within the zone where pH is less than 10 s.u. Assume soil cuttings are placed under PDCE Barrier. Capital costs occur in Year 0. No annual O&M costs. No Periodic costs.

PRESENT VALUE ANALYSIS:

COST TYPE	YEAR	TOTAL COST	TOTAL COST PER YEAR	DISCOUNT FACTOR (1.5%)	PRESENT VALUE	NOTES
Capital Cost	0	$ 75,564,000	$ 75,564,000	1	$ 75,564,000	
Annual O&M Cost	1-19	$ 171,000	$ 9,000	16.43	$ 147,840	19 Years
Periodic Cost	8	$ 5,551,560	$ 5,551,560	0.888	$ 4,928,190	Injection Event for ISB
Periodic Cost	10	$ 5,551,560	$ 5,551,560	0.862	$ 4,783,600	Injection Event for ISB
Periodic Cost	12	$ 5,551,560	$ 5,551,560	0.836	$ 4,643,260	Injection Event for ISB
Periodic Cost	14	$ 3,360,290	$ 3,360,290	0.812	$ 2,728,050	Injection Event for ISB
Periodic Cost	16	$ 3,360,290	$ 3,360,290	0.788	$ 2,648,020	Injection Event for ISB
Periodic Cost	18	$ 3,360,290	$ 3,360,290	0.765	$ 2,570,330	Injection Event for ISB
Periodic Cost	19	$ 140,000	$ 140,000	0.754	$ 105,510	Injection Event for ISB
		$102,610,550			$ 98,118,800	

TOTAL PRESENT VALUE OF ALTERNATIVE **$ 98,118,800**

VOC Mass Removal Alternative M9
SHALLOW SOIL TREATMENT BY ERH/SVE
AND SHALLOW/DEEP GROUNDWATER/SOIL
TREATMENT BY ISCO/ISB

COST ESTIMATE SUMMARY M9

Site: "Occidental" Site
Location: Tacoma, Washington
Phase: Feasibility Study (-30% to +50%) - 7%
Base Year: 2016
Date: December 8, 2016

Description: Mass Reduction Alternative M9 was designed to further reduce, by in situ treatment, TCVOC concentrations in deep groundwater and in deep soil potentially containing DNAPL (PTW) that could be a future source of contamination in soil and groundwater. The M9 alternative includes the M8 alternative plus ISCO and ISB to treat deep groundwater and soil below -60 ft NGVD containing TCVOC concentrations greater than 10 mg/L within the zone where pH is between 10 s.u. and 12.5 s.u. (ISCO) and within the zone where pH is less than 10 s.u. (ISB). Assume soil cuttings are placed under PDCE Barrier. Capital costs occur in Year 0. No annual O&M costs. No Periodic costs.

CAPITAL COSTS:

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
VOC Mass Removal Alternative M8				$ 75,564,000	See Cost Estimate Summary M8
In Situ Chemical Oxidation (ISCO)					
Installation of Shallow Injection Wells	1360	EA	$ 13,810	$ 18,781,600	See Cost Worksheet M-4
Injection Event 1	1	LS	$ 9,472,270	$ 9,472,270	See Cost Worksheet M-9
Injection Event 2	1	LS	$ 9,472,270	$ 9,472,270	See Cost Worksheet M-9
Injection Event 3	1	LS	$ 9,472,270	$ 9,472,270	See Cost Worksheet M-9
Injection Event 4	1	LS	$ 9,472,270	$ 9,472,270	See Cost Worksheet M-9
Well Abandonment	1	LS	$ 680,000	$ 680,000	Estimate
SUBTOTAL				$ 57,350,680	
Enhanced In Situ Bioremediation (ISB)					
Installation of Shallow Injection Wells	450	EA	$ 13,810	$ 6,214,500	See Cost Worksheet M-4
Injection Event 1	1	LS	$ 24,476,415	$ 24,476,415	See Cost Worksheet M-10
Injection Event 2	1	LS	$ 24,476,415	$ 24,476,415	See Cost Worksheet M-10
Injection Event 3	1	LS	$ 24,476,415	$ 24,476,415	See Cost Worksheet M-10
SUBTOTAL				$ 79,643,750	
Monitoring, Sampling, Testing, Analysis				$ -	Included in containment alternative
SUBTOTAL				$ 212,558,430	
Contingency		25%		$ 53,139,610	10% scope + 15% bid
SUBTOTAL				$ 265,698,000	
Project Management		5%		$ 13,284,900	
Remedial Design		8%		$ 21,255,900	
Construction Management		6%		$ 15,941,900	
TOTAL CAPITAL COSTS				**$ 316,180,700**	

ANNUAL O&M COSTS:

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Inspection	1	LS	$ 10,000	$ 10,000	5 days
Monitoring Groundwater					
Monitoring, Sampling, and Reporting	0	LS	$ -	$ -	Included in containment alternative
SUBTOTAL				$ 10,000	
Contingency		30%		$ 3,000	10% scope + 20% bid
SUBTOTAL				$ 13,000	
Project Management		5%		$ 700	
Technical Support		10%		$ 1,300	
TOTAL ANNUAL O&M COSTS				**$ 15,000**	

PERIODIC COSTS:

DESCRIPTION	YEAR	QTY	UNIT	UNIT COST	TOTAL	NOTES
Enhanced In Situ Bioremediation (ISB)						
Injection Event 4	8	1	EA	$ 14,019,723	$ 14,019,723	See Cost Worksheet M-11
Injection Event 5	10	1	EA	$ 14,019,723	$ 14,019,723	See Cost Worksheet M-11
Injection Event 6	12	1	EA	$ 14,019,723	$ 14,019,723	See Cost Worksheet M-11
Injection Event 7	14	1	EA	$ 8,791,377	$ 8,791,377	See Cost Worksheet M-12
Injection Event 8	16	1	EA	$ 8,791,377	$ 8,791,377	See Cost Worksheet M-12
Injection Event 9	18	1	EA	$ 8,791,377	$ 8,791,377	See Cost Worksheet M-12
Well Abandonment	19	1	EA	$ 225,000	$ 225,000	Estimate

VOC Mass Removal Alternative M9
SHALLOW SOIL TREATMENT BY ERH/SVE
AND SHALLOW/DEEP GROUNDWATER/SOIL
TREATMENT BY ISCO/ISB

COST ESTIMATE SUMMARY M9

Site: "Occidental" Site
Location: Tacoma, Washington
Phase: Feasibility Study (-30% to +50%) - 7%
Base Year: 2016
Date: December 8, 2016

Description: Mass Reduction Alternative M9 was designed to further reduce, by in situ treatment, TCVOC concentrations in deep groundwater and in deep soil potentially containing DNAPL (PTW) that could be a future source of contamination in soil and groundwater. The M9 alternative includes the M8 alternative plus ISCO and ISB to treat deep groundwater and soil below -60 ft NGVD containing TCVOC concentrations greater than 10 mg/L within the zone where pH is between 10 s.u. and 12.5 s.u. (ISCO) and within the zone where pH is less than 10 s.u. (ISB). Assume soil cuttings are placed under PDCE Barrier. Capital costs occur in Year 0. No annual O&M costs. No Periodic costs.

PRESENT VALUE ANALYSIS:

COST TYPE	YEAR	TOTAL COST	TOTAL COST PER YEAR	DISCOUNT FACTOR (7%)	PRESENT VALUE	NOTES
Capital Cost	0	$ 316,180,700	$ 316,180,700	1	$ 316,180,700	
Annual O&M Cost	1-19	$ 285,000	$ 15,000	10.34	$ 155,040	19 Years
Periodic Cost	8	$ 14,019,723	$ 14,019,723	0.582	$ 8,159,610	Injection Event for ISB
Periodic Cost	10	$ 14,019,723	$ 14,019,723	0.508	$ 7,126,920	Injection Event for ISB
Periodic Cost	12	$ 14,019,723	$ 14,019,723	0.444	$ 6,224,930	Injection Event for ISB
Periodic Cost	14	$ 8,791,377	$ 8,791,377	0.388	$ 3,409,450	Injection Event for ISB
Periodic Cost	16	$ 8,791,377	$ 8,791,377	0.339	$ 2,977,950	Injection Event for ISB
Periodic Cost	18	$ 8,791,377	$ 8,791,377	0.296	$ 2,601,060	Injection Event for ISB
Periodic Cost	19	$ 225,000	$ 225,000	0.277	$ 62,220	Injection Event for ISB
		$385,124,000			$ 346,897,880	

TOTAL PRESENT VALUE OF ALTERNATIVE **$ 346,897,880**

VOC Mass Removal Alternative M9
SHALLOW SOIL TREATMENT BY ERH/SVE
AND SHALLOW/DEEP GROUNDWATER/SOIL
TREATMENT BY ISCO/ISB

COST ESTIMATE SUMMARY M9

Site: "Occidental" Site
Location: Tacoma, Washington
Phase: Feasibility Study (-30% to +50%) - 1.5%
Base Year: 2016
Date: December 8, 2016

Description: Mass Reduction Alternative M9 was designed to further reduce, by in situ treatment, TCVOC concentrations in deep groundwater and in deep soil potentially containing DNAPL (PTW) that could be a future source of contamination in soil and groundwater. The M9 alternative includes the M8 alternative plus ISCO and ISB to treat deep groundwater and soil below -60 ft NGVD containing TCVOC concentrations greater than 10 mg/L within the zone where pH is between 10 s.u. and 12.5 s.u. (ISCO) and within the zone where pH is less than 10 s.u. (ISB). Assume soil cuttings are placed under PDCE Barrier. Capital costs occur in Year 0. No annual O&M costs. No Periodic costs.

CAPITAL COSTS:

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
VOC Mass Removal Alternative M8				$ 75,564,000	See Cost Estimate Summary M8
In Situ Chemical Oxidation (ISCO)					
Installation of Shallow Injection Wells	1360	EA	$ 13,810	$ 18,781,600	See Cost Worksheet M-4
Injection Event 1	1	LS	$ 9,472,270	$ 9,472,270	See Cost Worksheet M-9
Injection Event 2	1	LS	$ 9,472,270	$ 9,472,270	See Cost Worksheet M-9
Injection Event 3	1	LS	$ 9,472,270	$ 9,472,270	See Cost Worksheet M-9
Injection Event 4	1	LS	$ 9,472,270	$ 9,472,270	See Cost Worksheet M-9
Well Abandonment	1	LS	$ 680,000	$ 680,000	Estimate
SUBTOTAL				$ 57,350,680	
Enhanced In Situ Bioremediation (ISB)					
Installation of Shallow Injection Wells	450	EA	$ 13,810	$ 6,214,500	See Cost Worksheet M-4
Injection Event 1	1	LS	$ 24,476,415	$ 24,476,415	See Cost Worksheet M-10
Injection Event 2	1	LS	$ 24,476,415	$ 24,476,415	See Cost Worksheet M-10
Injection Event 3	1	LS	$ 24,476,415	$ 24,476,415	See Cost Worksheet M-10
SUBTOTAL				$ 79,643,750	
Monitoring, Sampling, Testing, Analysis				$ -	Included in containment alternative
SUBTOTAL				$ 212,558,430	
Contingency		25%		$ 53,139,610	10% scope + 15% bid
SUBTOTAL				$ 265,698,000	
Project Management		5%		$ 13,284,900	
Remedial Design		8%		$ 21,255,900	
Construction Management		6%		$ 15,941,900	
TOTAL CAPITAL COSTS				**$ 316,180,700**	

ANNUAL O&M COSTS:

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Inspection	1	LS	$ 10,000	$ 10,000	5 days
Monitoring Groundwater					
Monitoring, Sampling, and Reporting	0	LS	$ -	$ -	Included in containment alternative
SUBTOTAL				$ 10,000	
Contingency		30%		$ 3,000	10% scope + 20% bid
SUBTOTAL				$ 13,000	
Project Management		5%		$ 700	
Technical Support		10%		$ 1,300	
TOTAL ANNUAL O&M COSTS				**$ 15,000**	

PERIODIC COSTS:

DESCRIPTION	YEAR	QTY	UNIT	UNIT COST	TOTAL	NOTES
Enhanced In Situ Bioremediation (ISB)						
Injection Event 4	8	1	EA	$ 14,019,723	$ 14,019,723	See Cost Worksheet M-11
Injection Event 5	10	1	EA	$ 14,019,723	$ 14,019,723	See Cost Worksheet M-11
Injection Event 6	12	1	EA	$ 14,019,723	$ 14,019,723	See Cost Worksheet M-11
Injection Event 7	14	1	EA	$ 8,791,377	$ 8,791,377	See Cost Worksheet M-12
Injection Event 8	16	1	EA	$ 8,791,377	$ 8,791,377	See Cost Worksheet M-12
Injection Event 9	18	1	EA	$ 8,791,377	$ 8,791,377	See Cost Worksheet M-12
Well Abandonment	19	1	EA	$ 225,000	$ 225,000	Estimate

VOC Mass Removal Alternative M9
SHALLOW SOIL TREATMENT BY ERH/SVE AND SHALLOW/DEEP GROUNDWATER/SOIL TREATMENT BY ISCO/ISB

COST ESTIMATE SUMMARY M9

Site: "Occidental" Site
Location: Tacoma, Washington
Phase: Feasibility Study (-30% to +50%) - 1.5%
Base Year: 2016
Date: December 8, 2016

Description: Mass Reduction Alternative M9 was designed to further reduce, by in situ treatment, TCVOC concentrations in deep groundwater and in deep soil potentially containing DNAPL (PTW) that could be a future source of contamination in soil and groundwater. The M9 alternative includes the M8 alternative plus ISCO and ISB to treat deep groundwater and soil below -60 ft NGVD containing TCVOC concentrations greater than 10 mg/L within the zone where pH is between 10 s.u. and 12.5 s.u. (ISCO) and within the zone where pH is less than 10 s.u. (ISB). Assume soil cuttings are placed under PDCE Barrier. Capital costs occur in Year 0. No annual O&M costs. No Periodic costs.

PRESENT VALUE ANALYSIS:

COST TYPE	YEAR	TOTAL COST	TOTAL COST PER YEAR	DISCOUNT FACTOR (1.5%)	PRESENT VALUE	NOTES
Capital Cost	0	$ 316,180,700	$ 316,180,700	1	$ 316,180,700	
Annual O&M Cost	1-19	$ 285,000	$ 15,000	16.43	$ 246,400	19 Years
Periodic Cost	8	$ 14,019,723	$ 14,019,723	0.888	$ 12,445,470	Injection Event for ISB
Periodic Cost	10	$ 14,019,723	$ 14,019,723	0.862	$ 12,080,340	Injection Event for ISB
Periodic Cost	12	$ 14,019,723	$ 14,019,723	0.836	$ 11,725,920	Injection Event for ISB
Periodic Cost	14	$ 8,791,377	$ 8,791,377	0.812	$ 7,137,280	Injection Event for ISB
Periodic Cost	16	$ 8,791,377	$ 8,791,377	0.788	$ 6,927,880	Injection Event for ISB
Periodic Cost	18	$ 8,791,377	$ 8,791,377	0.765	$ 6,724,630	Injection Event for ISB
Periodic Cost	19	$ 225,000	$ 225,000	0.754	$ 169,570	Injection Event for ISB
		$385,124,000			$ 373,638,190	

TOTAL PRESENT VALUE OF ALTERNATIVE **$ 373,638,190**

VOC Mass Removal/Reduction Alternatives M100, M150, and M200
Capital Cost Sub-Element
GROUNDWATER EXTRACTION WELLS AND CONVEYANCE

COST WORKSHEET M-1

Site: "Occidental" Site
Location: Tacoma, Washington
Phase: Feasibility Study (-30% to +50%)
Base Year: 2016

Prepared By: AW
Date: 6/2/2016

Checked By: RJH
Date: 12/6/2016

Work Statement:

Install two six-inch diameter groundwater extraction wells, well vaults, and forcemain. Installation includes drilling subcontractor, well materials including twenty-foot screens, pumps, piping, conduit, electrical hookup, asphalt removal/disposal and restoration. Assumes system will be constructed with a containment system GWETS.

Cost analysis:

Costs for major equipment, preparation, and Installation.

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	UNIT TOTAL	TOTAL	
Well Installation								
Mobilization/Demobilization	1	LS	-	-	-	5,125	5,125	Driller invoice
Wells Installation (-45 ft NGVD)	1	EA	incl.	30,900	incl.	30,900	30,900	6 inch well; Driller Invoice
Well Installation (-70 ft NGVD)	1	EA	incl.	34,500	incl.	34,500	34,500	6 inch well; Driller Invoice
Drilling Oversight	7	DAY	1,920	-	-	1,920	13,440	One drill rig operating
Surveyor	0	LS	20,000	-	-	20,000	-	Included with containment
Pumps	2	EA	-	2,800	-	2,800	5,600	Vendor pricing
Wiring	2	EA	-	1,800	-	1,800	3,600	GHD Estimate
Well Development @ 8 hours each	16	HR	250	-	-	250	4,000	GHD Estimate
Well Vaults (3' x 4' x 4') w/HD 20 Cover	2	EA	-	3,500	-	3,500	7,000	Vendor pricing
Asphalt Removal (Assume 6")	167	SY	10	-	-	10	1,583	GHD Estimate
Asphalt Disposal	22	TN	incl.	incl.	-	260	5,720	Vendor pricing
Excavation	156	CY	9	-	-	9	1,322	GHD Estimate
Sand Fill	56	CY	30	-	-	30	1,653	GHD Estimate
Aggregate Fill	100	CY	35	-	-	35	3,500	GHD Estimate
Asphalt Replacement	22	TN	105	-	-	105	2,333	GHD Estimate
SUBTOTAL							120,280	
Piping/Electrical								
Electrical Power Allowance	0	LS	35,000	-	-	35,000	-	Included with containment
Piping (HDPE)	300	LF	-	4	-	4	1,106	Vendor pricing
Electrical Conduit (2.0")	300	LF	-	12	-	12	3,600	Vendor pricing
Electrical Pull Boxes	1	EA	-	315	-	315	315	Vendor pricing
Hydro-Test Piping	0	LOT	-	2,500	-	2,500	-	Included with containment
SUBTOTAL							5,020	
Prime Contractor Overhead						15%	6,200	
SUBTOTAL							131,500	
Prime Contractor Profit						10%	4,750	
TOTAL UNIT COST							$ 136,250	

Source of Cost Data:

Estimate from GHD Construction Division (April 27, 2016) and Drilling Contractor Previous Invoices for Site Work (2013)

Cost Adjustment Checklist:

	FACTOR:	NOTES:
☑	H&S Productivity	Assume Level D
☑	Escalation to Base Year	2016
☑	Area Cost Factor	Based on local pricing
☑	Subcontractor Overhead and Profit	Not included in unit prices except for well construction and oversight
☑	Prime Contractor Overhead and Profit	Not included in unit prices except for well construction and oversight

VOC Mass Removal/Reduction Alternatives M100, M150, and M200
Maintenance Cost Sub-Element
EQUIPMENT REPLACEMENT COST - EXTRACTION PUMPS

COST WORKSHEET M-2

Site: "Occidental" Site
Location: Tacoma, Washington
Phase: Feasibility Study (-30% to +50%)
Base Year: 2016

Prepared By: AW
Date: 6/12/2016

Checked By: RJH
Date: 12/6/2016

Work Statement:

Replace pumps in extraction wells.

Cost analysis:

Costs for major equipment.

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	UNIT TOTAL	TOTAL
5 Year Replacement:							
EXT-22d Pump	1	EA	-	2,800	-	2800	2800
EXT-23s Pump	1	EA	-	2,800	-	2800	2800
SUBTOTAL							5600
Prime Contractor Overhead						15%	840
SUBTOTAL							6,440
Prime Contractor Profit						10%	640
TOTAL UNIT COST							$ 7,080

Source of Cost Data:

Estimate from Gary Pritchard, GHD Process Engineer, April 18, 2016

Cost Adjustment Checklist:

	FACTOR:	NOTES:
☑	H&S Productivity	Assume Level D
☑	Escalation to Base Year	2016
☑	Area Cost Factor	Based on local pricing
☑	Subcontractor Overhead and Profit	Added
☑	Prime Contractor Overhead and Profit	Added

VOC Mass Removal/Reduction Alternatives M8 and M9
Capital Cost Sub-Element
INJECTION WELL - SHALLOW

COST WORKSHEET M-3

Site: "Occidental" Site
Location: Tacoma, Washington
Phase: Feasibility Study (-30% to +50%)
Base Year: 2016

Prepared By: AW
Date: 6/2/2016

Checked By: RJH
Date: 12/6/2016

Work Statement:

Install an injection well in the shallow impacted zone to a depth of approximately -60 ft NGVD (approximately 75 ft bgs). The well would be 4-inch diameter PVC, Schedule 40. In the injection zone a No. 10 slot 5-foot long screen would be alternated with a 5-foot long length of casing. Bentonite chips would be placed in between each screened interval.

Cost analysis:

Costs per injection well.

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	UNIT TOTAL	TOTAL	
Mobilization/Demobilization	1	LS	-	-	-	140	140	% mob/demob for wells
Setup/Decontamination/Clearance	1.5	HR	255	-	-	255	383	
PPE	1.5	DAY	-	-	35	35	53	
Drill	75	FEET	45	incl.	-	45	3375	
Well Install -4" PVC	75	FEET	incl.	incl.	15	15	1125	
Flush Mount Casing	1	EA	incl.	incl.	550	550	550	
Development	8	HR	250	incl.	-	250	2000	
IDW Handling	1.5	HR	300	-	-	300	450	
SUBTOTAL							8075	
Prime Contractor Overhead						0%	0	
SUBTOTAL							8075	
Prime Contractor Profit						0%	0	
TOTAL UNIT COST							$ 8,075	

Source of Cost Data:

Estimate from Drilling Contractor Previous Invoices for Site Work (2013)

Cost Adjustment Checklist:

	FACTOR:	NOTES:
☑	H&S Productivity	Assume Level D
☑	Escalation to Base Year	2016
☑	Area Cost Factor	Based on local pricing
☑	Subcontractor Overhead and Profit	Included in unit pricing
☑	Prime Contractor Overhead and Profit	Included in unit pricing

VOC Mass Removal/Reduction Alternatives M8 and M9
Capital Cost Sub-Element
INJECTION WELL - DEEP

COST WORKSHEET M-4

Site: "Occidental" Site
Location: Tacoma, Washington
Phase: Feasibility Study (-30% to +50%)
Base Year: 2016

Prepared By: AW Date: 6/2/2016

Checked By: RJH Date: 12/6/2016

Work Statement:

Install an injection well in the deep impacted zone to a depth of approximately -150 ft NGVD (approximately 165 ft bgs). The well would be 4-inch diameter PVC, Schedule 40. In the injection zone a No. 10 slot 5-foot long screen would be alternated with a 5-foot long length of casing. Bentonite chips would be placed in between each screened interval.

Cost analysis:

Costs per injection well.

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	UNIT TOTAL	TOTAL	
Mobilization/Demobilization	1	LS	-	-	-	140	140	% mob/demob for wells
Setup/Decontamination/Clearance	1.5	HR	255	-	-	255	383	
PPE	2.5	DAY	-	-	35	35	88	
Drill	170	FEET	45	incl.	-	45	7650	
Well Install -4" PVC	170	FEET	incl.	incl.	15	15	2550	
Flush Mount Casing	1	EA	incl.	incl.	550	550	550	
Development	8	HR	250	incl.	-	250	2000	
IDW Handling	1.5	HR	300	-	-	300	450	
SUBTOTAL							13810	
Prime Contractor Overhead						0%	0	
SUBTOTAL							13810	
Prime Contractor Profit						0%	0	
TOTAL UNIT COST							$ 13,810	

Source of Cost Data:

Estimate from Drilling Contractor Previous Invoices for Site Work (2013)

Cost Adjustment Checklist:

	FACTOR:	NOTES:
☑	H&S Productivity	Assume Level D
☑	Escalation to Base Year	2016
☑	Area Cost Factor	Based on local pricing
☑	Subcontractor Overhead and Profit	Included in unit pricing
☑	Prime Contractor Overhead and Profit	Included in unit pricing

VOC Mass Removal/Reduction Alternatives M8 and M9
Capital Cost Sub-Element
IN SITU CHEMICAL OXIDATION (ISCO) INJECTION - SHALLOW

COST WORKSHEET M-5

Site: "Occidental" Site
Location: Tacoma, Washington
Phase: Feasibility Study (-30% to +50%)
Base Year: 2016

Prepared By: AW Date: 6/2/2016

Checked By: RJH Date: 12/6/2016

Work Statement:

Injection of alkaline persulfate. This cost sheet includes the shallow target zone.

Cost analysis:

Costs per ISCO treatment event.

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	UNIT TOTAL	TOTAL	
Mobilization/Demobilization	1	LS	-	-	-	50000	50000	
Equipment (tubing, pumps,)	1	LS	-	-	-	25000	25000	Assumption
Reagent (alkaline persulfate)	62038	CY	-	-	15	15	930570	15 lbs/cy
Injection Labor	170	DAYS	3000	-	-	3000	510000	1/2 day/well; 340 Wells
Waste Management	1%	%	-	-	-	1515570	15160	1% of injection costs
SUBTOTAL							1530730	
Prime Contractor Overhead						15%	229610	
SUBTOTAL							1760340	
Prime Contractor Profit						10%	176030	
TOTAL UNIT COST							$1,936,370	

Source of Cost Data:

Estimate

Cost Adjustment Checklist:

	FACTOR:	NOTES:
☑	H&S Productivity	Assume Level D
☑	Escalation to Base Year	2016
☑	Area Cost Factor	Based on general pricing
☑	Subcontractor Overhead and Profit	Added
☑	Prime Contractor Overhead and Profit	Added

VOC Mass Removal/Reduction Alternatives M8 and M9
Capital Cost Sub-Element
ENHANCED IN SITU BIOREMEDIATION (ISB) INJECTION - SHALLOW

COST WORKSHEET M-6

Site: "Occidental" Site
Location: Tacoma, Washington
Phase: Feasibility Study (-30% to +50%)
Base Year: 2016

Prepared By: AW
Date: 6/2/2016

Checked By: RJH
Date: 12/6/2016

Work Statement:

Injection of substrate, DHC, and enhancements at a rate of 100 percent of the original dosage in years 2, 4, 6. This cost sheet includes the shallow target zone.

Cost analysis:

Costs per ISB treatment event.

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	UNIT TOTAL	TOTAL	
Mobilization/Demobilization	1	LS	-	-	-	50000	50000	
Equipment (tubing, pumps, etc.)	1	LS	-	-	-	25000	25000	Assumption
Substrate (emulsified veg. oil)	428766	CY	-	-	6	6	2572596	3 lbs per CY
DHC and Enhancements	428766	CY	-	-	10	10	4287660	1 dose per CY
Injection - field techs	280	DAYS	3000	-	-	3000	840000	1 day/well; 280 Wells
Waste Management	1%	%	-	-	-	7775256	77753	1% of injection costs
SUBTOTAL							7853010	
Prime Contractor Overhead						15%	1177950	
SUBTOTAL							9030960	
Prime Contractor Profit						10%	903100	
TOTAL UNIT COST							$9,934,060	

Source of Cost Data:

Estimate

Cost Adjustment Checklist:

	FACTOR:	NOTES:
☑	H&S Productivity	Assume Level D
☑	Escalation to Base Year	2016
☑	Area Cost Factor	Based on general pricing
☑	Subcontractor Overhead and Profit	Added
☑	Prime Contractor Overhead and Profit	Added

VOC Mass Removal/Reduction Alternatives M8 and M9
Capital Cost Sub-Element
ENHANCED IN SITU BIOREMEDIATION (ISB) INJECTION - SHALLOW

COST WORKSHEET M-7

Site: "Occidental" Site
Location: Tacoma, Washington
Phase: Feasibility Study (-30% to +50%)
Base Year: 2016

Prepared By: AW
Date: 6/2/2016

Checked By: RJH
Date: 12/6/2016

Work Statement:

Injection of substrate, DHC, and enhancements at a rate of 50 percent of the original dosage in years 8, 10, 12 because of anticipated mass reduction. This cost sheet includes the shallow target zone.

Cost analysis:

Costs per ISB treatment event.

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	UNIT TOTAL	TOTAL	
Mobilization/Demobilization	1	LS	-	-	-	50000	50000	
Equipment (tubing, pumps, etc.)	1	LS	-	-	-	25000	25000	Assumption
Substrate (emulsified veg. oil)	428766	CY	-	-	3	3	1286298	1.5 lbs per CY
DHC and Enhancements	428766	CY	-	-	5	5	2143830	1/2 dose per CY
Injection - field techs	280	DAYS	3000	-	-	3000	840000	1 day/well; 280 Wells
Waste Management	1%	%	-	-	-	4345128	43451	1% of injection costs
SUBTOTAL							4388580	
Prime Contractor Overhead						15%	658290	
SUBTOTAL							5046870	
Prime Contractor Profit						10%	504690	
TOTAL UNIT COST							$5,551,560	

Source of Cost Data:

Estimate

Cost Adjustment Checklist:

	FACTOR:	NOTES:
☑	H&S Productivity	Assume Level D
☑	Escalation to Base Year	2016
☑	Area Cost Factor	Based on general pricing
☑	Subcontractor Overhead and Profit	Added
☑	Prime Contractor Overhead and Profit	Added

VOC Mass Removal/Reduction Alternatives M8 and M9
Capital Cost Sub-Element
ENHANCED IN SITU BIOREMEDIATION (ISB) INJECTION - SHALLOW

COST WORKSHEET M-8

Site: "Occidental" Site
Location: Tacoma, Washington
Phase: Feasibility Study (-30% to +50%)
Base Year: 2016

Prepared By: AW
Date: 6/2/2016

Checked By: RJH
Date: 12/6/2016

Work Statement:

Injection of substrate, DHC, and enhancements at a rate of 25 percent of the original dosage in years 14, 16, 18 because of anticipated mass reduction. This cost sheet includes the shallow target zone.

Cost analysis:

Costs per ISB treatment event.

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	UNIT TOTAL	TOTAL	
Mobilization/Demobilization	1	LS	-	-	-	50000	50000	
Equipment (tubing, pumps, etc.)	1	LS	-	-	-	25000	25000	Assumption
Substrate (emulsified veg. oil)	428766	CY	-	-	1.5	1.5	643149	0.75 lbs per CY
DHC and Enhancements	428766	CY	-	-	3	3	1071915	1/4 dose per CY
Injection - field techs	280	DAYS	3000	-	-	3000	840000	1 day/well; 280 Wells
Waste Management	1%	%	-	-	-	2630064	26301	1% of injection costs
SUBTOTAL							2656360	
Prime Contractor Overhead						15%	398450	
SUBTOTAL							3054810	
Prime Contractor Profit						10%	305480	
TOTAL UNIT COST							$3,360,290	

Source of Cost Data:

Estimate

Cost Adjustment Checklist:

	FACTOR:	NOTES:
☑	H&S Productivity	Assume Level D
☑	Escalation to Base Year	2016
☑	Area Cost Factor	Based on general pricing
☑	Subcontractor Overhead and Profit	Added
☑	Prime Contractor Overhead and Profit	Added

VOC Mass Removal/Reduction Alternative M9
Capital Cost Sub-Element
IN SITU CHEMICAL OXIDATION (ISCO) INJECTION - DEEP

COST WORKSHEET M-9

Site: "Occidental" Site
Location: Tacoma, Washington
Phase: Feasibility Study (-30% to +50%)
Base Year: 2016

Prepared By: AW Date: 6/2/2016

Checked By: RJH Date: 12/6/2016

Work Statement:

Injection of alkaline persulfate. This cost sheet includes the deep target zone.

Cost analysis:

Costs per ISCO treatment event.

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	UNIT TOTAL	TOTAL	
Mobilization/Demobilization	1	LS	-	-	-	50000	50000	
Equipment (tubing, pumps,)	1	LS	-	-	-	25000	25000	Assumption
Reagent (alkaline persulfate)	350820	CY	-	-	15	15	5262300	15 lbs/cy
Injection Labor	680	DAYS	3000	-	-	3000	2040000	1/2 day/well; 1360 Wells
Waste Management	1.5%	%	-	-	-	7377300	110660	1.5% of injection costs
SUBTOTAL							7487960	
Prime Contractor Overhead						15%	1123190	
SUBTOTAL							8611150	
Prime Contractor Profit						10%	861120	
TOTAL UNIT COST							$9,472,270	

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Source of Cost Data:

Estimate

Cost Adjustment Checklist:

	FACTOR:	NOTES:
☑	H&S Productivity	Assume Level D
☑	Escalation to Base Year	2016
☑	Area Cost Factor	Based on general pricing
☑	Subcontractor Overhead and Profit	Added
☑	Prime Contractor Overhead and Profit	Added

VOC Mass Removal/Reduction Alternative M9
Capital Cost Sub-Element
ENHANCED IN SITU BIOREMEDIATION (ISB) INJECTION - DEEP

COST WORKSHEET M-10

Site: "Occidental" Site
Location: Tacoma, Washington
Phase: Feasibility Study (-30% to +50%)
Base Year: 2016

Prepared By: AW
Date: 6/2/2016

Checked By: RJH
Date: 12/6/2016

Work Statement:

Injection of substrate, DHC, and enhancements at a rate of 100 percent of the original dosage in years 2, 4, 6. This cost sheet includes the deep target zone.

Cost analysis:

Costs per ISB treatment event.

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	UNIT TOTAL	TOTAL	
Mobilization/Demobilization	1	LS	-	-	-	50000	50000	
Equipment (tubing, pumps, etc.)	1	LS	-	-	-	25000	25000	Assumption
Substrate (emulsified veg. oil)	1018000	CY	-	-	6	6	6108000	3 lbs per CY
DHC and Enhancements	1018000	CY	-	-	10	10	10180000	1 dose per CY
Injection - field techs	900	DAYS	3000	-	-	3000	2700000	2 days/well; 450 Wells
Waste Management	1.5%	%	-	-	-	19063000	285945	1.5% of injection costs
SUBTOTAL							19348945	
Prime Contractor Overhead						15%	2902342	
SUBTOTAL							22251287	
Prime Contractor Profit						10%	2225129	
TOTAL UNIT COST							$24,476,415	

Source of Cost Data:

Estimate

Cost Adjustment Checklist:

	FACTOR:	NOTES:
☑	H&S Productivity	Assume Level D
☑	Escalation to Base Year	2016
☑	Area Cost Factor	Based on general pricing
☑	Subcontractor Overhead and Profit	Added
☑	Prime Contractor Overhead and Profit	Added

VOC Mass Removal/Reduction Alternative M9
Capital Cost Sub-Element
ENHANCED IN SITU BIOREMEDIATION (ISB) INJECTION - DEEP

COST WORKSHEET M-11

Site: "Occidental" Site
Location: Tacoma, Washington
Phase: Feasibility Study (-30% to +50%)
Base Year: 2016

Prepared By: AW
Date: 6/2/2016

Checked By: RJH
Date: 12/6/2016

Work Statement:

Injection of substrate, DHC, and enhancements at a rate of 50 percent of the original dosage in years 8, 10, 12 because of anticipated mass reduction. This cost sheet includes the deep target zone.

Cost analysis:

Costs per ISB treatment event.

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	UNIT TOTAL	TOTAL	
Mobilization/Demobilization	1	LS	-	-	-	50000	50000	
Equipment (tubing, pumps, etc.)	1	LS	-	-	-	25000	25000	Assumption
Substrate (emulsified veg. oil)	1018000	CY	-	-	3	3	3054000	1.5 lbs per CY
DHC and Enhancements	1018000	CY	-	-	5	5	5090000	1/2 dose per CY
Injection - field techs	900	DAYS	3000	-	-	3000	2700000	2 days/well; 450 Wells
Waste Management	1.5%	%	-	-	-	10919000	163785	1.5% of injection costs
SUBTOTAL							11082785	
Prime Contractor Overhead						15%	1662418	
SUBTOTAL							12745203	
Prime Contractor Profit						10%	1274520	
TOTAL UNIT COST							$14,019,723	

Source of Cost Data:

Estimate

Cost Adjustment Checklist:

	FACTOR:	NOTES:
☑	H&S Productivity	Assume Level D
☑	Escalation to Base Year	2016
☑	Area Cost Factor	Based on general pricing
☑	Subcontractor Overhead and Profit	Added
☑	Prime Contractor Overhead and Profit	Added

VOC Mass Removal/Reduction Alternative M9
Capital Cost Sub-Element
ENHANCED IN SITU BIOREMEDIATION (ISB) INJECTION - DEEP

COST WORKSHEET M-12

Site: "Occidental" Site
Location: Tacoma, Washington
Phase: Feasibility Study (-30% to +50%)
Base Year: 2016

Prepared By: AW
Date: 6/2/2016

Checked By: RJH
Date: 12/6/2016

Work Statement:

Injection of substrate, DHC, and enhancements at a rate of 25 percent of the original dosage in years 14, 16, 18 because of anticipated mass reduction. This cost sheet includes the deep target zone.

Cost analysis:

Costs per ISB treatment event.

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	UNIT TOTAL	TOTAL	
Mobilization/Demobilization	1	LS	-	-	-	50000	50000	
Equipment (tubing, pumps, etc.)	1	LS	-	-	-	25000	25000	Assumption
Substrate (emulsified veg. oil)	1018000	CY	-	-	1.5	1.5	1527000	0.75 lbs per CY
DHC and Enhancements	1018000	CY	-	-	3	3	2545000	1/4 dose per CY
Injection - field techs	900	DAYS	3000	-	-	3000	2700000	2 days/well; 450 Wells
Waste Management	1.5%	%	-	-	-	6847000	102705	1.5% of injection costs
SUBTOTAL							6949705	
Prime Contractor Overhead						15%	1042456	
SUBTOTAL							7992161	
Prime Contractor Profit						10%	799216	
TOTAL UNIT COST							$8,791,377	

Source of Cost Data:

Estimate

Cost Adjustment Checklist:

	FACTOR:	NOTES:
☑	H&S Productivity	Assume Level D
☑	Escalation to Base Year	2016
☑	Area Cost Factor	Based on general pricing
☑	Subcontractor Overhead and Profit	Added
☑	Prime Contractor Overhead and Profit	Added

VOC Mass Reduction Alternative MSP
Capital Cost Sub-Element
EXTRACTION WELLS AND CONVEYANCES

COST WORKSHEET M-13

Site: "Occidental" Site
Location: Tacoma, Washington
Phase: Feasibility Study (-30% to +50%)
Base Year: 2016

Prepared By: AW
Date: 11/21/2016

Checked By: RJH
Date: 12/8/2016

Work Statement:

The work includes groundwater extraction wells, pumps, well vaults, forcemains, electrical conduit, etc. to extract and convey groundwater to the treatment system.

Cost analysis:

Costs for equipment, preparation, and installation.

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	UNIT TOTAL	TOTAL	
Well Installation								
Mobilization/Demobilization	1	LS	-	-	-	44,800	44,800	Driller Invoice
Wells Installation (-18.75 ft NGVD)	1	EA	incl.	27,200	incl.	27,200	27,200	6 inch well - Driller Invoice
Wells Installation (-36.25 ft NGVD)	2	EA	incl.	29,700	incl.	29,700	59,400	6 inch well - Driller Invoice
Wells Installation (-38.75 ft NGVD)	1	EA	incl.	30,100	incl.	30,100	30,100	6 inch well - Driller Invoice
Wells Installation (-76.25 ft NGVD)	1	EA	incl.	35,400	incl.	35,400	35,400	6 inch well - Driller Invoice
Wells Installation (-120 ft NGVD)	3	EA	incl.	41,700	incl.	41,700	125,100	6 inch well - Driller Invoice
Wells Installation (-123.75 ft NGVD)	1	EA	incl.	42,300	incl.	42,300	42,300	6 inch well - Driller Invoice
Well Installation (-141.25 ft NGVD)	1	EA	incl.	44,800	incl.	44,800	44,800	6 inch well - Driller Invoice
Well Installation (-153.75 ft NGVD)	1	EA	incl.	46,600	incl.	46,600	46,600	6 inch well - Driller Invoice
Drilling Oversight	44	DAY	1,920	-	-	1,920	84,480	Two drill rigs operating
Surveyor	1	LS	20,000	-	-	20,000	20,000	
Pumps	11	EA	-	1,736	-	1,736	19,100	
Wiring	11	EA	-	1,800	-	1,800	19,800	
Well Development @ 8 hours each	88	HR	250	incl.	incl.	250	22,000	
Well Vaults (3' x 4' x 4') w/HD 20 Cover	11	EA	-	3,500	-	3,500	38,500	
Asphalt Removal (Assume 6")	2000	SY	10	-	-	10	19,000	
Asphalt Disposal	260	TN	incl.	incl.	-	-	-	
Excavation	2250	CY	9	incl.	-	9	19,125	
Sand Fill	1850	CY	30	incl.	incl.	30	55,038	
Aggregate Fill	400	CY	35	incl.	incl.	35	14,000	
Asphalt Replacement	550	TN	105	incl.	incl.	105	57,750	
SUBTOTAL							824,490	
Piping/Electrical								
Electrical Power Allowance	1	LS	35,000	incl.	incl.	35,000	35,000	
Piping (HDPE)	3600	LF	incl.	incl.	5.75	6	20,700	
Electrical Conduit (2.0")	3500	LF	incl.	incl.	12	12	42,000	
Electrical Pull Boxes	12	EA	incl.	incl.	315	315	3,780	
Hydro-Test Piping	1	LS	2,500	incl.	-	2,500	2,500	
SUBTOTAL							103,980	
Prime Contractor Overhead						15%	58,244	
SUBTOTAL							986,714	
Prime Contractor Profit						10%	44,650	
TOTAL UNIT COST							$1,031,360	

Source of Cost Data:

Estimate from GHD Construction Division (April 27, 2016) and Drilling Contractor Previous Invoices for Site Work (2013)

Cost Adjustment Checklist:

	FACTOR:	NOTES:
☑	H&S Productivity	Assume Level D
☑	Escalation to Base Year	2016
☑	Area Cost Factor	Based on general pricing
☑	Subcontractor Overhead and Profit	Not included in unit prices except for well construction and oversight
☑	Prime Contractor Overhead and Profit	Not included in unit prices except for well construction and oversight

VOC Mass Reduction Alternative MSP
O&M Sub-Element
TREATMENT SYSTEM EQUIPMENT - 300 GPM SYSTEM

COST WORKSHEET M-14

Site: "Occidental" Site
Location: Tacoma, Washington
Phase: Feasibility Study (-30% to +50%)
Base Year: 2016

Prepared By: AW
Date: 11/21/2016

Checked By: RJH
Date: 12/8/2016

Work Statement:

This work sheet includes equipment replacement costs based on typical product lives.

Cost analysis:

Costs for equipment, preparation, and installation.

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	UNIT TOTAL	TOTAL
5 Year Replacement							
MR1 - Pump	1	EA	-	1,736	-	1,736	1,736
MR2 - Pump	1	EA	-	1,736	-	1,736	1,736
MR3 - Pump	1	EA	-	1,736	-	1,736	1,736
NW1 - Pump	1	EA	-	1,736	-	1,736	1,736
NW2 - Pump	1	EA	-	1,736	-	1,736	1,736
NW3 - Pump	1	EA	-	1,736	-	1,736	1,736
NW4 - Pump	1	EA	-	1,736	-	1,736	1,736
NW5 - Pump	1	EA	-	1,736	-	1,736	1,736
NW6 - Pump	1	EA	-	1,736	-	1,736	1,736
NW7 - Pump	1	EA	-	1,736	-	1,736	1,736
NW8 - Pump	1	EA	-	1,736	-	1,736	1,736
SUBTOTAL							19,100
15 Year Replacement							
Inclined Plate Clarifier	1	LS	incl.	260,000	incl.	260,000	260,000
Air Stripper Blower	1	LS	incl.	83,440	incl.	83,440	83,440
Regenerative Thermal Oxidizer Package	1	LS	incl.	900,200	incl.	900,200	900,200
Air Compressor	1	LS	incl.	14,600	incl.	14,600	14,600
Compressed Air Desiccant Dryer	1	LS	incl.	5,483	incl.	5,483	5,483
Clarifier Feed Pump	1	EA	incl.	18,280	incl.	18,280	18,280
Air Stripper Transfer Pump	1	EA	incl.	22,356	incl.	22,356	22,356
Building Sump Pump	1	EA	incl.	2,563	incl.	2,563	2,563
Clarifier Bottoms Pump	1	EA	incl.	1,941	incl.	1,941	1,941
Dirty Backwash Recycle Pump	1	EA	incl.	1,941	incl.	1,941	1,941
Coagulant Metering Pump	1	LS	incl.	2,000	incl.	2,000	2,000
Polymer Metering / Blending Unit	1	LS	incl.	15,000	incl.	15,000	15,000
Sequestering Agent Metering Pump	1	LS	incl.	2,000	incl.	2,000	2,000
Equalization Tank	1	EA	incl.	39,371	incl.	39,371	39,371
Clarifier Sludge Tank	1	EA	incl.	25,096	incl.	25,096	25,096
Dirty Backwash Tank	1	EA	incl.	47,081	incl.	47,081	47,081
Effluent Tank	1	EA	incl.	16,469	incl.	16,469	16,469
Add metal tanks higher grade lining	1	LS	-	11,155	-	11,155	11,155
Add tanks high seismic zone - extra 10%	10	%	-	158,372	-	158,372	15,837
SUBTOTAL							1,484,810
20 Year Replacement							
Filter Press	1	LS	incl.	208,000	incl.	208,000	208,000
Multimedia Filter Skid	1	LS	incl.	180,000	incl.	180,000	180,000
Cartridge Filter Skid	1	LS	incl.	13,429	incl.	13,429	13,429
Carbon Filters (2 vessels)	1	LS	incl.	300,000	incl.	300,000	300,000
Sand Filter Feed Pump	1	EA	incl.	22,356	incl.	22,356	22,356
Sand Filter Backwash Pump	1	EA	incl.	24,243	incl.	24,243	24,243
Filter Press Sludge Pump	1	EA	incl.	2,561	incl.	2,561	2,561
Filter Feed Tank	1	EA	incl.	19,200	incl.	19,200	19,200
SUBTOTAL							769,790
Prime Contractor Overhead						15%	2,865
SUBTOTAL							2,276,565
Prime Contractor Profit						10%	1,910
TOTAL UNIT COST							$2,278,480

Source of Cost Data:

Estimate from Gary Pritchard, GHD Process Engineer, April 29, 2016

VOC Mass Reduction Alternative MSP
O&M Sub-Element
TREATMENT SYSTEM EQUIPMENT - 300 GPM SYSTEM

COST WORKSHEET M-14

Site:	"Occidental" Site	Prepared By: AW	Checked By: RJH
Location:	Tacoma, Washington	Date: 11/21/2016	Date: 12/8/2016
Phase:	Feasibility Study (-30% to +50%)		
Base Year:	2016		

Cost Adjustment Checklist:

	FACTOR:	NOTES:
☑	H&S Productivity	Assume Level D
☑	Escalation to Base Year	2016
☑	Area Cost Factor	Based on general pricing
☑	Subcontractor Overhead and Profit	Included in unit pricing except pumps
☑	Prime Contractor Overhead and Profit	Included in unit pricing except pumps

VOC Mass Alternative M100
GROUNDWATER EXTRACTION AND TREATMENT

COST ESTIMATE SUMMARY M100

Site: "Occidental" Site
Location: Tacoma, Washington
Phase: Feasibility Study (-30% to +50%)
Base Year: 2016
Date: December 8, 2016

Description: 100-Year Cash Flow Projection at 7 percent

PRESENT VALUE ANALYSIS ***Base YR 2016*** 7.0% Discount Rate

Year	Cost Type	Cost	Discount Rate	Present Value	Notes
0	Capital Costs	$ 202,950	1.000	$ 202,950	
1	Annual O&M Costs	$ 70,000	0.935	$ 65,421	
2	Annual O&M Costs	$ 70,000	0.873	$ 61,141	
3	Annual O&M Costs	$ 70,000	0.816	$ 57,141	
4	Annual O&M Costs	$ 70,000	0.763	$ 53,403	
5	Annual O&M Costs	$ 70,000	0.713	$ 49,909	
5	Periodic Costs	$ 7,080	0.713	$ 5,048	Pump replacement
6	Annual O&M Costs	$ 70,000	0.666	$ 46,644	
7	Annual O&M Costs	$ 70,000	0.623	$ 43,592	
8	Annual O&M Costs	$ 70,000	0.582	$ 40,741	
9	Annual O&M Costs	$ 70,000	0.544	$ 38,075	
10	Annual O&M Costs	$ 70,000	0.508	$ 35,584	
10	Periodic Costs	$ 7,080	0.508	$ 3,599	Pump replacement
11	Annual O&M Costs	$ 70,000	0.475	$ 33,256	
12	Annual O&M Costs	$ 70,000	0.444	$ 31,081	
13	Annual O&M Costs	$ 70,000	0.415	$ 29,048	
14	Annual O&M Costs	$ 70,000	0.388	$ 27,147	
15	Annual O&M Costs	$ 70,000	0.362	$ 25,371	
15	Periodic Costs	$ 7,080	0.362	$ 2,566	Pump replacement
16	Annual O&M Costs	$ 70,000	0.339	$ 23,711	
17	Annual O&M Costs	$ 70,000	0.317	$ 22,160	
18	Annual O&M Costs	$ 70,000	0.296	$ 20,710	
19	Annual O&M Costs	$ 70,000	0.277	$ 19,356	
20	Annual O&M Costs	$ 70,000	0.258	$ 18,089	
20	Periodic Costs	$ 7,080	0.258	$ 1,830	Pump replacement
21	Annual O&M Costs	$ 70,000	0.242	$ 16,906	
22	Annual O&M Costs	$ 70,000	0.226	$ 15,800	
23	Annual O&M Costs	$ 70,000	0.211	$ 14,766	
24	Annual O&M Costs	$ 70,000	0.197	$ 13,800	
25	Annual O&M Costs	$ 70,000	0.184	$ 12,897	
25	Periodic Costs	$ 7,080	0.184	$ 1,304	Pump replacement
26	Annual O&M Costs	$ 70,000	0.172	$ 12,054	
27	Annual O&M Costs	$ 70,000	0.161	$ 11,265	
28	Annual O&M Costs	$ 70,000	0.150	$ 10,528	
29	Annual O&M Costs	$ 70,000	0.141	$ 9,839	
30	Annual O&M Costs	$ 70,000	0.131	$ 9,196	
30	Periodic Costs	$ 7,080	0.131	$ 930	Pump replacement
31	Annual O&M Costs	$ 70,000	0.123	$ 8,594	
32	Annual O&M Costs	$ 70,000	0.115	$ 8,032	
33	Annual O&M Costs	$ 70,000	0.107	$ 7,506	
34	Annual O&M Costs	$ 70,000	0.100	$ 7,015	
35	Annual O&M Costs	$ 70,000	0.094	$ 6,556	
35	Periodic Costs	$ 7,080	0.094	$ 663	Pump replacement
36	Annual O&M Costs	$ 70,000	0.088	$ 6,127	
37	Annual O&M Costs	$ 70,000	0.082	$ 5,727	
38	Annual O&M Costs	$ 70,000	0.076	$ 5,352	
39	Annual O&M Costs	$ 70,000	0.071	$ 5,002	
40	Annual O&M Costs	$ 70,000	0.067	$ 4,675	
40	Periodic Costs	$ 7,080	0.067	$ 473	Pump replacement
41	Annual O&M Costs	$ 70,000	0.062	$ 4,369	
42	Annual O&M Costs	$ 70,000	0.058	$ 4,083	
43	Annual O&M Costs	$ 70,000	0.055	$ 3,816	
44	Annual O&M Costs	$ 70,000	0.051	$ 3,566	
45	Annual O&M Costs	$ 70,000	0.048	$ 3,333	
45	Periodic Costs	$ 7,080	0.048	$ 337	Pump replacement
46	Annual O&M Costs	$ 70,000	0.044	$ 3,115	
47	Annual O&M Costs	$ 70,000	0.042	$ 2,911	
48	Annual O&M Costs	$ 70,000	0.039	$ 2,721	
49	Annual O&M Costs	$ 70,000	0.036	$ 2,543	
50	Annual O&M Costs	$ 70,000	0.034	$ 2,376	
50	Periodic Costs	$ 7,080	0.034	$ 240	Pump replacement
51	Annual O&M Costs	$ 70,000	0.032	$ 2,221	
52	Annual O&M Costs	$ 70,000	0.030	$ 2,076	
53	Annual O&M Costs	$ 70,000	0.028	$ 1,940	
54	Annual O&M Costs	$ 70,000	0.026	$ 1,813	
55	Annual O&M Costs	$ 70,000	0.024	$ 1,694	
55	Periodic Costs	$ 7,080	0.024	$ 171	Pump replacement
56	Annual O&M Costs	$ 70,000	0.023	$ 1,583	
57	Annual O&M Costs	$ 70,000	0.021	$ 1,480	
58	Annual O&M Costs	$ 70,000	0.020	$ 1,383	
59	Annual O&M Costs	$ 70,000	0.018	$ 1,293	
60	Annual O&M Costs	$ 70,000	0.017	$ 1,208	
60	Periodic Costs	$ 7,080	0.017	$ 122	Pump replacement
61	Annual O&M Costs	$ 70,000	0.016	$ 1,129	
62	Annual O&M Costs	$ 70,000	0.015	$ 1,055	
63	Annual O&M Costs	$ 70,000	0.014	$ 986	
64	Annual O&M Costs	$ 70,000	0.013	$ 922	
65	Annual O&M Costs	$ 70,000	0.012	$ 861	
65	Periodic Costs	$ 7,080	0.012	$ 87	Pump replacement
66	Annual O&M Costs	$ 70,000	0.011	$ 805	
67	Annual O&M Costs	$ 70,000	0.011	$ 752	
68	Annual O&M Costs	$ 70,000	0.010	$ 703	
69	Annual O&M Costs	$ 70,000	0.009	$ 657	
70	Annual O&M Costs	$ 70,000	0.009	$ 614	
70	Periodic Costs	$ 7,080	0.009	$ 62	Pump replacement

VOC Mass Alternative M100
GROUNDWATER EXTRACTION AND TREATMENT

COST ESTIMATE SUMMARY M100

Site:	"Occidental" Site	Description:	100-Year Cash Flow Projection at 7 percent
Location:	Tacoma, Washington		
Phase:	Feasibility Study (-30% to +50%)		
Base Year:	2016		
Date:	December 8, 2016		

PRESENT VALUE ANALYSIS ***Base YR 2016*** 7.0% Discount Rate

Year	Cost Type	Cost	Discount Rate	Present Value	Notes
71	Annual O&M Costs	$ 70,000	0.008	$ 574	
72	Annual O&M Costs	$ 70,000	0.008	$ 536	
73	Annual O&M Costs	$ 70,000	0.007	$ 501	
74	Annual O&M Costs	$ 70,000	0.007	$ 468	
75	Annual O&M Costs	$ 70,000	0.006	$ 438	
75	Periodic Costs	$ 7,080	0.006	$ 44	Pump replacement
76	Annual O&M Costs	$ 70,000	0.006	$ 409	
77	Annual O&M Costs	$ 70,000	0.005	$ 382	
78	Annual O&M Costs	$ 70,000	0.005	$ 357	
79	Annual O&M Costs	$ 70,000	0.005	$ 334	
80	Annual O&M Costs	$ 70,000	0.004	$ 312	
80	Periodic Costs	$ 7,080	0.004	$ 32	Pump replacement
81	Annual O&M Costs	$ 70,000	0.004	$ 292	
82	Annual O&M Costs	$ 70,000	0.004	$ 273	
83	Annual O&M Costs	$ 70,000	0.004	$ 255	
84	Annual O&M Costs	$ 70,000	0.003	$ 238	
85	Annual O&M Costs	$ 70,000	0.003	$ 223	
85	Periodic Costs	$ 7,080	0.003	$ 23	Pump replacement
86	Annual O&M Costs	$ 70,000	0.003	$ 208	
87	Annual O&M Costs	$ 70,000	0.003	$ 194	
88	Annual O&M Costs	$ 70,000	0.003	$ 182	
89	Annual O&M Costs	$ 70,000	0.002	$ 170	
90	Annual O&M Costs	$ 70,000	0.002	$ 159	
90	Periodic Costs	$ 7,080	0.002	$ 16	Pump replacement
91	Annual O&M Costs	$ 70,000	0.002	$ 148	
92	Annual O&M Costs	$ 70,000	0.002	$ 139	
93	Annual O&M Costs	$ 70,000	0.002	$ 130	
94	Annual O&M Costs	$ 70,000	0.002	$ 121	
95	Annual O&M Costs	$ 70,000	0.002	$ 113	
95	Periodic Costs	$ 7,080	0.002	$ 11	Pump replacement
96	Annual O&M Costs	$ 70,000	0.002	$ 106	
97	Annual O&M Costs	$ 70,000	0.001	$ 99	
98	Annual O&M Costs	$ 70,000	0.001	$ 92	
99	Annual O&M Costs	$ 70,000	0.001	$ 86	
100	Annual O&M Costs	$ 70,000	0.001	$ 81	
100	Demolition	$ 50,000	0.001	$ 58	
100	Final Completion Report	$ 5,000	0.001	$ 6	
		$ 7,390,000		**$ 1,220,000**	

TOTAL PRESENT VALUE OF ALTERNATIVE	**$ 1,220,000**

VOC Mass Alternative M100
GROUNDWATER EXTRACTION AND TREATMENT

COST ESTIMATE SUMMARY M100

Site: "Occidental" Site
Location: Tacoma, Washington
Phase: Feasibility Study (-30% to +50%)
Base Year: 2016
Date: December 8, 2016

Description: 100-Year Cash Flow Projection at 1.5 percent

PRESENT VALUE ANALYSIS ***Base YR 2016*** 1.5% Discount Rate

Year	Cost Type	Cost	Discount Rate	Present Value	Notes
0	Capital Costs	$ 202,950	1.000	$ 202,950	
1	Annual O&M Costs	$ 70,000	0.985	$ 68,966	
2	Annual O&M Costs	$ 70,000	0.971	$ 67,946	
3	Annual O&M Costs	$ 70,000	0.956	$ 66,942	
4	Annual O&M Costs	$ 70,000	0.942	$ 65,953	
5	Annual O&M Costs	$ 70,000	0.928	$ 64,978	
5	Periodic Costs	$ 7,080	0.928	$ 6,572	Pump replacement
6	Annual O&M Costs	$ 70,000	0.915	$ 64,018	
7	Annual O&M Costs	$ 70,000	0.901	$ 63,072	
8	Annual O&M Costs	$ 70,000	0.888	$ 62,140	
9	Annual O&M Costs	$ 70,000	0.875	$ 61,221	
10	Annual O&M Costs	$ 70,000	0.862	$ 60,317	
10	Periodic Costs	$ 7,080	0.862	$ 6,101	Pump replacement
11	Annual O&M Costs	$ 70,000	0.849	$ 59,425	
12	Annual O&M Costs	$ 70,000	0.836	$ 58,547	
13	Annual O&M Costs	$ 70,000	0.824	$ 57,682	
14	Annual O&M Costs	$ 70,000	0.812	$ 56,829	
15	Annual O&M Costs	$ 70,000	0.800	$ 55,990	
15	Periodic Costs	$ 7,080	0.800	$ 5,663	Pump replacement
16	Annual O&M Costs	$ 70,000	0.788	$ 55,162	
17	Annual O&M Costs	$ 70,000	0.776	$ 54,347	
18	Annual O&M Costs	$ 70,000	0.765	$ 53,544	
19	Annual O&M Costs	$ 70,000	0.754	$ 52,753	
20	Annual O&M Costs	$ 70,000	0.742	$ 51,973	
20	Periodic Costs	$ 7,080	0.742	$ 5,257	Pump replacement
21	Annual O&M Costs	$ 70,000	0.731	$ 51,205	
22	Annual O&M Costs	$ 70,000	0.721	$ 50,448	
23	Annual O&M Costs	$ 70,000	0.710	$ 49,703	
24	Annual O&M Costs	$ 70,000	0.700	$ 48,968	
25	Annual O&M Costs	$ 70,000	0.689	$ 48,244	
25	Periodic Costs	$ 7,080	0.689	$ 4,880	Pump replacement
26	Annual O&M Costs	$ 70,000	0.679	$ 47,531	
27	Annual O&M Costs	$ 70,000	0.669	$ 46,829	
28	Annual O&M Costs	$ 70,000	0.659	$ 46,137	
29	Annual O&M Costs	$ 70,000	0.649	$ 45,455	
30	Annual O&M Costs	$ 70,000	0.640	$ 44,783	
30	Periodic Costs	$ 7,080	0.640	$ 4,530	Pump replacement
31	Annual O&M Costs	$ 70,000	0.630	$ 44,122	
32	Annual O&M Costs	$ 70,000	0.621	$ 43,470	
33	Annual O&M Costs	$ 70,000	0.612	$ 42,827	
34	Annual O&M Costs	$ 70,000	0.603	$ 42,194	
35	Annual O&M Costs	$ 70,000	0.594	$ 41,571	
35	Periodic Costs	$ 7,080	0.594	$ 4,205	Pump replacement
36	Annual O&M Costs	$ 70,000	0.585	$ 40,956	
37	Annual O&M Costs	$ 70,000	0.576	$ 40,351	
38	Annual O&M Costs	$ 70,000	0.568	$ 39,755	
39	Annual O&M Costs	$ 70,000	0.560	$ 39,167	
40	Annual O&M Costs	$ 70,000	0.551	$ 38,588	
40	Periodic Costs	$ 7,080	0.551	$ 3,903	Pump replacement
41	Annual O&M Costs	$ 70,000	0.543	$ 38,018	
42	Annual O&M Costs	$ 70,000	0.535	$ 37,456	
43	Annual O&M Costs	$ 70,000	0.527	$ 36,903	
44	Annual O&M Costs	$ 70,000	0.519	$ 36,357	
45	Annual O&M Costs	$ 70,000	0.512	$ 35,820	
45	Periodic Costs	$ 7,080	0.512	$ 3,623	Pump replacement
46	Annual O&M Costs	$ 70,000	0.504	$ 35,291	
47	Annual O&M Costs	$ 70,000	0.497	$ 34,769	
48	Annual O&M Costs	$ 70,000	0.489	$ 34,255	
49	Annual O&M Costs	$ 70,000	0.482	$ 33,749	
50	Annual O&M Costs	$ 70,000	0.475	$ 33,250	
50	Periodic Costs	$ 7,080	0.475	$ 3,363	Pump replacement
51	Annual O&M Costs	$ 70,000	0.468	$ 32,759	
52	Annual O&M Costs	$ 70,000	0.461	$ 32,275	
53	Annual O&M Costs	$ 70,000	0.454	$ 31,798	
54	Annual O&M Costs	$ 70,000	0.448	$ 31,328	
55	Annual O&M Costs	$ 70,000	0.441	$ 30,865	
55	Periodic Costs	$ 7,080	0.441	$ 3,122	Pump replacement
56	Annual O&M Costs	$ 70,000	0.434	$ 30,409	
57	Annual O&M Costs	$ 70,000	0.428	$ 29,959	
58	Annual O&M Costs	$ 70,000	0.422	$ 29,517	
59	Annual O&M Costs	$ 70,000	0.415	$ 29,080	
60	Annual O&M Costs	$ 70,000	0.409	$ 28,651	
60	Periodic Costs	$ 7,080	0.409	$ 2,898	Pump replacement
61	Annual O&M Costs	$ 70,000	0.403	$ 28,227	
62	Annual O&M Costs	$ 70,000	0.397	$ 27,810	
63	Annual O&M Costs	$ 70,000	0.391	$ 27,399	
64	Annual O&M Costs	$ 70,000	0.386	$ 26,994	
65	Annual O&M Costs	$ 70,000	0.380	$ 26,595	
65	Periodic Costs	$ 7,080	0.380	$ 2,690	Pump replacement
66	Annual O&M Costs	$ 70,000	0.374	$ 26,202	
67	Annual O&M Costs	$ 70,000	0.369	$ 25,815	
68	Annual O&M Costs	$ 70,000	0.363	$ 25,434	
69	Annual O&M Costs	$ 70,000	0.358	$ 25,058	
70	Annual O&M Costs	$ 70,000	0.353	$ 24,687	
70	Periodic Costs	$ 7,080	0.353	$ 2,497	Pump replacement

VOC Mass Alternative M100
GROUNDWATER EXTRACTION AND TREATMENT

COST ESTIMATE SUMMARY M100

Site:	"Occidental" Site	Description:	100-Year Cash Flow Projection at 1.5 percent
Location:	Tacoma, Washington		
Phase:	Feasibility Study (-30% to +50%)		
Base Year:	2016		
Date:	December 8, 2016		

PRESENT VALUE ANALYSIS ***Base YR 2016*** 1.5% Discount Rate

Year	Cost Type	Cost	Discount Rate	Present Value	Notes
71	Annual O&M Costs	$ 70,000	0.347	$ 24,323	
72	Annual O&M Costs	$ 70,000	0.342	$ 23,963	
73	Annual O&M Costs	$ 70,000	0.337	$ 23,609	
74	Annual O&M Costs	$ 70,000	0.332	$ 23,260	
75	Annual O&M Costs	$ 70,000	0.327	$ 22,916	
75	Periodic Costs	$ 7,080	0.327	$ 2,318	Pump replacement
76	Annual O&M Costs	$ 70,000	0.323	$ 22,578	
77	Annual O&M Costs	$ 70,000	0.318	$ 22,244	
78	Annual O&M Costs	$ 70,000	0.313	$ 21,915	
79	Annual O&M Costs	$ 70,000	0.308	$ 21,591	
80	Annual O&M Costs	$ 70,000	0.304	$ 21,272	
80	Periodic Costs	$ 7,080	0.304	$ 2,152	Pump replacement
81	Annual O&M Costs	$ 70,000	0.299	$ 20,958	
82	Annual O&M Costs	$ 70,000	0.295	$ 20,648	
83	Annual O&M Costs	$ 70,000	0.291	$ 20,343	
84	Annual O&M Costs	$ 70,000	0.286	$ 20,042	
85	Annual O&M Costs	$ 70,000	0.282	$ 19,746	
85	Periodic Costs	$ 7,080	0.282	$ 1,997	Pump replacement
86	Annual O&M Costs	$ 70,000	0.278	$ 19,454	
87	Annual O&M Costs	$ 70,000	0.274	$ 19,167	
88	Annual O&M Costs	$ 70,000	0.270	$ 18,884	
89	Annual O&M Costs	$ 70,000	0.266	$ 18,605	
90	Annual O&M Costs	$ 70,000	0.262	$ 18,330	
90	Periodic Costs	$ 7,080	0.262	$ 1,854	Pump replacement
91	Annual O&M Costs	$ 70,000	0.258	$ 18,059	
92	Annual O&M Costs	$ 70,000	0.254	$ 17,792	
93	Annual O&M Costs	$ 70,000	0.250	$ 17,529	
94	Annual O&M Costs	$ 70,000	0.247	$ 17,270	
95	Annual O&M Costs	$ 70,000	0.243	$ 17,015	
95	Periodic Costs	$ 7,080	0.243	$ 1,721	Pump replacement
96	Annual O&M Costs	$ 70,000	0.239	$ 16,763	
97	Annual O&M Costs	$ 70,000	0.236	$ 16,516	
98	Annual O&M Costs	$ 70,000	0.232	$ 16,271	
99	Annual O&M Costs	$ 70,000	0.229	$ 16,031	
100	Annual O&M Costs	$ 70,000	0.226	$ 15,794	
100	GWTP Demolition	$ 50,000	0.226	$ 11,281	
100	Final Completion Report	$ 5,000	0.226	$ 1,128	
		$ 7,390,000		**$ 3,900,000**	

TOTAL PRESENT VALUE OF ALTERNATIVE	**$ 3,900,000**

VOC Mass Alternative M150
GROUNDWATER EXTRACTION AND TREATMENT

COST ESTIMATE SUMMARY M150

Site: "Occidental" Site
Location: Tacoma, Washington
Phase: Feasibility Study (-30% to +50%)
Base Year: 2016
Date: December 8, 2016

Description: 100-Year Cash Flow Projection at 7 percent

PRESENT VALUE ANALYSIS ***Base YR 2016*** 7.0% Discount Rate

Year	Cost Type	Cost	Discount Rate	Present Value	Notes
0	Capital Costs	$ 202,950	1.000	$ 202,950	
1	Annual O&M Costs	$ 101,940	0.935	$ 95,271	
2	Annual O&M Costs	$ 101,940	0.873	$ 89,038	
3	Annual O&M Costs	$ 101,940	0.816	$ 83,213	
4	Annual O&M Costs	$ 101,940	0.763	$ 77,770	
5	Annual O&M Costs	$ 101,940	0.713	$ 72,682	
5	Periodic Costs	$ 7,080	0.713	$ 5,048	Pump replacement
6	Annual O&M Costs	$ 101,940	0.666	$ 67,927	
7	Annual O&M Costs	$ 101,940	0.623	$ 63,483	
8	Annual O&M Costs	$ 101,940	0.582	$ 59,330	
9	Annual O&M Costs	$ 101,940	0.544	$ 55,449	
10	Annual O&M Costs	$ 101,940	0.508	$ 51,821	
10	Periodic Costs	$ 7,080	0.508	$ 3,599	Pump replacement
11	Annual O&M Costs	$ 101,940	0.475	$ 48,431	
12	Annual O&M Costs	$ 101,940	0.444	$ 45,263	
13	Annual O&M Costs	$ 101,940	0.415	$ 42,301	
14	Annual O&M Costs	$ 101,940	0.388	$ 39,534	
15	Annual O&M Costs	$ 101,940	0.362	$ 36,948	
15	Periodic Costs	$ 7,080	0.362	$ 2,566	Pump replacement
16	Annual O&M Costs	$ 101,940	0.339	$ 34,531	
17	Annual O&M Costs	$ 101,940	0.317	$ 32,272	
18	Annual O&M Costs	$ 101,940	0.296	$ 30,160	
19	Annual O&M Costs	$ 101,940	0.277	$ 28,187	
20	Annual O&M Costs	$ 101,940	0.258	$ 26,343	
20	Periodic Costs	$ 7,080	0.258	$ 1,830	Pump replacement
21	Annual O&M Costs	$ 101,940	0.242	$ 24,620	
22	Annual O&M Costs	$ 101,940	0.226	$ 23,009	
23	Annual O&M Costs	$ 101,940	0.211	$ 21,504	
24	Annual O&M Costs	$ 101,940	0.197	$ 20,097	
25	Annual O&M Costs	$ 101,940	0.184	$ 18,782	
25	Periodic Costs	$ 7,080	0.184	$ 1,304	Pump replacement
26	Annual O&M Costs	$ 101,940	0.172	$ 17,554	
27	Annual O&M Costs	$ 101,940	0.161	$ 16,405	
28	Annual O&M Costs	$ 101,940	0.150	$ 15,332	
29	Annual O&M Costs	$ 101,940	0.141	$ 14,329	
30	Annual O&M Costs	$ 101,940	0.131	$ 13,392	
30	Periodic Costs	$ 7,080	0.131	$ 930	Pump replacement
31	Annual O&M Costs	$ 101,940	0.123	$ 12,515	
32	Annual O&M Costs	$ 101,940	0.115	$ 11,697	
33	Annual O&M Costs	$ 101,940	0.107	$ 10,932	
34	Annual O&M Costs	$ 101,940	0.100	$ 10,216	
35	Annual O&M Costs	$ 101,940	0.094	$ 9,548	
35	Periodic Costs	$ 7,080	0.094	$ 663	Pump replacement
36	Annual O&M Costs	$ 101,940	0.088	$ 8,923	
37	Annual O&M Costs	$ 101,940	0.082	$ 8,340	
38	Annual O&M Costs	$ 101,940	0.076	$ 7,794	
39	Annual O&M Costs	$ 101,940	0.071	$ 7,284	
40	Annual O&M Costs	$ 101,940	0.067	$ 6,808	
40	Periodic Costs	$ 7,080	0.067	$ 473	Pump replacement
41	Annual O&M Costs	$ 101,940	0.062	$ 6,362	
42	Annual O&M Costs	$ 101,940	0.058	$ 5,946	
43	Annual O&M Costs	$ 101,940	0.055	$ 5,557	
44	Annual O&M Costs	$ 101,940	0.051	$ 5,193	
45	Annual O&M Costs	$ 101,940	0.048	$ 4,854	
45	Periodic Costs	$ 7,080	0.048	$ 337	Pump replacement
46	Annual O&M Costs	$ 101,940	0.044	$ 4,536	
47	Annual O&M Costs	$ 101,940	0.042	$ 4,239	
48	Annual O&M Costs	$ 101,940	0.039	$ 3,962	
49	Annual O&M Costs	$ 101,940	0.036	$ 3,703	
50	Annual O&M Costs	$ 101,940	0.034	$ 3,461	
50	Periodic Costs	$ 7,080	0.034	$ 240	Pump replacement
51	Annual O&M Costs	$ 101,940	0.032	$ 3,234	
52	Annual O&M Costs	$ 101,940	0.030	$ 3,023	
53	Annual O&M Costs	$ 101,940	0.028	$ 2,825	
54	Annual O&M Costs	$ 101,940	0.026	$ 2,640	
55	Annual O&M Costs	$ 101,940	0.024	$ 2,467	
55	Periodic Costs	$ 7,080	0.024	$ 171	Pump replacement
56	Annual O&M Costs	$ 101,940	0.023	$ 2,306	
57	Annual O&M Costs	$ 101,940	0.021	$ 2,155	
58	Annual O&M Costs	$ 101,940	0.020	$ 2,014	
59	Annual O&M Costs	$ 101,940	0.018	$ 1,882	
60	Annual O&M Costs	$ 101,940	0.017	$ 1,759	
60	Periodic Costs	$ 7,080	0.017	$ 122	Pump replacement
61	Annual O&M Costs	$ 101,940	0.016	$ 1,644	
62	Annual O&M Costs	$ 101,940	0.015	$ 1,537	
63	Annual O&M Costs	$ 101,940	0.014	$ 1,436	
64	Annual O&M Costs	$ 101,940	0.013	$ 1,342	
65	Annual O&M Costs	$ 101,940	0.012	$ 1,254	
65	Periodic Costs	$ 7,080	0.012	$ 87	Pump replacement
66	Annual O&M Costs	$ 101,940	0.011	$ 1,172	
67	Annual O&M Costs	$ 101,940	0.011	$ 1,096	
68	Annual O&M Costs	$ 101,940	0.010	$ 1,024	
69	Annual O&M Costs	$ 101,940	0.009	$ 957	
70	Annual O&M Costs	$ 101,940	0.009	$ 894	
70	Periodic Costs	$ 7,080	0.009	$ 62	Pump replacement

VOC Mass Alternative M150
GROUNDWATER EXTRACTION AND TREATMENT

COST ESTIMATE SUMMARY M150

Site:	"Occidental" Site	Description:	100-Year Cash Flow Projection at 7 percent
Location:	Tacoma, Washington		
Phase:	Feasibility Study (-30% to +50%)		
Base Year:	2016		
Date:	December 8, 2016		

PRESENT VALUE ANALYSIS ***Base YR 2016*** 7.0% Discount Rate

Year	Cost Type	Cost	Discount Rate	Present Value	Notes
71	Annual O&M Costs	$ 101,940	0.008	$ 836	
72	Annual O&M Costs	$ 101,940	0.008	$ 781	
73	Annual O&M Costs	$ 101,940	0.007	$ 730	
74	Annual O&M Costs	$ 101,940	0.007	$ 682	
75	Annual O&M Costs	$ 101,940	0.006	$ 638	
75	Periodic Costs	$ 7,080	0.006	$ 44	Pump replacement
76	Annual O&M Costs	$ 101,940	0.006	$ 596	
77	Annual O&M Costs	$ 101,940	0.005	$ 557	
78	Annual O&M Costs	$ 101,940	0.005	$ 520	
79	Annual O&M Costs	$ 101,940	0.005	$ 486	
80	Annual O&M Costs	$ 101,940	0.004	$ 455	
80	Periodic Costs	$ 7,080	0.004	$ 32	Pump replacement
81	Annual O&M Costs	$ 101,940	0.004	$ 425	
82	Annual O&M Costs	$ 101,940	0.004	$ 397	
83	Annual O&M Costs	$ 101,940	0.004	$ 371	
84	Annual O&M Costs	$ 101,940	0.003	$ 347	
85	Annual O&M Costs	$ 101,940	0.003	$ 324	
85	Periodic Costs	$ 7,080	0.003	$ 23	Pump replacement
86	Annual O&M Costs	$ 101,940	0.003	$ 303	
87	Annual O&M Costs	$ 101,940	0.003	$ 283	
88	Annual O&M Costs	$ 101,940	0.003	$ 265	
89	Annual O&M Costs	$ 101,940	0.002	$ 247	
90	Annual O&M Costs	$ 101,940	0.002	$ 231	
90	Periodic Costs	$ 7,080	0.002	$ 16	Pump replacement
91	Annual O&M Costs	$ 101,940	0.002	$ 216	
92	Annual O&M Costs	$ 101,940	0.002	$ 202	
93	Annual O&M Costs	$ 101,940	0.002	$ 189	
94	Annual O&M Costs	$ 101,940	0.002	$ 176	
95	Annual O&M Costs	$ 101,940	0.002	$ 165	
95	Periodic Costs	$ 7,080	0.002	$ 11	Pump replacement
96	Annual O&M Costs	$ 101,940	0.002	$ 154	
97	Annual O&M Costs	$ 101,940	0.001	$ 144	
98	Annual O&M Costs	$ 101,940	0.001	$ 135	
99	Annual O&M Costs	$ 101,940	0.001	$ 126	
100	Annual O&M Costs	$ 101,940	0.001	$ 117	
100	GWTP Demolition	$ 50,000	0.001	$ 58	
100	Final Completion Report	$ 5,000	0.001	$ 6	
		$ 10,590,000		**$ 1,680,000**	

TOTAL PRESENT VALUE OF ALTERNATIVE **$ 1,680,000**

VOC Mass Alternative M150
GROUNDWATER EXTRACTION AND TREATMENT

COST ESTIMATE SUMMARY M150

Site:	"Occidental" Site	Description:	100-Year Cash Flow Projection at 1.5 percent
Location:	Tacoma, Washington		
Phase:	Feasibility Study (-30% to +50%)		
Base Year:	2016		
Date:	December 8, 2016		

PRESENT VALUE ANALYSIS ***Base YR 2016*** 1.5% Discount Rate

Year	Cost Type	Cost	Discount Rate	Present Value	Notes
0	Capital Costs	$ 202,950	1.000	$ 202,950	
1	Annual O&M Costs	$ 101,940	0.985	$ 100,433	
2	Annual O&M Costs	$ 101,940	0.971	$ 98,949	
3	Annual O&M Costs	$ 101,940	0.956	$ 97,487	
4	Annual O&M Costs	$ 101,940	0.942	$ 96,046	
5	Annual O&M Costs	$ 101,940	0.928	$ 94,627	
5	Periodic Costs	$ 7,080	0.928	$ 6,572	Pump replacement
6	Annual O&M Costs	$ 101,940	0.915	$ 93,228	
7	Annual O&M Costs	$ 101,940	0.901	$ 91,851	
8	Annual O&M Costs	$ 101,940	0.888	$ 90,493	
9	Annual O&M Costs	$ 101,940	0.875	$ 89,156	
10	Annual O&M Costs	$ 101,940	0.862	$ 87,838	
10	Periodic Costs	$ 7,080	0.862	$ 6,101	Pump replacement
11	Annual O&M Costs	$ 101,940	0.849	$ 86,540	
12	Annual O&M Costs	$ 101,940	0.836	$ 85,261	
13	Annual O&M Costs	$ 101,940	0.824	$ 84,001	
14	Annual O&M Costs	$ 101,940	0.812	$ 82,760	
15	Annual O&M Costs	$ 101,940	0.800	$ 81,537	
15	Periodic Costs	$ 7,080	0.800	$ 5,663	Pump replacement
16	Annual O&M Costs	$ 101,940	0.788	$ 80,332	
17	Annual O&M Costs	$ 101,940	0.776	$ 79,145	
18	Annual O&M Costs	$ 101,940	0.765	$ 77,975	
19	Annual O&M Costs	$ 101,940	0.754	$ 76,823	
20	Annual O&M Costs	$ 101,940	0.742	$ 75,687	
20	Periodic Costs	$ 7,080	0.742	$ 5,257	Pump replacement
21	Annual O&M Costs	$ 101,940	0.731	$ 74,569	
22	Annual O&M Costs	$ 101,940	0.721	$ 73,467	
23	Annual O&M Costs	$ 101,940	0.710	$ 72,381	
24	Annual O&M Costs	$ 101,940	0.700	$ 71,312	
25	Annual O&M Costs	$ 101,940	0.689	$ 70,258	
25	Periodic Costs	$ 7,080	0.689	$ 4,880	Pump replacement
26	Annual O&M Costs	$ 101,940	0.679	$ 69,219	
27	Annual O&M Costs	$ 101,940	0.669	$ 68,196	
28	Annual O&M Costs	$ 101,940	0.659	$ 67,189	
29	Annual O&M Costs	$ 101,940	0.649	$ 66,196	
30	Annual O&M Costs	$ 101,940	0.640	$ 65,217	
30	Periodic Costs	$ 7,080	0.640	$ 4,530	Pump replacement
31	Annual O&M Costs	$ 101,940	0.630	$ 64,254	
32	Annual O&M Costs	$ 101,940	0.621	$ 63,304	
33	Annual O&M Costs	$ 101,940	0.612	$ 62,368	
34	Annual O&M Costs	$ 101,940	0.603	$ 61,447	
35	Annual O&M Costs	$ 101,940	0.594	$ 60,539	
35	Periodic Costs	$ 7,080	0.594	$ 4,205	Pump replacement
36	Annual O&M Costs	$ 101,940	0.585	$ 59,644	
37	Annual O&M Costs	$ 101,940	0.576	$ 58,763	
38	Annual O&M Costs	$ 101,940	0.568	$ 57,894	
39	Annual O&M Costs	$ 101,940	0.560	$ 57,039	
40	Annual O&M Costs	$ 101,940	0.551	$ 56,196	
40	Periodic Costs	$ 7,080	0.551	$ 3,903	Pump replacement
41	Annual O&M Costs	$ 101,940	0.543	$ 55,365	
42	Annual O&M Costs	$ 101,940	0.535	$ 54,547	
43	Annual O&M Costs	$ 101,940	0.527	$ 53,741	
44	Annual O&M Costs	$ 101,940	0.519	$ 52,947	
45	Annual O&M Costs	$ 101,940	0.512	$ 52,164	
45	Periodic Costs	$ 7,080	0.512	$ 3,623	Pump replacement
46	Annual O&M Costs	$ 101,940	0.504	$ 51,393	
47	Annual O&M Costs	$ 101,940	0.497	$ 50,634	
48	Annual O&M Costs	$ 101,940	0.489	$ 49,886	
49	Annual O&M Costs	$ 101,940	0.482	$ 49,148	
50	Annual O&M Costs	$ 101,940	0.475	$ 48,422	
50	Periodic Costs	$ 7,080	0.475	$ 3,363	Pump replacement
51	Annual O&M Costs	$ 101,940	0.468	$ 47,706	
52	Annual O&M Costs	$ 101,940	0.461	$ 47,001	
53	Annual O&M Costs	$ 101,940	0.454	$ 46,307	
54	Annual O&M Costs	$ 101,940	0.448	$ 45,622	
55	Annual O&M Costs	$ 101,940	0.441	$ 44,948	
55	Periodic Costs	$ 7,080	0.441	$ 3,122	Pump replacement
56	Annual O&M Costs	$ 101,940	0.434	$ 44,284	
57	Annual O&M Costs	$ 101,940	0.428	$ 43,629	
58	Annual O&M Costs	$ 101,940	0.422	$ 42,985	
59	Annual O&M Costs	$ 101,940	0.415	$ 42,349	
60	Annual O&M Costs	$ 101,940	0.409	$ 41,724	
60	Periodic Costs	$ 7,080	0.409	$ 2,898	Pump replacement
61	Annual O&M Costs	$ 101,940	0.403	$ 41,107	
62	Annual O&M Costs	$ 101,940	0.397	$ 40,500	
63	Annual O&M Costs	$ 101,940	0.391	$ 39,901	
64	Annual O&M Costs	$ 101,940	0.386	$ 39,311	
65	Annual O&M Costs	$ 101,940	0.380	$ 38,730	
65	Periodic Costs	$ 7,080	0.380	$ 2,690	Pump replacement
66	Annual O&M Costs	$ 101,940	0.374	$ 38,158	
67	Annual O&M Costs	$ 101,940	0.369	$ 37,594	
68	Annual O&M Costs	$ 101,940	0.363	$ 37,039	
69	Annual O&M Costs	$ 101,940	0.358	$ 36,491	
70	Annual O&M Costs	$ 101,940	0.353	$ 35,952	
70	Periodic Costs	$ 7,080	0.353	$ 2,497	Pump replacement

VOC Mass Alternative M150
GROUNDWATER EXTRACTION AND TREATMENT

COST ESTIMATE SUMMARY M150

Site: "Occidental" Site
Location: Tacoma, Washington
Phase: Feasibility Study (-30% to +50%)
Base Year: 2016
Date: December 8, 2016

Description: 100-Year Cash Flow Projection at 1.5 percent

PRESENT VALUE ANALYSIS ***Base YR 2016*** 1.5% Discount Rate

Year	Cost Type	Cost	Discount Rate	Present Value	Notes
71	Annual O&M Costs	$ 101,940	0.347	$ 35,421	
72	Annual O&M Costs	$ 101,940	0.342	$ 34,897	
73	Annual O&M Costs	$ 101,940	0.337	$ 34,381	
74	Annual O&M Costs	$ 101,940	0.332	$ 33,873	
75	Annual O&M Costs	$ 101,940	0.327	$ 33,373	
75	Periodic Costs	$ 7,080	0.327	$ 2,318	Pump replacement
76	Annual O&M Costs	$ 101,940	0.323	$ 32,880	
77	Annual O&M Costs	$ 101,940	0.318	$ 32,394	
78	Annual O&M Costs	$ 101,940	0.313	$ 31,915	
79	Annual O&M Costs	$ 101,940	0.308	$ 31,443	
80	Annual O&M Costs	$ 101,940	0.304	$ 30,979	
80	Periodic Costs	$ 7,080	0.304	$ 2,152	Pump replacement
81	Annual O&M Costs	$ 101,940	0.299	$ 30,521	
82	Annual O&M Costs	$ 101,940	0.295	$ 30,070	
83	Annual O&M Costs	$ 101,940	0.291	$ 29,625	
84	Annual O&M Costs	$ 101,940	0.286	$ 29,188	
85	Annual O&M Costs	$ 101,940	0.282	$ 28,756	
85	Periodic Costs	$ 7,080	0.282	$ 1,997	Pump replacement
86	Annual O&M Costs	$ 101,940	0.278	$ 28,331	
87	Annual O&M Costs	$ 101,940	0.274	$ 27,913	
88	Annual O&M Costs	$ 101,940	0.270	$ 27,500	
89	Annual O&M Costs	$ 101,940	0.266	$ 27,094	
90	Annual O&M Costs	$ 101,940	0.262	$ 26,693	
90	Periodic Costs	$ 7,080	0.262	$ 1,854	Pump replacement
91	Annual O&M Costs	$ 101,940	0.258	$ 26,299	
92	Annual O&M Costs	$ 101,940	0.254	$ 25,910	
93	Annual O&M Costs	$ 101,940	0.250	$ 25,527	
94	Annual O&M Costs	$ 101,940	0.247	$ 25,150	
95	Annual O&M Costs	$ 101,940	0.243	$ 24,778	
95	Periodic Costs	$ 7,080	0.243	$ 1,721	Pump replacement
96	Annual O&M Costs	$ 101,940	0.239	$ 24,412	
97	Annual O&M Costs	$ 101,940	0.236	$ 24,051	
98	Annual O&M Costs	$ 101,940	0.232	$ 23,696	
99	Annual O&M Costs	$ 101,940	0.229	$ 23,346	
100	Annual O&M Costs	$ 101,940	0.226	$ 23,001	
100	GWTP Demolition	$ 50,000	0.226	$ 11,281	
100	Final Completion Report	$ 5,000	0.226	$ 1,128	
		$ 10,590,000		**$ 5,550,000**	

TOTAL PRESENT VALUE OF ALTERNATIVE **$ 5,550,000**

VOC Mass Alternative M200
GROUNDWATER EXTRACTION AND TREATMENT

COST ESTIMATE SUMMARY M200

Site:	"Occidental" Site	Description:	100-Year Cash Flow Projection at 7 percent
Location:	Tacoma, Washington		
Phase:	Feasibility Study (-30% to +50%)		
Base Year:	2016		
Date:	December 8, 2016		

PRESENT VALUE ANALYSIS ***Base YR 2016*** 7.0% Discount Rate

Year	Cost Type	Cost	Discount Rate	Present Value	Notes
0	Capital Costs	$ 202,950	1.000	$ 202,950	
1	Annual O&M Costs	$ 133,680	0.935	$ 124,935	
2	Annual O&M Costs	$ 133,680	0.873	$ 116,761	
3	Annual O&M Costs	$ 133,680	0.816	$ 109,123	
4	Annual O&M Costs	$ 133,680	0.763	$ 101,984	
5	Annual O&M Costs	$ 133,680	0.713	$ 95,312	
5	Periodic Costs	$ 7,080	0.713	$ 5,048	Pump replacement
6	Annual O&M Costs	$ 133,680	0.666	$ 89,077	
7	Annual O&M Costs	$ 133,680	0.623	$ 83,249	
8	Annual O&M Costs	$ 133,680	0.582	$ 77,803	
9	Annual O&M Costs	$ 133,680	0.544	$ 72,713	
10	Annual O&M Costs	$ 133,680	0.508	$ 67,956	
10	Periodic Costs	$ 7,080	0.508	$ 3,599	Pump replacement
11	Annual O&M Costs	$ 133,680	0.475	$ 63,510	
12	Annual O&M Costs	$ 133,680	0.444	$ 59,356	
13	Annual O&M Costs	$ 133,680	0.415	$ 55,472	
14	Annual O&M Costs	$ 133,680	0.388	$ 51,843	
15	Annual O&M Costs	$ 133,680	0.362	$ 48,452	
15	Periodic Costs	$ 7,080	0.362	$ 2,566	Pump replacement
16	Annual O&M Costs	$ 133,680	0.339	$ 45,282	
17	Annual O&M Costs	$ 133,680	0.317	$ 42,320	
18	Annual O&M Costs	$ 133,680	0.296	$ 39,551	
19	Annual O&M Costs	$ 133,680	0.277	$ 36,964	
20	Annual O&M Costs	$ 133,680	0.258	$ 34,545	
20	Periodic Costs	$ 7,080	0.258	$ 1,830	Pump replacement
21	Annual O&M Costs	$ 133,680	0.242	$ 32,285	
22	Annual O&M Costs	$ 133,680	0.226	$ 30,173	
23	Annual O&M Costs	$ 133,680	0.211	$ 28,199	
24	Annual O&M Costs	$ 133,680	0.197	$ 26,355	
25	Annual O&M Costs	$ 133,680	0.184	$ 24,630	
25	Periodic Costs	$ 7,080	0.184	$ 1,304	Pump replacement
26	Annual O&M Costs	$ 133,680	0.172	$ 23,019	
27	Annual O&M Costs	$ 133,680	0.161	$ 21,513	
28	Annual O&M Costs	$ 133,680	0.150	$ 20,106	
29	Annual O&M Costs	$ 133,680	0.141	$ 18,790	
30	Annual O&M Costs	$ 133,680	0.131	$ 17,561	
30	Periodic Costs	$ 7,080	0.131	$ 930	Pump replacement
31	Annual O&M Costs	$ 133,680	0.123	$ 16,412	
32	Annual O&M Costs	$ 133,680	0.115	$ 15,339	
33	Annual O&M Costs	$ 133,680	0.107	$ 14,335	
34	Annual O&M Costs	$ 133,680	0.100	$ 13,397	
35	Annual O&M Costs	$ 133,680	0.094	$ 12,521	
35	Periodic Costs	$ 7,080	0.094	$ 663	Pump replacement
36	Annual O&M Costs	$ 133,680	0.088	$ 11,702	
37	Annual O&M Costs	$ 133,680	0.082	$ 10,936	
38	Annual O&M Costs	$ 133,680	0.076	$ 10,221	
39	Annual O&M Costs	$ 133,680	0.071	$ 9,552	
40	Annual O&M Costs	$ 133,680	0.067	$ 8,927	
40	Periodic Costs	$ 7,080	0.067	$ 473	Pump replacement
41	Annual O&M Costs	$ 133,680	0.062	$ 8,343	
42	Annual O&M Costs	$ 133,680	0.058	$ 7,797	
43	Annual O&M Costs	$ 133,680	0.055	$ 7,287	
44	Annual O&M Costs	$ 133,680	0.051	$ 6,811	
45	Annual O&M Costs	$ 133,680	0.048	$ 6,365	
45	Periodic Costs	$ 7,080	0.048	$ 337	Pump replacement
46	Annual O&M Costs	$ 133,680	0.044	$ 5,949	
47	Annual O&M Costs	$ 133,680	0.042	$ 5,559	
48	Annual O&M Costs	$ 133,680	0.039	$ 5,196	
49	Annual O&M Costs	$ 133,680	0.036	$ 4,856	
50	Annual O&M Costs	$ 133,680	0.034	$ 4,538	
50	Periodic Costs	$ 7,080	0.034	$ 240	Pump replacement
51	Annual O&M Costs	$ 133,680	0.032	$ 4,241	
52	Annual O&M Costs	$ 133,680	0.030	$ 3,964	
53	Annual O&M Costs	$ 133,680	0.028	$ 3,704	
54	Annual O&M Costs	$ 133,680	0.026	$ 3,462	
55	Annual O&M Costs	$ 133,680	0.024	$ 3,236	
55	Periodic Costs	$ 7,080	0.024	$ 171	Pump replacement
56	Annual O&M Costs	$ 133,680	0.023	$ 3,024	
57	Annual O&M Costs	$ 133,680	0.021	$ 2,826	
58	Annual O&M Costs	$ 133,680	0.020	$ 2,641	
59	Annual O&M Costs	$ 133,680	0.018	$ 2,468	
60	Annual O&M Costs	$ 133,680	0.017	$ 2,307	
60	Periodic Costs	$ 7,080	0.017	$ 122	Pump replacement
61	Annual O&M Costs	$ 133,680	0.016	$ 2,156	
62	Annual O&M Costs	$ 133,680	0.015	$ 2,015	
63	Annual O&M Costs	$ 133,680	0.014	$ 1,883	
64	Annual O&M Costs	$ 133,680	0.013	$ 1,760	
65	Annual O&M Costs	$ 133,680	0.012	$ 1,645	
65	Periodic Costs	$ 7,080	0.012	$ 87	Pump replacement
66	Annual O&M Costs	$ 133,680	0.011	$ 1,537	
67	Annual O&M Costs	$ 133,680	0.011	$ 1,437	
68	Annual O&M Costs	$ 133,680	0.010	$ 1,343	
69	Annual O&M Costs	$ 133,680	0.009	$ 1,255	
70	Annual O&M Costs	$ 133,680	0.009	$ 1,173	
70	Periodic Costs	$ 7,080	0.009	$ 62	Pump replacement

VOC Mass Alternative M200
GROUNDWATER EXTRACTION AND TREATMENT

COST ESTIMATE SUMMARY M200

Site: "Occidental" Site
Location: Tacoma, Washington
Phase: Feasibility Study (-30% to +50%)
Base Year: 2016
Date: December 8, 2016

Description: 100-Year Cash Flow Projection at 7 percent

PRESENT VALUE ANALYSIS ***Base YR 2016*** 7.0% Discount Rate

Year	Cost Type	Cost	Discount Rate	Present Value	Notes
71	Annual O&M Costs	$ 133,680	0.008	$ 1,096	
72	Annual O&M Costs	$ 133,680	0.008	$ 1,024	
73	Annual O&M Costs	$ 133,680	0.007	$ 957	
74	Annual O&M Costs	$ 133,680	0.007	$ 895	
75	Annual O&M Costs	$ 133,680	0.006	$ 836	
75	Periodic Costs	$ 7,080	0.006	$ 44	Pump replacement
76	Annual O&M Costs	$ 133,680	0.006	$ 781	
77	Annual O&M Costs	$ 133,680	0.005	$ 730	
78	Annual O&M Costs	$ 133,680	0.005	$ 683	
79	Annual O&M Costs	$ 133,680	0.005	$ 638	
80	Annual O&M Costs	$ 133,680	0.004	$ 596	
80	Periodic Costs	$ 7,080	0.004	$ 32	Pump replacement
81	Annual O&M Costs	$ 133,680	0.004	$ 557	
82	Annual O&M Costs	$ 133,680	0.004	$ 521	
83	Annual O&M Costs	$ 133,680	0.004	$ 487	
84	Annual O&M Costs	$ 133,680	0.003	$ 455	
85	Annual O&M Costs	$ 133,680	0.003	$ 425	
85	Periodic Costs	$ 7,080	0.003	$ 23	Pump replacement
86	Annual O&M Costs	$ 133,680	0.003	$ 397	
87	Annual O&M Costs	$ 133,680	0.003	$ 371	
88	Annual O&M Costs	$ 133,680	0.003	$ 347	
89	Annual O&M Costs	$ 133,680	0.002	$ 324	
90	Annual O&M Costs	$ 133,680	0.002	$ 303	
90	Periodic Costs	$ 7,080	0.002	$ 16	Pump replacement
91	Annual O&M Costs	$ 133,680	0.002	$ 283	
92	Annual O&M Costs	$ 133,680	0.002	$ 265	
93	Annual O&M Costs	$ 133,680	0.002	$ 247	
94	Annual O&M Costs	$ 133,680	0.002	$ 231	
95	Annual O&M Costs	$ 133,680	0.002	$ 216	
95	Periodic Costs	$ 7,080	0.002	$ 11	Pump replacement
96	Annual O&M Costs	$ 133,680	0.002	$ 202	
97	Annual O&M Costs	$ 133,680	0.001	$ 189	
98	Annual O&M Costs	$ 133,680	0.001	$ 176	
99	Annual O&M Costs	$ 133,680	0.001	$ 165	
100	Annual O&M Costs	$ 133,680	0.001	$ 154	
100	GWTP Demolition	$ 50,000	0.001	$ 58	
100	Final Completion Report	$ 5,000	0.001	$ 6	
		$ 13,760,000		**$ 2,130,000**	

TOTAL PRESENT VALUE OF ALTERNATIVE **$ 2,130,000**

VOC Mass Alternative M200
GROUNDWATER EXTRACTION AND TREATMENT

COST ESTIMATE SUMMARY M200

Site: "Occidental" Site
Location: Tacoma, Washington
Phase: Feasibility Study (-30% to +50%)
Base Year: 2016
Date: December 8, 2016

Description: 100-Year Cash Flow Projection at 1.5 percent

PRESENT VALUE ANALYSIS ***Base YR 2016*** 1.5% Discount Rate

Year	Cost Type	Cost	Discount Rate	Present Value	Notes
0	Capital Costs	$ 202,950	1.000	$ 202,950	
1	Annual O&M Costs	$ 133,680	0.985	$ 131,704	
2	Annual O&M Costs	$ 133,680	0.971	$ 129,758	
3	Annual O&M Costs	$ 133,680	0.956	$ 127,840	
4	Annual O&M Costs	$ 133,680	0.942	$ 125,951	
5	Annual O&M Costs	$ 133,680	0.928	$ 124,090	
5	Periodic Costs	$ 7,080	0.928	$ 6,572	Pump replacement
6	Annual O&M Costs	$ 133,680	0.915	$ 122,256	
7	Annual O&M Costs	$ 133,680	0.901	$ 120,449	
8	Annual O&M Costs	$ 133,680	0.888	$ 118,669	
9	Annual O&M Costs	$ 133,680	0.875	$ 116,915	
10	Annual O&M Costs	$ 133,680	0.862	$ 115,188	
10	Periodic Costs	$ 7,080	0.862	$ 6,101	Pump replacement
11	Annual O&M Costs	$ 133,680	0.849	$ 113,485	
12	Annual O&M Costs	$ 133,680	0.836	$ 111,808	
13	Annual O&M Costs	$ 133,680	0.824	$ 110,156	
14	Annual O&M Costs	$ 133,680	0.812	$ 108,528	
15	Annual O&M Costs	$ 133,680	0.800	$ 106,924	
15	Periodic Costs	$ 7,080	0.800	$ 5,663	Pump replacement
16	Annual O&M Costs	$ 133,680	0.788	$ 105,344	
17	Annual O&M Costs	$ 133,680	0.776	$ 103,787	
18	Annual O&M Costs	$ 133,680	0.765	$ 102,253	
19	Annual O&M Costs	$ 133,680	0.754	$ 100,742	
20	Annual O&M Costs	$ 133,680	0.742	$ 99,253	
20	Periodic Costs	$ 7,080	0.742	$ 5,257	Pump replacement
21	Annual O&M Costs	$ 133,680	0.731	$ 97,787	
22	Annual O&M Costs	$ 133,680	0.721	$ 96,342	
23	Annual O&M Costs	$ 133,680	0.710	$ 94,918	
24	Annual O&M Costs	$ 133,680	0.700	$ 93,515	
25	Annual O&M Costs	$ 133,680	0.689	$ 92,133	
25	Periodic Costs	$ 7,080	0.689	$ 4,880	Pump replacement
26	Annual O&M Costs	$ 133,680	0.679	$ 90,771	
27	Annual O&M Costs	$ 133,680	0.669	$ 89,430	
28	Annual O&M Costs	$ 133,680	0.659	$ 88,108	
29	Annual O&M Costs	$ 133,680	0.649	$ 86,806	
30	Annual O&M Costs	$ 133,680	0.640	$ 85,523	
30	Periodic Costs	$ 7,080	0.640	$ 4,530	Pump replacement
31	Annual O&M Costs	$ 133,680	0.630	$ 84,260	
32	Annual O&M Costs	$ 133,680	0.621	$ 83,014	
33	Annual O&M Costs	$ 133,680	0.612	$ 81,788	
34	Annual O&M Costs	$ 133,680	0.603	$ 80,579	
35	Annual O&M Costs	$ 133,680	0.594	$ 79,388	
35	Periodic Costs	$ 7,080	0.594	$ 4,205	Pump replacement
36	Annual O&M Costs	$ 133,680	0.585	$ 78,215	
37	Annual O&M Costs	$ 133,680	0.576	$ 77,059	
38	Annual O&M Costs	$ 133,680	0.568	$ 75,920	
39	Annual O&M Costs	$ 133,680	0.560	$ 74,798	
40	Annual O&M Costs	$ 133,680	0.551	$ 73,693	
40	Periodic Costs	$ 7,080	0.551	$ 3,903	Pump replacement
41	Annual O&M Costs	$ 133,680	0.543	$ 72,604	
42	Annual O&M Costs	$ 133,680	0.535	$ 71,531	
43	Annual O&M Costs	$ 133,680	0.527	$ 70,474	
44	Annual O&M Costs	$ 133,680	0.519	$ 69,432	
45	Annual O&M Costs	$ 133,680	0.512	$ 68,406	
45	Periodic Costs	$ 7,080	0.512	$ 3,623	Pump replacement
46	Annual O&M Costs	$ 133,680	0.504	$ 67,395	
47	Annual O&M Costs	$ 133,680	0.497	$ 66,399	
48	Annual O&M Costs	$ 133,680	0.489	$ 65,418	
49	Annual O&M Costs	$ 133,680	0.482	$ 64,451	
50	Annual O&M Costs	$ 133,680	0.475	$ 63,499	
50	Periodic Costs	$ 7,080	0.475	$ 3,363	Pump replacement
51	Annual O&M Costs	$ 133,680	0.468	$ 62,560	
52	Annual O&M Costs	$ 133,680	0.461	$ 61,636	
53	Annual O&M Costs	$ 133,680	0.454	$ 60,725	
54	Annual O&M Costs	$ 133,680	0.448	$ 59,827	
55	Annual O&M Costs	$ 133,680	0.441	$ 58,943	
55	Periodic Costs	$ 7,080	0.441	$ 3,122	Pump replacement
56	Annual O&M Costs	$ 133,680	0.434	$ 58,072	
57	Annual O&M Costs	$ 133,680	0.428	$ 57,214	
58	Annual O&M Costs	$ 133,680	0.422	$ 56,368	
59	Annual O&M Costs	$ 133,680	0.415	$ 55,535	
60	Annual O&M Costs	$ 133,680	0.409	$ 54,715	
60	Periodic Costs	$ 7,080	0.409	$ 2,898	Pump replacement
61	Annual O&M Costs	$ 133,680	0.403	$ 53,906	
62	Annual O&M Costs	$ 133,680	0.397	$ 53,109	
63	Annual O&M Costs	$ 133,680	0.391	$ 52,325	
64	Annual O&M Costs	$ 133,680	0.386	$ 51,551	
65	Annual O&M Costs	$ 133,680	0.380	$ 50,789	
65	Periodic Costs	$ 7,080	0.380	$ 2,690	Pump replacement
66	Annual O&M Costs	$ 133,680	0.374	$ 50,039	
67	Annual O&M Costs	$ 133,680	0.369	$ 49,299	
68	Annual O&M Costs	$ 133,680	0.363	$ 48,571	
69	Annual O&M Costs	$ 133,680	0.358	$ 47,853	
70	Annual O&M Costs	$ 133,680	0.353	$ 47,146	
70	Periodic Costs	$ 7,080	0.353	$ 2,497	Pump replacement

VOC Mass Alternative M200
GROUNDWATER EXTRACTION AND TREATMENT

COST ESTIMATE SUMMARY M200

Site: "Occidental" Site
Location: Tacoma, Washington
Phase: Feasibility Study (-30% to +50%)
Base Year: 2016
Date: December 8, 2016

Description: 100-Year Cash Flow Projection at 1.5 percent

PRESENT VALUE ANALYSIS ***Base YR 2016*** 1.5% Discount Rate

Year	Cost Type	Cost	Discount Rate	Present Value	Notes
71	Annual O&M Costs	$ 133,680	0.347	$ 46,449	
72	Annual O&M Costs	$ 133,680	0.342	$ 45,763	
73	Annual O&M Costs	$ 133,680	0.337	$ 45,086	
74	Annual O&M Costs	$ 133,680	0.332	$ 44,420	
75	Annual O&M Costs	$ 133,680	0.327	$ 43,764	
75	Periodic Costs	$ 7,080	0.327	$ 2,318	Pump replacement
76	Annual O&M Costs	$ 133,680	0.323	$ 43,117	
77	Annual O&M Costs	$ 133,680	0.318	$ 42,480	
78	Annual O&M Costs	$ 133,680	0.313	$ 41,852	
79	Annual O&M Costs	$ 133,680	0.308	$ 41,233	
80	Annual O&M Costs	$ 133,680	0.304	$ 40,624	
80	Periodic Costs	$ 7,080	0.304	$ 2,152	Pump replacement
81	Annual O&M Costs	$ 133,680	0.299	$ 40,024	
82	Annual O&M Costs	$ 133,680	0.295	$ 39,432	
83	Annual O&M Costs	$ 133,680	0.291	$ 38,849	
84	Annual O&M Costs	$ 133,680	0.286	$ 38,275	
85	Annual O&M Costs	$ 133,680	0.282	$ 37,710	
85	Periodic Costs	$ 7,080	0.282	$ 1,997	Pump replacement
86	Annual O&M Costs	$ 133,680	0.278	$ 37,152	
87	Annual O&M Costs	$ 133,680	0.274	$ 36,603	
88	Annual O&M Costs	$ 133,680	0.270	$ 36,062	
89	Annual O&M Costs	$ 133,680	0.266	$ 35,529	
90	Annual O&M Costs	$ 133,680	0.262	$ 35,004	
90	Periodic Costs	$ 7,080	0.262	$ 1,854	Pump replacement
91	Annual O&M Costs	$ 133,680	0.258	$ 34,487	
92	Annual O&M Costs	$ 133,680	0.254	$ 33,977	
93	Annual O&M Costs	$ 133,680	0.250	$ 33,475	
94	Annual O&M Costs	$ 133,680	0.247	$ 32,981	
95	Annual O&M Costs	$ 133,680	0.243	$ 32,493	
95	Periodic Costs	$ 7,080	0.243	$ 1,721	Pump replacement
96	Annual O&M Costs	$ 133,680	0.239	$ 32,013	
97	Annual O&M Costs	$ 133,680	0.236	$ 31,540	
98	Annual O&M Costs	$ 133,680	0.232	$ 31,074	
99	Annual O&M Costs	$ 133,680	0.229	$ 30,615	
100	Annual O&M Costs	$ 133,680	0.226	$ 30,162	
100	GWTP Demolition	$ 50,000	0.226	$ 11,281	
100	Final Completion Report	$ 5,000	0.226	$ 1,128	
		$ 13,760,000		**$ 7,190,000**	

TOTAL PRESENT VALUE OF ALTERNATIVE **$ 7,190,000**

VOC Mass Reduction Alternative MSP
GROUNDWATER EXTRACTION AND TREATMENT

COST ESTIMATE SUMMARY MSP

Site:	"Occidental" Site	Description:	100-Year Cash Flow Projection at 7 percent
Location:	Tacoma, Washington		
Phase:	Feasibility Study (-30% to +50%)		
Base Year:	2016		
Date:	December 8, 2016		

PRESENT VALUE ANALYSIS ***Base YR 2016*** 7.0% Discount Rate

Year	Cost Type	Cost	Discount Rate	Present Value	Notes
0	Capital Costs	$ 38,854,780	1.000	$ 38,854,780	
1	Annual O&M Costs	$ 1,210,180	0.935	$ 1,131,009	
2	Annual O&M Costs	$ 1,210,180	0.873	$ 1,057,018	
3	Annual O&M Costs	$ 1,210,180	0.816	$ 987,867	
4	Annual O&M Costs	$ 1,210,180	0.763	$ 923,241	
5	Annual O&M Costs	$ 1,210,180	0.713	$ 862,842	
5	Periodic Costs	$ 97,100	0.713	$ 69,231	5 year review, update plan, and Repair Costs
6	Annual O&M Costs	$ 1,210,180	0.666	$ 806,394	
7	Annual O&M Costs	$ 1,210,180	0.623	$ 753,639	
8	Annual O&M Costs	$ 1,210,180	0.582	$ 704,336	
9	Annual O&M Costs	$ 1,210,180	0.544	$ 658,258	
10	Annual O&M Costs	$ 1,210,180	0.508	$ 615,194	
10	Periodic Costs	$ 72,100	0.508	$ 36,652	5 year review, update plan, and Repair Costs
11	Annual O&M Costs	$ 1,210,180	0.475	$ 574,948	
12	Annual O&M Costs	$ 1,210,180	0.444	$ 537,334	
13	Annual O&M Costs	$ 1,210,180	0.415	$ 502,182	
14	Annual O&M Costs	$ 1,210,180	0.388	$ 469,329	
15	Annual O&M Costs	$ 1,210,180	0.362	$ 438,625	
15	Periodic Costs	$ 1,857,480	0.362	$ 673,236	5 year review, update plan, and Repair Costs
16	Annual O&M Costs	$ 1,210,180	0.339	$ 409,930	
17	Annual O&M Costs	$ 1,210,180	0.317	$ 383,112	
18	Annual O&M Costs	$ 1,210,180	0.296	$ 358,049	
19	Annual O&M Costs	$ 1,210,180	0.277	$ 334,625	
20	Annual O&M Costs	$ 1,210,180	0.258	$ 312,734	
20	Periodic Costs	$ 831,890	0.258	$ 214,976	5 year review, update plan, and Repair Costs
21	Annual O&M Costs	$ 1,210,180	0.242	$ 292,274	
22	Annual O&M Costs	$ 1,210,180	0.226	$ 273,154	
23	Annual O&M Costs	$ 1,210,180	0.211	$ 255,284	
24	Annual O&M Costs	$ 1,210,180	0.197	$ 238,583	
25	Annual O&M Costs	$ 1,210,180	0.184	$ 222,975	
25	Periodic Costs	$ 62,100	0.184	$ 11,442	5 year review, update plan, and Repair Costs
26	Annual O&M Costs	$ 1,210,180	0.172	$ 208,388	
27	Annual O&M Costs	$ 1,210,180	0.161	$ 194,755	
28	Annual O&M Costs	$ 1,210,180	0.150	$ 182,014	
29	Annual O&M Costs	$ 1,210,180	0.141	$ 170,106	
30	Annual O&M Costs	$ 1,210,180	0.131	$ 158,978	
30	Periodic Costs	$ 1,857,480	0.131	$ 244,012	5 year review, update plan, and Repair Costs
31	Annual O&M Costs	$ 1,210,180	0.123	$ 148,577	
32	Annual O&M Costs	$ 1,210,180	0.115	$ 138,857	
33	Annual O&M Costs	$ 1,210,180	0.107	$ 129,773	
34	Annual O&M Costs	$ 1,210,180	0.100	$ 121,283	
35	Annual O&M Costs	$ 1,210,180	0.094	$ 113,349	
35	Periodic Costs	$ 62,100	0.094	$ 5,816	5 year review, update plan, and Repair Costs
36	Annual O&M Costs	$ 1,210,180	0.088	$ 105,934	
37	Annual O&M Costs	$ 1,210,180	0.082	$ 99,003	
38	Annual O&M Costs	$ 1,210,180	0.076	$ 92,527	
39	Annual O&M Costs	$ 1,210,180	0.071	$ 86,473	
40	Annual O&M Costs	$ 1,210,180	0.067	$ 80,816	
40	Periodic Costs	$ 831,890	0.067	$ 55,554	5 year review, update plan, and Repair Costs
41	Annual O&M Costs	$ 1,210,180	0.062	$ 75,529	
42	Annual O&M Costs	$ 1,210,180	0.058	$ 70,588	
43	Annual O&M Costs	$ 1,210,180	0.055	$ 65,970	
44	Annual O&M Costs	$ 1,210,180	0.051	$ 61,654	
45	Annual O&M Costs	$ 1,210,180	0.048	$ 57,621	
45	Periodic Costs	$ 1,857,480	0.048	$ 88,441	5 year review, update plan, and Repair Costs
46	Annual O&M Costs	$ 1,210,180	0.044	$ 53,851	
47	Annual O&M Costs	$ 1,210,180	0.042	$ 50,328	
48	Annual O&M Costs	$ 1,210,180	0.039	$ 47,036	
49	Annual O&M Costs	$ 1,210,180	0.036	$ 43,959	
50	Annual O&M Costs	$ 1,210,180	0.034	$ 41,083	
50	Periodic Costs	$ 62,100	0.034	$ 2,108	5 year review, update plan, and Repair Costs
50	Periodic Costs	$ 5,453,300	0.034	$ 185,127	Repair sheet pile wall (50 percent of full install)
51	Annual O&M Costs	$ 1,210,180	0.032	$ 38,395	
52	Annual O&M Costs	$ 1,210,180	0.030	$ 35,883	
53	Annual O&M Costs	$ 1,210,180	0.028	$ 33,536	
54	Annual O&M Costs	$ 1,210,180	0.026	$ 31,342	
55	Annual O&M Costs	$ 1,210,180	0.024	$ 29,292	
55	Periodic Costs	$ 62,100	0.024	$ 1,503	5 year review, update plan, and Repair Costs
56	Annual O&M Costs	$ 1,210,180	0.023	$ 27,375	
57	Annual O&M Costs	$ 1,210,180	0.021	$ 25,584	
58	Annual O&M Costs	$ 1,210,180	0.020	$ 23,911	
59	Annual O&M Costs	$ 1,210,180	0.018	$ 22,346	
60	Annual O&M Costs	$ 1,210,180	0.017	$ 20,884	
60	Periodic Costs	$ 831,890	0.017	$ 14,356	5 year review, update plan, and Repair Costs
61	Annual O&M Costs	$ 1,210,180	0.016	$ 19,518	
62	Annual O&M Costs	$ 1,210,180	0.015	$ 18,241	
63	Annual O&M Costs	$ 1,210,180	0.014	$ 17,048	
64	Annual O&M Costs	$ 1,210,180	0.013	$ 15,933	
65	Annual O&M Costs	$ 1,210,180	0.012	$ 14,890	
65	Periodic Costs	$ 62,100	0.012	$ 764	5 year review, update plan, and Repair Costs
66	Annual O&M Costs	$ 1,210,180	0.011	$ 13,916	
67	Annual O&M Costs	$ 1,210,180	0.011	$ 13,006	
68	Annual O&M Costs	$ 1,210,180	0.010	$ 12,155	
69	Annual O&M Costs	$ 1,210,180	0.009	$ 11,360	
70	Annual O&M Costs	$ 1,210,180	0.009	$ 10,617	
70	Periodic Costs	$ 62,100	0.009	$ 545	5 year review, update plan, and Repair Costs

VOC Mass Reduction Alternative MSP
GROUNDWATER EXTRACTION AND TREATMENT

COST ESTIMATE SUMMARY MSP

Site:	"Occidental" Site	Description:	100-Year Cash Flow Projection at 7 percent
Location:	Tacoma, Washington		
Phase:	Feasibility Study (-30% to +50%)		
Base Year:	2016		
Date:	December 8, 2016		

PRESENT VALUE ANALYSIS ***Base YR 2016*** 7.0% Discount Rate

Year	Cost Type	Cost	Discount Rate	Present Value	Notes
71	Annual O&M Costs	$ 1,210,180	0.008	$ 9,922	
72	Annual O&M Costs	$ 1,210,180	0.008	$ 9,273	
73	Annual O&M Costs	$ 1,210,180	0.007	$ 8,666	
74	Annual O&M Costs	$ 1,210,180	0.007	$ 8,099	
75	Annual O&M Costs	$ 1,210,180	0.006	$ 7,569	
75	Periodic Costs	$ 1,857,480	0.006	$ 11,618	5 year review, update plan, and Repair Costs
76	Annual O&M Costs	$ 1,210,180	0.006	$ 7,074	
77	Annual O&M Costs	$ 1,210,180	0.005	$ 6,611	
78	Annual O&M Costs	$ 1,210,180	0.005	$ 6,179	
79	Annual O&M Costs	$ 1,210,180	0.005	$ 5,775	
80	Annual O&M Costs	$ 1,210,180	0.004	$ 5,397	
80	Periodic Costs	$ 831,890	0.004	$ 3,710	5 year review, update plan, and Repair Costs
81	Annual O&M Costs	$ 1,210,180	0.004	$ 5,044	
82	Annual O&M Costs	$ 1,210,180	0.004	$ 4,714	
83	Annual O&M Costs	$ 1,210,180	0.004	$ 4,406	
84	Annual O&M Costs	$ 1,210,180	0.003	$ 4,117	
85	Annual O&M Costs	$ 1,210,180	0.003	$ 3,848	
85	Periodic Costs	$ 62,100	0.003	$ 197	5 year review, update plan, and Repair Costs
86	Annual O&M Costs	$ 1,210,180	0.003	$ 3,596	
87	Annual O&M Costs	$ 1,210,180	0.003	$ 3,361	
88	Annual O&M Costs	$ 1,210,180	0.003	$ 3,141	
89	Annual O&M Costs	$ 1,210,180	0.002	$ 2,936	
90	Annual O&M Costs	$ 1,210,180	0.002	$ 2,744	
90	Periodic Costs	$ 1,857,480	0.002	$ 4,211	5 year review, update plan, and Repair Costs
91	Annual O&M Costs	$ 1,210,180	0.002	$ 2,564	
92	Annual O&M Costs	$ 1,210,180	0.002	$ 2,396	
93	Annual O&M Costs	$ 1,210,180	0.002	$ 2,240	
94	Annual O&M Costs	$ 1,210,180	0.002	$ 2,093	
95	Annual O&M Costs	$ 1,210,180	0.002	$ 1,956	
95	Periodic Costs	$ 62,100	0.002	$ 100	5 year review, update plan, and Repair Costs
96	Annual O&M Costs	$ 1,210,180	0.002	$ 1,828	
97	Annual O&M Costs	$ 1,210,180	0.001	$ 1,709	
98	Annual O&M Costs	$ 1,210,180	0.001	$ 1,597	
99	Annual O&M Costs	$ 1,210,180	0.001	$ 1,492	
100	Annual O&M Costs	$ 1,210,180	0.001	$ 1,395	
100	GWTP Demolition	$ 1,000,000	0.001	$ 1,152	
100	Final Completion Report	$ 100,000	0.001	$ 115	
		$ 179,710,000		**$ 57,750,000**	

TOTAL PRESENT VALUE OF ALTERNATIVE **$ 57,750,000**

VOC Mass Reduction Alternative MSP
GROUNDWATER EXTRACTION AND TREATMENT

COST ESTIMATE SUMMARY MSP

Site: "Occidental" Site
Location: Tacoma, Washington
Phase: Feasibility Study (-30% to +50%)
Base Year: 2016
Date: December 8, 2016

Description: 100-Year Cash Flow Projection at 1.5 percent

PRESENT VALUE ANALYSIS ***Base YR 2016*** 1.5% Discount Rate

Year	Cost Type	Cost	Discount Rate	Present Value	Notes
0	Capital Costs	$ 38,854,780	1.000	$ 38,854,780	
1	Annual O&M Costs	$ 1,210,180	0.985	$ 1,192,296	
2	Annual O&M Costs	$ 1,210,180	0.971	$ 1,174,675	
3	Annual O&M Costs	$ 1,210,180	0.956	$ 1,157,316	
4	Annual O&M Costs	$ 1,210,180	0.942	$ 1,140,213	
5	Annual O&M Costs	$ 1,210,180	0.928	$ 1,123,362	
5	Periodic Costs	$ 97,100	0.928	$ 90,134	5 year review, update plan, and Repair Costs
6	Annual O&M Costs	$ 1,210,180	0.915	$ 1,106,761	
7	Annual O&M Costs	$ 1,210,180	0.901	$ 1,090,405	
8	Annual O&M Costs	$ 1,210,180	0.888	$ 1,074,290	
9	Annual O&M Costs	$ 1,210,180	0.875	$ 1,058,414	
10	Annual O&M Costs	$ 1,210,180	0.862	$ 1,042,772	
10	Periodic Costs	$ 72,100	0.862	$ 62,126	5 year review, update plan, and Repair Costs
11	Annual O&M Costs	$ 1,210,180	0.849	$ 1,027,362	
12	Annual O&M Costs	$ 1,210,180	0.836	$ 1,012,179	
13	Annual O&M Costs	$ 1,210,180	0.824	$ 997,221	
14	Annual O&M Costs	$ 1,210,180	0.812	$ 982,484	
15	Annual O&M Costs	$ 1,210,180	0.800	$ 967,964	
15	Periodic Costs	$ 1,857,480	0.800	$ 1,485,708	5 year review, update plan, and Repair Costs
16	Annual O&M Costs	$ 1,210,180	0.788	$ 953,659	
17	Annual O&M Costs	$ 1,210,180	0.776	$ 939,566	
18	Annual O&M Costs	$ 1,210,180	0.765	$ 925,681	
19	Annual O&M Costs	$ 1,210,180	0.754	$ 912,001	
20	Annual O&M Costs	$ 1,210,180	0.742	$ 898,523	
20	Periodic Costs	$ 831,890	0.742	$ 617,654	5 year review, update plan, and Repair Costs
21	Annual O&M Costs	$ 1,210,180	0.731	$ 885,244	
22	Annual O&M Costs	$ 1,210,180	0.721	$ 872,162	
23	Annual O&M Costs	$ 1,210,180	0.710	$ 859,273	
24	Annual O&M Costs	$ 1,210,180	0.700	$ 846,574	
25	Annual O&M Costs	$ 1,210,180	0.689	$ 834,063	
25	Periodic Costs	$ 62,100	0.689	$ 42,800	5 year review, update plan, and Repair Costs
26	Annual O&M Costs	$ 1,210,180	0.679	$ 821,737	
27	Annual O&M Costs	$ 1,210,180	0.669	$ 809,593	
28	Annual O&M Costs	$ 1,210,180	0.659	$ 797,629	
29	Annual O&M Costs	$ 1,210,180	0.649	$ 785,841	
30	Annual O&M Costs	$ 1,210,180	0.640	$ 774,228	
30	Periodic Costs	$ 1,857,480	0.640	$ 1,188,346	5 year review, update plan, and Repair Costs
31	Annual O&M Costs	$ 1,210,180	0.630	$ 762,786	
32	Annual O&M Costs	$ 1,210,180	0.621	$ 751,513	
33	Annual O&M Costs	$ 1,210,180	0.612	$ 740,407	
34	Annual O&M Costs	$ 1,210,180	0.603	$ 729,465	
35	Annual O&M Costs	$ 1,210,180	0.594	$ 718,685	
35	Periodic Costs	$ 62,100	0.594	$ 36,879	5 year review, update plan, and Repair Costs
36	Annual O&M Costs	$ 1,210,180	0.585	$ 708,064	
37	Annual O&M Costs	$ 1,210,180	0.576	$ 697,600	
38	Annual O&M Costs	$ 1,210,180	0.568	$ 687,291	
39	Annual O&M Costs	$ 1,210,180	0.560	$ 677,134	
40	Annual O&M Costs	$ 1,210,180	0.551	$ 667,127	
40	Periodic Costs	$ 831,890	0.551	$ 458,590	5 year review, update plan, and Repair Costs
41	Annual O&M Costs	$ 1,210,180	0.543	$ 657,268	
42	Annual O&M Costs	$ 1,210,180	0.535	$ 647,554	
43	Annual O&M Costs	$ 1,210,180	0.527	$ 637,985	
44	Annual O&M Costs	$ 1,210,180	0.519	$ 628,556	
45	Annual O&M Costs	$ 1,210,180	0.512	$ 619,267	
45	Periodic Costs	$ 1,857,480	0.512	$ 950,500	5 year review, update plan, and Repair Costs
46	Annual O&M Costs	$ 1,210,180	0.504	$ 610,115	
47	Annual O&M Costs	$ 1,210,180	0.497	$ 601,099	
48	Annual O&M Costs	$ 1,210,180	0.489	$ 592,216	
49	Annual O&M Costs	$ 1,210,180	0.482	$ 583,464	
50	Annual O&M Costs	$ 1,210,180	0.475	$ 574,841	
50	Periodic Costs	$ 62,100	0.475	$ 29,498	5 year review, update plan, and Repair Costs
50	Periodic Costs	$ 5,453,300	0.475	$ 2,590,343	Repair sheet pile wall (50 percent of full install)
51	Annual O&M Costs	$ 1,210,180	0.468	$ 566,346	
52	Annual O&M Costs	$ 1,210,180	0.461	$ 557,976	
53	Annual O&M Costs	$ 1,210,180	0.454	$ 549,730	
54	Annual O&M Costs	$ 1,210,180	0.448	$ 541,606	
55	Annual O&M Costs	$ 1,210,180	0.441	$ 533,602	
55	Periodic Costs	$ 62,100	0.441	$ 27,382	5 year review, update plan, and Repair Costs
56	Annual O&M Costs	$ 1,210,180	0.434	$ 525,716	
57	Annual O&M Costs	$ 1,210,180	0.428	$ 517,947	
58	Annual O&M Costs	$ 1,210,180	0.422	$ 510,293	
59	Annual O&M Costs	$ 1,210,180	0.415	$ 502,752	
60	Annual O&M Costs	$ 1,210,180	0.409	$ 495,322	
60	Periodic Costs	$ 831,890	0.409	$ 340,489	5 year review, update plan, and Repair Costs
61	Annual O&M Costs	$ 1,210,180	0.403	$ 488,002	
62	Annual O&M Costs	$ 1,210,180	0.397	$ 480,790	
63	Annual O&M Costs	$ 1,210,180	0.391	$ 473,685	
64	Annual O&M Costs	$ 1,210,180	0.386	$ 466,684	
65	Annual O&M Costs	$ 1,210,180	0.380	$ 459,788	
65	Periodic Costs	$ 62,100	0.380	$ 23,594	5 year review, update plan, and Repair Costs
66	Annual O&M Costs	$ 1,210,180	0.374	$ 452,993	
67	Annual O&M Costs	$ 1,210,180	0.369	$ 446,298	
68	Annual O&M Costs	$ 1,210,180	0.363	$ 439,703	
69	Annual O&M Costs	$ 1,210,180	0.358	$ 433,205	
70	Annual O&M Costs	$ 1,210,180	0.353	$ 426,803	
70	Periodic Costs	$ 62,100	0.353	$ 21,901	5 year review, update plan, and Repair Costs

VOC Mass Reduction Alternative MSP
GROUNDWATER EXTRACTION AND TREATMENT

COST ESTIMATE SUMMARY MSP

Site:	"Occidental" Site	Description:	100-Year Cash Flow Projection at 1.5 percent
Location:	Tacoma, Washington		
Phase:	Feasibility Study (-30% to +50%)		
Base Year:	2016		
Date:	December 8, 2016		

PRESENT VALUE ANALYSIS ***Base YR 2016*** 1.5% Discount Rate

Year	Cost Type	Cost	Discount Rate	Present Value	Notes
71	Annual O&M Costs	$ 1,210,180	0.347	$ 420,495	
72	Annual O&M Costs	$ 1,210,180	0.342	$ 414,281	
73	Annual O&M Costs	$ 1,210,180	0.337	$ 408,159	
74	Annual O&M Costs	$ 1,210,180	0.332	$ 402,127	
75	Annual O&M Costs	$ 1,210,180	0.327	$ 396,184	
75	Periodic Costs	$ 1,857,480	0.327	$ 608,094	5 year review, update plan, and Repair Costs
76	Annual O&M Costs	$ 1,210,180	0.323	$ 390,329	
77	Annual O&M Costs	$ 1,210,180	0.318	$ 384,561	
78	Annual O&M Costs	$ 1,210,180	0.313	$ 378,877	
79	Annual O&M Costs	$ 1,210,180	0.308	$ 373,278	
80	Annual O&M Costs	$ 1,210,180	0.304	$ 367,762	
80	Periodic Costs	$ 831,890	0.304	$ 252,803	5 year review, update plan, and Repair Costs
81	Annual O&M Costs	$ 1,210,180	0.299	$ 362,327	
82	Annual O&M Costs	$ 1,210,180	0.295	$ 356,972	
83	Annual O&M Costs	$ 1,210,180	0.291	$ 351,697	
84	Annual O&M Costs	$ 1,210,180	0.286	$ 346,499	
85	Annual O&M Costs	$ 1,210,180	0.282	$ 341,379	
85	Periodic Costs	$ 62,100	0.282	$ 17,518	5 year review, update plan, and Repair Costs
86	Annual O&M Costs	$ 1,210,180	0.278	$ 336,334	
87	Annual O&M Costs	$ 1,210,180	0.274	$ 331,363	
88	Annual O&M Costs	$ 1,210,180	0.270	$ 326,466	
89	Annual O&M Costs	$ 1,210,180	0.266	$ 321,642	
90	Annual O&M Costs	$ 1,210,180	0.262	$ 316,888	
90	Periodic Costs	$ 1,857,480	0.262	$ 486,385	5 year review, update plan, and Repair Costs
91	Annual O&M Costs	$ 1,210,180	0.258	$ 312,205	
92	Annual O&M Costs	$ 1,210,180	0.254	$ 307,591	
93	Annual O&M Costs	$ 1,210,180	0.250	$ 303,046	
94	Annual O&M Costs	$ 1,210,180	0.247	$ 298,567	
95	Annual O&M Costs	$ 1,210,180	0.243	$ 294,155	
95	Periodic Costs	$ 62,100	0.243	$ 15,094	5 year review, update plan, and Repair Costs
96	Annual O&M Costs	$ 1,210,180	0.239	$ 289,808	
97	Annual O&M Costs	$ 1,210,180	0.236	$ 285,525	
98	Annual O&M Costs	$ 1,210,180	0.232	$ 281,305	
99	Annual O&M Costs	$ 1,210,180	0.229	$ 277,148	
100	Annual O&M Costs	$ 1,210,180	0.226	$ 273,052	
100	GWTP Demolition	$ 1,000,000	0.226	$ 225,629	
100	Final Completion Report	$ 100,000	0.226	$ 22,563	
		$ 179,710,000		**$ 110,920,000**	

TOTAL PRESENT VALUE OF ALTERNATIVE **$ 110,920,000**

Appendix G-3
pH Alternatives Cost Estimates

COMPARISON OF TOTAL COST OF pH REMEDIAL ALTERNATIVES

Site: "Occidental" Site
Location: Tacoma, Washington
Phase: Feasibility Study (-30% to +50%)

Base Year: 2016
Date: January 11, 2017

DESCRIPTION	Alternative pH1 No Additional Action	Alternative pH2 pH Reduction Mixing Shallow Zone	Alternative pH3 Enhanced Containment Mixing Shallow Zone	Alternative pH4 Enhanced Containment Slurry Wall Shallow Zone	Alternative pH5 pH Reduction Mixing Shallow and Deep Zones	Alternative pH6 Enhanced Containment Mixing Shallow and Deep Zones	Alternative pH7 Enhanced Containment Slurry Wall Shallow and Deep Zones
Total Project Duration without C150 (Years)	0	2	2	0.5	4	4	1.5
Total Project Duration with C150 (Years)	30	30	30	30	30	30	30
Capital Cost	$38,700,240	$91,895,240	$55,682,540	$41,086,040	$174,488,040	$101,386,040	$50,548,440
Annual O&M Cost	$1,180,644	$1,180,644	$1,180,644	$1,180,644	$1,180,644	$1,180,644	$1,180,644
Total Periodic Cost	$2,920,670	$2,920,670	$2,920,670	$2,920,670	$2,920,670	$2,920,670	$2,920,670
Total Present Value of Alternative (7%)	$54,356,480	$107,551,480	$71,338,780	$56,742,280	$190,144,280	$117,042,280	$66,204,680
Total Present Value of Alternative (1.5%)	$69,352,840	$122,547,840	$86,335,140	$71,738,640	$205,140,640	$132,038,640	$81,201,040

pH Reduction Alternative pH2
pH REDUCTION BY SODIUM PERSULFATE MIXING

COST ESTIMATE SUMMARY pH2

Site: "Occidental" Site
Location: Tacoma, Washington
Phase: Feasibility Study (-30% to +50%)
Base Year: 2016
Date: December 8, 2016

Description: Reduce, by in situ treatment, pH >12.5 s.u. in shallow soil and groundwater that could be a future source of contamination in soil and groundwater. The pH2 alternative includes the following elements: Treatment using in situ mixing of sodium persulfate with shallow soil and groundwater above -60 ft NGVD containing pH greater than 12.5 s.u. Capital costs occur in Year 0. No annual O&M costs. No Periodic costs.

CAPITAL COSTS

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Bench Scale Testing	1	LS	$50,000	$50,000	GHD Quote
Mobilization / Demobilization					
Equipment and Facilities	1	LS	$250,000	$250,000	Vendor quote
H&S Plans and Submittals	1	LS	$15,000	$15,000	Estimated
HASP Implementation	1	LS	$984,620	$984,620	Estimated from vendor bids(1)
Grading	1	LS	$246,160	$246,160	Estimated from vendor bids
Erosion Controls	1	LS	$738,470	$738,470	Estimated from vendor bids
Demobilization	1	LS	$92,000	$92,000	Estimated from vendor bids
SUBTOTAL				$2,326,300	
Mixing					
Asphalt/debris Removal (6" thickness)	14,400	SY	$10	$136,800	GHD Construction Division Estimate
Target Area pH2a (12 to 5ft NGVD)	226	CY	$32	$7,232	Low end of range from vendor quote(1)
Target Area pH2b (12 to 2.5ft NGVD)	28,430	CY	$32	$909,760	Low end of range from vendor quote
Target Area pH2b (2.5 to -10ft NGVD)	37,410	CY	$32	$1,197,120	Low end of range from vendor quote
Target Area pH2b (-10 to -20ft NGVD)	29,930	CY	$32	$957,760	Low end of range from vendor quote
Target Area pH2b (-20 to -30ft NGVD)	29,930	CY	$32	$957,760	Low end of range from vendor quote
Target Area pH2b (-30 to -40ft NGVD)	29,930	CY	$32	$957,760	Low end of range from vendor quote
Target Area pH2b (-40 to -50ft NGVD)	29,930	CY	$32	$957,760	Low end of range from vendor quote
Target Area pH2b (-50 to -60ft NGVD)	29,930	CY	$37	$1,107,410	$5 above low end of range from vendor quote
Target Area pH2c (12 to 2.5ft NGVD)	12,570	CY	$32	$402,240	Low end of range from vendor quote
Target Area pH2c (2.5 to -11ft NGVD)	17,870	CY	$32	$571,840	Low end of range from vendor quote
SUBTOTAL				$8,163,400	
Reagent (sodium persulfate)(2)					
Target Area pH2a (12 to 5ft NGVD)	8,140	LB	$1.5	$12,210	Approximately 1.3% by weight and current market cost
Target Area pH2b (12 to 2.5ft NGVD)(3)	511,810	LB	$1.5	$767,720	Approximately 1.3% by weight and current market cost
Target Area pH2b (2.5 to -10ft NGVD)	3,591,640	LB	$1.5	$5,387,460	Approximately 3.5% by weight and current market cost
Target Area pH2b (-10 to -20ft NGVD)	2,873,320	LB	$1.5	$4,309,980	Approximately 3.5% by weight and current market cost
Target Area pH2b (-20 to -30ft NGVD)	2,873,320	LB	$1.5	$4,309,980	Approximately 3.5% by weight and current market cost
Target Area pH2b (-30 to -40ft NGVD)	2,873,320	LB	$1.5	$4,309,980	Approximately 3.5% by weight and current market cost
Target Area pH2b (-40 to -50ft NGVD)	2,873,320	LB	$1.5	$4,309,980	Approximately 3.5% by weight and current market cost
Target Area pH2b (-50 to -60ft NGVD)	2,873,320	LB	$1.5	$4,309,980	Approximately 3.5% by weight and current market cost
Target Area pH2c (12 to 2.5ft NGVD)	63,260	LB	$1.5	$94,890	Approximately 1.3% by weight and current market cost
Target Area pH2c (2.5 to -11ft NGVD)	1,715,470	LB	$1.5	$2,573,210	Approximately 3.5% by weight and current market cost
SUBTOTAL				$30,385,400	
Field Sampling and Analysis	1	LS	$25,000	$25,000	Estimated (50 x 50 grid; approximately 50 boreholes)
SUBTOTAL				$40,950,100	
Contingency		25%		$10,237,500	10% scope + 15% bid
SUBTOTAL				$51,187,600	
Project Management		5%		$528,300	Excludes reagent costs
Remedial Design		8%		$845,200	Excludes reagent costs
Construction Management		6%		$633,900	Excludes reagent costs
TOTAL CAPITAL COSTS				$53,195,000	

ANNUAL O&M COSTS:
No annual O&M costs

PERIODIC COSTS:
No periodic costs

PRESENT VALUE ANALYSIS

COST TYPE	YEAR	TOTAL COST	TOTAL COST PER YEAR	DISCOUNT FACTOR (1.5%)	PRESENT VALUE	NOTES
Capital Cost	0	$53,195,000	$53,195,000	1.000	$53,195,000	
Annual O&M Cost	-	$0	$0	-	$0	No annual O&M
Periodic Cost	-	$0	$0	-	$0	No periodic costs
		$53,195,000			$53,195,000	
TOTAL PRESENT VALUE OF ALTERNATIVE					$53,195,000	

Notes: (1) Vendor would not breakdown quote for mixing. Vendor quote is $40 to $70 per cubic yard. A typical breakdown of a mixing cost is provided in an associated Cost Worksheet pH-1 and is based on a bid for a different project. Vendor indicated that the price is expected to rise for depths greater than 65 feet.
(2) Dosage (96 lbs/cy) based on pH pilot study to reduce average shallow groundwater pH = 13.036 s.u. by 0.536 s.u.
Dosage (36 lbs/cy) based on pH pilot study to reduce average shallow soil pH = 12.742 s.u. by 0.242 s.u.
ANC calculations suggest dosage rate could be approximately 1.9 times higher (96 lbs/cy compared to 184 lbs/cy).
(3) Assume 50 percent of soil above water table has pH > 12.5 s.u.

pH Enhanced Containment Alternative pH3
ENHANCED CONTAINMENT BY CEMENT MIXING

COST ESTIMATE SUMMARY pH3

Site: "Occidental" Site
Location: Tacoma, Washington
Phase: Feasibility Study (-30% to +50%)
Base Year: 2016
Date: December 8, 2016

Description: Contain, by in situ treatment, pH >12.5 s.u. in shallow soil and groundwater that could be a future source of contamination in soil and groundwater. The pH3 alternative includes the following elements: Treatment using in situ mixing of cement with shallow soil and groundwater above -60 ft NGVD containing pH greater than 12.5 s.u. Capital costs occur in Year 0. No annual O&M costs. No Periodic costs.

CAPITAL COSTS

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Bench Scale Testing	1	LS	$50,000	$50,000	GHD Quote
Mobilization / Demobilization					
Equipment and Facilities	1	LS	$250,000	$250,000	Vendor quote
H&S Plans and Submittals	1	LS	$15,000	$15,000	Estimated
HASP Implementation	1	LS	$984,620	$984,620	Estimated from vendor bids(1)
Grading	1	LS	$246,160	$246,160	Estimated from vendor bids
Erosion Controls	1	LS	$738,470	$738,470	Estimated from vendor bids
Demobilization	1	LS	$92,000	$92,000	Estimated from vendor bids
SUBTOTAL				$2,326,300	
Mixing					
Asphalt/debris Removal (6" thickness)	14,400	SY	$10	$136,800	GHD Construction Division Estimate
Target Area pH2a (12 to 5ft NGVD)	226	CY	$32	$7,232	Low end of range from vendor quote(1)
Target Area pH2b (12 to 2.5ft NGVD)	28,430	CY	$32	$909,760	Low end of range from vendor quote
Target Area pH2b (2.5 to -10ft NGVD)	37,410	CY	$32	$1,197,120	Low end of range from vendor quote
Target Area pH2b (-10 to -20ft NGVD)	29,930	CY	$32	$957,760	Low end of range from vendor quote
Target Area pH2b (-20 to -30ft NGVD)	29,930	CY	$32	$957,760	Low end of range from vendor quote
Target Area pH2b (-30 to -40ft NGVD)	29,930	CY	$32	$957,760	Low end of range from vendor quote
Target Area pH2b (-40 to -50ft NGVD)	29,930	CY	$32	$957,760	Low end of range from vendor quote
Target Area pH2b (-50 to -60ft NGVD)	29,930	CY	$37	$1,107,410	$5 above low end of range from vendor quote
Target Area pH2c (12 to 2.5ft NGVD)	12,570	CY	$32	$402,240	Low end of range from vendor quote
Target Area pH2c (2.5 to -11ft NGVD)	17,870	CY	$32	$571,840	Low end of range from vendor quote
SUBTOTAL				$8,163,400	
Reagent (cement)(2)					
Target Area pH2a (12 to 5ft NGVD)	36,160	LB	$0.04	$1,450	Approximately 6.0% by weight and current market cost
Target Area pH2b (12 to 2.5ft NGVD)(3)	2,274,710	LB	$0.04	$90,990	Approximately 6.0% by weight and current market cost
Target Area pH2b (2.5 to -10ft NGVD)	5,986,070	LB	$0.04	$239,440	Approximately 6.0% by weight and current market cost
Target Area pH2b (-10 to -20ft NGVD)	4,788,860	LB	$0.04	$191,550	Approximately 6.0% by weight and current market cost
Target Area pH2b (-20 to -30ft NGVD)	4,788,860	LB	$0.04	$191,550	Approximately 6.0% by weight and current market cost
Target Area pH2b (-30 to -40ft NGVD)	4,788,860	LB	$0.04	$191,550	Approximately 6.0% by weight and current market cost
Target Area pH2b (-40 to -50ft NGVD)	4,788,860	LB	$0.04	$191,550	Approximately 6.0% by weight and current market cost
Target Area pH2b (-50 to -60ft NGVD)	4,788,860	LB	$0.04	$191,550	Approximately 6.0% by weight and current market cost
Target Area pH2c (12 to 2.5ft NGVD)	281,150	LB	$0.04	$11,250	Approximately 6.0% by weight and current market cost
Target Area pH2c (2.5 to -11ft NGVD)	2,859,120	LB	$0.04	$114,360	Approximately 6.0% by weight and current market cost
SUBTOTAL				$1,415,200	
Field Sampling and Analysis	1	LS	$25,000	$25,000	Estimated (50 x 50 grid; approximately 50 boreholes)
SUBTOTAL				$11,979,900	
Contingency		25%		$2,995,000	10% scope + 15% bid
SUBTOTAL				$14,974,900	
Project Management		5%		$528,300	Excludes reagent costs
Remedial Design		8%		$845,200	Excludes reagent costs
Construction Management		6%		$633,900	Excludes reagent costs
TOTAL CAPITAL COSTS				$16,982,300	

ANNUAL O&M COSTS:
No annual O&M costs

PERIODIC COSTS:
No periodic costs

PRESENT VALUE ANALYSIS

COST TYPE	YEAR	TOTAL COST	TOTAL COST PER YEAR	DISCOUNT FACTOR (1.5%)	PRESENT VALUE	NOTES
Capital Cost	0	$16,982,300	$16,982,300	1.000	$16,982,300	
Annual O&M Cost	-	$0	$0	-	$0	No annual O&M
Periodic Cost	-	$0	$0	-	$0	No periodic costs
		$16,982,300			$16,982,300	
TOTAL PRESENT VALUE OF ALTERNATIVE					$16,982,300	

Notes: (1) Vendor would not breakdown quote for mixing. Vendor quote is $40 to $70 per cubic yard. A typical breakdown of a mixing cost is provided in an associated Cost Worksheet pH-1 and is based on a bid for a different project. Vendor indicated that the price is expected to rise for depths greater than 65 feet.
(2) Dosage based on vendor estimate of typical cement addition rate between 5 and 7 percent by soil weight.
(3) Assume 50 percent of soil above water table has pH > 12.5 s.u.

pH Enhanced Containment Alternative pH4
ENHANCED CONTAINMENT BY VERTICAL SLURRY WALL

COST ESTIMATE SUMMARY pH4

Site: "Occidental" Site
Location: Tacoma, Washington
Phase: Feasibility Study (-30% to +50%)
Base Year: 2016
Date: December 8, 2016

Description: Contain, by in situ vertical barrier, pH >12.5 s.u. in shallow soil and groundwater that could be a future source of contamination in soil and groundwater. The pH4 alternative includes the following elements: Construction of a vertical slurry wall around shallow soil and groundwater above -60 ft NGVD containing pH greater than 12.5 s.u. Capital costs occur in Year 0. No annual O&M costs. No Periodic costs.

CAPITAL COSTS

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Mobilization / Demobilization					
Equipment and Facilities	1	LS	$75,000	$75,000	Vendor quote
H&S plans and submittals	1	LS	$25,000	$25,000	Estimated
SUBTOTAL				$100,000	
Vertical Slurry Wall					
Asphalt/debris Removal (6" thickness)	400	SY	$10	$3,800	GHD Construction Division Estimate
North wall (410 ft)	30,750	SF	$12.5	$384,380	mid range from vendor quote(1)
West wall (860 ft)	64,500	SF	$12.5	$806,250	mid range from vendor quote(1)
South wall (330 ft)	24,750	SF	$12.5	$309,380	mid range from vendor quote(1)
SUBTOTAL				$1,503,800	
SUBTOTAL				$1,603,800	
Contingency		25%		$401,000	10% scope + 15% bid
SUBTOTAL				$2,004,800	
Project Management		5%		$100,300	Excludes reagent costs
Remedial Design		8%		$160,400	Excludes reagent costs
Construction Management		6%		$120,300	Excludes reagent costs
TOTAL CAPITAL COSTS				$2,385,800	

ANNUAL O&M COSTS:
No annual O&M costs

PERIODIC COSTS:
No periodic costs

PRESENT VALUE ANALYSIS

COST TYPE	YEAR	TOTAL COST	TOTAL COST PER YEAR	DISCOUNT FACTOR (1.5%)	PRESENT VALUE	NOTES
Capital Cost	0	$2,385,800	$2,385,800	1.000	$2,385,800	
Annual O&M Cost	-	$0	$0	-	$0	No annual O&M
Periodic Cost	-	$0	$0	-	$0	No periodic costs
		$2,385,800			$2,385,800	
TOTAL PRESENT VALUE OF ALTERNATIVE					$2,385,800	

Notes: (1) Vendor quote is $10 to $15 per square yard (horizontal x vertical) for 2-feet thick wall. No dewatering. Includes air monitoring for personnel and Level D PPE.

pH Reduction Alternative pH5
pH REDUCTION BY SODIUM PERSULFATE MIXING

COST ESTIMATE SUMMARY pH5

Site: "Occidental" Site
Location: Tacoma, Washington
Phase: Feasibility Study (-30% to +50%)
Base Year: 2016
Date: December 8, 2016

Description: Reduce, by in situ treatment, pH >12.5 s.u. in shallow and deep soil and groundwater that could be a future source of contamination in soil and groundwater. The pH5 alternative includes the following elements: Treatment using in situ mixing of sodium persulfate with shallow and deep soil and groundwater containing pH greater than 12.5 s.u. Capital costs occur in Year 0. No annual O&M costs. No Periodic costs.

CAPITAL COSTS

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Bench Scale Testing	1	LS	$50,000	$50,000	GHD Quote
Mobilization / Demobilization					
Equipment and Facilities	1	LS	$250,000	$250,000	Vendor quote
H&S Plans and Submittals	1	LS	$15,000	$15,000	Estimated
HASP Implementation	1	LS	$3,710,600	$3,710,600	Estimated from vendor bids[1]
Grading	1	LS	$927,650	$927,650	Estimated from vendor bids
Erosion Controls	1	LS	$2,782,950	$2,782,950	Estimated from vendor bids
Demobilization	1	LS	$92,000	$92,000	Estimated from vendor bids
SUBTOTAL				$7,778,200	
Mixing					
Asphalt/debris Removal (6" thickness)	31,400	SY	$10	$298,300	GHD Construction Division Estimate
Target Area pH2b (12 to 2.5ft NGVD)	28,430	CY	$32	$909,760	Low end of range from vendor quote[1]
Target Area pH2b (2.5 to -10ft NGVD)	37,410	CY	$32	$1,197,120	Low end of range from vendor quote
Target Area pH2b (-10 to -20ft NGVD)	29,930	CY	$32	$957,760	Low end of range from vendor quote
Target Area pH2b (-20 to -30ft NGVD)	29,930	CY	$32	$957,760	Low end of range from vendor quote
Target Area pH2b (-30 to -40ft NGVD)	29,930	CY	$32	$957,760	Low end of range from vendor quote
Target Area pH2b (-40 to -50ft NGVD)	29,930	CY	$32	$957,760	Low end of range from vendor quote
Target Area pH2b (-50 to -60ft NGVD)	29,930	CY	$37	$1,107,410	$5 above low end of range from vendor quote
Target Area pH5b1 (-60 to -70ft NGVD)	29,930	CY	$37	$1,107,410	$5 above low end of range from vendor quote
Target Area pH5b1 (-70 to -80ft NGVD)	29,930	CY	$37	$1,107,410	$5 above low end of range from vendor quote
Target Area pH5b1 (-80 to -90ft NGVD)	29,930	CY	$42	$1,257,060	$10 above low end of range from vendor quote
Target Area pH5b1 (-90 to -100ft NGVD)	29,930	CY	$42	$1,257,060	$10 above low end of range from vendor quote
Target Area pH5b2 (12 to 2.5ft NGVD)	31,410	CY	$40	$1,005,120	Low end of range from vendor quote
Target Area pH5b2 (2.5 to -10ft NGVD)	41,320	CY	$32	$1,322,240	Low end of range from vendor quote
Target Area pH5b2 (-10 to -20ft NGVD)	33,060	CY	$32	$1,057,920	Low end of range from vendor quote
Target Area pH5b2 (-20 to -30ft NGVD)	33,060	CY	$32	$1,057,920	Low end of range from vendor quote
Target Area pH5b2 (-30 to -40ft NGVD)	33,060	CY	$32	$1,057,920	Low end of range from vendor quote
Target Area pH5b2 (-40 to -50ft NGVD)	33,060	CY	$32	$1,057,920	Low end of range from vendor quote
Target Area pH5b2 (-50 to -60ft NGVD)	33,060	CY	$37	$1,223,220	$5 above low end of range from vendor quote
Target Area pH5b2 (-60 to -70ft NGVD)	33,060	CY	$37	$1,223,220	$5 above low end of range from vendor quote
Target Area pH5b2 (-70 to -80ft NGVD)	33,060	CY	$37	$1,223,220	$5 above low end of range from vendor quote
Target Area pH5b2 (-80 to -90ft NGVD)	33,060	CY	$42	$1,388,520	$10 above low end of range from vendor quote
Target Area pH5b3 (12 to 2.5ft NGVD)	15,700	CY	$32	$502,400	Low end of range from vendor quote
Target Area pH5b3 (2.5 to -10ft NGVD)	20,660	CY	$32	$661,120	Low end of range from vendor quote
Target Area pH5b3 (-10 to -20ft NGVD)	16,530	CY	$32	$528,960	Low end of range from vendor quote
Target Area pH5b3 (-20 to -30ft NGVD)	16,530	CY	$32	$528,960	Low end of range from vendor quote
Target Area pH5b3 (-30 to -40ft NGVD)	16,530	CY	$32	$528,960	Low end of range from vendor quote
Target Area pH5b3 (-40 to -50ft NGVD)	16,530	CY	$32	$528,960	Low end of range from vendor quote
Target Area pH5b3 (-50 to -60ft NGVD)	16,530	CY	$37	$611,610	$5 above low end of range from vendor quote
Target Area pH5b3 (-60 to -70ft NGVD)	16,530	CY	$37	$611,610	$5 above low end of range from vendor quote
Target Area pH5b3 (-70 to -80ft NGVD)	16,530	CY	$37	$611,610	$5 above low end of range from vendor quote
Target Area pH5b3 (-80 to -90ft NGVD)	16,530	CY	$42	$694,260	$10 above low end of range from vendor quote
Target Area pH5b3 (-90 to -100ft NGVD)	16,530	CY	$42	$694,260	$10 above low end of range from vendor quote
Target Area pH2c (12 to 2.5ft NGVD)	12,570	CY	$32	$402,240	Low end of range from vendor quote
Target Area pH2c (2.5 to -11ft NGVD)	17,870	CY	$32	$571,840	Low end of range from vendor quote
Target Area pH5a (12 to 2.5ft NGVD)	2,380	CY	$32	$76,160	Low end of range from vendor quote
Target Area pH5a (2.5 to -10ft NGVD)	3,140	CY	$32	$100,480	Low end of range from vendor quote
Target Area pH5a (-10 to -20ft NGVD)	2,510	CY	$32	$80,320	Low end of range from vendor quote
Target Area pH5a (-20 to -30ft NGVD)	2,510	CY	$32	$80,320	Low end of range from vendor quote
Target Area pH5a (-30 to -40ft NGVD)	2,510	CY	$32	$80,320	Low end of range from vendor quote
Target Area pH5a (-40 to -50ft NGVD)	2,510	CY	$32	$80,320	Low end of range from vendor quote
Target Area pH5a (-50 to -60ft NGVD)	2,510	CY	$37	$92,870	$5 above low end of range from vendor quote
Target Area pH5a (-60 to -70ft NGVD)	2,510	CY	$37	$92,870	$5 above low end of range from vendor quote
Target Area pH5a (-70 to -80ft NGVD)	2,510	CY	$37	$92,870	$5 above low end of range from vendor quote
Target Area pH5a (-80 to -90ft NGVD)	2,510	CY	$42	$105,420	$10 above low end of range from vendor quote
Target Area pH5a (-90 to -100ft NGVD)	2,510	CY	$42	$105,420	$10 above low end of range from vendor quote
Target Area pH5a (-100 to -110ft NGVD)	2,510	CY	$47	$117,970	$15 above low end of range from vendor quote
Target Area pH5a (-110 to -120ft NGVD)	2,510	CY	$47	$117,970	$15 above low end of range from vendor quote
Target Area pH5a (-120 to -130ft NGVD)	2,510	CY	$52	$130,520	$20 above low end of range from vendor quote
Target Area pH5a (-130 to -140ft NGVD)	2,510	CY	$57	$143,070	$25 above low end of range from vendor quote
Target Area pH5a (-140 to -146ft NGVD)	1,510	CY	$62	$93,620	high end of range from vendor quote
SUBTOTAL				$32,757,100	

pH Reduction Alternative pH5
pH REDUCTION BY SODIUM PERSULFATE MIXING

COST ESTIMATE SUMMARY pH5

Site: "Occidental" Site
Location: Tacoma, Washington
Phase: Feasibility Study (-30% to +50%)
Base Year: 2016
Date: December 8, 2016

Description: Reduce, by in situ treatment, pH >12.5 s.u. in shallow and deep soil and groundwater that could be a future source of contamination in soil and groundwater. The pH5 alternative includes the following elements: Treatment using in situ mixing of sodium persulfate with shallow and deep soil and groundwater containing pH greater than 12.5 s.u. Capital costs occur in Year 0. No annual O&M costs. No Periodic costs.

CAPITAL COSTS

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Reagent (sodium persulfate)(2)					
Target Area pH2a (12 to 5ft NGVD)	8,140	LB	$1.5	$12,210	Approximately 1.3% by weight and current market cost
Target Area pH2b (12 to 2.5ft NGVD)(3)	511,810	LB	$1.5	$767,720	Approximately 1.3% by weight and current market cost
Target Area pH2b (2.5 to -10ft NGVD)	3,591,640	LB	$1.5	$5,387,460	Approximately 3.5% by weight and current market cost
Target Area pH2b (-10 to -20ft NGVD)	2,873,320	LB	$1.5	$4,309,980	Approximately 3.5% by weight and current market cost
Target Area pH2b (-20 to -30ft NGVD)	2,873,320	LB	$1.5	$4,309,980	Approximately 3.5% by weight and current market cost
Target Area pH2b (-30 to -40ft NGVD)	2,873,320	LB	$1.5	$4,309,980	Approximately 3.5% by weight and current market cost
Target Area pH2b (-40 to -50ft NGVD)	2,873,320	LB	$1.5	$4,309,980	Approximately 3.5% by weight and current market cost
Target Area pH2b (-50 to -60ft NGVD)	2,873,320	LB	$1.5	$4,309,980	Approximately 3.5% by weight and current market cost
Target Area pH5b1 (-60 to -70ft NGVD)	2,095,130	LB	$1.5	$3,142,700	Approximately 2.6% by weight and current market cost
Target Area pH5b1 (-70 to -80ft NGVD)	2,095,130	LB	$1.5	$3,142,700	Approximately 2.6% by weight and current market cost
Target Area pH5b1 (-80 to -90ft NGVD)	2,095,130	LB	$1.5	$3,142,700	Approximately 2.6% by weight and current market cost
Target Area pH5b1 (-90 to -100ft NGVD)	2,095,130	LB	$1.5	$3,142,700	Approximately 2.6% by weight and current market cost
Target Area pH5b2 (12 to 2.5ft NGVD)	0	LB	$1.5	$0	
Target Area pH5b2 (2.5 to -10ft NGVD)	0	LB	$1.5	$0	
Target Area pH5b2 (-10 to -20ft NGVD)	0	LB	$1.5	$0	
Target Area pH5b2 (-20 to -30ft NGVD)	0	LB	$1.5	$0	
Target Area pH5b2 (-30 to -40ft NGVD)	0	LB	$1.5	$0	
Target Area pH5b2 (-40 to -50ft NGVD)	0	LB	$1.5	$0	
Target Area pH5b2 (-50 to -60ft NGVD)	0	LB	$1.5	$0	
Target Area pH5b2 (-60 to -70ft NGVD)	1,047,560	LB	$1.5	$1,571,340	Approximately 2.6% by weight and current market cost
Target Area pH5b2 (-70 to -80ft NGVD)	2,095,130	LB	$1.5	$3,142,700	Approximately 2.6% by weight and current market cost
Target Area pH5b2 (-80 to -90ft NGVD)	2,095,130	LB	$1.5	$3,142,700	Approximately 2.6% by weight and current market cost
Target Area pH5b3 (12 to 2.5ft NGVD)	0	LB	$1.5	$0	
Target Area pH5b3 (2.5 to -10ft NGVD)	0	LB	$1.5	$0	
Target Area pH5b3 (-10 to -20ft NGVD)	0	LB	$1.5	$0	
Target Area pH5b3 (-20 to -30ft NGVD)	0	LB	$1.5	$0	
Target Area pH5b3 (-30 to -40ft NGVD)	0	LB	$1.5	$0	
Target Area pH5b3 (-40 to -50ft NGVD)	0	LB	$1.5	$0	
Target Area pH5b3 (-50 to -60ft NGVD)	0	LB	$1.5	$0	
Target Area pH5b3 (-60 to -70ft NGVD)	0	LB	$1.5	$0	
Target Area pH5b3 (-70 to -80ft NGVD)	1,047,560	LB	$1.5	$1,571,340	Approximately 2.6% by weight and current market cost
Target Area pH5b3 (-80 to -90ft NGVD)	2,095,130	LB	$1.5	$3,142,700	Approximately 2.6% by weight and current market cost
Target Area pH5b3 (-90 to -100ft NGVD)	2,095,130	LB	$1.5	$3,142,700	Approximately 2.6% by weight and current market cost
Target Area pH2c (12 to 2.5ft NGVD)	63,260	LB	$1.5	$94,890	Approximately 1.3% by weight and current market cost
Target Area pH2c (2.5 to -11ft NGVD)	1,715,470	LB	$1.5	$2,573,210	Approximately 3.5% by weight and current market cost
Target Area pH5a (12 to 2.5ft NGVD)	0	LB	$1.5	$0	
Target Area pH5a (2.5 to -10ft NGVD)	0	LB	$1.5	$0	
Target Area pH5a (-10 to -20ft NGVD)	0	LB	$1.5	$0	
Target Area pH5a (-20 to -30ft NGVD)	0	LB	$1.5	$0	
Target Area pH5a (-30 to -40ft NGVD)	0	LB	$1.5	$0	
Target Area pH5a (-40 to -50ft NGVD)	0	LB	$1.5	$0	
Target Area pH5a (-50 to -60ft NGVD)	0	LB	$1.5	$0	
Target Area pH5a (-60 to -70ft NGVD)	0	LB	$1.5	$0	
Target Area pH5a (-70 to -80ft NGVD)	0	LB	$1.5	$0	
Target Area pH5a (-80 to -90ft NGVD)	0	LB	$1.5	$0	
Target Area pH5a (-90 to -100ft NGVD)	0	LB	$1.5	$0	
Target Area pH5a (-100 to -110ft NGVD)	0	LB	$1.5	$0	
Target Area pH5a (-110 to -120ft NGVD)	0	LB	$1.5	$0	
Target Area pH5a (-120 to -130ft NGVD)	0	LB	$1.5	$0	
Target Area pH5a (-130 to -140ft NGVD)	838,050	LB	$1.5	$1,257,080	Approximately 2.6% by weight and current market cost
Target Area pH5a (-140 to -146ft NGVD)	1,257,080	LB	$1.5	$1,885,620	Approximately 2.6% by weight and current market cost
SUBTOTAL				$61,812,400	
Field Sampling and Analysis	1	LS	$55,000	$55,000	Estimated (50 x 50 grid; approximately 110 boreholes)
SUBTOTAL				$102,452,700	
Contingency		25%		$25,613,200	10% scope + 15% bid
SUBTOTAL				$128,065,900	
Project Management		5%		$2,032,100	Excludes reagent costs
Remedial Design		8%		$3,251,300	Excludes reagent costs
Construction Management		6%		$2,438,500	Excludes reagent costs
TOTAL CAPITAL COSTS				$135,787,800	

pH Reduction Alternative pH5
pH REDUCTION BY SODIUM PERSULFATE MIXING

COST ESTIMATE SUMMARY pH5

Site: "Occidental" Site
Location: Tacoma, Washington
Phase: Feasibility Study (-30% to +50%)
Base Year: 2016
Date: December 8, 2016

Description: Reduce, by in situ treatment, pH >12.5 s.u. in shallow and deep soil and groundwater that could be a future source of contamination in soil and groundwater. The pH5 alternative includes the following elements: Treatment using in situ mixing of sodium persulfate with shallow and deep soil and groundwater containing pH greater than 12.5 s.u. Capital costs occur in Year 0. No annual O&M costs. No Periodic costs.

ANNUAL O&M COSTS:
No annual O&M costs

PERIODIC COSTS:
No periodic costs

PRESENT VALUE ANALYSIS

COST TYPE	YEAR	TOTAL COST	TOTAL COST PER YEAR	DISCOUNT FACTOR (1.5%)	PRESENT VALUE	NOTES
Capital Cost	0	$135,787,800	$135,787,800	1.000	$135,787,800	
Annual O&M Cost	-	$0	$0	-	$0	No annual O&M
Periodic Cost	-	$0	$0	-	$0	No periodic costs
		$135,787,800			$135,787,800	

TOTAL PRESENT VALUE OF ALTERNATIVE $135,787,800

Notes: (1) Vendor would not breakdown quote for mixing. Vendor quote is $40 to $70 per cubic yard. A typical breakdown of a mixing cost is provided in an associated Cost Worksheet pH-1 and is based on a bid for a different project. Vendor indicated that the price is expected to rise for depths greater than 65 feet.
(2) Dosage (96 lbs/cy) based on pH pilot study to reduce average shallow groundwater pH = 13.036 s.u. by 0.536 s.u.
Dosage (36 lbs/cy) based on pH pilot study to reduce average shallow soil pH = 12.742 s.u. by 0.242 s.u.
Dosage (70 lbs/cy) based on pH pilot study to reduce average deep groundwater pH = 12.920 s.u. by 0.420 s.u.
ANC calculations suggest dosage rate could be approximately 1.9 times higher (96 lbs/cy compared to 184 lbs/cy and 70 lbs/cy compared to 134 lbs/cy).
(3) Assume 50 percent of soil above water table has pH > 12.5 s.u.

pH Reduction Alternative pH6
ENHANCED CONTAINMENT BY CEMENT MIXING

COST ESTIMATE SUMMARY pH6

Site: "Occidental" Site
Location: Tacoma, Washington
Phase: Feasibility Study (-30% to +50%)
Base Year: 2016
Date: December 8, 2016

Description: Contain, by in situ treatment, pH >12.5 s.u. in shallow and deep soil and groundwater that could be a future source of contamination in soil and groundwater. The pH6 alternative includes the following elements: Treatment using in situ mixing of cement with shallow and deep soil and groundwater containing pH greater than 12.5 s.u. Capital costs occur in Year 0. No annual O&M costs. No Periodic costs.

CAPITAL COSTS

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Bench Scale Testing	1	LS	$50,000	$50,000	GHD Quote
Mobilization / Demobilization					
Equipment and Facilities	1	LS	$250,000	$250,000	Vendor quote
H&S Plans and Submittals	1	LS	$15,000	$15,000	Estimated
HASP Implementation	1	LS	$3,710,600	$3,710,600	Estimated from vendor bids(1)
Grading	1	LS	$927,650	$927,650	Estimated from vendor bids
Erosion Controls	1	LS	$2,782,950	$2,782,950	Estimated from vendor bids
Demobilization	1	LS	$92,000	$92,000	Estimated from vendor bids
SUBTOTAL				$7,778,200	
Mixing					
Asphalt/debris Removal (6" thickness)	31,400	SY	$10	$298,300	GHD Construction Division Estimate
Target Area pH2b (12 to 2.5ft NGVD)	28,430	CY	$32	$909,760	Low end of range from vendor quote(1)
Target Area pH2b (2.5 to -10ft NGVD)	37,410	CY	$32	$1,197,120	Low end of range from vendor quote
Target Area pH2b (-10 to -20ft NGVD)	29,930	CY	$32	$957,760	Low end of range from vendor quote
Target Area pH2b (-20 to -30ft NGVD)	29,930	CY	$32	$957,760	Low end of range from vendor quote
Target Area pH2b (-30 to -40ft NGVD)	29,930	CY	$32	$957,760	Low end of range from vendor quote
Target Area pH2b (-40 to -50ft NGVD)	29,930	CY	$32	$957,760	Low end of range from vendor quote
Target Area pH2b (-50 to -60ft NGVD)	29,930	CY	$37	$1,107,410	$5 above low end of range from vendor quote
Target Area pH5b1 (-60 to -70ft NGVD)	29,930	CY	$37	$1,107,410	$5 above low end of range from vendor quote
Target Area pH5b1 (-70 to -80ft NGVD)	29,930	CY	$37	$1,107,410	$5 above low end of range from vendor quote
Target Area pH5b1 (-80 to -90ft NGVD)	29,930	CY	$42	$1,257,060	$10 above low end of range from vendor quote
Target Area pH5b1 (-90 to -100ft NGVD)	29,930	CY	$42	$1,257,060	$10 above low end of range from vendor quote
Target Area pH5b2 (12 to 2.5ft NGVD)	31,410	CY	$40	$1,005,120	Low end of range from vendor quote
Target Area pH5b2 (2.5 to -10ft NGVD)	41,320	CY	$32	$1,322,240	Low end of range from vendor quote
Target Area pH5b2 (-10 to -20ft NGVD)	33,060	CY	$32	$1,057,920	Low end of range from vendor quote
Target Area pH5b2 (-20 to -30ft NGVD)	33,060	CY	$32	$1,057,920	Low end of range from vendor quote
Target Area pH5b2 (-30 to -40ft NGVD)	33,060	CY	$32	$1,057,920	Low end of range from vendor quote
Target Area pH5b2 (-40 to -50ft NGVD)	33,060	CY	$32	$1,057,920	Low end of range from vendor quote
Target Area pH5b2 (-50 to -60ft NGVD)	33,060	CY	$37	$1,223,220	$5 above low end of range from vendor quote
Target Area pH5b2 (-60 to -70ft NGVD)	33,060	CY	$37	$1,223,220	$5 above low end of range from vendor quote
Target Area pH5b2 (-70 to -80ft NGVD)	33,060	CY	$37	$1,223,220	$5 above low end of range from vendor quote
Target Area pH5b2 (-80 to -90ft NGVD)	33,060	CY	$42	$1,388,520	$10 above low end of range from vendor quote
Target Area pH5b3 (12 to 2.5ft NGVD)	15,700	CY	$32	$502,400	Low end of range from vendor quote
Target Area pH5b3 (2.5 to -10ft NGVD)	20,660	CY	$32	$661,120	Low end of range from vendor quote
Target Area pH5b3 (-10 to -20ft NGVD)	16,530	CY	$32	$528,960	Low end of range from vendor quote
Target Area pH5b3 (-20 to -30ft NGVD)	16,530	CY	$32	$528,960	Low end of range from vendor quote
Target Area pH5b3 (-30 to -40ft NGVD)	16,530	CY	$32	$528,960	Low end of range from vendor quote
Target Area pH5b3 (-40 to -50ft NGVD)	16,530	CY	$32	$528,960	Low end of range from vendor quote
Target Area pH5b3 (-50 to -60ft NGVD)	16,530	CY	$37	$611,610	$5 above low end of range from vendor quote
Target Area pH5b3 (-60 to -70ft NGVD)	16,530	CY	$37	$611,610	$5 above low end of range from vendor quote
Target Area pH5b3 (-70 to -80ft NGVD)	16,530	CY	$37	$611,610	$5 above low end of range from vendor quote
Target Area pH5b3 (-80 to -90ft NGVD)	16,530	CY	$42	$694,260	$10 above low end of range from vendor quote
Target Area pH5b3 (-90 to -100ft NGVD)	16,530	CY	$42	$694,260	$10 above low end of range from vendor quote
Target Area pH2c (12 to 2.5ft NGVD)	12,570	CY	$32	$402,240	Low end of range from vendor quote
Target Area pH2c (2.5 to -11ft NGVD)	17,870	CY	$32	$571,840	Low end of range from vendor quote
Target Area pH5a (12 to 2.5ft NGVD)	2,380	CY	$32	$76,160	Low end of range from vendor quote
Target Area pH5a (2.5 to -10ft NGVD)	3,140	CY	$32	$100,480	Low end of range from vendor quote
Target Area pH5a (-10 to -20ft NGVD)	2,510	CY	$32	$80,320	Low end of range from vendor quote
Target Area pH5a (-20 to -30ft NGVD)	2,510	CY	$32	$80,320	Low end of range from vendor quote
Target Area pH5a (-30 to -40ft NGVD)	2,510	CY	$32	$80,320	Low end of range from vendor quote
Target Area pH5a (-40 to -50ft NGVD)	2,510	CY	$32	$80,320	Low end of range from vendor quote
Target Area pH5a (-50 to -60ft NGVD)	2,510	CY	$37	$92,870	$5 above low end of range from vendor quote
Target Area pH5a (-60 to -70ft NGVD)	2,510	CY	$37	$92,870	$5 above low end of range from vendor quote
Target Area pH5a (-70 to -80ft NGVD)	2,510	CY	$37	$92,870	$5 above low end of range from vendor quote
Target Area pH5a (-80 to -90ft NGVD)	2,510	CY	$42	$105,420	$10 above low end of range from vendor quote
Target Area pH5a (-90 to -100ft NGVD)	2,510	CY	$42	$105,420	$10 above low end of range from vendor quote
Target Area pH5a (-100 to -110ft NGVD)	2,510	CY	$47	$117,970	$15 above low end of range from vendor quote
Target Area pH5a (-110 to -120ft NGVD)	2,510	CY	$47	$117,970	$15 above low end of range from vendor quote
Target Area pH5a (-120 to -130ft NGVD)	2,510	CY	$52	$130,520	$20 above low end of range from vendor quote
Target Area pH5a (-130 to -140ft NGVD)	2,510	CY	$57	$143,070	$25 above low end of range from vendor quote
Target Area pH5a (-140 to -146ft NGVD)	1,510	CY	$62	$93,620	high end of range from vendor quote
SUBTOTAL				$32,757,100	

pH Reduction Alternative pH6
ENHANCED CONTAINMENT BY CEMENT MIXING

COST ESTIMATE SUMMARY pH6

Site: "Occidental" Site
Location: Tacoma, Washington
Phase: Feasibility Study (-30% to +50%)
Base Year: 2016
Date: December 8, 2016

Description: Contain, by in situ treatment, pH >12.5 s.u. in shallow and deep soil and groundwater that could be a future source of contamination in soil and groundwater. The pH6 alternative includes the following elements: Treatment using in situ mixing of cement with shallow and deep soil and groundwater containing pH greater than 12.5 s.u. Capital costs occur in Year 0. No annual O&M costs. No Periodic costs.

CAPITAL COSTS

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Reagent (sodium persulfate)(2)					
Target Area pH2a (12 to 5ft NGVD)	36,160	LB	$0.04	$1,450	Approximately 6.0% by weight and current market cost
Target Area pH2b (12 to 2.5ft NGVD)(3)	2,274,710	LB	$0.04	$90,990	Approximately 6.0% by weight and current market cost
Target Area pH2b (2.5 to -10ft NGVD)	5,986,070	LB	$0.04	$239,440	Approximately 6.0% by weight and current market cost
Target Area pH2b (-10 to -20ft NGVD)	4,788,860	LB	$0.04	$191,550	Approximately 6.0% by weight and current market cost
Target Area pH2b (-20 to -30ft NGVD)	4,788,860	LB	$0.04	$191,550	Approximately 6.0% by weight and current market cost
Target Area pH2b (-30 to -40ft NGVD)	4,788,860	LB	$0.04	$191,550	Approximately 6.0% by weight and current market cost
Target Area pH2b (-40 to -50ft NGVD)	4,788,860	LB	$0.04	$191,550	Approximately 6.0% by weight and current market cost
Target Area pH2b (-50 to -60ft NGVD)	4,788,860	LB	$0.04	$191,550	Approximately 6.0% by weight and current market cost
Target Area pH5b1 (-60 to -70ft NGVD)	4,788,860	LB	$0.04	$191,550	Approximately 6.0% by weight and current market cost
Target Area pH5b1 (-70 to -80ft NGVD)	4,788,860	LB	$0.04	$191,550	Approximately 6.0% by weight and current market cost
Target Area pH5b1 (-80 to -90ft NGVD)	4,788,860	LB	$0.04	$191,550	Approximately 6.0% by weight and current market cost
Target Area pH5b1 (-90 to -100ft NGVD)	4,788,860	LB	$0.04	$191,550	Approximately 6.0% by weight and current market cost
Target Area pH5b2 (12 to 2.5ft NGVD)	0	LB	$0.04	$0	
Target Area pH5b2 (2.5 to -10ft NGVD)	0	LB	$0.04	$0	
Target Area pH5b2 (-10 to -20ft NGVD)	0	LB	$0.04	$0	
Target Area pH5b2 (-20 to -30ft NGVD)	0	LB	$0.04	$0	
Target Area pH5b2 (-30 to -40ft NGVD)	0	LB	$0.04	$0	
Target Area pH5b2 (-40 to -50ft NGVD)	0	LB	$0.04	$0	
Target Area pH5b2 (-50 to -60ft NGVD)	0	LB	$0.04	$0	
Target Area pH5b2 (-60 to -70ft NGVD)	2,394,430	LB	$0.04	$95,780	Approximately 6.0% by weight and current market cost
Target Area pH5b2 (-70 to -80ft NGVD)	4,788,860	LB	$0.04	$191,550	Approximately 6.0% by weight and current market cost
Target Area pH5b2 (-80 to -90ft NGVD)	4,788,860	LB	$0.04	$191,550	Approximately 6.0% by weight and current market cost
Target Area pH5b3 (12 to 2.5ft NGVD)	0	LB	$0.04	$0	
Target Area pH5b3 (2.5 to -10ft NGVD)	0	LB	$0.04	$0	
Target Area pH5b3 (-10 to -20ft NGVD)	0	LB	$0.04	$0	
Target Area pH5b3 (-20 to -30ft NGVD)	0	LB	$0.04	$0	
Target Area pH5b3 (-30 to -40ft NGVD)	0	LB	$0.04	$0	
Target Area pH5b3 (-40 to -50ft NGVD)	0	LB	$0.04	$0	
Target Area pH5b3 (-50 to -60ft NGVD)	0	LB	$0.04	$0	
Target Area pH5b3 (-60 to -70ft NGVD)	0	LB	$0.04	$0	
Target Area pH5b3 (-70 to -80ft NGVD)	2,394,430	LB	$0.04	$95,780	Approximately 6.0% by weight and current market cost
Target Area pH5b3 (-80 to -90ft NGVD)	4,788,860	LB	$0.04	$191,550	Approximately 6.0% by weight and current market cost
Target Area pH5b3 (-90 to -100ft NGVD)	4,788,860	LB	$0.04	$191,550	Approximately 6.0% by weight and current market cost
Target Area pH2c (12 to 2.5ft NGVD)	281,150	LB	$0.04	$11,250	Approximately 6.0% by weight and current market cost
Target Area pH2c (2.5 to -11ft NGVD)	2,859,120	LB	$0.04	$114,360	Approximately 6.0% by weight and current market cost
Target Area pH5a (12 to 2.5ft NGVD)	0	LB	$0.04	$0	
Target Area pH5a (2.5 to -10ft NGVD)	0	LB	$0.04	$0	
Target Area pH5a (-10 to -20ft NGVD)	0	LB	$0.04	$0	
Target Area pH5a (-20 to -30ft NGVD)	0	LB	$0.04	$0	
Target Area pH5a (-30 to -40ft NGVD)	0	LB	$0.04	$0	
Target Area pH5a (-40 to -50ft NGVD)	0	LB	$0.04	$0	
Target Area pH5a (-50 to -60ft NGVD)	0	LB	$0.04	$0	
Target Area pH5a (-60 to -70ft NGVD)	0	LB	$0.04	$0	
Target Area pH5a (-70 to -80ft NGVD)	0	LB	$0.04	$0	
Target Area pH5a (-80 to -90ft NGVD)	0	LB	$0.04	$0	
Target Area pH5a (-90 to -100ft NGVD)	0	LB	$0.04	$0	
Target Area pH5a (-100 to -110ft NGVD)	0	LB	$0.04	$0	
Target Area pH5a (-110 to -120ft NGVD)	0	LB	$0.04	$0	
Target Area pH5a (-120 to -130ft NGVD)	0	LB	$0.04	$0	
Target Area pH5a (-130 to -140ft NGVD)	1,915,540	LB	$0.04	$76,620	Approximately 6.0% by weight and current market cost
Target Area pH5a (-140 to -146ft NGVD)	2,873,320	LB	$0.04	$114,930	Approximately 6.0% by weight and current market cost
SUBTOTAL				$3,330,800	
Field Sampling and Analysis	1	LS	$55,000	$55,000	Estimated (50 x 50 grid; approximately 110 boreholes)
SUBTOTAL				$43,971,100	
Contingency		25%		$10,992,800	10% scope + 15% bid
SUBTOTAL				$54,963,900	
Project Management		5%		$2,032,100	Excludes reagent costs
Remedial Design		8%		$3,251,300	Excludes reagent costs
Construction Management		6%		$2,438,500	Excludes reagent costs
TOTAL CAPITAL COSTS				$62,685,800	

pH Reduction Alternative pH6
ENHANCED CONTAINMENT BY CEMENT MIXING

COST ESTIMATE SUMMARY pH6

Site: "Occidental" Site
Location: Tacoma, Washington
Phase: Feasibility Study (-30% to +50%)
Base Year: 2016
Date: December 8, 2016

Description: Contain, by in situ treatment, pH >12.5 s.u. in shallow and deep soil and groundwater that could be a future source of contamination in soil and groundwater. The pH6 alternative includes the following elements: Treatment using in situ mixing of cement with shallow and deep soil and groundwater containing pH greater than 12.5 s.u. Capital costs occur in Year 0. No annual O&M costs. No Periodic costs.

ANNUAL O&M COSTS:

No annual O&M costs

PERIODIC COSTS:

No periodic costs

PRESENT VALUE ANALYSIS

COST TYPE	YEAR	TOTAL COST	TOTAL COST PER YEAR	DISCOUNT FACTOR (1.5%)	PRESENT VALUE	NOTES
Capital Cost	0	$62,685,800	$62,685,800	1.000	$62,685,800	
Annual O&M Cost	-	$0	$0	-	$0	No annual O&M
Periodic Cost	-	$0	$0	-	$0	No periodic costs
		$62,685,800			$62,685,800	

TOTAL PRESENT VALUE OF ALTERNATIVE $62,685,800

Notes: (1) Vendor would not breakdown quote for mixing. Vendor quote is $40 to $70 per cubic yard. A typical breakdown of a mixing cost is provided in an associated Cost Worksheet pH-1 and is based on a bid for a different project. Vendor indicated that the price is expected to rise for depths greater than 65 feet.
(2) Dosage based on vendor estimate of typical cement addition rate between 5 and 7 percent by soil weight.
(3) Assume 50 percent of soil above water table has pH > 12.5 s.u.

pH Enhanced Containment Alternative pH7
ENHANCED CONTAINMENT BY VERTICAL SLURRY WALL

COST ESTIMATE SUMMARY pH7

Site: "Occidental" Site
Location: Tacoma, Washington
Phase: Feasibility Study (-30% to +50%)
Base Year: 2016
Date: December 8, 2016

Description: Contain, by in situ vertical barrier, pH >12.5 s.u. in shallow and deep soil and groundwater that could be a future source of contamination in soil and groundwater. The pH7 alternative includes the following elements: Construction of a vertical slurry wall around shallow and deep soil and groundwater containing pH greater than 12.5 s.u. Capital costs occur in Year 0. No annual O&M costs. No Periodic costs.

CAPITAL COSTS

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Mobilization / Demobilization					
Equipment and Facilities	1	LS	$75,000	$75,000	Vendor quote
H&S plans and submittals	1	LS	$25,000	$25,000	Estimated
SUBTOTAL				$100,000	
Vertical Slurry Wall					
Asphalt/debris Removal (6" thickness)	1,000	SY	$10	$9,500	GHD Construction Division Estimate
North wall deep (320 ft)	51,840	SF	$15	$777,600	high end of range from vendor quote(1)
West wall shallow (640 ft)	48,000	SF	$12.5	$600,000	mid range from vendor quote(1)
West wall deep (803 ft)	130,090	SF	$15	$1,951,350	high end of range from vendor quote(1)
South wall shallow (330 ft)	22,500	SF	$12.5	$281,250	mid range from vendor quote(1)
South wall deep (475 ft)	76,950	SF	$15	$1,154,250	high end of range from vendor quote(1)
East wall deep (648 ft)	104,980	SF	$15	$1,574,700	high end of range from vendor quote(1)
POT Area deep (624 ft)	101,090	SF	$15	$1,516,350	high end of range from vendor quote(1)
SUBTOTAL				$7,865,000	
SUBTOTAL				$7,965,000	
Contingency		25%		$1,991,300	10% scope + 15% bid
SUBTOTAL				$9,956,300	
Project Management		5%		$497,900	Excludes reagent costs
Remedial Design		8%		$796,600	Excludes reagent costs
Construction Management		6%		$597,400	Excludes reagent costs
TOTAL CAPITAL COSTS				$11,848,200	

ANNUAL O&M COSTS:
No annual O&M costs

PERIODIC COSTS:
No periodic costs

PRESENT VALUE ANALYSIS

COST TYPE	YEAR	TOTAL COST	TOTAL COST PER YEAR	DISCOUNT FACTOR (1.5%)	PRESENT VALUE	NOTES
Capital Cost	0	$11,848,200	$11,848,200	1.000	$11,848,200	
Annual O&M Cost	-	$0	$0	-	$0	No annual O&M
Periodic Cost	-	$0	$0	-	$0	No periodic costs
		$11,848,200			$11,848,200	

TOTAL PRESENT VALUE OF ALTERNATIVE $11,848,200

Notes: (1) Vendor quote is $10 to $15 per square yard (horizontal x vertical) for 2-feet thick wall. No dewatering. Includes air monitoring for personnel and Level D PPE.

pH Reduction/Enhanced Containment Alternatives pH2, pH3, pH5, pH6
Capital Cost Sub-Element
IN SITU MIXING

COST WORKSHEET pH-1

Site: "Occidental" Site
Location: Tacoma, Washington
Phase: Feasibility Study (-30% to +50%)
Base Year: 2016

Prepared By: AW
Date: 5/29/2016

Checked By: RJH
Date: 12/8/2016

Work Statement:

The pH Enhanced containment includes using an auger to mix specified reagent directly into the soil at specific depth intervals.

Cost analysis:

Costs include equipment and labor for mixing. The costs do include the supply of the reagent.

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	UNIT TOTAL	TOTAL	NOTES
In Situ Mixing								
Soil Blending and Support	80	%	-	-	-	40	32	Estimated
Grading	3	%	-	-	-	40	1	Estimated
Erosion Controls	7	%	-	-	-	40	3	Estimated
HASP Implementation	10	%	-	-	-	40	4	Estimated
SUBTOTAL							40	
TOTAL UNIT COST							**$ 40**	

Source of Cost Data:

Vendor would not breakdown quote for mixing costs. Vendor quote is $40.00 to $70.00 per cubic yard. GHD utilized a 2013 schedule of prices for in situ mixing at a different superfund site to present a detailed percentage breakdown of the total mixing unit cost.

Cost Adjustment Checklist:

	FACTOR:	NOTES:
☑	H&S Productivity	Assume Level D
☑	Escalation to Base Year	2016
☑	Area Cost Factor	Based on local pricing
☑	Subcontractor Overhead and Profit	Included in unit pricing
☑	Prime Contractor Overhead and Profit	Included in unit pricing