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Final

Conceptual Site Model Report

Groundwater and Sediment Remediation

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Section 1.0 Introduction

Occidental Chemical Corporation (OCC) has been working with the United States Environmental Protection Agency (USEPA) and the Washington State Department of Ecology (Ecology) (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) (EPA, 2005a). The work activities required under the AOC are outlined in the "Statement of Work for the Administrative Order on Consent" (SOW) (CRA, 2005). Additional work not anticipated in the SOW has been conducted and scheduled consistent with the AOC.

This Report presents the Conceptual Site Model (CSM) for the Site. The CSM Report synthesizes and presents the physical conditions at the Site and the key relationships between sources, release mechanisms, migration pathways, contaminant distribution, and potential receptors as they are currently understood. The CSM is based on the findings of Site investigations completed through September 2013. The CSM is intended to present only the information necessary for the reader to understand the Site; detailed analyses are provided in Site investigation reports. The CSM may evolve with time as new insight is gained and project needs evolve.

The CSM Report is organized as follows:

i) Section 2.0 – Site Description and Historical Operations
ii) Section 3.0 – Contaminant Sources: presents a description of key primary and secondary sources of contamination
iii) Section 4.0 – Physical Site Setting and Geologic/Hydrogeologic Conditions: presents an overview of the physical Site setting and describes the key aspects of the regional and Site geologic/hydrogeologic conditions
iv) Section 5.0 – Contaminant Transport and Fate: describes the mechanism and routes of contaminant migration at the Site
v) Section 6.0 – Exposure Pathways and Receptors: summarizes the receptors that could be exposed to the Site contaminants of concern (COCs) and the pathways through which exposure could occur
v) Section 7.0 – Previous Remedial Actions
vi) Section 8.0 – References

Section 2.0 Site Description and Historical Operations

2.1 Site Description

The Site is located on the eastern-most[1] 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[2]. A general location map showing the Site, including the formerly OCC-owned properties and that portion of Segment 5 of the Hylebos Waterway (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 (former OCC Facility currently owned by Mariana Properties, Inc. [Mariana])
- 709 Alexander Avenue (currently owned by Mariana)

The properties are referred to as the 'Former OCC Facility (605) and Mariana Properties (709)' on Figure 2.2. The properties are bounded on the west, north, and south by former Navy property (now owned by the POT or U.S. Navy), and on the east by the Waterway.

The approximate extent of groundwater contamination at the Site is shown on Figure 2.1. The Site is within the 10-12 square mile area Commencement Bay Nearshore/Tideflats (CB/NT) Superfund Site which includes several waterway problem areas and adjoining uplands as described by the CB/NT Record of Decision (EPA 1989). The Site includes part of Segment 5 of the Mouth of Hylebos Problem Area where contaminated sediments were dredged and disposed in 2003-5 (CRA, 2014), or excavated and capped 2007-08 (Hart Crowser, 2014). This work was performed under the Mouth of Hylebos Consent Decree (EPA, 2005b). Sediment contaminants removed from the dredged areas of the Waterway included hexachlorobenzene (HCB), hexachlorobutadiene (HCBD), polychlorinated biphenyls (PCBs), various metals, and other organic chemicals. Remaining sediment contamination within the Site is to be addressed under the AOC (EPA, 2005a).

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[1] Note that all directional references are relative to plant-north that points toward Commencement Bay, approximately aligned with the centerline of the Site peninsula.

[2] Note that the AOC definition of the Occidental Site is repeated in the RD/RA Consent Decree for the Mouth of Hylebos Problem Area of the Commencement Bay Nearshore/Tideflats Superfund Site, which excludes the Occidental Site from the RD/RA Consent Decree activities for the Mouth of Hylebos problem Area but grants access to POT property for response actions within the Occidental Site (EPA, 2005b).

2.2 Historical OCC Operations

OCC's predecessor's manufacturing operations began at the Site in 1929 and continued by OCC and others until 2002. The operations undertaken on the Former OCC Facility (605) and Mariana Properties (709) are described below.

605 Alexander Avenue

The chemical processes, products, and by-products associated with the property are summarized below, based on information provided in Attachment 9 (Tacoma Groundwater Continuing Releases Program Groundwater Treatment Technology Assessment) of the RCRA Facility Investigation (CRA, 1989) and other sources.

Processes	***Products***	***By-Products***	***Period of Operation***
Chlorine/Caustic soda production	Chlorine/Caustic soda	Calcium carbonate, magnesium hydroxide, sodium chloride (recycled into brine), chlorinated organic residue, dioxins/furans	1929 to 2002
Sodium hypochlorite production	Sodium hypochlorite	Sodium chloride (recycled into brine), water	1974 to 1992
Chlorinated solvent production	Trichloroethene/ Tetrachloroethene (TCE/PCE)	Calcium chloride, calcium hydroxide, chlorinated organic residue with VOC and SVOC compounds including HCB, HCBD, and other by-products	1947 to 1973
Ammonia production	Ammonia	None	1952 to 1992
Muriatic acid production	Muriatic Acid	None	1936 to 2002
Calcium chloride production	Calcium chloride	Carbon dioxide, water, magnesium and transition metal precipitate	1964 to 2002
Fish oils hydrogenation	Saturated (hydrogenated) oil	Used catalyst (e.g., nickel)	1939 to 1952
Aluminum chloride production	Aluminum chloride	None	1942 to 1945
Sodium aluminate production	Sodium aluminate	Water	1959 to 1960

Wastes generated during the manufacturing processes were managed on this property. Waste management practices included: wastewater treatment (settling) ponds, settling barges, landfills, disposal pits, and waste piles. Available historical information does not indicate whether pits, ponds, landfills, piles, etc. were partly contained or, if so, how they were contained. Based on the presence of contaminants in the vicinity of these waste management units (WMUs), it is apparent that releases to the subsurface occurred.

The locations and descriptions of historical chemical activity areas are shown on Figure 2.3. Seventeen (17) WMUs were historically located on the property. The locations of the WMUs, and the chemicals associated with them, are shown on Figure 2.4.

From 1929 to 2002, chlorine was produced using electrolytic cells. Linseed and other oils were originally used to bind the graphite electrodes used for chlorine production, and were later replaced by phenolic resin binders. According to European Commission (2001)[3], spent graphite anodes are a potential source of dioxin/furan compounds. However, the lack of available oxygen in the process combined with the lack of a significant heat source would have made the production of dioxins and furans at the Site minimal. The change to phenolic resin binders increased the potential for dioxin/furan formation. Graphite waste was disposed in WMUs L, M, P, and Q, and has also been observed in the embankment area. Results for spent anodes analyzed during 1987[4] and 1988 showed that total 2,3,7,8-TCDD equivalent concentrations were all less than 1 µg/kg, and as a result, anodes were disposed off Site as non-TCDD RCRA waste.

From 1947 to 1973, a chlorinated solvents process producing PCE and TCE was in operation on the northern section of the property proximate to Area 5106 (see Figure 2.3). The chlorinated solvent production process consisted of the chlorination of acetylene to produce pentachloroethane (PCA). The PCA was heated to 100^0C with lime to form TCE, which was then chlorinated to form pentachloroethylene. The pentachloroethylene was treated with lime to produce PCE. By-products in the residue from the process included (in approximate decreasing relative amounts):

- Calcium chloride and calcium hydroxide
- HCB and HCBD[5], as well as hexachloroethane, trichloroethane, dichloroethylenes
- Other chlorobutadienes

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[3] European Commission, 2001. Integrated Pollution Prevention and Control (IPPC). Reference Document on Best Available Techniques in the Chlor-Alkali Manufacturing Industry. December. http://eippcb.jrc.ec.europa.eu/reference/BREF/cak_bref_1201.pdf.

[4] Results transmitted by OCC's September 16, 1987 letter to USEPA (Catherine Massimino) and Ecology (Steve Robb).

[5] "Chlorine, Its Manufacture, Properties, and Uses" Ed. Sconce. ACS Monograph Series No. 154, 1962.

During the first year of production, effluent from the chlorinated solvents process (consisting of an aqueous slurry composed of byproduct calcium chloride [lime sludge], and chlorinated organic [solvent] residue) was discharged directly to the Waterway. The location of the direct discharge line, labeled on historical drawings as '4" Lime', is shown on Figure 2.3. From approximately 1949 to 1952, and again from 1972 to 1973, the process effluent was passed through one of a series of upland settling ponds where the solids settled out, and the supernatant was discharged to the Waterway. During the period from 1952 to 1972, the effluent was discharged to a settling barge berthed alongside the present northern walking pier (WMU F on Figure 2.4). The solids settled in the barge, and the supernatant was discharged to the Waterway. The solids in the barge were taken to a deep water disposal site. Between 1949 and 1971, a small landfill shown as WMU C on Figure 2.4 was used for the disposal of lime and calcium chloride from the chlorinated solvents process.

As discussed in the Embankment Area Characterization Report (CRA, 1999), the embankment area is defined as the area along the Waterway that extends from the northwest boundary of the 605 Alexander Avenue property to the southeast boundary of the adjacent property at 709 Alexander Avenue (otherwise identified as the former PRI property). Previous reports segregated the embankment area into the following sections, which are shown on Figure 2.5:

- Northern Section
- Central Section
- Southern Section
- PRI Section

The Northern Section is approximately 500 feet (ft) of embankment area extending southward from the facility's northern property boundary, and was acquired prior to OCC by Hooker Chemical Corporation (Hooker) from Todd Shipyards. Heavy industrial activities took place in this area both before and after Hooker's ownership, most notably war-related shipyard activities undertaken by the U.S. Navy and Todd Shipyards for both World War One and World War Two. Historical information indicates that landfilling and incinerating operations (among other activities) took place along the shoreline and in the uplands during the World War Two shipyard activities. Following acquisition of the property by Hooker, a landfill was developed, identified as WMU C. Additionally, settling ponds were installed in the Northern Section identified as WMU H.

The Central Section is approximately 600 ft of embankment area between the Northern Section and the Southern Section. Due to extensive development in this area for active industrial use, limited to no landfilling or disposal operations were performed, and therefore no documented WMUs exist in this area.

The Southern Section is approximately 400 ft of the embankment area between the Central Section and the PRI Section. Historical information indicates that this area was used for a landfill, and is identified as WMU N.

The PRI Section is approximately 200 ft of the embankment area extending southward from the south edge of the 605 Alexander Avenue property boundary, and is distinctly identified as part of the 709 Alexander Avenue property. Historical information indicates that an embankment fill area exists that extends south from the N Landfill (WMU N) on the 605 Alexander Avenue property.

As discussed in the Embankment Area Characterization Report (CRA, 1999), historical investigations were performed in each of the above-stated sections to identify physical properties of the embankment materials and collect samples of materials, groundwater, and seeps for analysis of various chemical parameters. The investigations identified several types of materials that were placed along the embankment area. These materials include riprap (stone), concrete rubble, slag, anodes (graphite), yellow bricks, red bricks, sludge, and sediment. Contaminants associated with the waste sludge include VOCs and SVOCs. The shipyard incineration wastes and spent graphite anodes described above are potential sources of dioxin/furan compounds (European Commission, 2001).

The primary embankment materials identified in each section are as follows:

- Northern Section – Sediment, sludge, slag, concrete, bricks, and riprap
- Central Section – Sediment, concrete, bricks, and riprap
- Southern Section – Sediment, sludge, concrete, and riprap
- PRI Section – Sediment, sludge, anodes, and concrete

The historical embankment area investigations included the collection of composite and discrete samples from the embankment area materials. Discrete samples were also collected from groundwater and seeps along the embankment. Samples were analyzed for the following parameter groups:

- VOCs
- SVOCs

- Pesticides
- PCBs
- Hydrocarbons
- General Chemistry
- Metals

The Embankment Area Characterization Report (CRA, 1999) compared the analytical results to Sediment Quality Objectives (SQOs), and sample results with a minimum two-times exceedance factor relative to the respective SQOs were identified. It is noted that SQOs were not reported for hydrocarbon and general chemistry parameters.

Figure 2.5 presents the areas along the embankment where materials samples were collected and had detected results at two-times exceedance factors or greater. An inventory of the specific parameters with two-times exceedance factors or greater is as follows:

Parameter Group	***Northern Section***	***Central Section***	***Southern Section***	***PRI Section***
VOCs	VOCs (not speciated)			PCE, EB
SVOCs	HCBD, HCB, bis(2-Ethylhexyl)phthalate	HCBD, HCB	HCBD, HCB	HCBD, HCB, 1,2,4-TMB
Metals	Hg, Pb, Cu, As, Ni, Zn, Ag	Pb, Ni	Pb, Cu, As, Ni	Pb, Cu, As, Ni, Sb, Zn
Pesticides	Pesticides (not speciated)	4,4'-DDD	4,4'-DDD, 4,4'DDE, 4,4'-DDT, Aldrin	4,4'-DDD, 4,4'-DDE
PCBs	Total PCBs	Total PCBs	Total PCBs	Total PCBs

Figure 2.5 depicts information provided in the Embankment Area Characterization Report (CRA, January 1999).

709 Alexander Avenue

OCC and its predecessors did not conduct any manufacturing operations on this property. However, fill materials including wastes from the activities at the 605 Alexander Avenue property, and likely other sources, were placed on the 709 Alexander Avenue property along the embankment of the Waterway.

2.3 Other Historical Operations

Historical operations on 605 Alexander Avenue and the adjacent properties are provided below.

Prior to the use of the 605 Alexander Avenue property by OCC and its predecessors for chemical manufacturing, a portion of the property (North 10 Acres) was used by the U.S. Navy and Todd Shipyards Corporation for operations associated with ship building and dismantling activities, as well as for the gathering and incineration of shipyard wastes. In approximately 1945, these activities ceased and the facilities on the North 10 Acres were decommissioned. In 1945, shipyard wastes were dumped on uplands and on the shoreline and partially pushed into the Waterway. This area is now described as the "Navy Todd Dump" (shown on Figure 2.2).

The other historical operations of properties adjacent to 605 Alexander Avenue are summarized below:

401 Alexander Avenue

i) Ship building and dismantling, and related activities, during World War One and World War Two

ii) U.S. Naval Station Tacoma's ship storage, maintenance, and dismantling from World War Two to 1960

iii) Port Industrial Yard (Early Business Center) and numerous tenant operations since 1960, including ship building and dismantling

Most of the Pier 25 Hylebos Waterway embankment on this property was remediated with installation of a sediment cap, after excavating areas of more pronounced contamination, in 2007-08 under the Mouth of Hylebos RD/RA Consent Decree (Hart Crowser, 2014). The southern 400 feet of contaminated sediment were not capped. EPA, POT, and OCC agreed that activities in this area will be incorporated with the sediment remediation activities to be accomplished under the AOC.

Shallow soil and groundwater contamination associated with historic (1940-1960) underground storage tanks and the Pier 23 area near the Army Reserve Building is being investigated under Ecology Agreed Order No. DE9553 with the Port of Tacoma. Contaminants found include petroleum products and metals. Response actions conducted under the MTCA Agreed Order and the Occidental Site AOC, respectively, will be coordinated.

709 Alexander Avenue

i) Bulk petroleum fuel storage and distribution terminal between the 1930s and 1980s
ii) Tetraethyl lead plant, blending lead with gasoline in the late 1970s and early 1980s
iii) Topping plant for crude oil distillation in the 1970s and early 1980s

721 Alexander Avenue

i) Fuel distribution depot and bulk petroleum storage depot from 1936 through 1965
ii) Petroleum storage facility from 1966 through 1983
iii) Materials storage yard since 1983

Historical Site features on 709 and 721 Alexander Avenue are shown on Figure 2.6. These properties will be further investigated under Agreed Order No. DE 9835 between Ecology, Mariana, and the POT, effective on October 3, 2013.

Section 3.0 Contaminant Sources

Manufacturing operations at the Site 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, seventeen (17) 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 Draft Site Characterization Report (CRA, 20-08). WMUs that are significant sources of COCs are identified below.

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

- Chlorinated volatile organic compounds (CVOCs)
- Fuel-related volatile organic compounds (fuel-related VOCs)
- Caustic (sodium hydroxide)
- Salt (NaCl)
- Metals (Arsenic, chromium, copper, lead, mercury, nickel, thallium, zinc)
- Semi-volatile organic compounds (SVOCs) (HCB and HCBD, which are by-products of solvent production)

- PCBs
- Dioxins/furans

Several of the principal COCs were used, produced, and stored in many locations across the Site. In addition, wastes generated in the production processes were managed on Site. Key "source areas" where the vast majority of releases occurred are described below.

The metals listed above as principal COCs were not used in former OCC 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. Some of the metals listed above as principal COCs were used in the ship building, maintenance, and dismantling operations at the Site. Other metals were used and produced on Site (e.g., aluminum oxide, sodium aluminate, calcium chloride). However, these metals are not currently listed as COCs.

The principal COCs listed above do not represent every chemical detected in the subsurface at the Site. However, examination of these principal COCs provides the range of source locations, migration pathways, and ultimate distributions necessary to illustrate the CSM for the Site.

3.1 VOC 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 3.1. A single area around the former solvent production plant and WMUs is shown on Figure 3.1 as the "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 settling barge over time, and in the first year of operation were discharged to the Waterway through the direct discharge line shown on Figure 2.3.

The chlorinated solvents were present in the solvent residue released to the environment over time, and once released would behave as a dense non-aqueous phase liquid (DNAPL). The DNAPL source locations correspond to the WMUs within the CVOC Source Area. Areas of confirmed DNAPL have been identified below the groundwater table through hydrophobic dye testing and evaluation of soil and groundwater concentrations. Suspected DNAPL has been identified in areas surrounding the confirmed DNAPL. The DNAPL areas are on-going sources of CVOCs to groundwater. Considering the wide distribution of the DNAPL areas and the several decades that have passed since releases occurred, the DNAPL likely exists as residual ganglia that are largely stable and no longer mobile.

CVOC and fuel-related VOC groundwater contamination is present on the 709 and 721 Alexander Avenue properties. These properties will be further investigated under MTCA Agreed Order No. DE 9835 effective October 3, 2013, being implemented by Mariana Properties, Inc. and the POT under Ecology oversight. Response actions conducted under the MTCA Agreed Order and the Occidental Site AOC, respectively, will be coordinated.

3.2 Caustic 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 3.2. The principal 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 3.2 as the "Caustic Source Area"

The sodium hydroxide released to the subsurface resulted in elevated soil alkalinity. Some of the hydroxide ions subsequently reacted with silicon dioxide (found in sand) to release silicate ions, so that a portion of the alkalinity currently present in the soil and groundwater is attributable to those ions. Soil alkalinity is highest in the Caustic Source Area, and the soil acts as a continuing source of ions that elevate the pH of the groundwater. As water with lower pH infiltrates through soil in this area, the hydroxide and silicate ions currently in the soil solution will be flushed out, but others will be released from the soil to replace them. Eventually (albeit only after a long time if no acids are injected into the ground), the vast majority of the hydroxide and silicate ions will be flushed out of the system, although a small fraction of the silicate will be converted back to silicon dioxide solids.

3.3 Salt Sources

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 3.3 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.

The produced brine was collected in the sump and pumped for purification and processing before use in the chemical production processes. Brine sludge, or residue, resulted from impurities in the brine after it was filtered and may have been kept in storage tanks on the southern portion of the Site (the southern portion of S10 and S11 as shown on Figure 3.2) prior to disposal. Brine sludge is not known to have been disposed on Site but was reportedly taken to an industrial landfill, although some may have been disposed in the N Landfill.

3.4 Metals Sources

Figure 3.4 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 received the following waste materials: lead, corrosives, chlorinated organics, and non-burnable wastes. N Landfill investigations have shown that the waste material contains metals (primarily copper and lead). The Navy Todd Dump was created in approximately 1945, as a result of World War Two ship construction and waste disposal/incineration activities. Navy Today 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 a metals source.

Figure 2.5 shows the approximate boundary of metals contaminated embankment contaminated fill areas, and is also shown on Figure 3.4. In addition to the N Landfill and Navy Todd Dump, metals contaminated waste material derived from shipbuilding and dismantling activities during and after World War Two and chemical production using electrolysis methods 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 COCs. The geochemical conditions mobilize (dissolve) metals at concentrations above what would naturally be observed in groundwater. This process is described in Section 5.4.

3.5 SVOC Sources

Sources of SVOCs are shown on Figure 3.5. The two SVOCs 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 manufactured, or where the waste products of this process were handled and disposed.

About 36,000 cubic yards of VOC and SVOC contaminated sediment were removed from Area 5106 in 2002-03 (EPA, 2002). Post-dredging characterization of the Area 5106 footprint identified SVOC (mostly HCB and HCBD) and VOC contamination in subsurface sediment and groundwater. Concentrations of HCB and HCBD above Site screening levels have been found (mixed with VOCs) in upland soil beneath and adjacent to source areas.

3.6 PCBs and Dioxins/Furans Sources

Sources of the PCBs in the soils and sediments at the Site would be releases from equipment such as transformers and capacitors containing PCBs. Another source of PCBs at the Site would be from the U.S. Navy ship building, maintenance, and dismantling operations performed at the Site involving many components, paints, liquids, and other materials containing PCBs. The World War Two shipyard purchased and used many such materials, according to records obtained from the National Archives. The U.S. Navy, EPA rulemaking, and Congressional investigations have focused upon U.S. Navy ships and ship dismantling as significant sources of PCBs.

Dioxins and furans are two closely related groups of chemical byproducts that are found at background levels in most industrial areas.

Dioxins and furans are not synthesized or formulated for industrial or domestic use. They are formed from the thermal breakdown and molecular rearrangement of chlorinated precursor compounds. Almost any chlorinated compound has the potential to form dioxins if subjected to high temperatures (such as in a fire). Typically, incidental formation of dioxins requires a source of carbon, chlorine, and oxygen, and a temperature of at least 300°C. Some precursor compounds include PCBs, chlorinated phenols, and chlorinated benzenes. Combustion is the primary source of dioxins/furans formation.

On-Site source areas of each chemical are shown on Figure 3.6. A potential source of dioxins/furans was likely the incinerator installed and used at the Site for waste disposal by the U.S. Navy and Todd Shipyards during World War Two. Site maps/diagrams from the National Archives prepared during World War Two depict the location of the incinerator on the "North 10 Acres" of 605 Alexander Avenue in a scrap disposal and salvage yard, which was near the Navy-Todd Dump.

Another potential source of dioxins/furans is spent graphite anodes used at the former chemical production facility, and disposed onsite. Other potential sources of dioxins/furans at the Site would have included overheated electrical equipment (such as transformers and capacitors) containing PCBs

3.7 Anthropogenic Density Plume 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 sources for the ADP consist of:

- Chlorinated solvents/solvent residue, as well as lime sludge, were sent to WMUs A, F, G, H, and C shown on Figure 2.4. 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). The chlorinated solvents/solvent residue consisted mainly of TCE and PCE each having a specific gravity in pure form of 1.46 and 1.62, respectively. Lime sludge and solvent residue were sent to in WMU A, WMU F, WMU G, and WMU H, while lime/calcium chloride was placed in WMU C, and represent potential source locations for the ADP.
- Caustic soda, with a specific gravity of approximately 1.3 to 1.5, is another component of the ADP. The Caustic Source Area shown on Figure 3.2 represents a 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 3.3, represents a source location for the ADP.

The effects of the ADP on groundwater flow and contaminant transport at the Site are described in Sections 4.0 and 5.0, respectively.

Section 4.0 Physical Site Setting and Geologic/Hydrogeologic Conditions

4.1 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 ft above the Site peninsula.

The Site peninsula is man-made and was created in the early 1900s by dredging the Hylebos and Blair Waterways located on the east and west sides of the Site peninsula, respectively. The waterways were dredged through the tidal mud flats that existed at the mouth of the Puyallup River Valley. Figures 4.1 and 4.2 show the location of the Former OCC Facility (605) and Mariana Properties (709) relative to POT pre-development and post-development conditions, respectively.

4.1.1 Tidal Influence

Tidal fluctuations occur in Commencement Bay and the Hylebos and Blair Waterways. The amplitude of the tidal fluctuations at the Site is about 10 to 14 ft. The tidal fluctuations propagate inland and cause groundwater level fluctuations throughout the Site. Due to these fluctuations, it is not practical to collect manual groundwater elevation measurements across the Site monitoring well network that represent either an instantaneous condition across the Site, or more importantly, an average groundwater flow condition.

The tidally influenced groundwater level fluctuations are short-term transient conditions that are of little value in assessing bulk contaminant transport and overall Site remediation in the long-term. The rate and direction of groundwater flow at the Site, and thus bulk contaminant transport, must be resolved using average groundwater and surface water levels. In close proximity to the Waterway, contaminant flux with fresh groundwater discharge to surface water can vary with tidal stage and amplitude. Surface water recharge will occur under high tide and fresh groundwater discharge will occur under average and low tide.

Average groundwater levels are determined from groundwater levels measured across the Site monitoring well network using electronic pressure transducers and data recorders collecting data at five-minute intervals. Average groundwater and surface water levels are determined using the Serfes (1991) averaging method and approximately three days of recorded water level data. It is the average data that are used to assess groundwater flow rate and direction.

4.1.2 Fresh Groundwater and Salt Water Distributions

Commencement Bay and the downstream portions of the Hylebos and Blair Waterways approaching Commencement Bay contain salt water with an average specific gravity of approximately 1.022 (or density of 63.77 pounds per cubic feet [lbs/ft^3]). Fresh groundwater, with a specific gravity of 1.0 (or density of 62.4 lbs/ft^3), discharges into these surface water features, as shown schematically in Figure 4.3. The locations where fresh groundwater discharges along the salt water margins are controlled by the hydraulic pressure and fresh groundwater flow rate in the aquifer, the thickness and hydraulic properties of the aquifer and adjacent confining units, and the relative densities of saltwater and freshwater, among other variables. Fresh groundwater tends to remain above the salt water zones because of its lower density, although in heterogeneous or multilayered aquifer systems, fresh groundwater can discharge upward through lower-permeability units into overlying salt water, as shown in Figure 4.3b (Barlow, 2003).

The fresh groundwater and salt water zones are separated by a transition zone within which there is mixing between fresh groundwater and salt water. The width of these transition zones varies, but may be on the order of hundreds to over a thousand feet in coastal aquifers (Barlow, 2003). The transition zone width depends on the amount of mixing between the fresh groundwater and salt water that occurs within the aquifer. This mixing is caused by geologic heterogeneities and by dynamic forces that operate over a range of time scales, including daily fluctuations in tide stages, seasonal and annual variations in groundwater recharge rates, and long-term changes in aquifer-level and sea-level positions. These dynamic forces cause the fresh groundwater and salt water zones to move seaward at times and landward at times (Barlow, USGS 2003).

Salt water and fresh groundwater distributions in the vicinity of the Site have been mapped using bromide as a tracer or indicator for the presence of salt water. The results obtained from the bromide data show a relatively complex distribution of salt water and fresh groundwater, with fresh groundwater underlying salt water in some locations in the upper portion of the deltaic deposits, relatively extensive transition zones that contain mixtures of both fresh groundwater and salt water. This type of distribution is expected and is consistent with the geologic heterogeneities and complex flow dynamics at the Site.

4.1.3 Fresh Water Equivalent Head (FEH)

At sites where groundwater and surface water are all fresh, density-dependent groundwater flow is not a concern. Hydraulic gradients and groundwater flow directions are resolved based on groundwater level measurements. In environments with water of varying density, like this Site, the assessment of hydraulic gradients and groundwater flow direction is more complex. Density variations at the Site are caused by the fresh groundwater/salt water distribution and the ADP. Due to the density variations, water level measurements are converted to "freshwater equivalent heads" (FEHs) to interpret horizontal groundwater flow directions (i.e., along horizontal planes), and "environmental heads" (ENV) to interpret vertical groundwater flow directions (i.e., at a monitoring well nest).

The method of FEH and ENV calculation is presented in CRA (2011). Maps of FEHs within a common hydrogeologic unit can be used to interpret horizontal groundwater flow directions in horizontal planes. ENVs, calculated from FEHs and the average water density between screens in a monitoring well nest, are used to interpret vertical groundwater flow directions at a well nest location. The discussions of hydraulic gradients and groundwater flow directions presented in this CSM are based on FEHs and ENVs rather than "groundwater levels".

The inputs for calculating FEH values include the transducer pressure reading, transducer elevation, and groundwater density. These inputs are used as follows:

- The pressure readings from the transducer in pounds per square inch (psi) converted to a pressure in feet of water (ft H_2O), which represents the height of fresh water above the transducer
- The pressure in ft H_2O is converted to FEH at the transducer in terms of the Site elevation datum based on the transducer elevation
- Where a transducer for a particular depth zone is offset from the selected horizontal plane, or elevation, of the depth zone, referred to as the zone grouping plane (ZGP), the FEH at the transducer is translated to the ZGP using the groundwater density measured at the well screen

The uncertainty associated with the transducer pressure reading is the transducer accuracy, quantified in terms of a ± percentage of the transducer full scale.

The FEHs at the transducer elevation are based on the measured depth of the transducer as installed within the well casing for a standard monitoring well, or sand pack for a CMT multilevel monitoring well, and then converted to the Site elevation datum (i.e., ft NGVD). There could be uncertainty associated within the transducer elevation due to potential measurement inaccuracies in the transducer depth.

The FEH at the transducer elevation is translated to the ZGP using the formation density measured at the well screen based on laboratory groundwater sample analysis for specific gravity. There can be variability in the accuracy of formation density due to typical groundwater sampling variations and due to variations in the laboratory measurement of specific gravity. The transducers are installed in the well screen, and for the most part, are offset only a short distance from the ZGP elevation (approximately 70 percent of the transducers are less than 0.5 ft off of the ZGP). In these cases, translating the transducer FEH to the ZGP results in only minor adjustments to the FEH, and the uncertainty here is related to variability in the measured density. Where the transducer is off the ZGP a significant distance, there can be uncertainty in translating the FEH to the ZGP using the formation density measured at the well screen. Approximately 5 percent of the transducers installed at the Site are offset more than 5 ft from the ZGP. The uncertainty here is related to potential density variations in the formation within the offset distance, and likely is most significant for wells installed within the ADP where the largest variations in groundwater density occur.

4.2 Regional Geologic/Hydrogeologic Conditions

Regional Geologic Conditions

An overview of regional geologic conditions based on studies completed for the Puyallup River Valley and Bluffs in the Site vicinity is presented in Appendix A. A summary of the regional geologic conditions is provided below.

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 4.4 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.

Regional Hydrogeologic Conditions

Regional surface water and groundwater flow through the Puyallup River Valley discharges to Commencement Bay. 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 POT waterways/Commencement Bay. Groundwater discharge into surface-water features occurs as described in Section 4.1.2.

4.3 Site Geologic/Hydrogeologic Conditions

Site Geologic Conditions

Figure 4.5 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.

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 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 ft 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 4.5. The glacial deposits are not encountered at borings in the west, southwest, and south portion of the Site peninsula and is inferred to dip downward in this area below the depth of the Site borings.

The 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 4.5.

Within the Bluffs, Figure 4.5 shows an alternating sequence of sand/gravel and silt/clay layers based on the regional geologic conditions described in Appendix A.

Site Hydrogeologic Conditions

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. As shown on Figures 4.1 and 4.2, the mud flats historically existed throughout the POT and extended as far south as East Eleventh Street. The mud flats have not been identified consistently in all Site borings. This may be due to a lack of precision in the stratigraphic logs, or may 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 4.5. It is understood that this conceptualization is a simplification of the actual complex physical setting.

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 where detailed investigation of groundwater levels within the fill has been completed. Here, groundwater elevations in the fill are approximately 2 feet higher than groundwater elevations in the deltaic deposits immediately beneath the mud flats. The mud flats are colored dark brown on Figure 4.5 where the hydraulic separation between the fill and deltaic deposits is observed in the southern portion of the Site, and a lighter brown where this hydraulic separation is not confirmed.

The majority of the Site-related contamination exists within the deltaic deposits. Groundwater quality data indicates that the vertical limit of contamination 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 limits 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 are encountered[6]
- Fresh to relatively fresh groundwater observed within the glacial deposits
- Downward migration of the COCs appears to be limited to within the lower deltaic deposits or top of the underlying glacial deposits

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[6] Just west, southwest and south of the Site, the glacial deposits are not encountered. Here, the deltaic deposits extend to the depth investigated, and observed vertical hydraulic gradients in the deltaic deposits are downward in this area.

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 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 CSM of hydrogeologic conditions in the Site vicinity on Figure 4.6. The salt water distributions and groundwater flow conditions illustrated on Figure 4.6 are generalized representations of pre-contamination conditions. The groundwater flow conditions illustrated on Figure 4.6 are summarized as follows:

- Recharge from precipitation infiltration contributes shallow fresh groundwater in the fill. This recharge migrates downward into the underlying deltaic deposits and laterally to the 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 FEHs in the Bluffs limit the inland extent of the salt water along the east side of the Waterway, as shown on Figure 4.6.
- Available salinity data from borings completed beneath the waterway show a zone of fresher groundwater from the eastern bluffs extending adjacent to and beneath the Hylebos Waterway.
- Available bromide data used as a tracer for identifying naturally-occurring saltwater suggest a relatively complex pattern of saltwater 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 Section 5.0.

Section 5.0 Contaminant Transport and Fate

Site investigations have confirmed that there are four primary groundwater plumes: the ADP, pH plume, CVOCs, and metals. These plumes have been defined through the Site monitoring well network shown in plan and section views on Figures 5.1 and 5.2, respectively. Other COCs 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 Site monitoring well network consists of wells screened within seven depth zones, or ZGPs, representing nominal depths of 15, 25, 50, 75, 100, 130, and 160 ft below ground surface (bgs). The depth zones are referred to as the 15-ft zone, 25-ft zone, 50-ft zone, 75-ft zone, 100-ft zone, 130-ft zone, and 160-ft zone. These depth zones are indicated on Figure 5.2.

The primary groundwater plumes have migrated from the sources noted in Section 3.0 via several transport mechanisms that are summarized below.

COC Type	***Transport Mechanism***
ADP	• Density-dependent flow • Migration with groundwater
pH plume	• Density-dependent flow • Migration with groundwater
CVOCs	• DNAPL migration • Migration with the ADP • Displacement by the ADP • Migration with groundwater • Volatilization to ambient air and indoor air
Metals	• Migration with the ADP • Migration with groundwater • Surface water runoff
SVOCs	• Migration with groundwater • Surface water runoff
PCBs	• Migration with groundwater • Surface water runoff

COC Type	***Transport Mechanism***
Dioxins/Furans	• Migration with groundwater • Surface water runoff

5.1 Bulk COC Migration Rate

A conceptual average bulk COC migration rate is estimated for the dissolved groundwater plumes for each main group of COCs. The distance each COC group has traveled from the suspected source areas was divided by the time since the source is thought to have been in place. Due to the uncertainty in the starting time for the sources, a range of values was used for the start times (1940 – 1960).

The table below presents the conceptual migration rates for each of the COC groups using the lateral migration distance and release date approach.

COC Group	***Assumed Starting Area***	***Estimated Lateral Migration Distance as of 2013 (ft)***	***Range in Estimated Migration Rates (ft/yr)***
CVOCs (vinyl chloride)	WMU H	1,700	23 - 32
Caustic (pH)	Caustic House	1,500	21 - 29
ADP	Salt Pad/WMUs C, F, G, H	1,600	22 - 30
Metals	Navy-Todd Dump	400	6 - 8

Vinyl chloride and zinc were chosen because of the COCs from their respective groupings, they have traveled farthest from their respective source areas. SVOCs, PCBs, and dioxins/furans were not included because these COCs do not form distinct enough groundwater plumes to allow the calculation of migration rates.

It should be noted that the estimated migration rates presented above are conceptual in nature. These historical plume migration rate estimates may not be representative of current conditions and may not be predictive of future migration rates.

Uncertainty in the estimates using this approach is due to the following:

- Higher density releases, greater than what is currently observed in the ADP, likely occurred at early time and likely caused faster initial (downward) migration rates. As dilution of the ADP has occurred over time, the migration rates due to density effects have likely slowed.

- The assumption of a starting point. Input to the subsurface would have started immediately after the initial discharge of solvent waste to the subsurface. However, the time for the initial release of a large enough volume of product to cause DNAPL migration is not available.
- The velocities that are estimated represent average values. There are spatial and temporal variations in velocity due to DNAPL transport and the presence of the ADP. Presence of DNAPL at depth beneath the Site is direct evidence that a dense, separate phase migrated downward vertically from discharge point(s) at the surface. Accounts of experimental vertical DNAPL migration from the literature indicate that the DNAPL migration rates would be different from the dissolved groundwater plume migration rates. Currently there is no reliable method to separate DNAPL migration rates from estimates of dissolved groundwater plume migration rates. The migration rate of CVOCs within the ADP will be different from the migration rate within the groundwater outside the ADP. There is no way to account for these differences that occurred historically.

The bulk or average COC migration rate can also be estimated based on average groundwater linear velocity and retardation factors for different COCs. Uncertainties in estimation of COC migration rate using average groundwater linear velocity and retardation factors include the following:

- Aquifer hydraulic conductivity (K) derived from multiple hydraulic tests (slug tests and pumping tests) ranges several orders of magnitude; better average K value may be determined from the future calibrated groundwater flow models.
- Retardation factors for ADP and pH plume migration are uncertain. Conceptually, the retardation factors for ADP and pH equal to one if only sorption is considered because the compounds forming the ADP and pH plumes are readily soluble in groundwater. However, chemical reactions may play a significant role in ADP and pH transport.
- Significant uncertainties exist in determining retardation factors for metals under variable pH/Eh conditions at the site.

5.2 Anthropogenic Density Plume

Historical Site operations resulted in surface releases of high density fluids from the sources described in Section 3.0 (primarily the settling ponds/barge, 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 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 5.3. 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[7]), Salt Pad, and 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 5.3.

Over time, the ADP migrated away from the source areas via density-dependent (i.e., gravity-driven) flow. While migrating downwards, the higher density plume displaced the fresh 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 the 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 5.4. The primary CVOC found beneath the Waterway currently is vinyl chloride, which is the 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 will 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 prevent eastward migration of the ADP into the sediments beneath the Bluffs.
- Vertical migration will 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.

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[7] Although lime sludge/solvent residue reportedly was sent to WMU A, the ADP under current conditions is not focused beneath this area. As a result, WMU A was not shown on Figure 5.3 as a source location for the ADP.

The distribution of the current ADP is shown on Figure 5.5. The ADP is centered beneath the settling ponds/barge and Salt Pad, with the southern portion of the ADP underlying the Caustic Source Area. The ADP has remained relatively consistent since 2006 based on comparison of 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 will be the predominant mechanism for any further migration of the ADP, and COCs comingled with the ADP.

The distribution of the ADP shown on Figure 5.5 is based on, and is consistent with, the observed density data. The highest density observations occur east of the Salt Pad, corresponding to the locations of the settling ponds/barge, and elevated density observations also occur to the north/northwest of the Salt Pad. The highest density beneath the settling ponds/barge indicates this area is where the releases of highest density material occurred historically, consistent with the release of lime sludge and solvent residue in this area. The elevated density to the north/northwest of the Salt Pad is consistent with the trough in the surface of the glacial deposits that appears to slope downward to the northwest. The current ADP distribution appears centered beneath the settling ponds/barge just east of the Salt Pad, where the release of highest density material occurred, spreads radially outward from this area and then northwestward consistent with the zone of apparent confining effect in the lower deltaic deposits following the trough in the glacial deposits.

5.3 pH PLUME

Historical Site operations resulted in surface releases of high density/high pH caustic fluids from the Caustic Source Area described in Section 3.0. As described in Section 5.2, 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 5.6.

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 soils that were impacted with caustic are a continuing source of elevated pH to groundwater.

Reaction of the pH plume with the aquifer material is an exothermic reaction that results in a localized increase in groundwater temperature. This process is most apparent in the areas of the highest pH groundwater where geochemical reactions are actively occurring. Currently the temperature data indicate this is occurring under the Salt Pad and surrounding area where the reactions would be most vigorous. Groundwater temperatures measured under the Salt Pad and surrounding area are up to 10 degrees Celsius warmer than the groundwater temperatures measured upgradient of the Site.

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

5.4 CVOCs

The migration of CVOCs 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 indoor (potentially) and ambient air

These CVOC migration mechanisms are summarized below.

5.4.1 DNAPL Migration

The subsurface migration of DNAPL is a complex process that is strongly influenced by geology, properties of the DNAPL, and release location. DNAPL has a high density and tends to migrate vertically downward. The DNAPL density is greater than that of the ADP and can displace the high density water within the ADP. Unlike the ADP, which is totally miscible in water, DNAPL is essentially immiscible. During transport, some DNAPL is immobilized in pore spaces in the form of disconnected blobs and ganglia referred to as residual DNAPL. In this way, the volume of DNAPL is gradually distributed along the flow path, and the mass of DNAPL subject to active migration is depleted. The DNAPL will continue to migrate until the DNAPL mass becomes immobile, or stable (i.e., remains as residual bound in pore spaces, or "pools" above a low permeability layer).

The distribution of DNAPL in the subsurface is shown on Figure 5.7. This figure shows the general distribution of the confirmed and suspected 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 5.7. 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 CVOCs. 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.

5.4.2 Migration with the ADP

Figure 5.8 shows the current distribution of CVOCs in groundwater at the Site. The CVOC sources were in close proximity to the Salt Pad, and as a result, dissolved CVOCs have comingled and migrated with the ADP. As the ADP displaced fresh groundwater or salt water in the subsurface, comingled CVOCs within the ADP were carried by the ADP as it migrated laterally and downward. In addition, CVOCs 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 CVOCs beneath the Hylebos Waterway east of the CVOC source areas even though the average groundwater flow direction observed under current conditions is more north to northwest.

5.4.3 Migration in Groundwater

Dissolved-phase CVOCs 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 an apparent shallow component of CVOC plume at the northern end of the Site peninsula illustrated on Figure 5.8.

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

Adsorption of CVOCs 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 CVOCs 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 CVOCs is occurring both biologically and abiotically. Figure 5.9 shows the generally accepted degradation pathways for PCE and TCE (USEPA, 1998; Weidemeier et al., 1999). Biological degradation of PCE and TCE (parent compounds) has produced cis-1,2-dichloroethene (cis-1,2-DCE) and vinyl chloride (daughter products) at the Site. The distribution of the parent and daughter products in groundwater is shown on Figures 5.10 through 5.12. In general, the concentrations of PCE/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/TCE plume. The presence of cis-1,2-DCE and vinyl chloride, which are daughter products of the biological degradation of PCE and TCE, confirms that PCE/TCE biodegradation is occurring. Ethene has also been detected in groundwater samples, indicating that complete degradation of vinyl chloride is occurring at least in some areas of the Site. Dissolved organic carbon is required for microbial growth and therefore the biodegradation of Site-related compounds. The dissolved organic carbon concentrations were detected at concentrations above 10 mg/L, which is sufficient to support microbial activity.

The abiotic degradation of PCE and TCE may be occurring as suggested by the presence of dissolved acetylene in groundwater. The U.S. EPA Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents (U.S. EPA 1998) states that pH values above 9 are outside the optimal range for reductive dechlorination, indicating that microbial activity may be inhibited above a pH of 9.

A detailed evaluation of the effects of Site-specific conditions on microbial activity will be conducted in the Site Characterization Report. Data evaluations will include dissolved organic carbon, pH, ORP, electron acceptors, and metabolic by-product distributions.

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 CVOCs are non-polar molecules. Biological activity is inhibited under high pH conditions; however, the extent of the inhibition cannot currently be quantified.

The concentrations of CVOCs at the base of the Waterway are much 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, the expected net flow condition is for salt water recharge to the aquifer to maintain salt water zone. The lower concentrations could also be due to surface water influence during sampling and dilution from unimpacted groundwater migrating from the bluff. 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. However, impacted groundwater has been detected near the mudline along the center and eastern shores of the Hylebos.

5.4.4 Migration to Ambient Air and Indoor Air

CVOCs can volatilize from impacted shallow groundwater or from the impacted vadose zone soils. CVOCs 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.

5.5 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

These metals migration mechanisms are shown schematically on Figure 5.13 and are summarized below.

5.5.1 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.

5.5.2 Migration in Groundwater

Infiltrating groundwater that comes into contact with soils containing metals will dissolve some of the metals, carrying them to the water table and into groundwater. Once in groundwater, the metals will be 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

Remediation of metals in groundwater is highly dependent on addressing the pH plume and the ADP. Once the groundwater pH decreases and the ADP dissipates, natural sorption processes will precipitate metals and reduce the concentrations of metals dissolved in groundwater.

5.5.3 Surface Runoff

Precipitation at the Site comes into contact with impacted surficial soil and carries soil particles with the surface 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 undertaken at the Site designed to determine if storm water discharge is within regulatory limits. The monitoring program has not identified any significant impacts. It is unlikely that future impacts will occur and this migration pathway is not considered significant. Stormwater monitoring data will be summarized and presented in the draft SCR.

5.6 SVOCs

The migration of SVOCs could potentially occur via several mechanisms:

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

5.6.1 DNAPL Migration

Because the SVOCs 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 SVOCs would have then migrated downward along with the DNAPL as described in Section 5.4.1. The presence of HCB and HCBD in deep soil and sediment samples is consistent with this hypothesis.

5.6.2 Migration in Groundwater

The most predominant Site SVOCs (HCB and HCBD) tend to sorb strongly to the soil or sediment and have limited mobility in groundwater compared to the CVOCs. Some dissolution will occur, as will the sorption to suspended particles (i.e., colloids) in groundwater. However, the migration of the SVOCs in the groundwater is much more limited than CVOCs. Detected concentrations above the Site screening level tend to be near to the identified source areas described in Section 3.5.

5.7 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 may occur, which could result in a limited enhancement of PCBs and dioxins/furans migration. Surface runoff could carry suspended soil particles with PCBs or dioxins/furans into surface water bodies, and sediment impacted with PCBs and dioxins/furans could be carried along the waterways adjacent to the Site.

However, 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 indicates detected concentrations tend to be near to the identified source areas described in Section 3.6.

Section 6.0 Exposure Pathways and Receptors

The transport of the Site COCs occurs through several processes, as described in Section 5.0. The transport of COCs may lead to the exposure and uptake of COCs by human and ecological receptors. Potentially complete human and ecological exposure pathways and receptors are shown schematically on Figure 6.1. 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.

Receptor	***Exposure Pathway***
Industrial/Commercial Worker	• Inhalation of indoor air impacted by VOCs 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 contaminated groundwater while conducted subsurface excavations that extend to the groundwater table • Inhalation of soil particulates and/or ambient air

Receptor	***Exposure Pathway***
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

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 discharge of contaminated 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.

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

Section 7.0 Previous Remedial Actions

7.1 Soil Removal After TCE/PCE Process Decommissioning

The former solvent production plant (TCE/PCE process) at 605 Alexander Avenue ceased operations in 1973 and was decommissioned in 1979. In 1980 and 1981, a soil sampling and analytical program was conducted in this area to delineate the extent of soil in the vadose zone. Soils containing chlorinated organics at concentrations greater than 150 milligrams per kilogram (mg/kg) were excavated in 1981 and disposed off Site. The excavation was backfilled with clean soil.

Additional soil removal was conducted from the TCE/PCE process area in 1993/1994 during the construction of the on-Site groundwater treatment plant. This material was disposed off Site.

7.2 Groundwater Extraction and Treatment System

The existing groundwater extraction and treatment partial containment system was designed and constructed by OCC in 1996 based on the findings of a RCRA Facility Investigation conducted for the Site. Figure 7.1 shows the existing extraction system in plan view. The extraction system consists of 25 extraction wells. Twenty-two of the 25 extraction wells are screened approximately 40 to 70 ft bgs. The remaining three extraction wells are screened as follows: A-2A (84 to 134 ft bgs), D-4 (95 to 105 ft bgs), and D-5 (70 to 120 ft bgs). The extracted groundwater is treated by the on-Site groundwater treatment plant and discharged to the Waterway under a National Pollutant Discharge Elimination System (NPDES) permit.

Injection wells were installed in 1996 and originally used for the injection of treated groundwater. The injection system consisted of 21 injection wells located adjacent to the Waterway, as shown on Figure 7.1. There were on-going operational difficulties (injection well clogging by mineral precipitations) and concern about further mobilizing contaminants in soil and sediment on the Waterway side of the injection well line. Accordingly, use of the injection system ceased in 2006.

The extraction system pumping is limited to a maximum of 150 gallons per minute (gpm) by the terms of the current NPDES permit. Current extraction rates are approximately 60 to 70 gpm.

Remedial investigations since 1996 have found groundwater contamination to be more extensive than what the groundwater extraction system captures. The capture zone of the current system will be estimated as part of the groundwater flow modeling effort at the Site.

7.3 Area 5106 Sediment Removal Action

The Area 5106 Removal Action addressed Waterway sediment containing elevated chlorinated organic chemicals that required treatment prior to disposal (EPA, 2002). Dredging, treatment, and dewatering of Area 5106 sediment began on October 15, 2002 and continued until February 28, 2003. In total, over 36,000 cubic yards (yd^3) of Area 5106 sediment and underlying contaminated native sediments were removed from the Waterway and treated to reduce VOC and SVOC mass. The treated sediment was disposed in the Slip 1 Confined Disposal Facility (CDF) located in the northeast corner of the peninsula immediately west of the Blair Waterway.

As presented in the RACR Segment 5, post-treatment laboratory analyses consisted of PCE, TCE, HCB, and HCBD (CRA, 2014). Confirmation sampling performed following the initial dredging, completed between October 2002 and February 2003, indicated chlorinated organic chemical concentrations exceeded the established sediment quality objective (SQO) chemical criteria within the underlying native sediment by several orders of magnitude. Consequently, additional post-treatment Area 5106 sediment removal investigations were performed to delineate the nature and extent of remaining subsurface sediment and groundwater contamination in this area. Borings PT-1 through PT-18 were advanced in July 2003 and June 2004 and two additional borings PT-13A and PT-15A were advanced in November 2005. Data from these Area 5106 footprint borings identified subsurface sediment and groundwater VOC and SVOC contamination beneath the Waterway.

Remaining work under the Area 5106 Removal Action UAO has been incorporated into the AOC (EPA, 2005a). The Area 5106 footprint is shown as one of the CVOC and SVOC source areas identified in this report.

7.4 Hylebos Sediment Cleanup Action

Following the Area 5106 Removal Action, OCC and the POT jointly completed the Hylebos Waterway RD/RA construction activities pursuant to the Mouth RD/RA Consent Decree that involved additional dredging within the Area 5106 footprint and remedial action dredging other Waterway segments (CRA, 2014). Sediment cleanup work was generally within the navigation channel, and contaminated sediment may be found along those subtidal and intertidal slopes where remediation did not occur, including the Occidental Site.

Section 8.0 References

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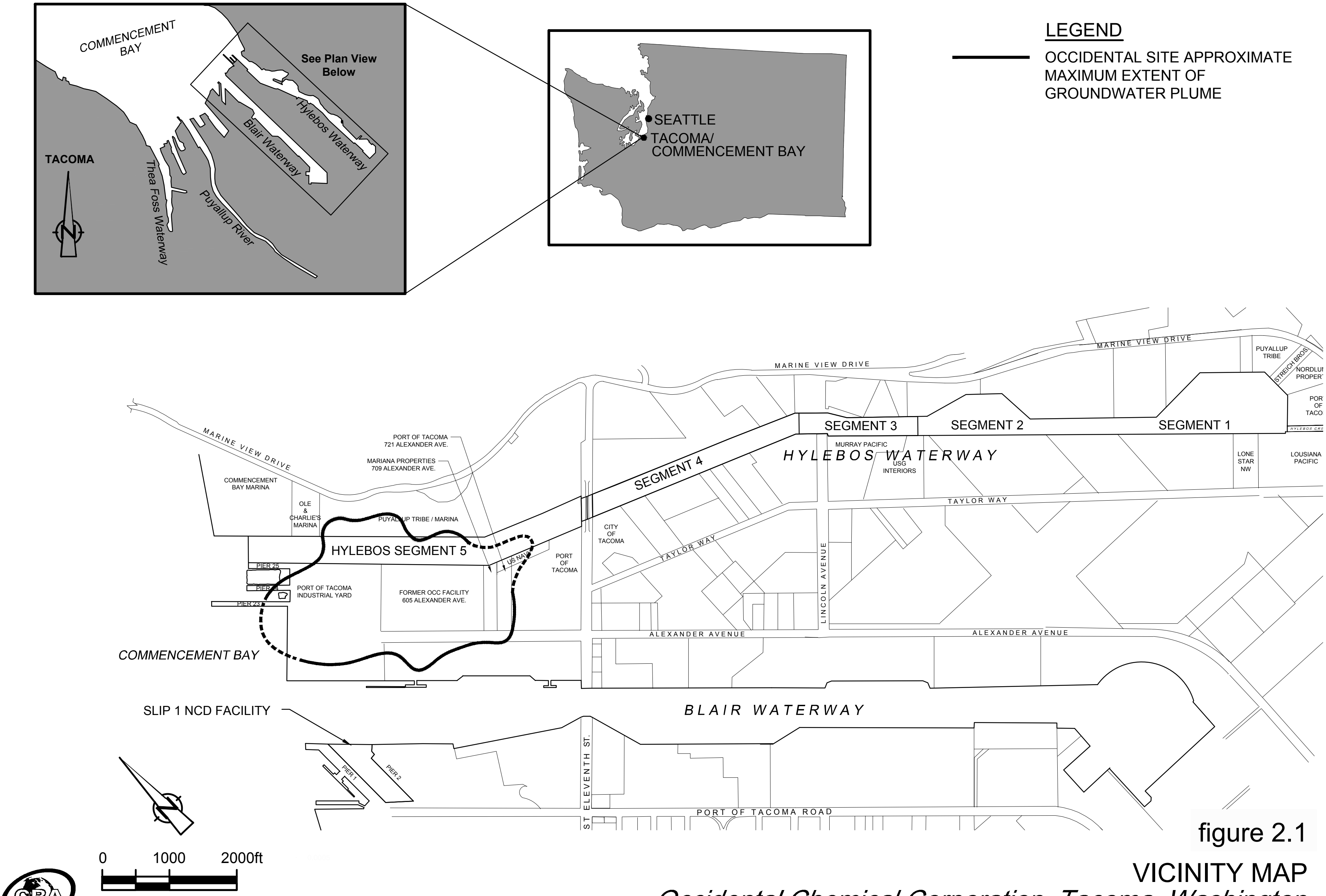


figure 2.1

VICINITY MAP

Occidental Chemical Corporation, Tacoma, Washington

SOURCE: ELECTRONIC FILE PROVIDED BY ANCHOR ENVIRONMENTAL LLC, JUNE 01, 2004.

07843-A6(131)GN-WA015 MAR 3/2014

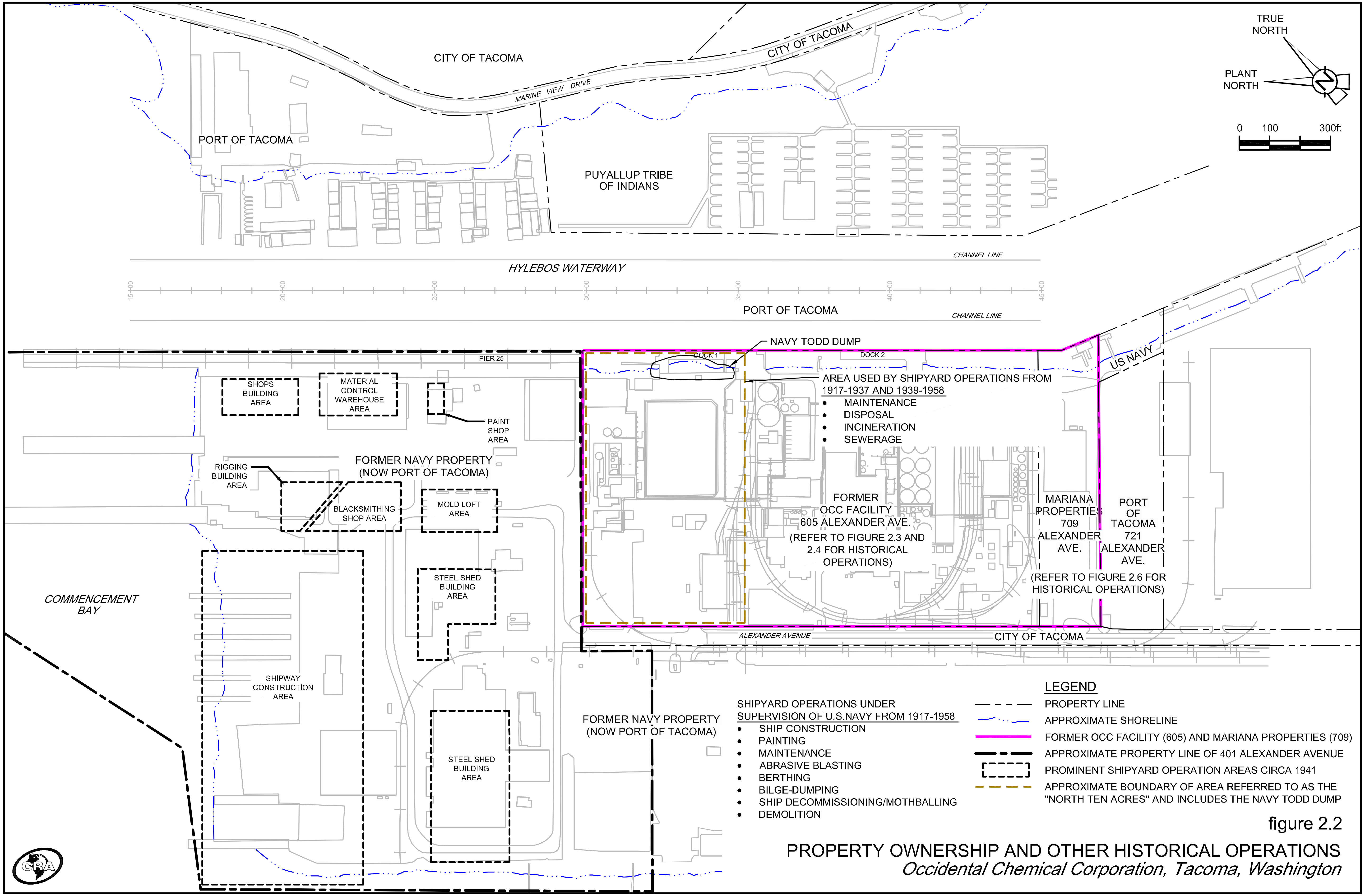
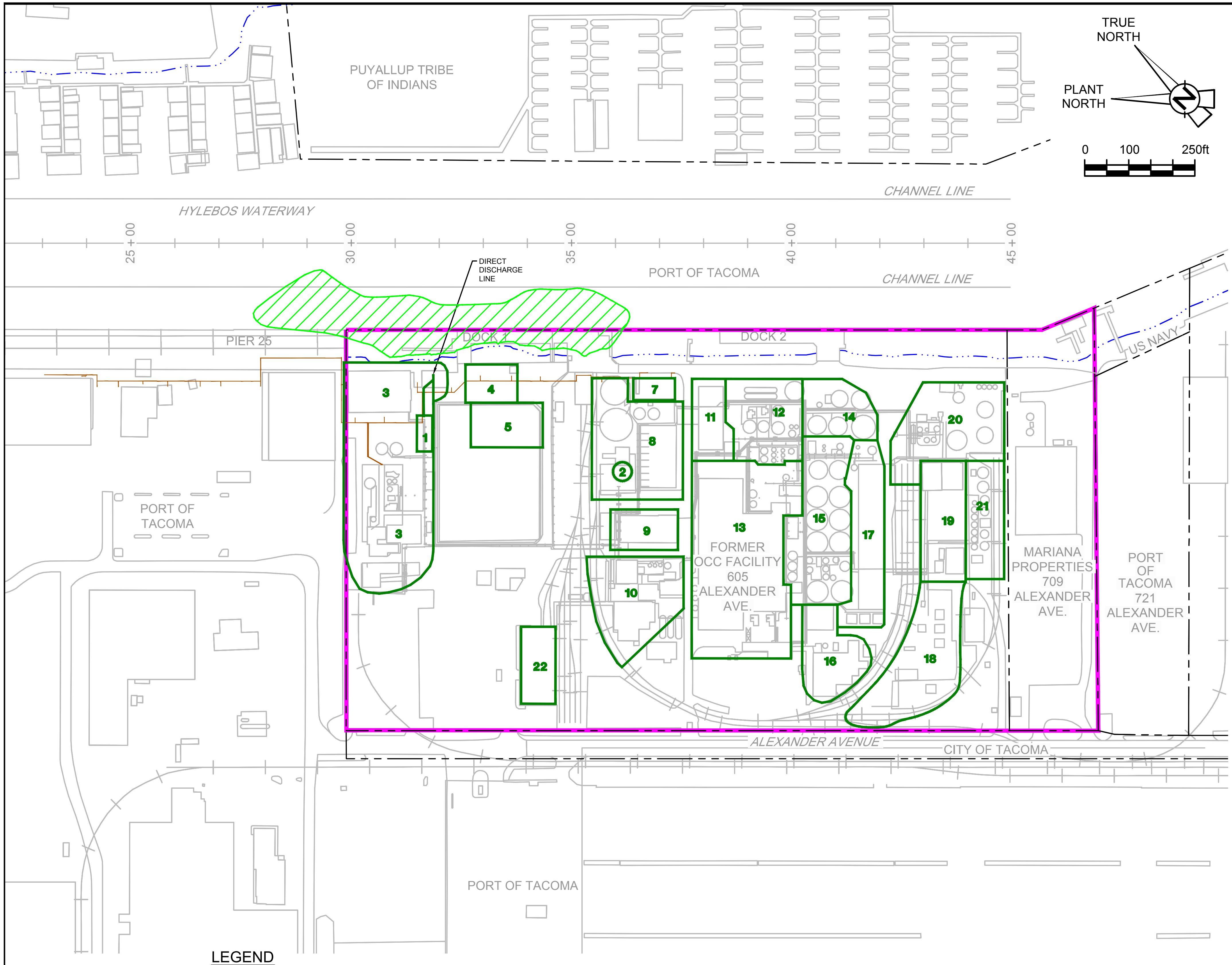


figure 2.2

PROPERTY OWNERSHIP AND OTHER HISTORICAL OPERATIONS
Occidental Chemical Corporation, Tacoma, Washington

07843-A6(131)GN-WA002 JAN 13/2014



LEGEND

- ▭ 22 CHEMICAL ACTIVITY AREA
- ▨ AREA 5106
- — — — PROPERTY LINE
- —·· — APPROXIMATE SHORELINE
- ━━ FORMER OCC FACILITY (605) AND MARIANA PROPERTIES (709)

Area	Operations	Chemicals
1	calcium chloride decantation	calcium chloride
2	calcium chloride concentrator caustic processing area	calcium chloride, sodium hydroxide
3	TCE/PCE processes, manufacture of tetrachloroethane & pentachloroethane, receiving department, salt pad, cell liquor, calcium chloride & caustic storage	calcium carbide, carbon tetrachloride, chlorine, chloroform, TCE, chlorinated ethanes, hexachlorobutadiene, tetrachloroethanes, 1,1,2,2-tetrachloroethane, PCE, hexachloroethane, solvent stabilizers, hexachlorobenzene, pentachloroethane, lime, calcium chloride, acetylene, chlorinated butanes, sodium chloride, sodium hydroxide, calcium chloride, calcium hydroxide, magnesium hydroxide, calcium carbonate
4	PCE/TCE, cell liquor, caustic, & calcium chloride storage	sodium chloride, PCE, TCE, sodium hydroxide
5	drummed caustic storage, salt pad	sodium hydroxide & sodium chloride
6	Todd shipyard & operations described for Areas 1, 3, 4, 5, & 22	shipyard chemicals unknown
7	fuel oil storage	#2 & #6 fuel oil
8	caustic processing & loading, heating fusion pots, processing storage & loading of caustic soda, storage of hydrochloric acid & sodium hypochlorite	sodium hydroxide, sodium hypochlorite, sodium chloride, HCl, #2 & #6 fuel oil
9	laboratory, shop area	various laboratory chemicals
10	equipment cleaning using cell liquor, TCE, & PCE, & cooling, drying, compression, purification & liquifaction of chlorine	chlorine, sulfuric acid, freon, carbon tetrachloride, chloroform, PCE, TCE, hexachloroethane
11	boiler house	#6 fuel oil, water treatment chemicals
12	sodium carbonate production, TCE, caustic soda, liquid chlorine & sodium hypochlorite storage	chlorine, ferric chloride, sodium chloride, sodium carbonate, sodium sulfate, sodium hydroxide, sodium hypochlorite, TCE
13	stores receiving, cell house & reneval, transformer yard, HCl storage, ESP blade cleaning, emergency vent scrubber	sodium chloride, chlorine, HCl, sodium hydroxide, sodium hypochlorite, lead and compounds, mercury and compounds, 1,1,1-TCA
14	salt conveyor and slurry tanks, caustic storage	sodium chloride, sodium hydroxide
15	salt, sodium carbonate, caustic soda & brine sludge storage, brine storage & processing	sodium chloride, sodium hydroxide, sodium carbonate, HCl, sodium hypochlorite
16	cell renewal, transformer	HCl, PCBs, sodium hydroxide, form oil
17	equipment storage, 50% caustic and calcium chloride storage, cell house	chlorine, sodium hydroxide, sodium chloride, sulfur dioxide, calcium chloride, sulfur dioxide, calcium chloride
18	aluminun chloride manufacture, transformer, waste graghite storage, anhydrous ammonia production	ammonia, PCBs, 1,1,1-TCA, TCE
19	hydrogenation of fish oils, graphite impregnation, sodium aluminate production, sludge filtration, transformer, anhydrous ammonia storage, railcar loading, solvent storage	aluminum oxide, fish oils, linseed oil, sodiumhydroxide, sodium aluminate, cobalt naphthalate, calcium carbonate, magnesium hydroxide, sodium hydroxide, ammonia, PCBs, sodium chloride, 1,1,1-TCA, calcium chloride
20	50% caustic soda storage, waste graphite storage, muriatic acid and calcium chloride production, lime & lime rock storage, fuel oil storage	sodium hydroxide, sodium chloride, lead, #6 fuel oil, HCl, calcium hydroxic chlorine calcium carbonate, calcium chloride
21	hydrogenation of fish oils, caustic soda & calcium chloride storage, ammonium hydroxide production	ammoniumhydroxide, ammonia, sodium hydroxide, sodium chloride, calcium chloride
22	chlorine ton drum filling & cleaning, chlorine tank car servicing	chlorine

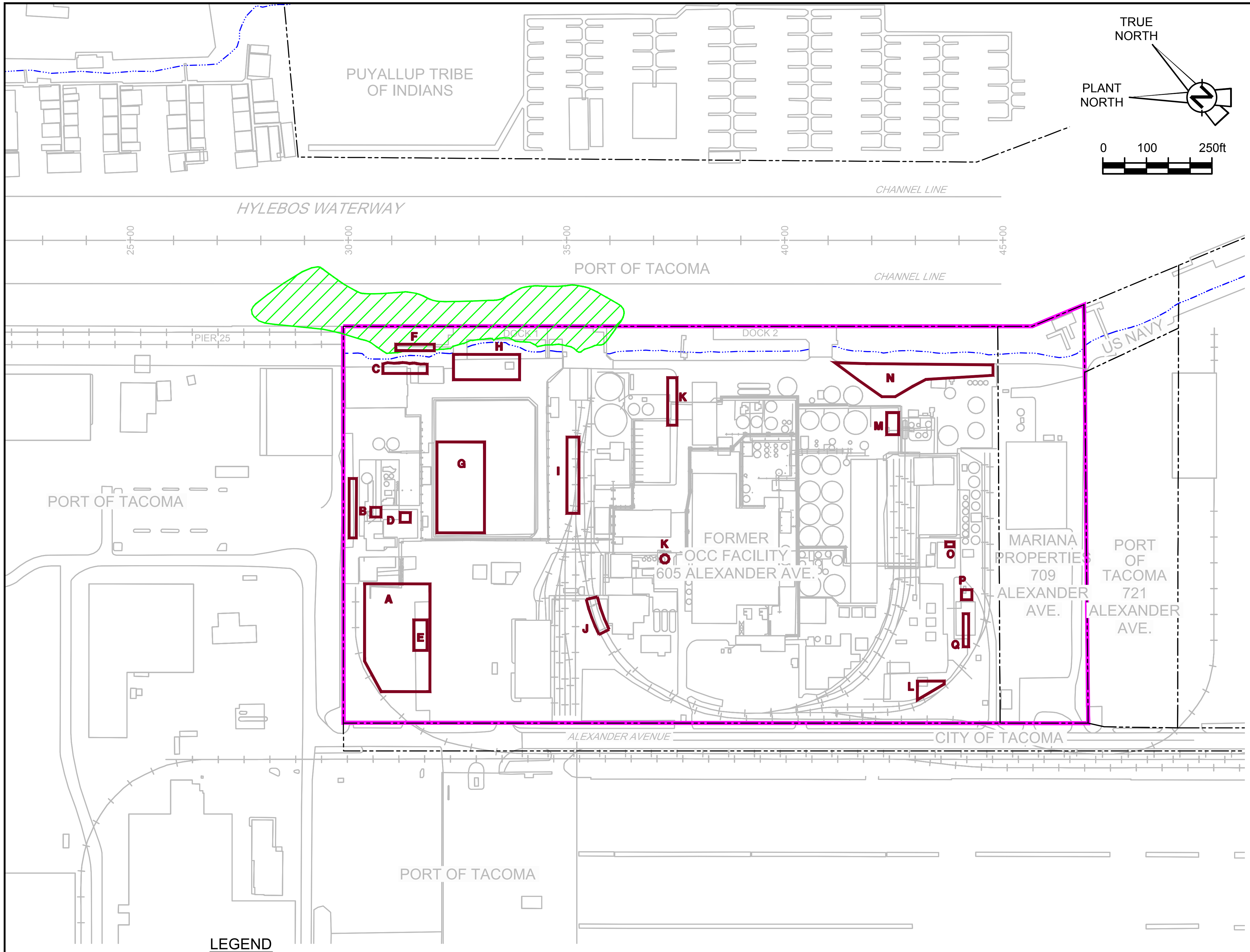
figure 2.3

CHEMICAL ACTIVITY AREAS

Occidental Chemical Corporation, Tacoma, Washington

CRA

07843-A6(131)GN-WA003 JAN 17/2014



Area	Waste Management Unit	Chemicals
A	Ponds (1972-1978)	carbon tetrachloride, chloroform, TCE, chlorinated ethanes, hexachlorobutadiene, tetrachloroethanes, 1,1,2,2-tetrachloroethane, PCE, hexachloroethane, solvent stabilizers, hexachlorobenzene, pentachloroethane, lime, calcium chloride, chlorinated butanes, calcium carbonate, magnesium hydroxide, sodium chloride
B	Tank Car Storage (up to 1995)	chloroform, TCE, hexachloroethane, hexachlorocyclopentadiene, chlorinated ethanes, hexachlorobutadiene, 1,1,1-trichloroethane, PCE
C	Landfill (1949-1971)	lime, calcium chloride
D	Drainage ponds (1948-1973)	tetrachloroethane, pentachloroethane, iron
E	Drum storage (1978-1979)	TCE, PCE
F	Lime barge(1950-1972)	See WMU A
G	Ponds (1949-1952)	carbon tetrachloride, chloroform, TCE, chlorinated ethanes, hexachlorobutadiene, tetrachloroethanes, 1,1,2,2-tetrachloroethane, PCE, hexachloroethane, solvent stabilizers, hexachlorobenzene, pentachloroethane, lime, calcium chloride, chlorinated butanes
H	Ponds (1949-1952)	See WMU G
I	Tank car storage (up to 1990)	See WMU B
J	Tank car storage (up to 1990)	See WMU B
K	Elementary neutralization system (1929-1988 & 1998-2002)	sulfuric acid, sodium hydroxide & sodium chloride
L	Graphite pile (1978-1980)	halogenated hydrocarbons, lead, carbon
M	Intermittent graphite pile (1950-1978)	See WMU L
N	Landfill (1929-1971)	corrosives, chlorinated organics, lead, non-burnable solid waste
O	Sodium aluminate pit (1959-1960)	sodium hydroxide, sodium aluminate, aluminum oxide
P	Waste pile area	graphite, lead, halogenated hydrocarbons
Q	Drum storage (1980-2002)	chlorinated hydrocarbons, carbon tetrachloride, 1,1,1-TCA, sodium hydrovide, sodium chloride, calcium chloride, graphite, asbestos, filter media, lead, filter cake

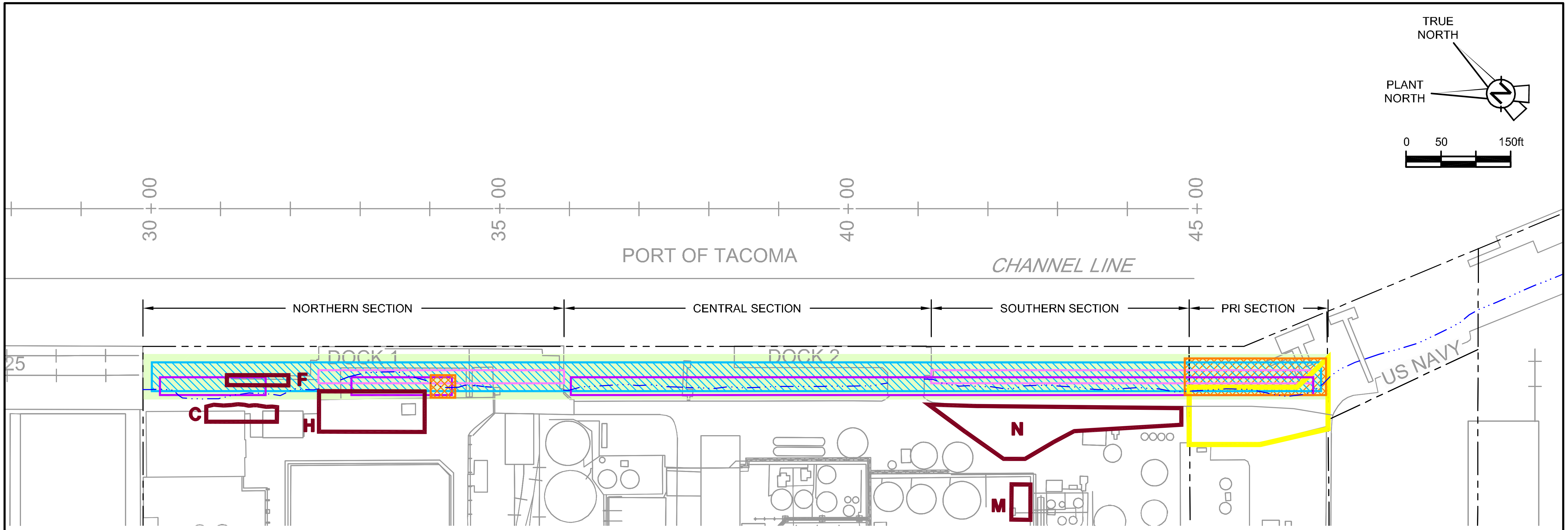
LEGEND

▭ A	FORMER WASTE MANAGEMENT UNIT
▨	AREA 5106
—·—·—	PROPERTY LINE
·-·-·	APPROXIMATE SHORELINE
━━	FORMER OCC FACILITY (605) AND MARIANA PROPERTIES (709)

figure 2.4

FORMER WASTE MANAGEMENT UNITS

Occidental Chemical Corporation, Tacoma, Washington



LEGEND

🟥 C	FORMER WASTE MANAGEMENT UNIT
— — —	PROPERTY LINE
-·-·-	APPROXIMATE SHORELINE
🟨	709 PROPERTY EMBANKMENT FILL AREA
🟧	VOCs EXCEEDANCE
▨	METALS EXCEEDANCE
🟩	SVOCs EXCEEDANCE
◻	PCBs EXCEEDANCE
🟪	PESTICIDES EXCEEDANCE

Area	Waste Management Unit
C	Landfill (1949-1971)
F	Lime barge (1950-1972)
H	Ponds (1949-1952)
M	Intermittent graphite pile (1950-1978)
N	Landfill (1929-1971)

NOTE:
EXCEEDANCE REPRESENTS MINIMUM 2x FACTOR ABOVE APPLICABLE SQOs

figure 2.5

APPROXIMATE BOUNDARIES OF HYLEBOS EMBANKMENT CONTAMINATED FILL AREAS

Occidental Chemical Corporation, Tacoma, Washington

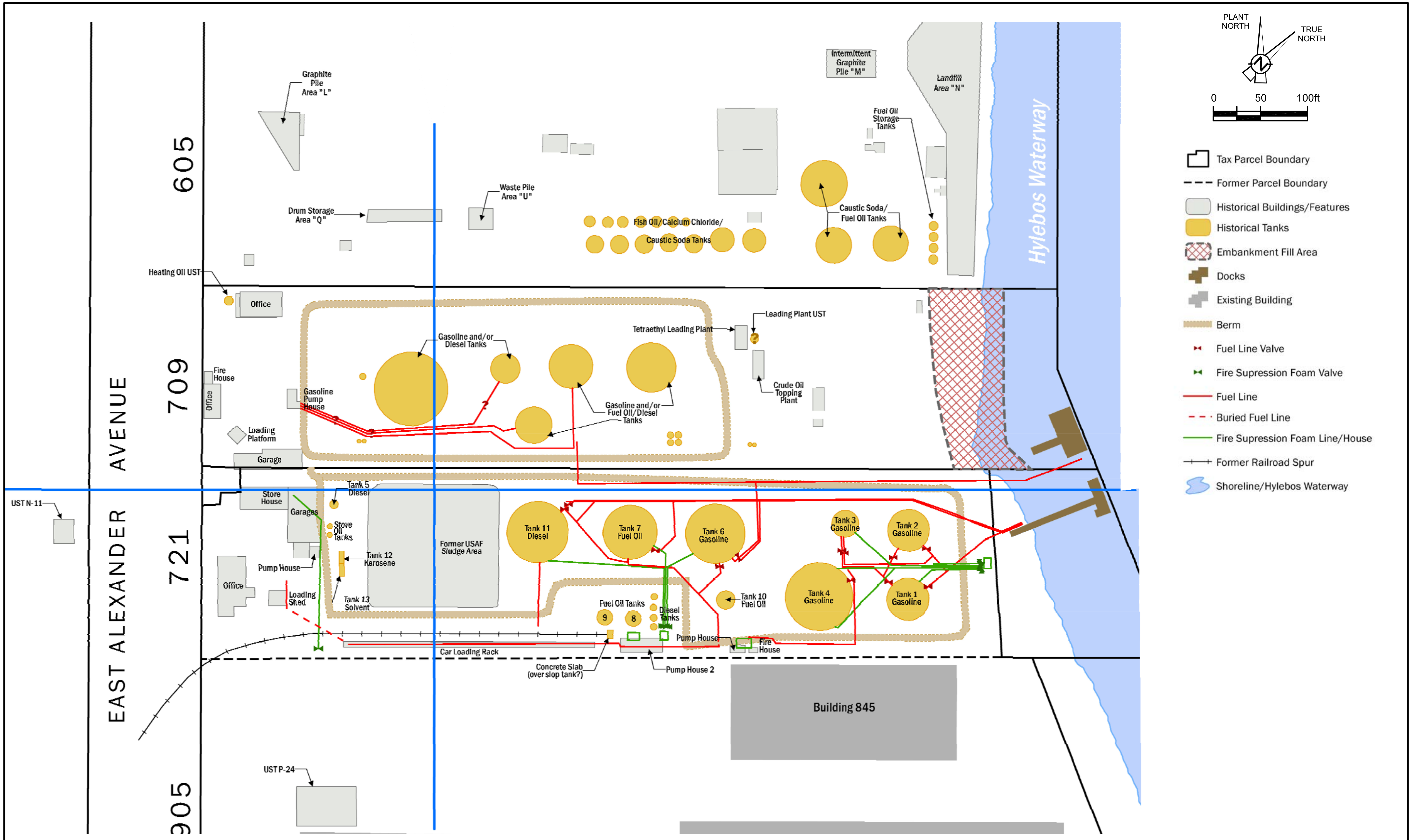


figure 2.6

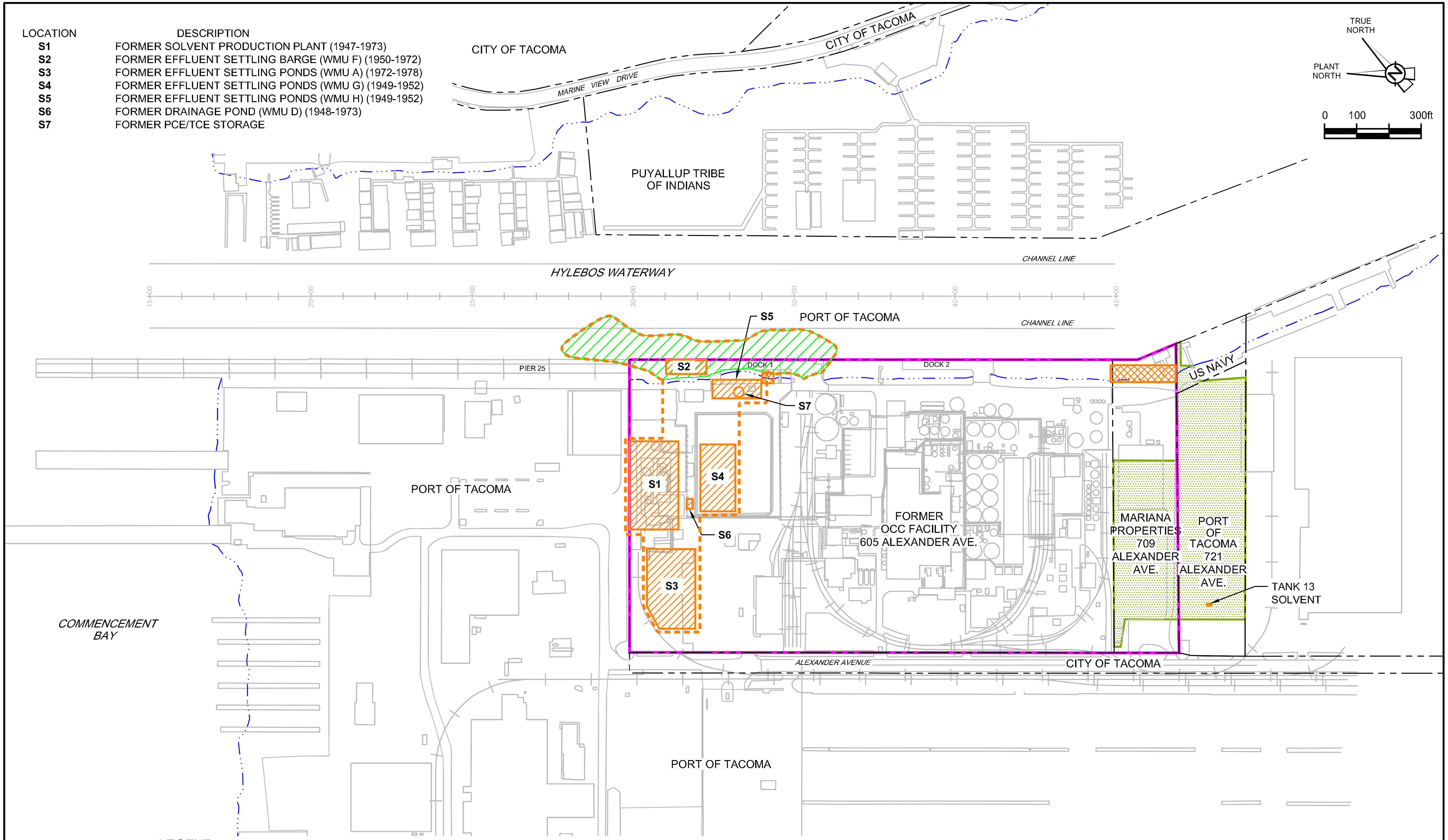
HISTORICAL SITE FEATURES ON 709/721 ALEXANDER AVENUE

Occidental Chemical Corporation, Tacoma, Washington

SOURCE: ASPECT CONSULTING, PROJECT NO. 130097-01B, FIGURE NO. 2.2, DEC-2013.

07843-A6(131)GN-WA016 DEC 11/2013

LOCATION	DESCRIPTION
S1	FORMER SOLVENT PRODUCTION PLANT (1947-1973)
S2	FORMER EFFLUENT SETTLING BARGE (WMU F) (1950-1972)
S3	FORMER EFFLUENT SETTLING PONDS (WMU A) (1972-1978)
S4	FORMER EFFLUENT SETTLING PONDS (WMU G) (1949-1952)
S5	FORMER EFFLUENT SETTLING PONDS (WMU H) (1949-1952)
S6	FORMER DRAINAGE POND (WMU D) (1948-1973)
S7	FORMER PCE/TCE STORAGE



LEGEND

- — — — PROPERTY LINE
- ‒·‒·‒ APPROXIMATE SHORELINE
- ━━ FORMER OCC FACILITY (605) AND MARIANA PROPERTIES (709)
- ▨ CVOC SOURCE
- ┅┅ CVOC SOURCE AREA
- ▦ FORMER FUEL-RELATED STRUCTURES AREA
- ▨ AREA 5106
- ▩ VOC CONTAMINATED EMBANKMENT FILL AREA (SEE FIGURE 2.5)

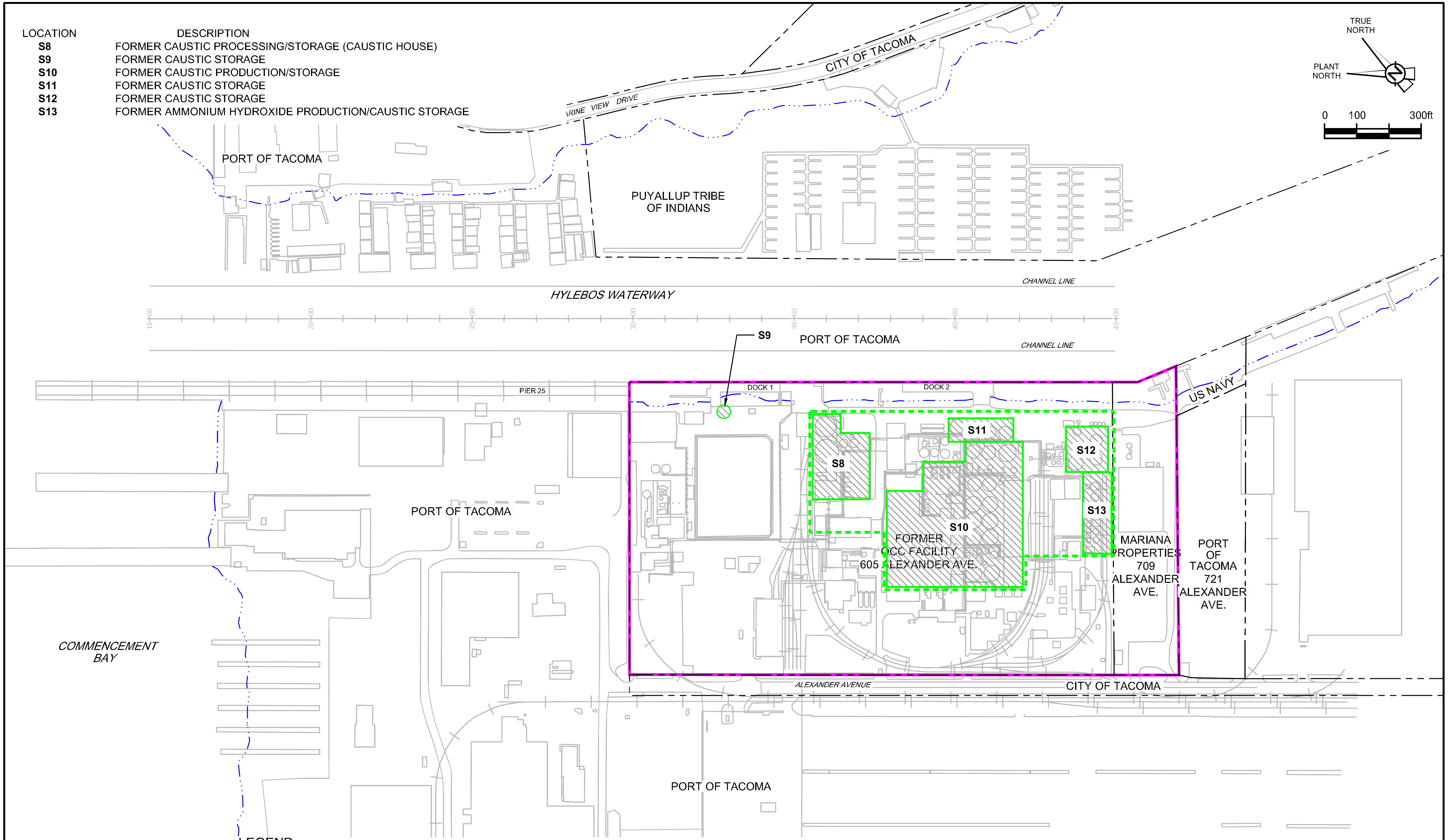
figure 3.1

SOURCES OF VOCs

Occidental Chemical Corporation, Tacoma, Washington

07843-A6(131)GN-WA006 JAN 13/2014

LOCATION	DESCRIPTION
S8	FORMER CAUSTIC PROCESSING/STORAGE (CAUSTIC HOUSE)
S9	FORMER CAUSTIC STORAGE
S10	FORMER CAUSTIC PRODUCTION/STORAGE
S11	FORMER CAUSTIC STORAGE
S12	FORMER CAUSTIC STORAGE
S13	FORMER AMMONIUM HYDROXIDE PRODUCTION/CAUSTIC STORAGE



LEGEND

— — —	PROPERTY LINE
—·—·—	APPROXIMATE SHORELINE
▬	FORMER OCC FACILITY (605) AND MARIANA PROPERTIES (709)
▨	CAUSTIC SOURCE
- - -	CAUSTIC SOURCE AREA

figure 3.2

SOURCES OF CAUSTIC

Occidental Chemical Corporation, Tacoma, Washington

07843-A6(131)GN-WA008 JAN 13/2014

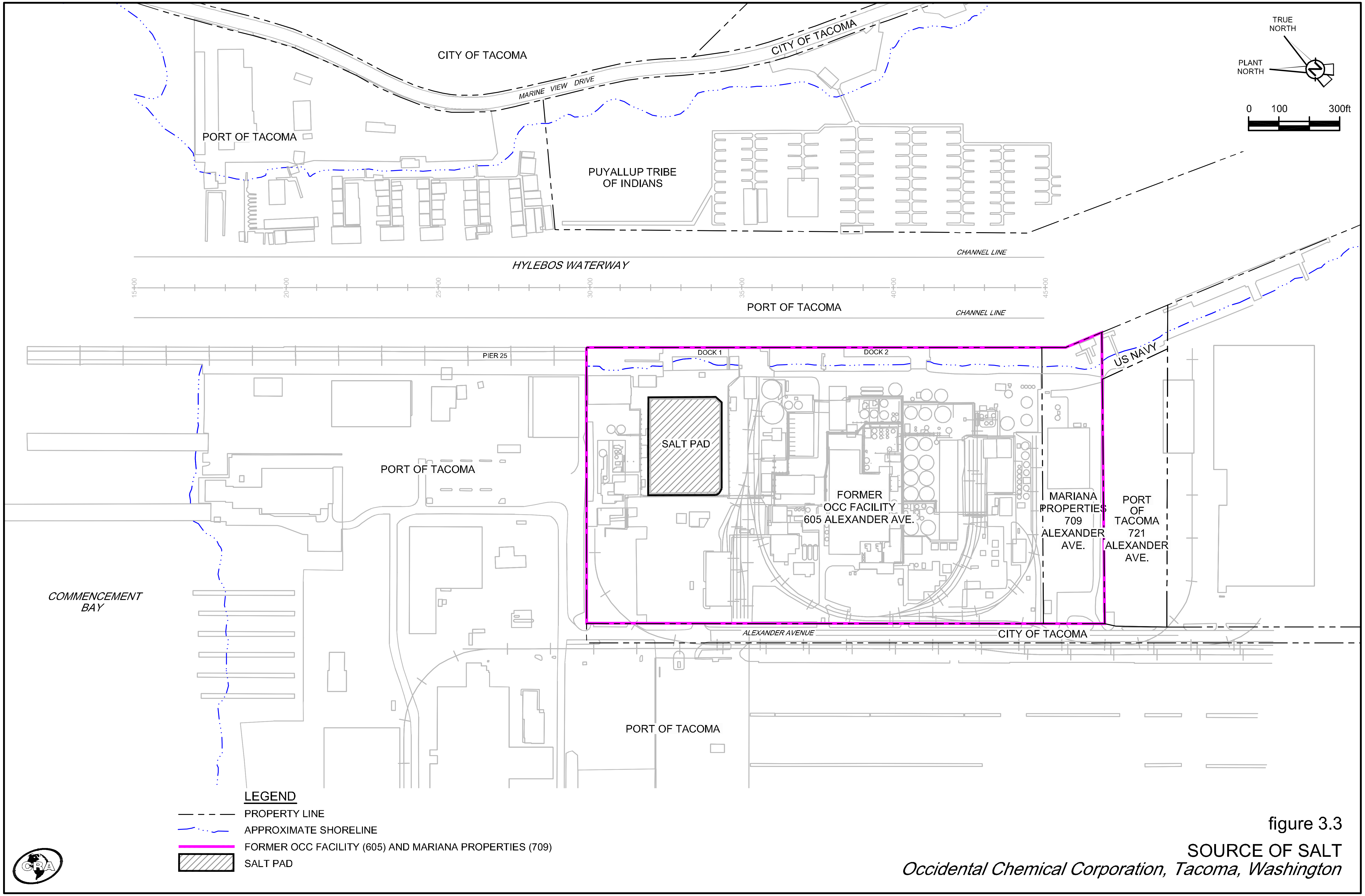
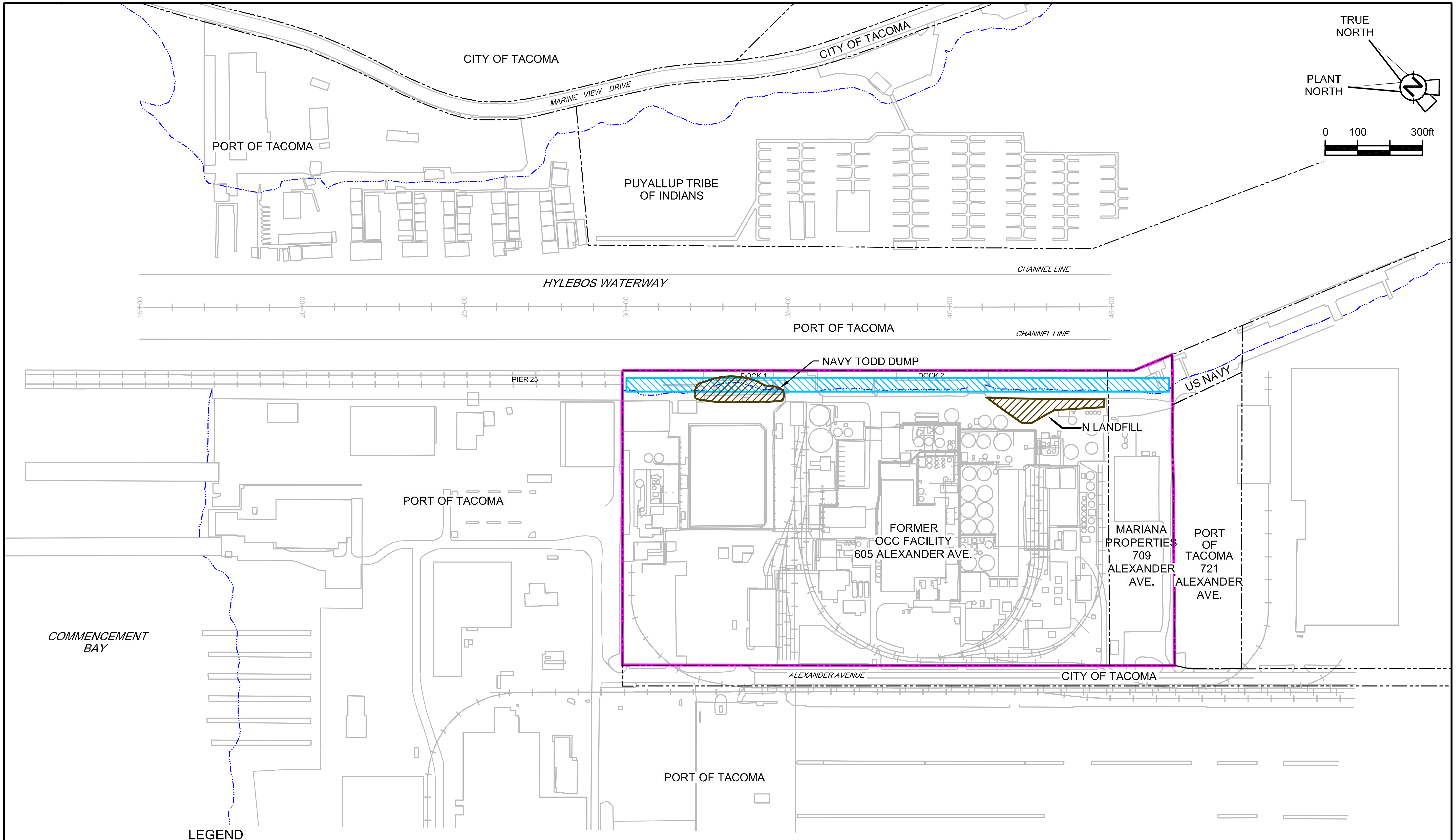


figure 3.3

SOURCE OF SALT

Occidental Chemical Corporation, Tacoma, Washington

07843-A6(131)GN-WA009 JAN 13/2014



LEGEND

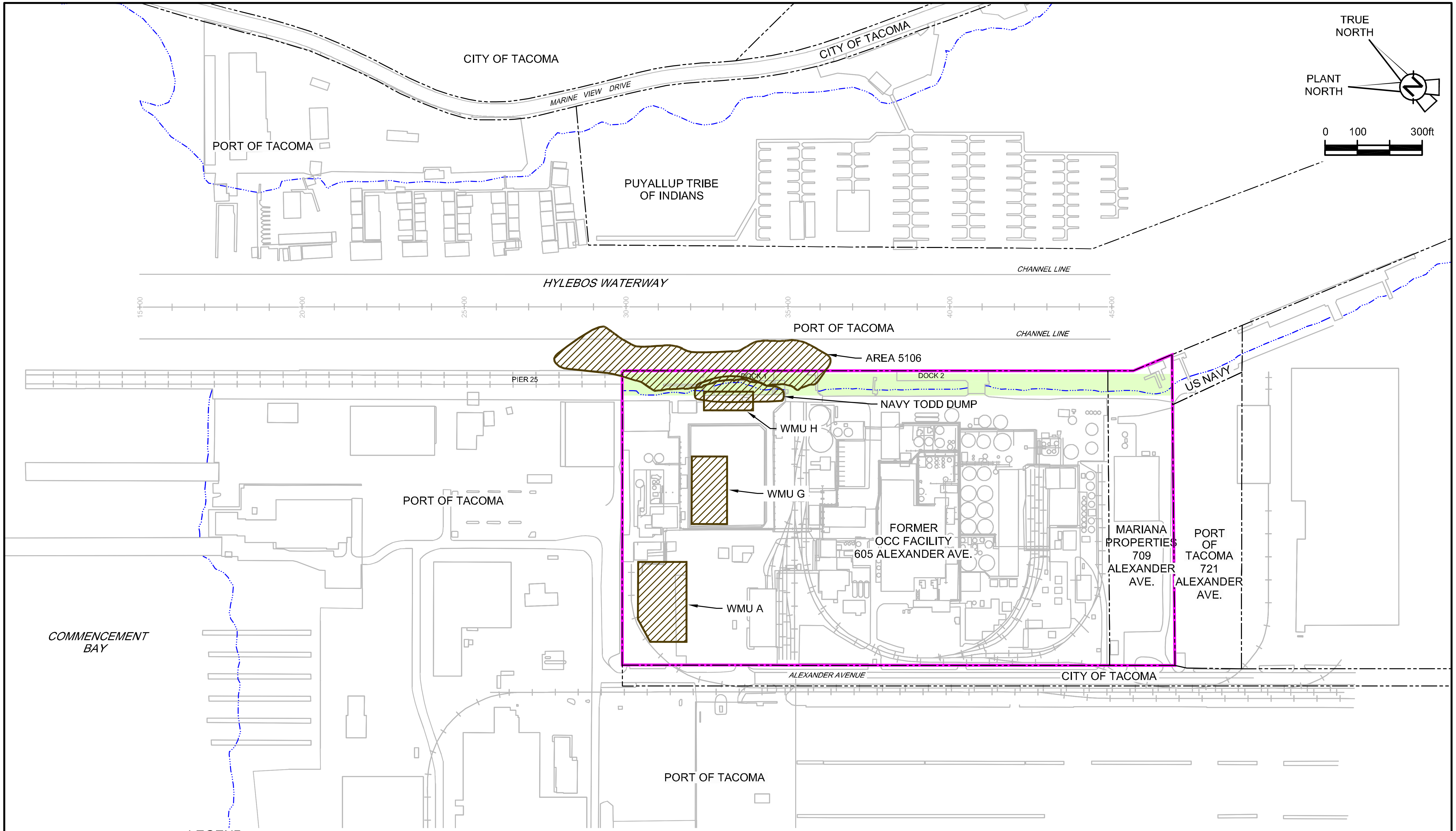
- PROPERTY LINE
- APPROXIMATE SHORELINE
- FORMER OCC FACILITY (605) AND MARIANA PROPERTIES (709)
- ▨ METALS SOURCE AREA
- ▨ METALS IN EMBANKMENT FILL (SEE FIGURE 2.5)

figure 3.4

SOURCES OF METALS

Occidental Chemical Corporation, Tacoma, Washington

07843-A6(131)GN-WA011 JAN 13/2014



LEGEND

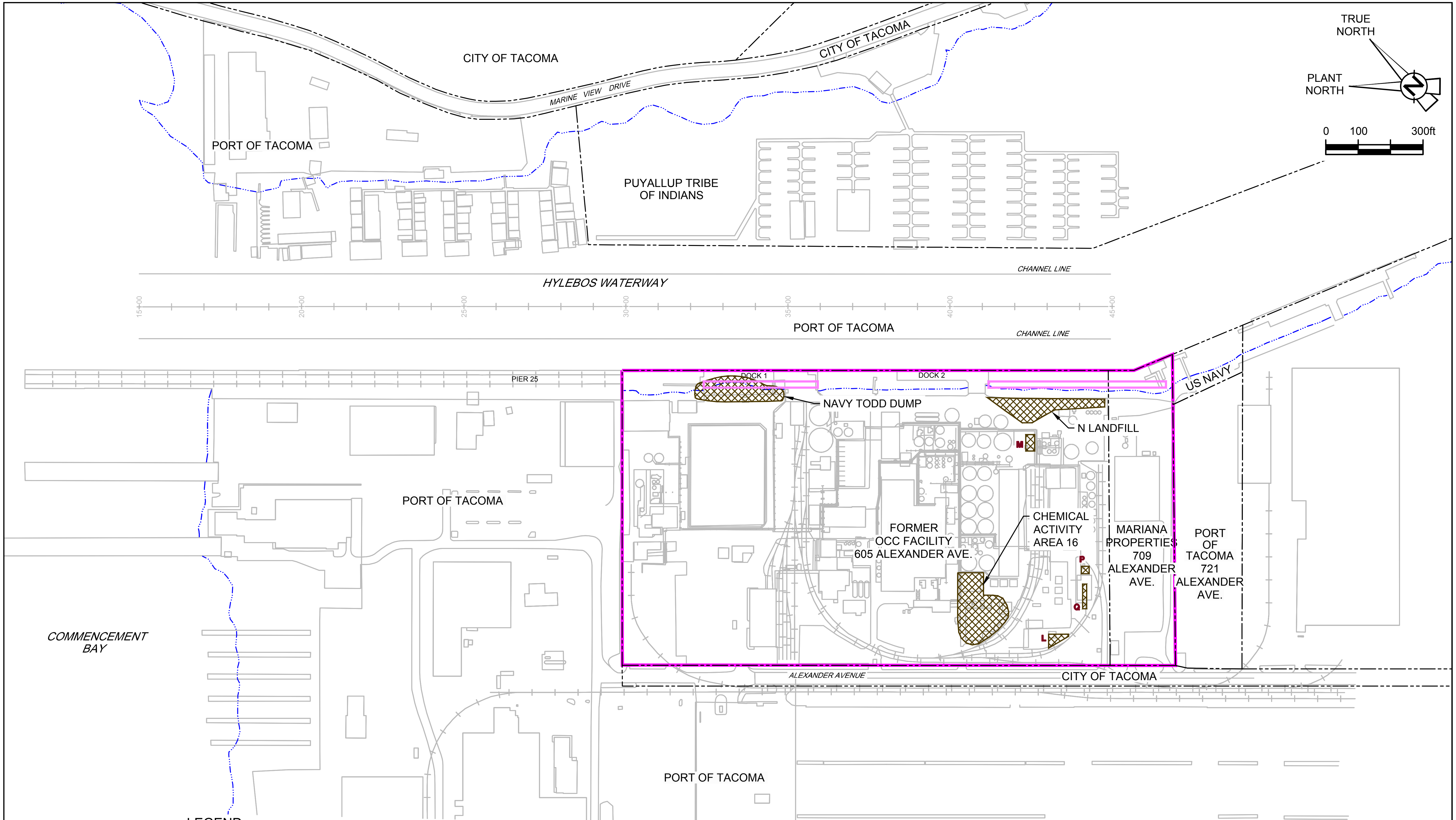
- ‒ · ‒ PROPERTY LINE
- - · - APPROXIMATE SHORELINE
- ━ FORMER OCC FACILITY (605) AND MARIANA PROPERTIES (709)
- ▨ SVOCs SOURCE AREA
- 🟩 SVOCs CONTAMINATED EMBANKMENT FILL AREA (SEE FIGURE 2.5)

figure 3.5

SOURCES OF SVOCs

Occidental Chemical Corporation, Tacoma, Washington

07843-A6(131)GN-WA018 JAN 13/2014



LEGEND

—·—·— PROPERTY LINE

-·-·-·- APPROXIMATE SHORELINE

━━ FORMER OCC FACILITY (605) AND MARIANA PROPERTIES (709)

▨ POTENTIAL SOURCE OF PCBs AND DIOXINS/FURANS

▭ PCBs IN EMBANKMENT FILL (SEE FIGURE 2.5)

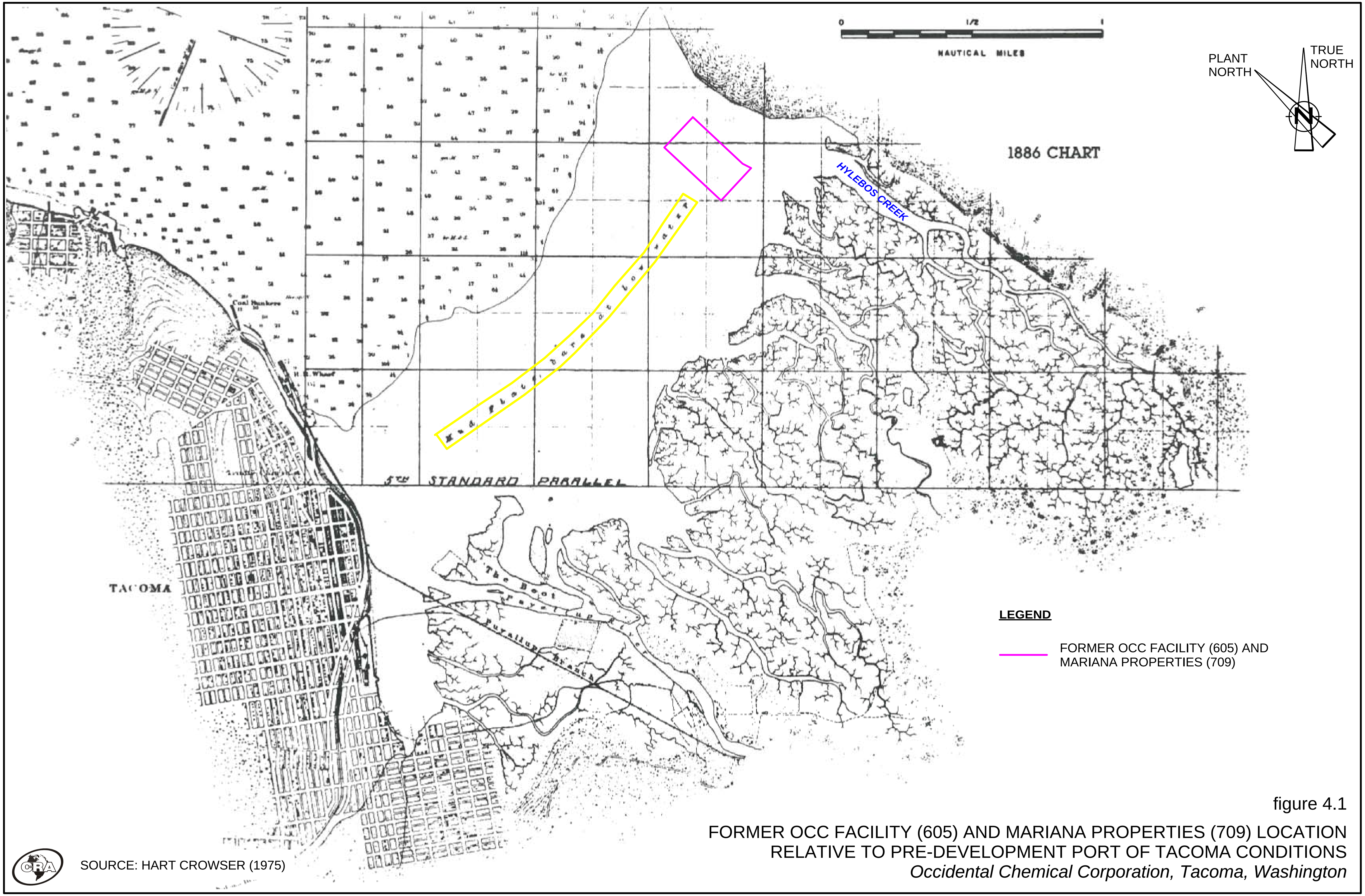
A FORMER WASTE MANAGEMENT UNIT

figure 3.6

SOURCES OF PCBs AND DIOXINS/FURANS

Occidental Chemical Corporation, Tacoma, Washington

07843-A6(131)GN-WA019 APR 15/2014

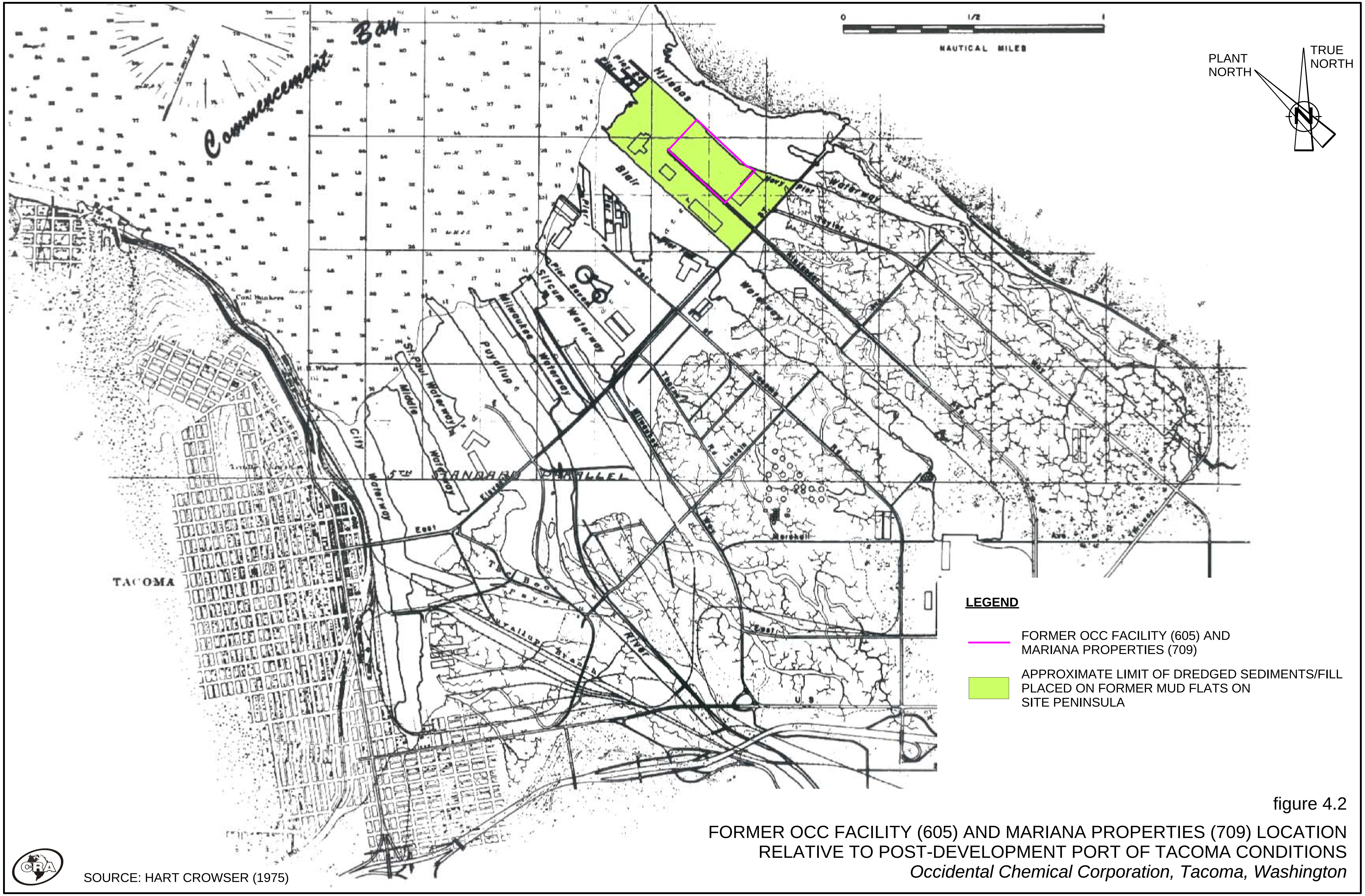


SOURCE: HART CROWSER (1975)

figure 4.1

FORMER OCC FACILITY (605) AND MARIANA PROPERTIES (709) LOCATION
RELATIVE TO PRE-DEVELOPMENT PORT OF TACOMA CONDITIONS
Occidental Chemical Corporation, Tacoma, Washington

07843-A6(131)GN-WA-HYD (N:\HEG\07843\Report131-CSM-Aug-2013\Figures\Figure 4.1.srf) JAN 17/2014



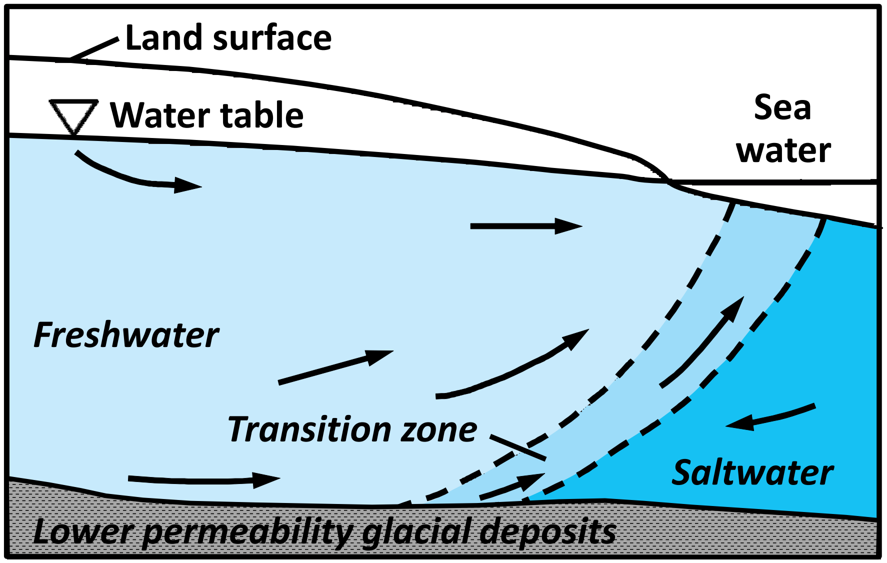
SOURCE: HART CROWSER (1975)

figure 4.2

FORMER OCC FACILITY (605) AND MARIANA PROPERTIES (709) LOCATION RELATIVE TO POST-DEVELOPMENT PORT OF TACOMA CONDITIONS

Occidental Chemical Corporation, Tacoma, Washington

A. GROUNDWATER DISCHARGE TO A SALT WATER BODY IN A RELATIVELY HOMOGENEOUS AQUIFER



B. EXAMPLE EFFECT OF HETEROGENEITIES ON GROUNDWATER DISCHARGE TO A SALT WATER BODY

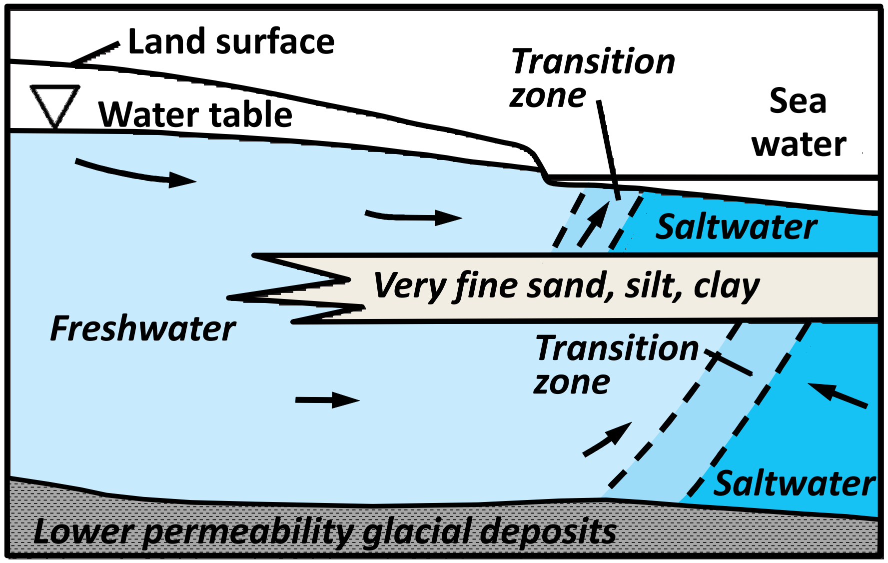


figure 4.3

GROUNDWATER DISCHARGE TO SALT WATER BODY
Occidental Chemical Corporation, Tacoma, Washington

SOURCE: BARLOW (2003)

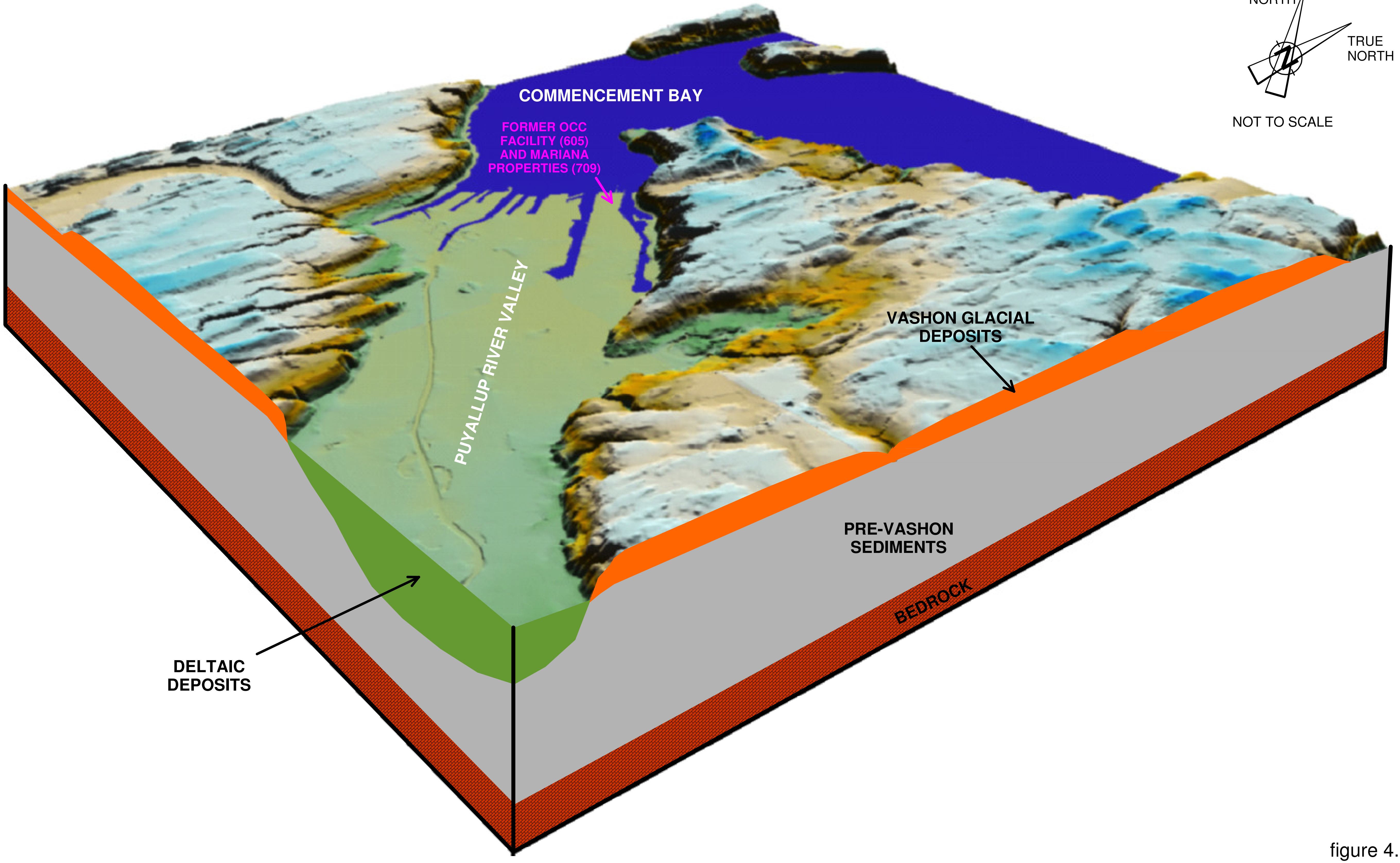
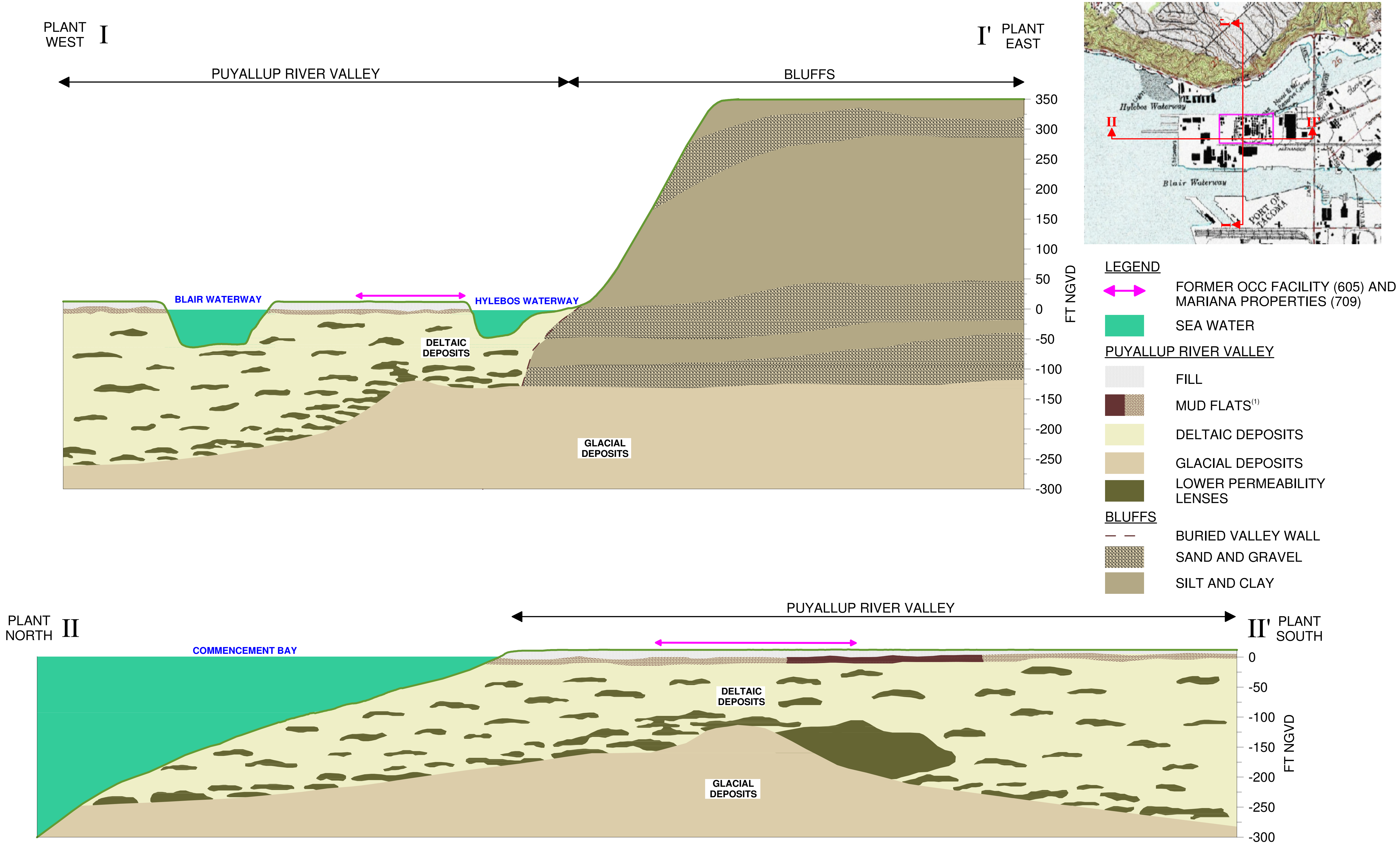


figure 4.4

REGIONAL GEOLOGY

Occidental Chemical Corporation, Tacoma, Washington

07843-A6(131)GN-WA-HYD (N:\HEG\07843\Report131-CSM-Aug-2013\Figures\Fig 4.4.srf) MAR 3/2014

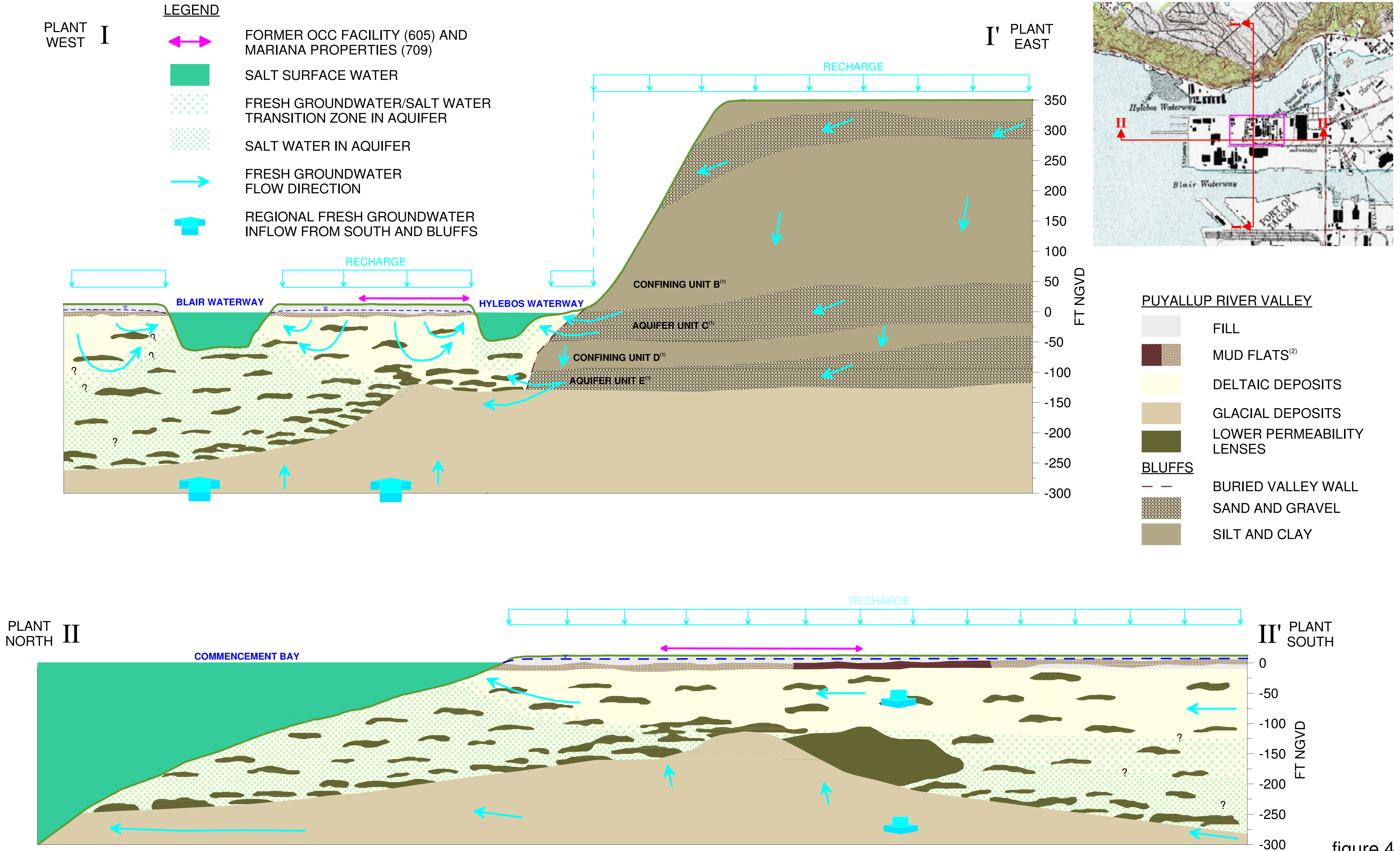


NOTES:
(1) DARK BROWN INDICATES WHERE MUD FLATS ARE OBSERVED TO PROVIDE HYDRAULIC SEPARATION BETWEEN THE FILL AND DELTAIC DEPOSITS; LIGHT BROWN INDICATES WHERE HYDRAULIC SEPARATION BY THE MUD FLATS IS NOT CONFIRMED

figure 4.5

CONCEPTUAL SITE GEOLOGIC CONDITIONS

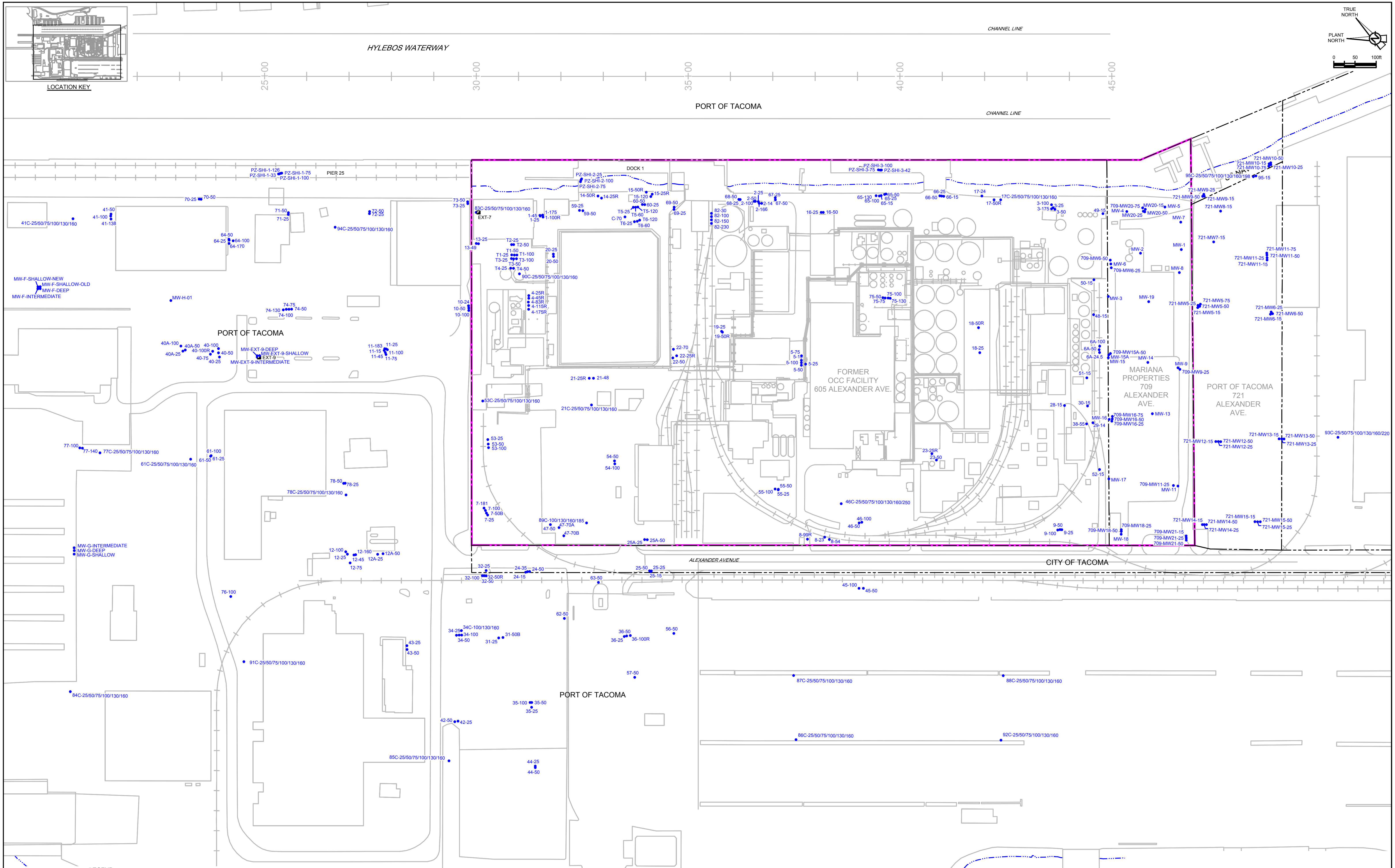
Occidental Chemical Corporation, Tacoma, Washington



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; LIGHT BROWN INDICATES WHERE HYDRAULIC SEPARATION BY THE MUD FLATS IS NOT CONFIRMED
? FRESH GROUNDWATER/SALT WATER TRANSITION ZONE AND SALT WATER DISTRIBUTION ASSUMED

figure 4.6

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



LEGEND

- PROPERTY LINE
- APPROXIMATE SHORELINE
- FORMER OCC FACILITY (605) AND MARIANA PROPERTIES (709)
- ● 44-50 MONITORING WELL LOCATION
- ■ EXT-7 EXTRACTION WELL

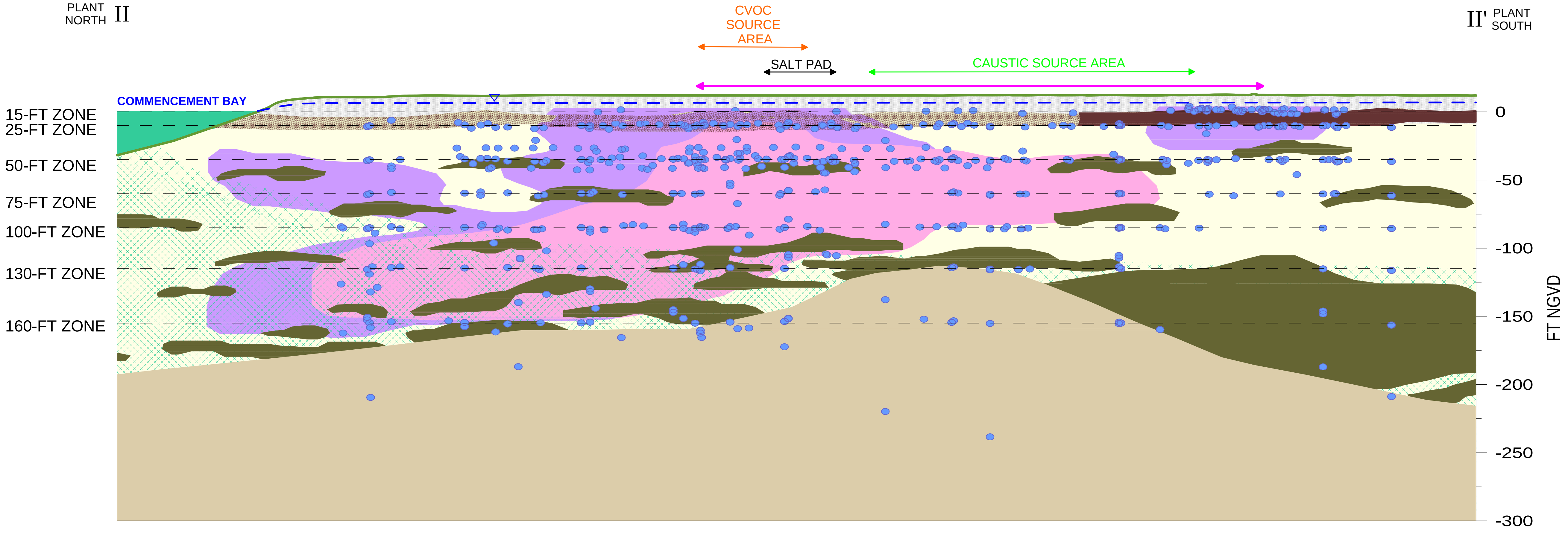
figure 5.1

MONITORING WELL LOCATIONS - PLAN VIEW

Occidental Chemical Corporation, Tacoma, Washington

CRA

07843-A6(131)GN-WA005 JAN 13/2014



LEGEND

↔ FORMER OCC FACILITY (605) AND MARIANA PROPERTIES (709)

▇ SALT SURFACE WATER

▨ FRESH GROUNDWATER/SALT WATER TRANSITION ZONE IN AQUIFER

▨ SALT WATER IN AQUIFER

▇ ANTHROPOGENIC DENSITY PLUME(1)

▇ TOTAL CVOC PLUME(1)

● WELL MID-SCREEN LOCATION

PUYALLUP RIVER VALLEY

▇ FILL

▇ MUD FLATS(2)

▇ DELTAIC DEPOSITS

▇ GLACIAL DEPOSITS

▇ LOWER PERMEABILITY LENSES

NOTE:

(1) THE ADP AND TOTAL CVOC PLUMES ARE SHOWN ALONG THE LOCATION OF CROSS-SECTION II-II' AS PRESENTED ON FIGURES 5.5 AND 5.8, RESPECTIVELY, AND ARE BASED ON THE INTERPOLATION OF SITE DATA.

(2) DARK BROWN INDICATES WHERE MUD FLATS ARE OBSERVED TO PROVIDE HYDRAULIC SEPARATION BETWEEN THE FILL AND DELTAIC DEPOSITS; LIGHT BROWN INDICATES WHERE HYDRAULIC SEPARATION BY THE MUD FLATS IS NOT CONFIRMED

figure 5.2

MONITORING WELL LOCATIONS - SECTION VIEW

Occidental Chemical Corporation, Tacoma, Washington

07843-A6(131)GN-WA-HYD (N:\HEG\07843\Report131-CSM-Aug-2013\Figures\Figure 5.2.srf) MAR 13/2014

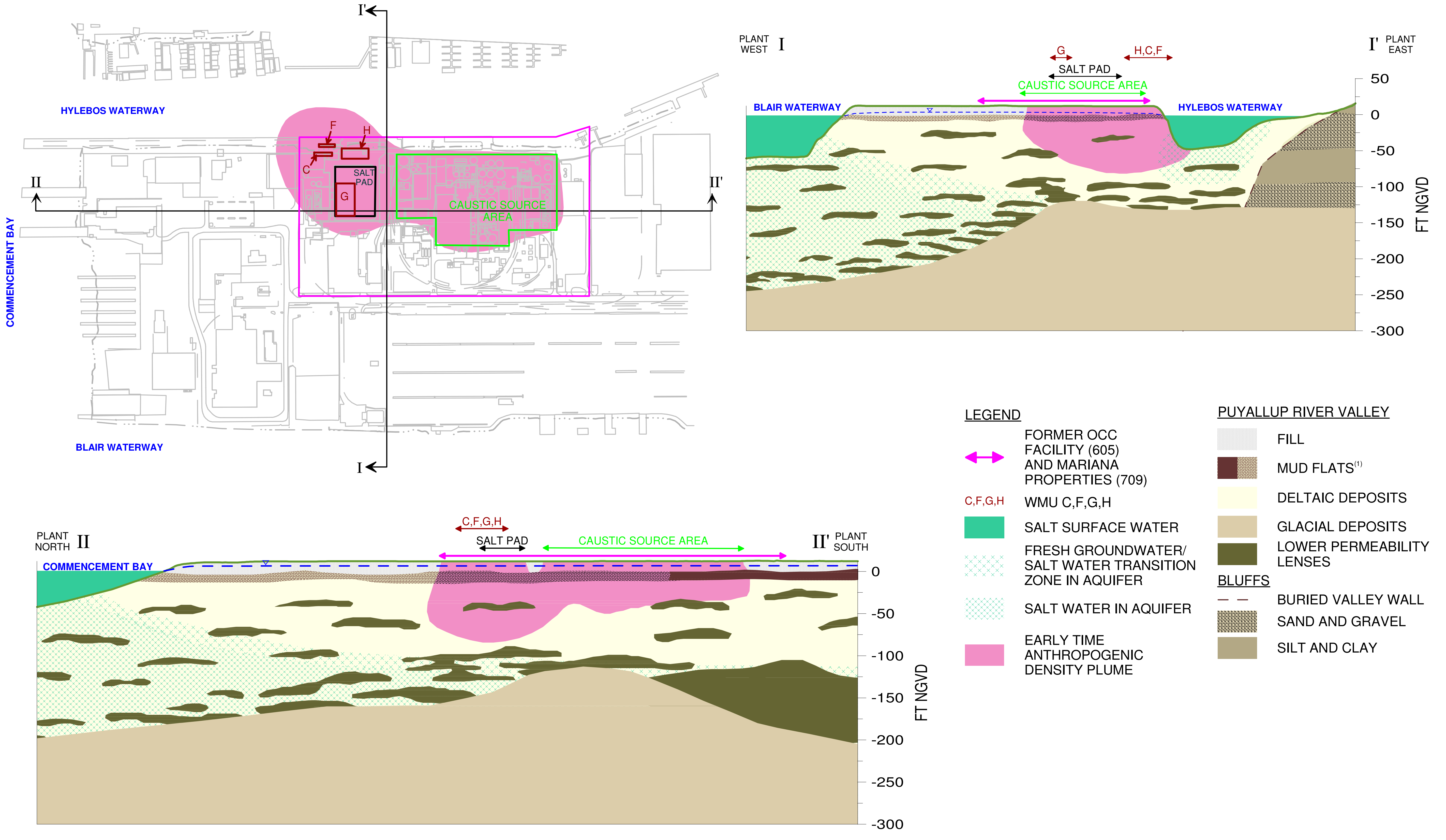


figure 5.3

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

EARLY TIME ANTHROPOGENIC DENSITY PLUME
Occidental Chemical Corporation, Tacoma, Washington

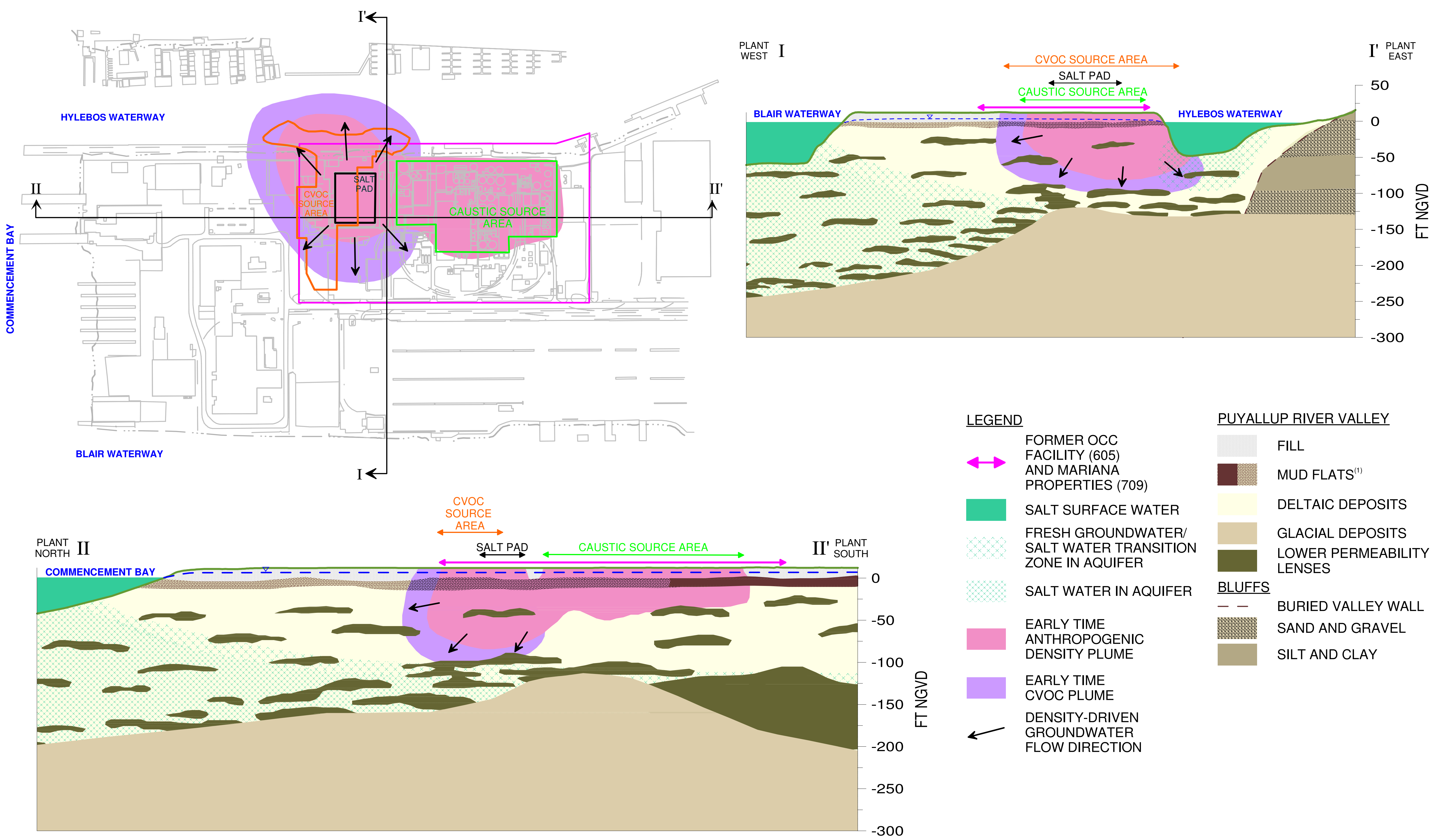


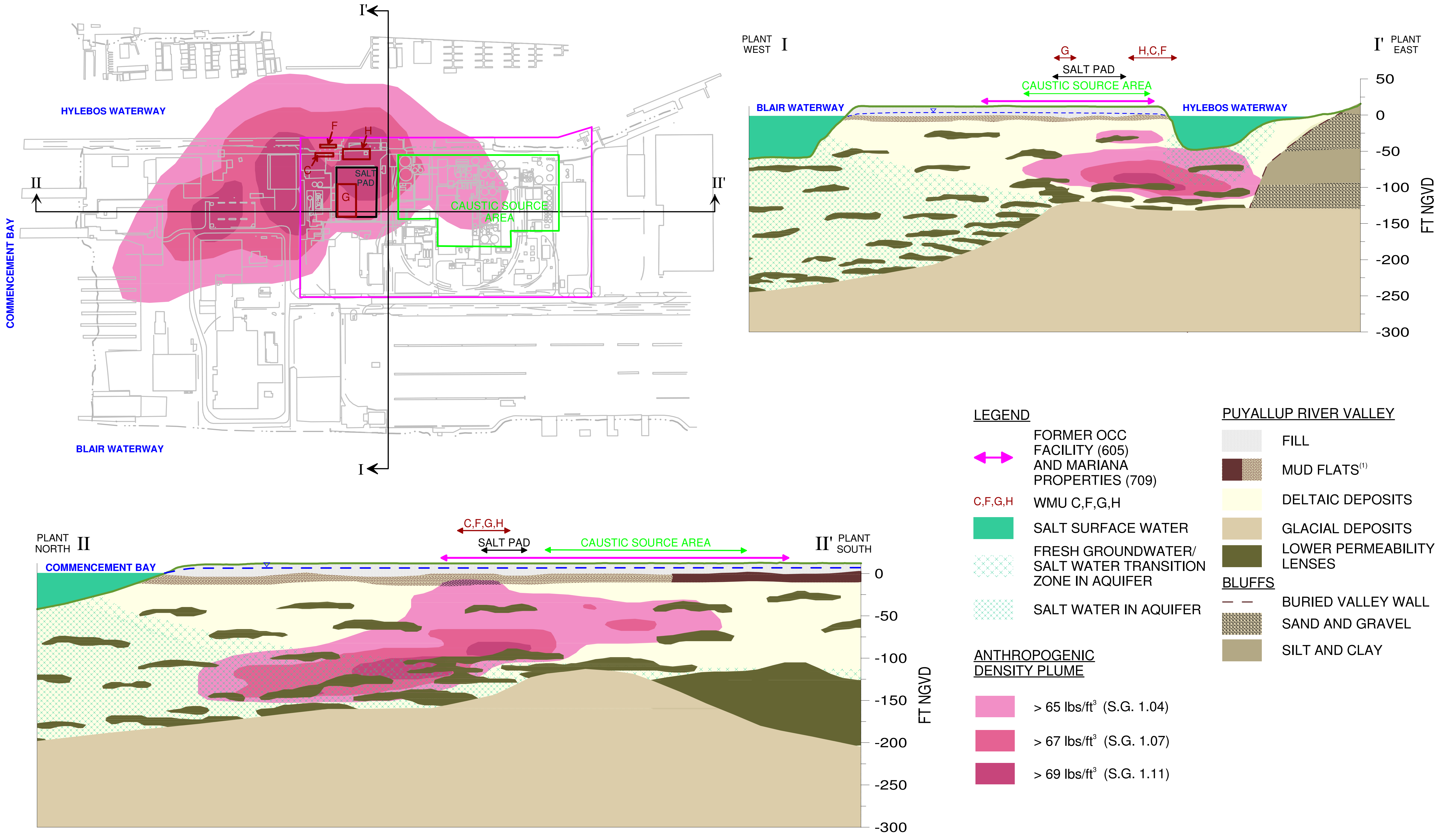
figure 5.4

EARLY TIME ANTHROPOGENIC DENSITY PLUME INFLUENCE ON TOTAL CVOC PLUME MIGRATION

Occidental Chemical Corporation, Tacoma, Washington

NOTES:

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



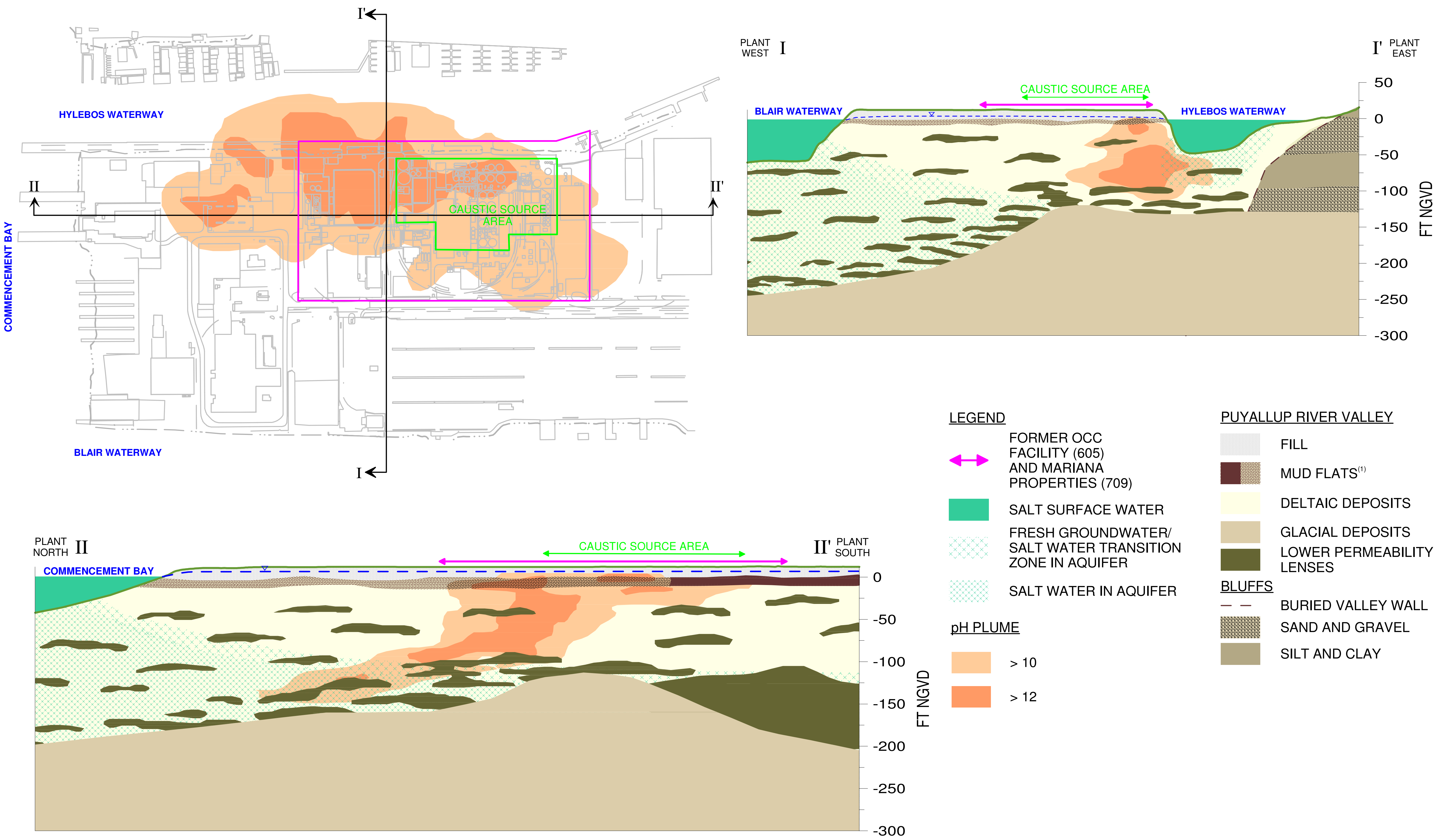
NOTES:
(1) DARK BROWN INDICATES WHERE MUD FLATS ARE OBSERVED TO PROVIDE HYDRAULIC SEPARATION BETWEEN THE FILL AND DELTAIC DEPOSITS; LIGHT BROWN INDICATES WHERE HYDRAULIC SEPARATION BY THE MUD FLATS IS NOT CONFIRMED

figure 5.5

CURRENT ANTHROPOGENIC DENSITY PLUME

Occidental Chemical Corporation, Tacoma, Washington

07843-A6(131)GN-WA-HYD (N:\HEG\07843\Report131-CSM-Aug-2013\Figures\Figure 5.5.srf) APR 11/2014

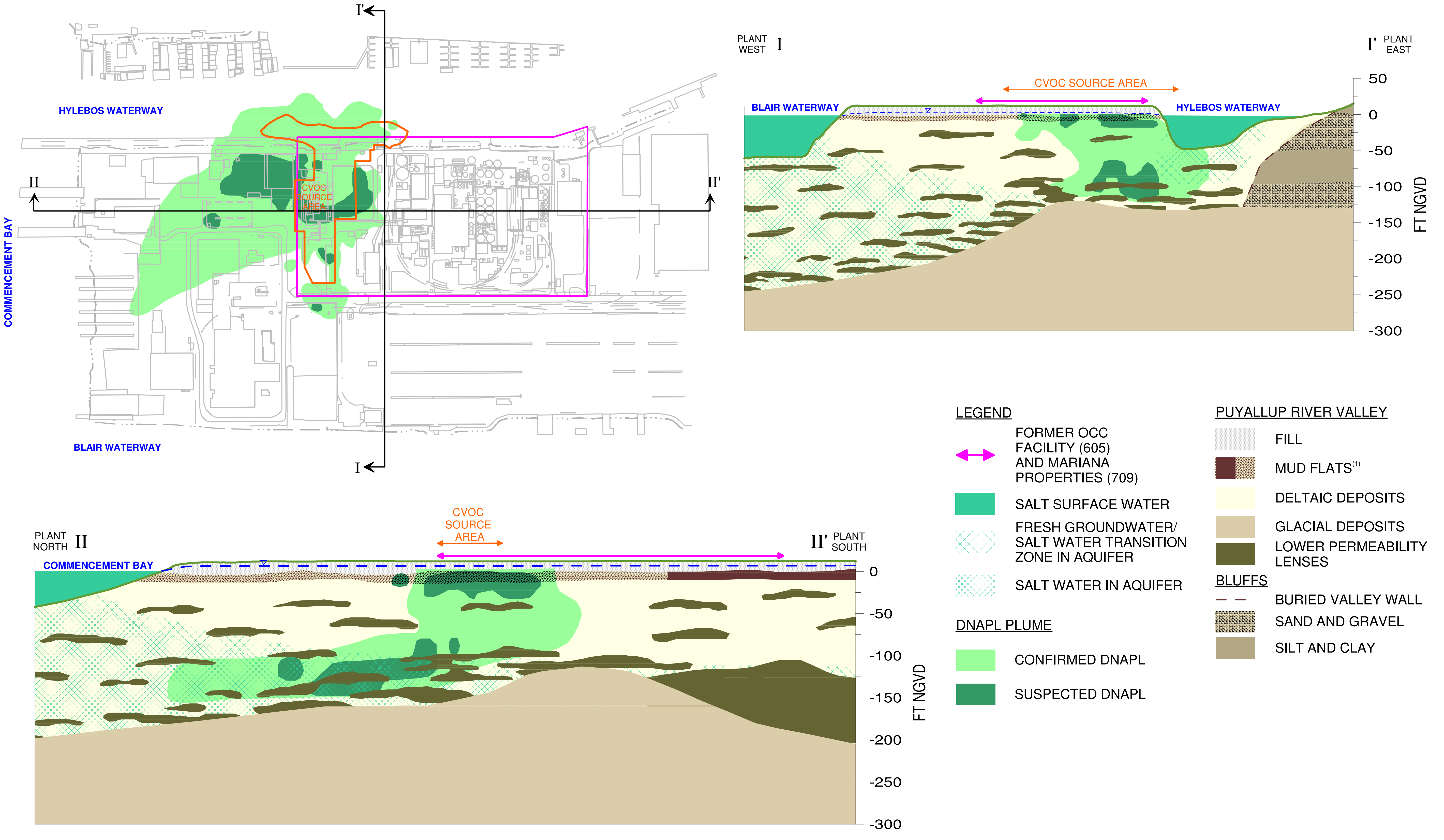


NOTES:
(1) DARK BROWN INDICATES WHERE MUD FLATS ARE OBSERVED TO PROVIDE HYDRAULIC SEPARATION BETWEEN THE FILL AND DELTAIC DEPOSITS; LIGHT BROWN INDICATES WHERE HYDRAULIC SEPARATION BY THE MUD FLATS IS NOT CONFIRMED

figure 5.6

pH PLUME

Occidental Chemical Corporation, Tacoma, Washington



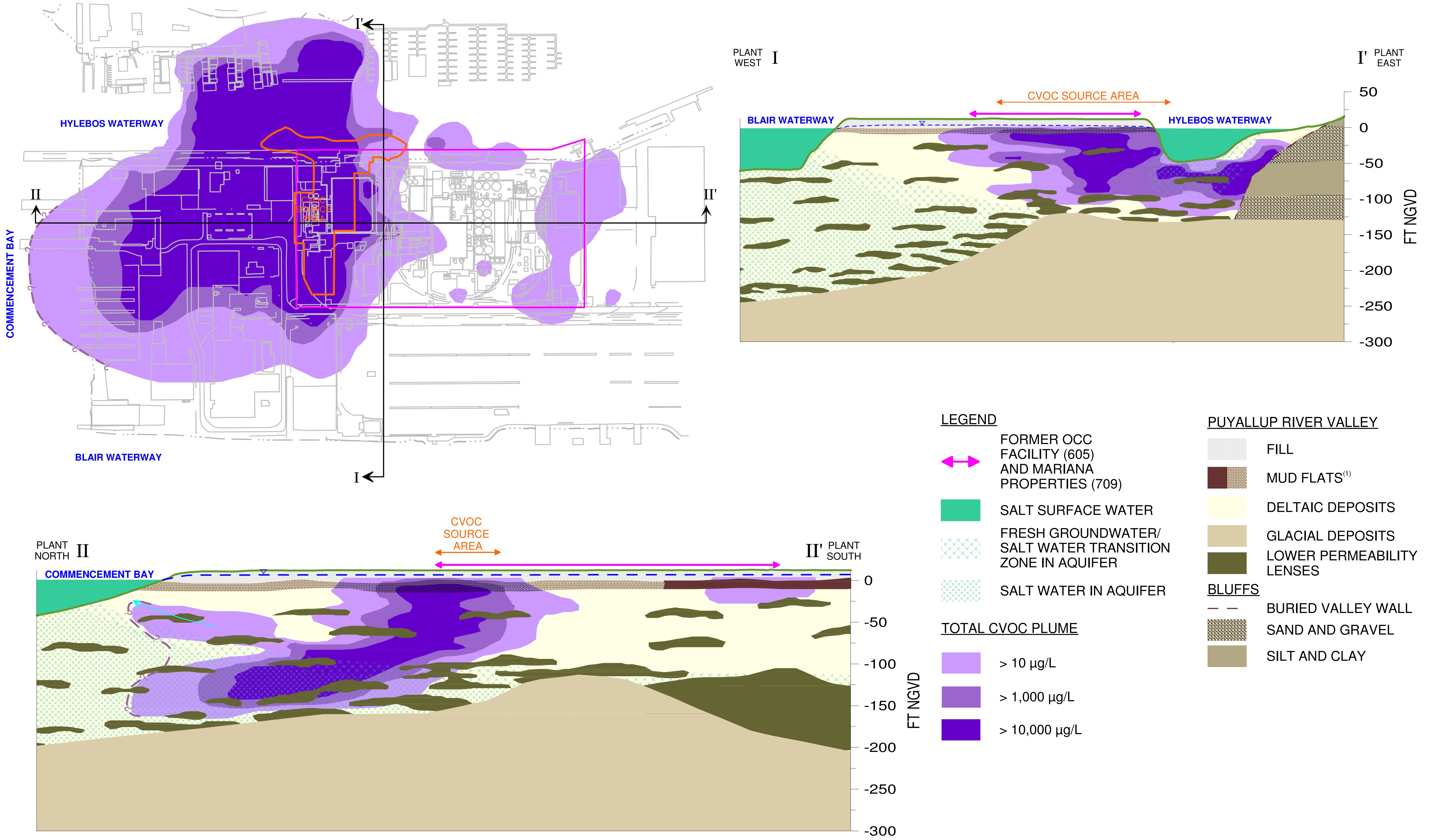
NOTES:
(1) DARK BROWN INDICATES WHERE MUD FLATS ARE OBSERVED TO PROVIDE HYDRAULIC SEPARATION BETWEEN THE FILL AND DELTAIC DEPOSITS; LIGHT BROWN INDICATES WHERE HYDRAULIC SEPARATION BY THE MUD FLATS IS NOT CONFIRMED

figure 5.7

DNAPL DISTRIBUTION

Occidental Chemical Corporation, Tacoma, Washington

07843-A6(131)GN-WA-HYD (N:\HEG\07843\Report131-CSM-Aug-2013\Figures\Figure 5.7.srf)APR 11/2014

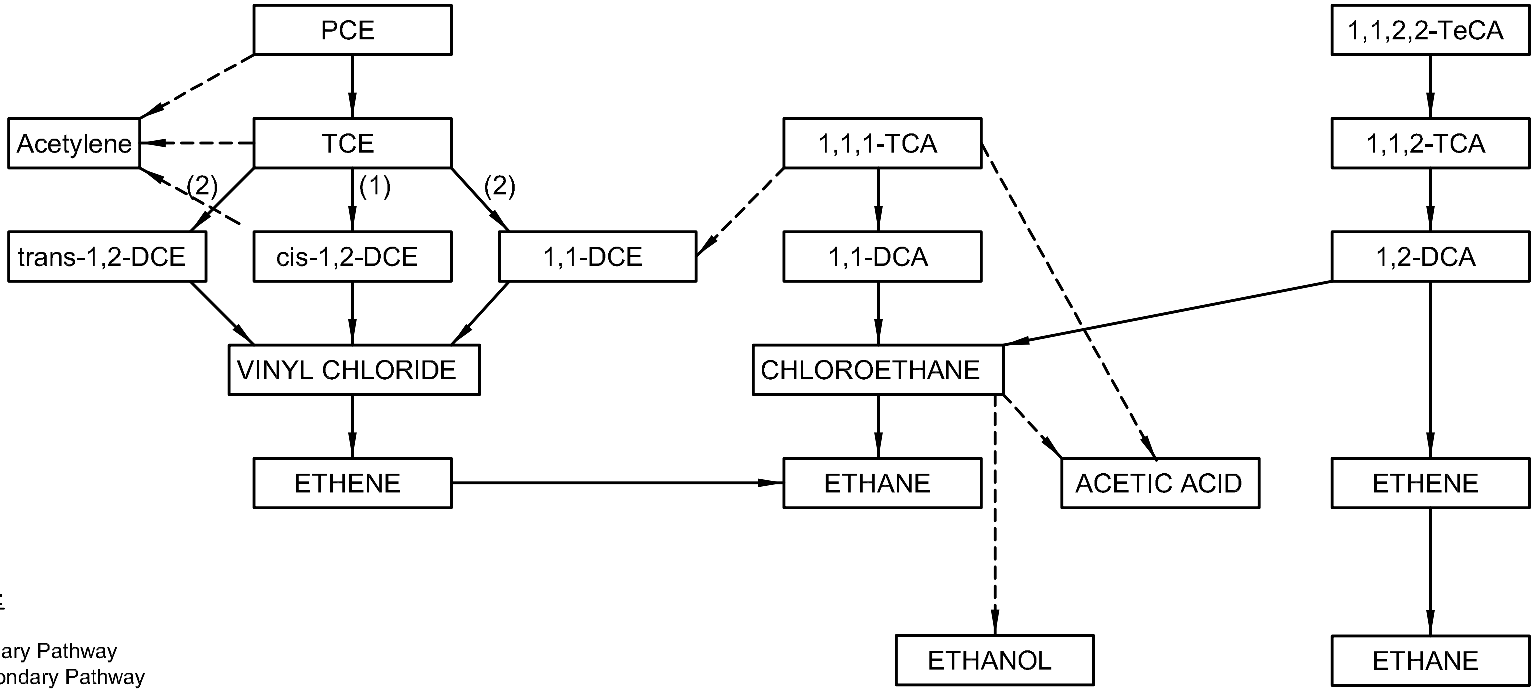


NOTES:
(1) DARK BROWN INDICATES WHERE MUD FLATS ARE OBSERVED TO PROVIDE HYDRAULIC SEPARATION BETWEEN THE FILL AND DELTAIC DEPOSITS; LIGHT BROWN INDICATES WHERE HYDRAULIC SEPARATION BY THE MUD FLATS IS NOT CONFIRMED

figure 5.8

TOTAL CVOC PLUME IN GROUNDWATER

Occidental Chemical Corporation, Tacoma, Washington



NOTES:

(1) Primary Pathway
(2) Secondary Pathway

The tendency for degradation along a given pathway is dependent on various factors, such as oxidation-reduction conditions, microbiological conditions, or nutrient availability.

Vinyl chloride, 1,2-DCA and Chloroethane may undergo aerobic mineralization to CO_2.

TCE, DCE, Vinyl choride and 1,1-DCA may undergo aerobic cometabolism to CO_2.

Source(s):
Weidemeier, T.H., H.S. Rifai, C.J. Newell and J.T. Wilson, 1999.
Natural Attenuation of Fuels and Chlorinated Solvents in the Subsurface, John Wiley & Sons, Inc., U.S.A.

U.S.EPA, September 1998, Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Ground Water, EPA/600/R-98/128.

LEGEND

⟶	BIOTIC PATHWAYS
⇢	ABIOTIC PATHWAYS

figure 5.9

OVERVIEW OF DEGRADATION PATHWAYS FOR CHLORINATED ALIPHATIC HYDROCARBONS

Occidental Chemical Corporation, Tacoma, Washington

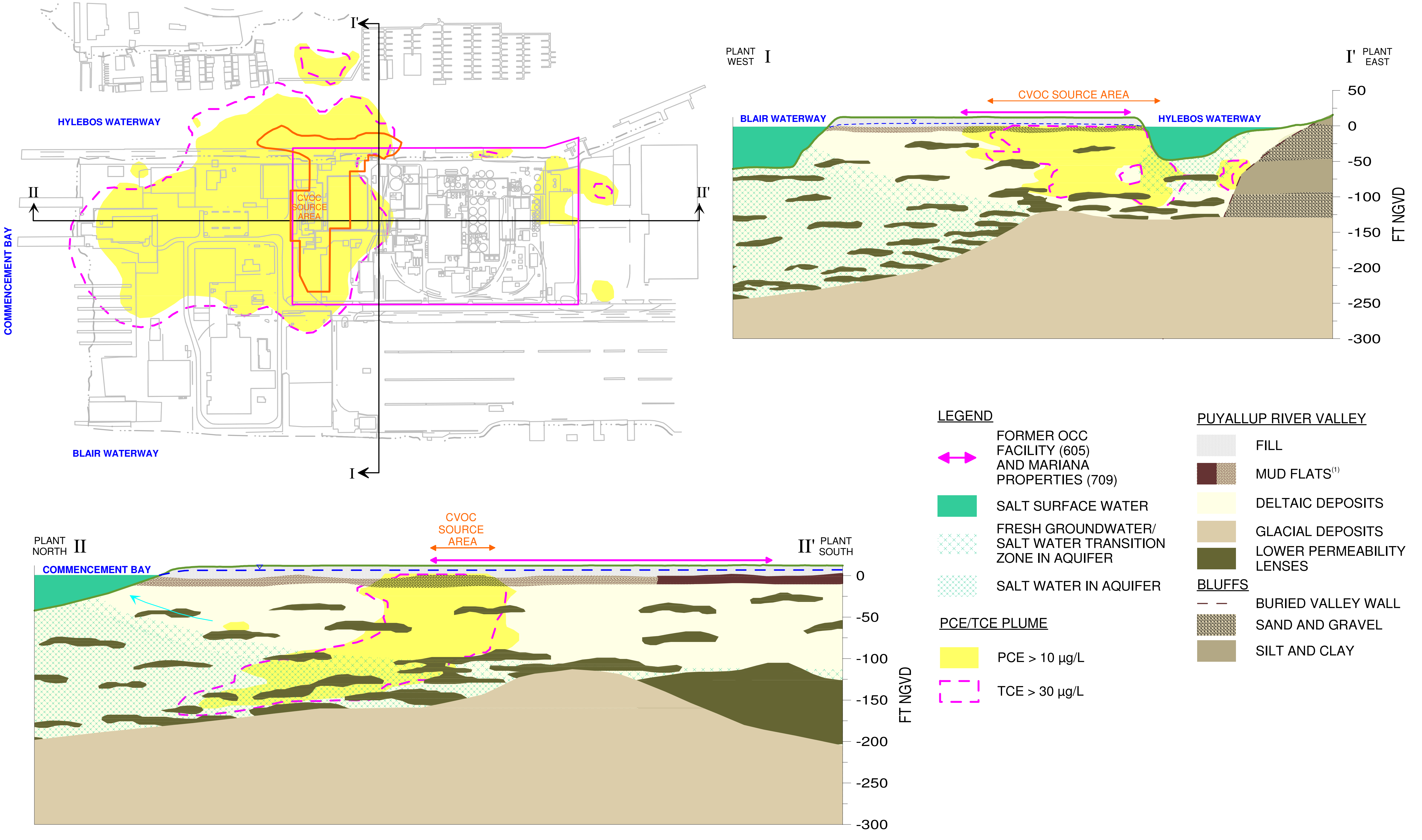
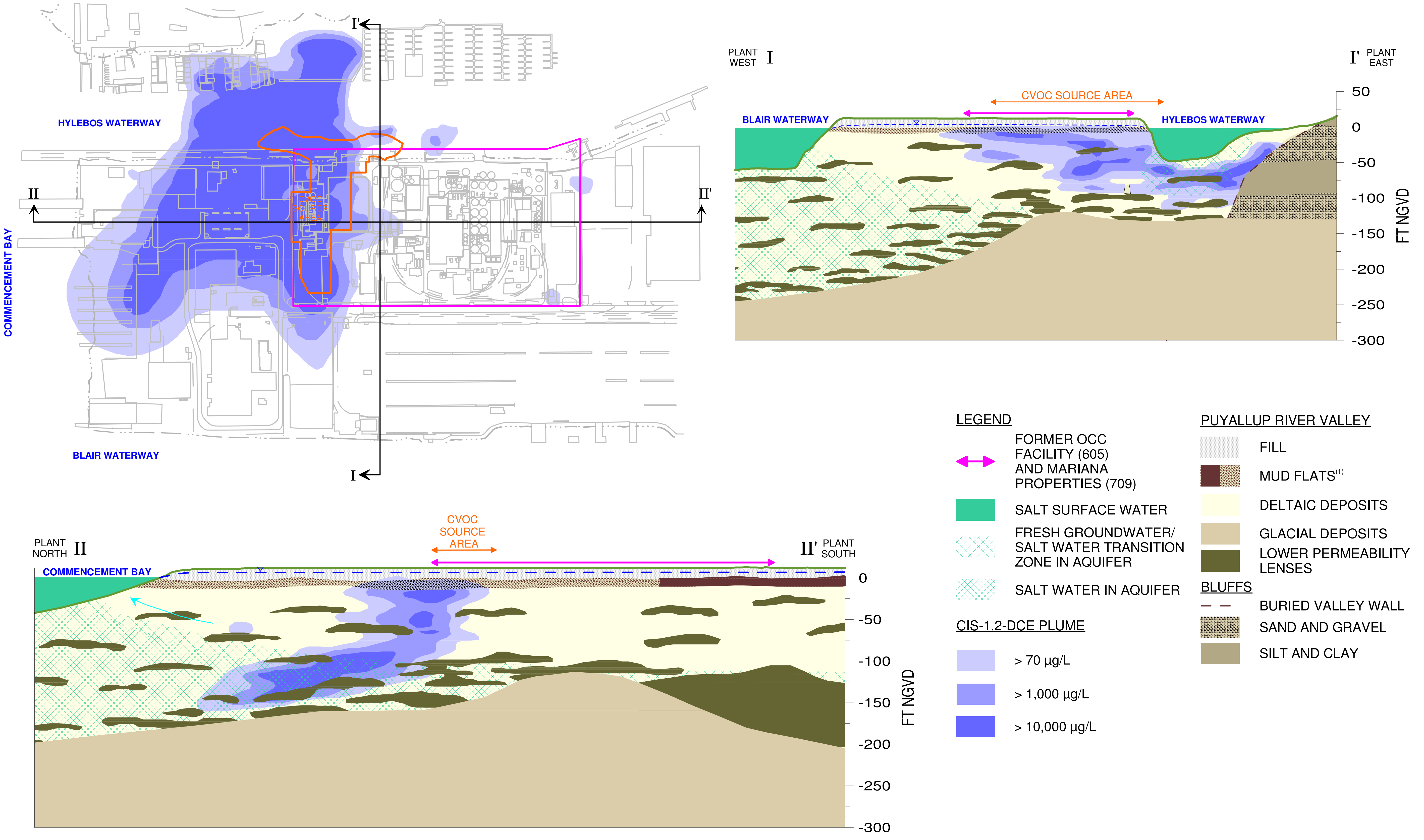


figure 5.10

TCE/PCE PLUME IN GROUNDWATER

Occidental Chemical Corporation, Tacoma, Washington

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



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

figure 5.11

CIS-1,2-DCE PLUME IN GROUNDWATER

Occidental Chemical Corporation, Tacoma, Washington

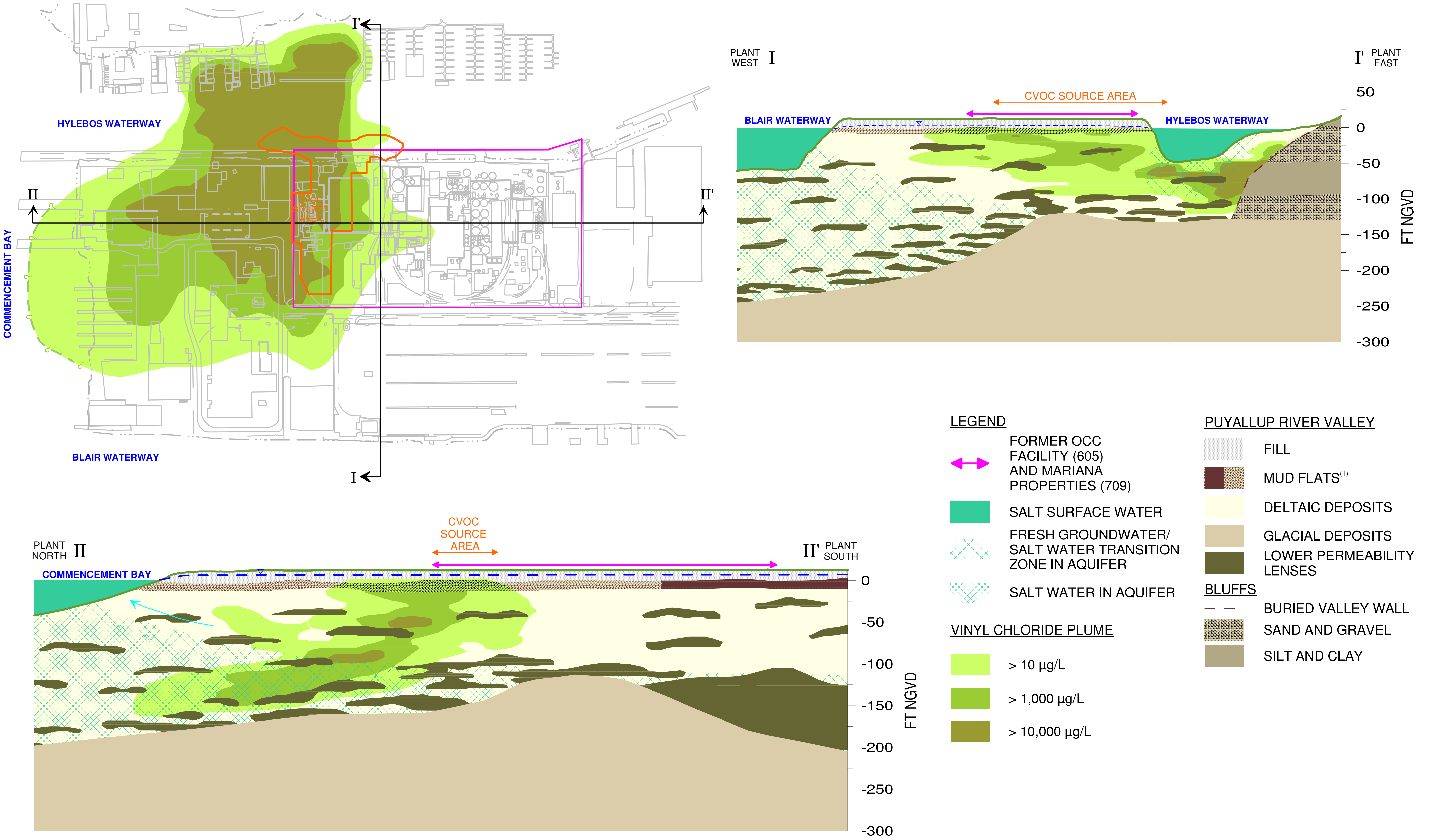


figure 5.12

VINYL CHLORIDE PLUME IN GROUNDWATER

Occidental Chemical Corporation, Tacoma, Washington

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

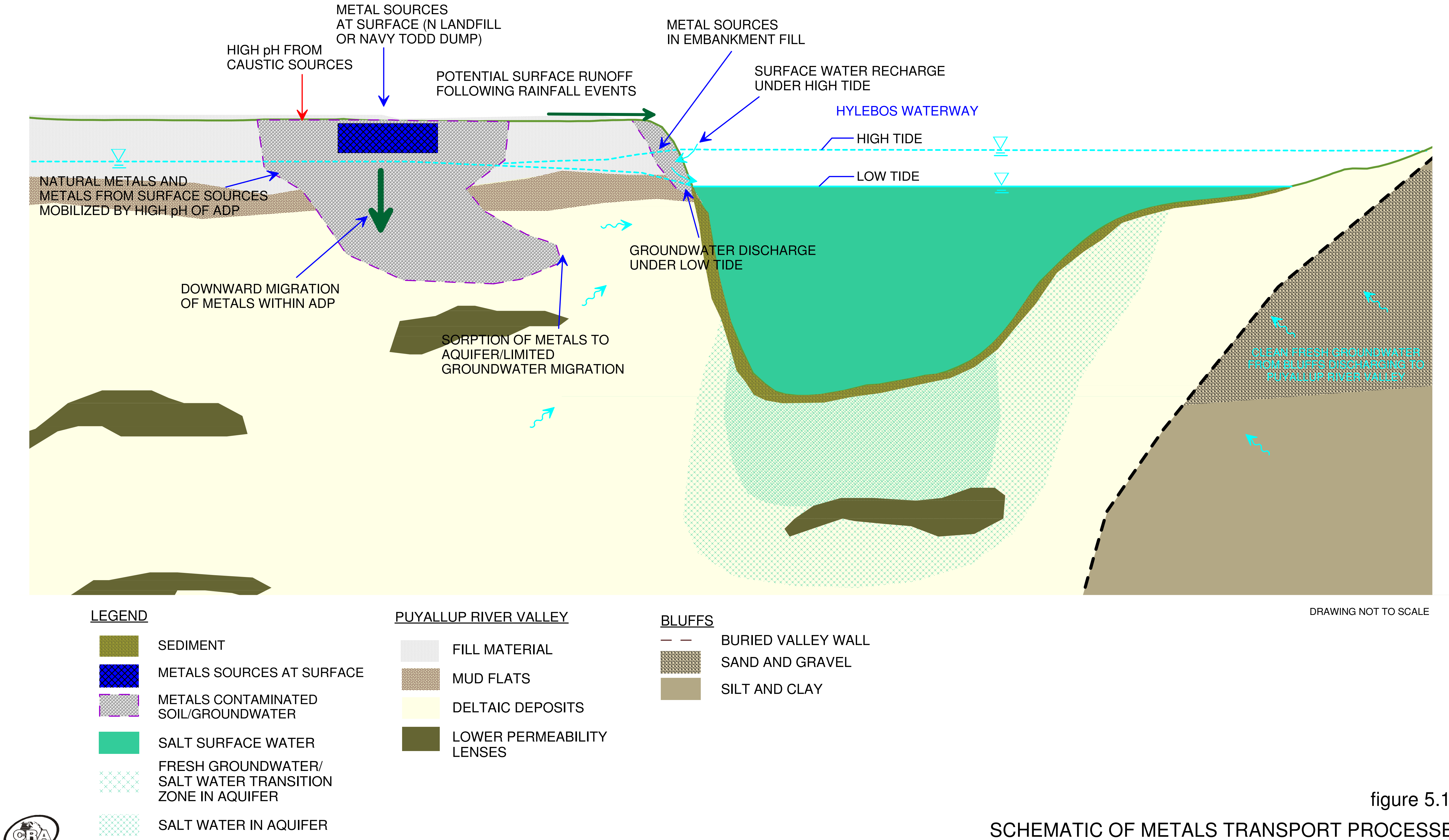
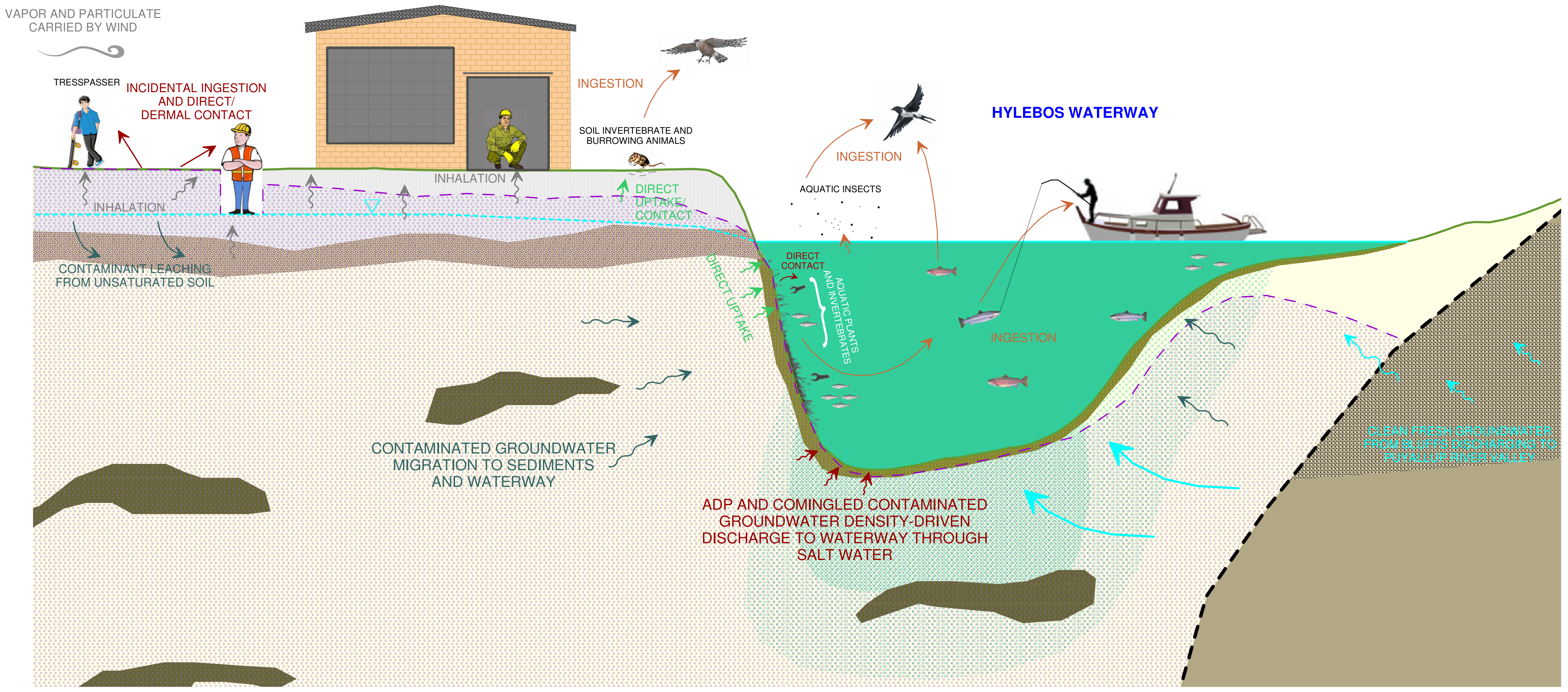


figure 5.13

SCHEMATIC OF METALS TRANSPORT PROCESSES

Occidental Chemical Corporation, Tacoma, Washington



DRAWING NOT TO SCALE

LEGEND

- ▨ SEDIMENT
- ▨ CONTAMINATED SOIL/SEDIMENTS/ GROUNDWATER
- 🟩 SALT SURFACE WATER
- ▨ SALT WATER IN AQUIFER
- ▨ FRESH/SALT WATER TRANSITION ZONE IN AQUIFER

PUYALLUP RIVER VALLEY

- ▨ FILL MATERIAL
- ▨ MUD FLATS
- ▨ DELTAIC DEPOSITS
- ▨ LOWER PERMEABILITY LENSES

BLUFFS

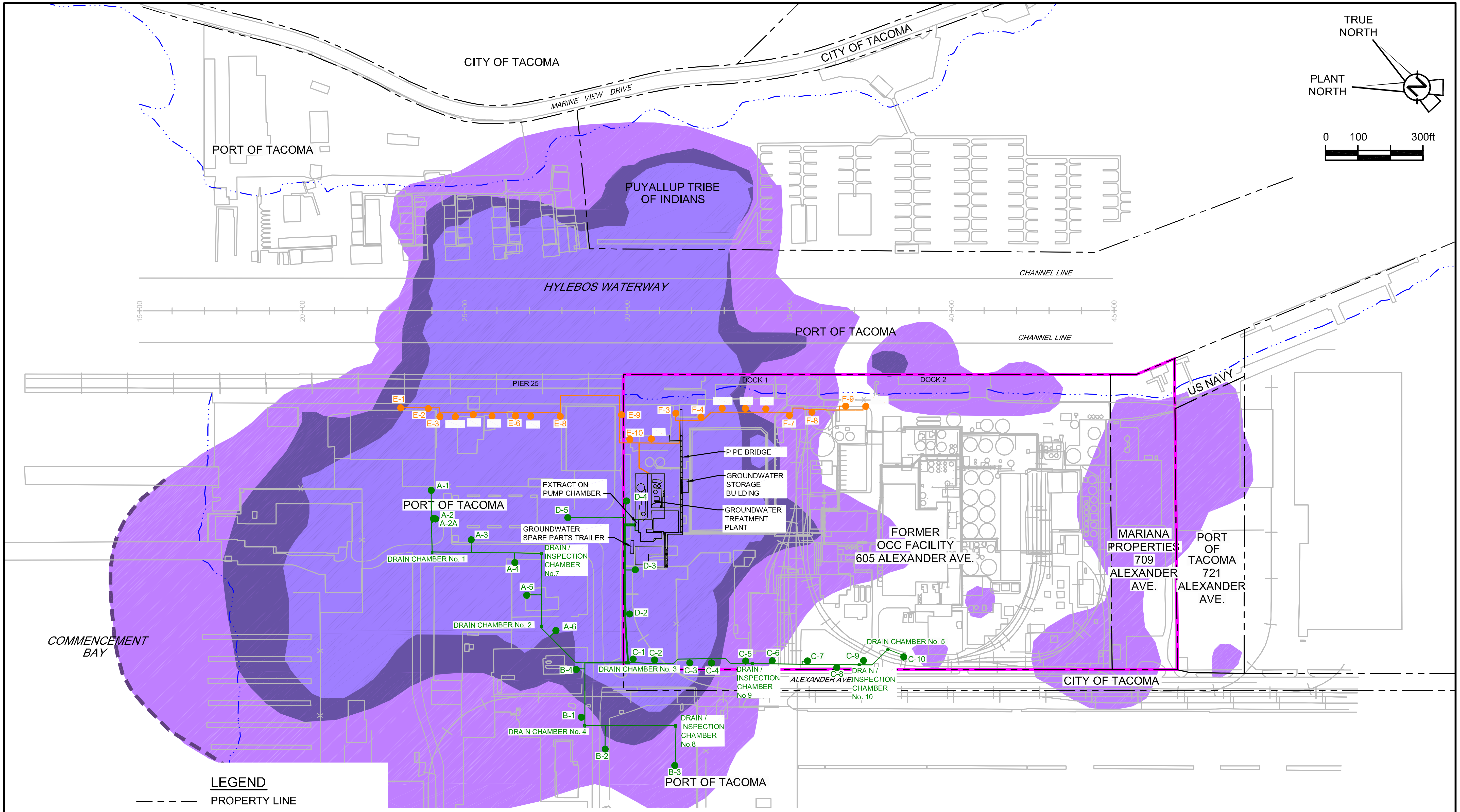
- – – BURIED VALLEY WALL
- ▨ SAND AND GRAVEL
- ▨ SILT AND CLAY

figure 6.1

SCHEMATIC OF EXPOSURE PATHWAYS AND RECEPTORS

Occidental Chemical Corporation, Tacoma, Washington

07843-A6(131)GN-WA-HYD (N:\HEG\07843\Report131-CSM-Aug-2013\Figures\Figure 6.1.srf) APR 11/2014



LEGEND

— — —	PROPERTY LINE
—·· —	APPROXIMATE SHORELINE
━━━	FORMER OCC FACILITY (605) AND MARIANA PROPERTIES (709)
———	EXTRACTION SYSTEM PIPE/CONDUIT
———	INJECTION SYSTEM PIPE / CONDUIT
DRAIN CHAMBER No. 1 ☐	EXTRACTION SYSTEM DRAIN CHAMBER
A-3 ●	EXTRACTION SYSTEM VAULT / WELL
E-3 ●	INJECTION SYSTEM VAULT / WELL

TOTAL CVOC PLUME

▨	>10 μg/L
▨	>1,000 μg/L
▨	>10,000 μg/L

figure 7.1

EXISTING GROUNDWATER EXTRACTION AND TREATMENT SYSTEMS - PLAN VIEW

Occidental Chemical Corporation, Tacoma, Washington

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Appendix A

Summary of Regional Geologic Conditions

Table of Contents

List of Figures
(Following Text)

Section 1.0 Introduction

This Appendix presents an overview of the regional geologic conditions based on studies completed for the Puyallup River Valley and Bluffs in the Site vicinity. The regional geologic conditions form the basis for the generalized geologic framework for the Puyallup River Valley and Bluffs near the Site, and the conceptual geologic conditions in the Site vicinity, applied in the Conceptual Site Model (CSM).

Section 2.0 Summary of Regional Geologic Conditions

The regional geologic framework of the Puyallup River Valley consists of nearly 2,000 feet 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 4.4 of the main report shows a conceptual model of the regional geology where the channel scoured into the pre-Vashon sediments is in-filled initially 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.

Morgan and Jones (1996) developed a generalized regional geologic framework for the Puget Sound Lowlands that is reproduced on Figure A.1. This framework is directly applicable to the Puyallup River Valley and Bluffs in the Site vicinity, and is consistent with the conceptual geologic model shown on Figure 4.4 of the main report. A major stream valley is depicted on the west side of the section consisting of alluvial deposits, similar to the Puyallup River Valley. The Bluffs rise steeply to the east of the stream valley and consist of a sequence of older glacial deposits that were scoured during the last glacial advance.

Three regional studies of geologic/hydrogeologic conditions within the Puyallup River Valley and Bluffs key to the Site are:

- *Geology of the Port of Tacoma* (Hart Crowser & Associates, Inc. [Hart Crowser], 1975)
- *Hydrogeologic Analysis of the Federal Way Area* (Robinson & Noble, Inc. [Robinson & Noble], 1992)
- *Hydrogeologic Framework, Groundwater Movement, and Water Budget in the Chambers-Clover Creek Watershed and Vicinity, Pierce County, Washington* (Savoca et al., 2010)

Cross-Sections I-I', II-II', and A-A' developed by Hart Crowser (1975) pass through the Site peninsula, and are reproduced on Figures A.2, A.3, and A.4, respectively. The key aspects shown on these cross-sections are:

- Fill was placed on the tidal mud flats to develop the waterways and form the Port of Tacoma peninsulas, as shown on Figure A.4
- Deltaic deposits consisting of variable layers of sand and silt exist within the Puyallup River Valley
- Glacial deposits form the east and west walls of the Puyallup River Valley on Figure A.2, and appear on the west side of the Puyallup River Valley on Figure A.3

The Hart Crowser (1975) cross-sections are consistent with the conceptual model of regional geology shown on Figure 4.4 of the main report and the generalized regional geologic framework of Morgan and Jones (1996) shown on Figure A.1.

Robinson & Noble (1992) conducted a hydrogeologic study of the Bluffs in the Federal Way area east of the Site. Robinson & Noble (1992) developed cross-sections through the Bluffs east of the Site, as presented on Figure A.5. Cross-Section B-B' approaches the Site, and is reproduced on Figure A.6. The Bluffs are shown to be heterogeneous, consisting of a sequence of glacial and interglacial sedimentary units with widespread presence of glacial till, outwash sands, and gravels. Consistent with Morgan and Jones (1996) and Hart Crowser (1975), Cross-Section B-B' shows a buried valley wall extending downward from the Bluffs where the pre-Vashon sediments within the Puyallup River Valley were scoured.

Robinson & Noble (1992) identified a series of aquifers within their Layer 4 (see Figure A.6) immediately east of the Site consisting of highly permeable soils, which they referred to as the North Shore Aquifers. Figure A.7 shows the location of the North Shore Aquifers in plan view. As shown on Figure A.6, the North Shore Aquifers are interpreted to extend to the upper portion of the Puyallup River Valley in their Layer 4. Robinson & Noble (1992) indicated that the North Shore Aquifers may consist of upper and lower zones.

Site borings advanced along the eastern shoreline of the Hylebos Waterway extended into the buried valley wall extending down from the Bluffs. These borings encountered permeable sands and gravels, similar to glacial outwash deposits, at upper and lower depths separated by lower permeability silts and clays. These observations are consistent with the presence of the North Shore Aquifers interpreted by Robinson & Noble (1992).

Savoca et al. (2010) developed hydrogeologic cross-sections through the Chambers-Clover Creek Watershed and vicinity in Pierce County, approximately 8 to 10 miles south of the Site. The northern portion of the Savoca et al. (2010) study area includes the Puyallup River Valley and much of the POT area. The locations of cross-section in the general vicinity of the Site are presented on Figure A.8. The eastern limit of Cross-Sections E-E' and F-F' extend into the Puyallup River Valley south of the Site, and are reproduced on Figure A.9. Cross-Section E-E' ends just west of the Site and Cross-Section F-F' ends approximately 4 miles south of the Site.

On Cross-Section F-F', Savoca et al. (2010) interpret a sequence of aquifers and aquitards under the Bluffs (i.e., Aquifer Unit C/Confining Unit D/Aquifer Unit E) consistent with Robinson & Noble (1992). However, Savoca et al. (2010) continue these units beneath the Puyallup River Valley, which is not consistent with the glacially scoured channel of Morgan and Jones (1996) and Hart Crowser (1975). The characteristics of the deltaic deposits observed in the Site borings suggest that it may be more likely that the sequence of aquifers and aquitards within the pre-Vashon sediments under Bluffs do not extend into the Puyallup River Valley, as annotated on Figure A.9.

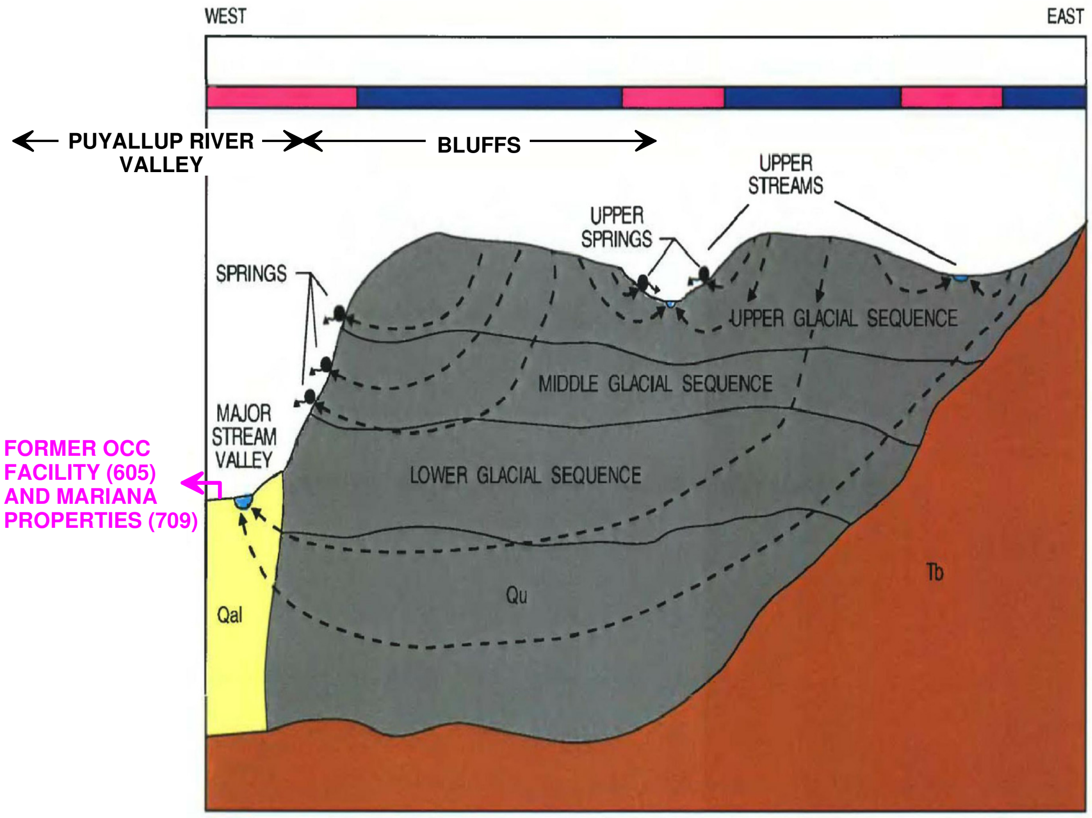
Section 3.0 References

Hart-Crowser and Associates, Inc., 1975. Geology of the Port of Tacoma, May.

Morgan, D.S. and J.L. Jones, 1996. Numerical Model Analysis of the Effects of Ground-Water Withdrawals on Discharge to Streams and Springs in Small Basins Typical of the Puget Sound Lowland, Washington, USGS Open-File Report 95-470.

Robinson & Noble, Inc., 1992. Hydrogeologic Analysis of the Federal Way Area, Washington, December.

Savoca, M.E., W.B. Welch, K.H. Johnson, R.C. Lane, B.G. Clothier, and E.T. Fasser, 2010. Hydrogeologic Framework, Groundwater Movement, and Water Budget in the Chambers-Clover Creek Watershed and Vicinity, Pierce County, Washington, U.S. Geological Survey Scientific Investigations Report 2010–5055, 46 p.



NOT DRAWN TO SCALE

AGE ↓
TIME ↑

	SYMBOL	GEOLOGIC LAYER	HYDROGEOLOGIC CHARACTERISTICS
	Qal	ALLUVIUM	AQUIFERS AND CONFINING LAYERS
UPPER GLACIAL SEQUENCE (DETAIL)	Qr	RECESSIONAL OUTWASH	AQUIFER
	Qt	TILL	CONFINING LAYER
	Qa	ADVANCE OUTWASH	AQUIFER
	Qf	INTERGLACIAL SEDIMENTS	CONFINING LAYER
	Qr, Qt, Qa, Qf	MIDDLE GLACIAL SEQUENCE	AQUIFERS AND CONFINING LAYERS
	Qr, Qt, Qa, Qf	LOWER GLACIAL SEQUENCE	AQUIFERS AND CONFINING LAYERS
	Qu	UNDIFFERENTIATED DEPOSITS	AQUIFERS AND CONFINING LAYERS
	Tb	BEDROCK	IMPERMEABLE BOUNDARY

EXPLANATION

🟥 GROUND-WATER DISCHARGE AREA
🟦 GROUND-WATER RECHARGE AREA
↖ - - GROUND-WATER FLOW DIRECTION

SOURCE: MORGAN, D.S. AND J.L. JONES, 1996. NUMERICAL MODEL ANALYSIS OF THE EFFECTS OF GROUND-WATER WITHDRAWLS ON DISCHARGE TO STREAMS AND SPRINGS IN SMALL BASINS TYPICAL OF THE PUGET SOUND LOWLAND, WASHINGTON, USGS OPEN-FILE REPORT 95-470.

figure A.1

GENERALIZED PUGET SOUND LOWLANDS
REGIONAL GEOLOGIC CONDITIONS
Occidental Chemical Corporation, Tacoma, Washington

07843-A6(131)GN-WA-HYD (N:\HEG\07843\Report131-CSM-Aug-2013\Figures\Figure A.1.srf) JAN 17/2014

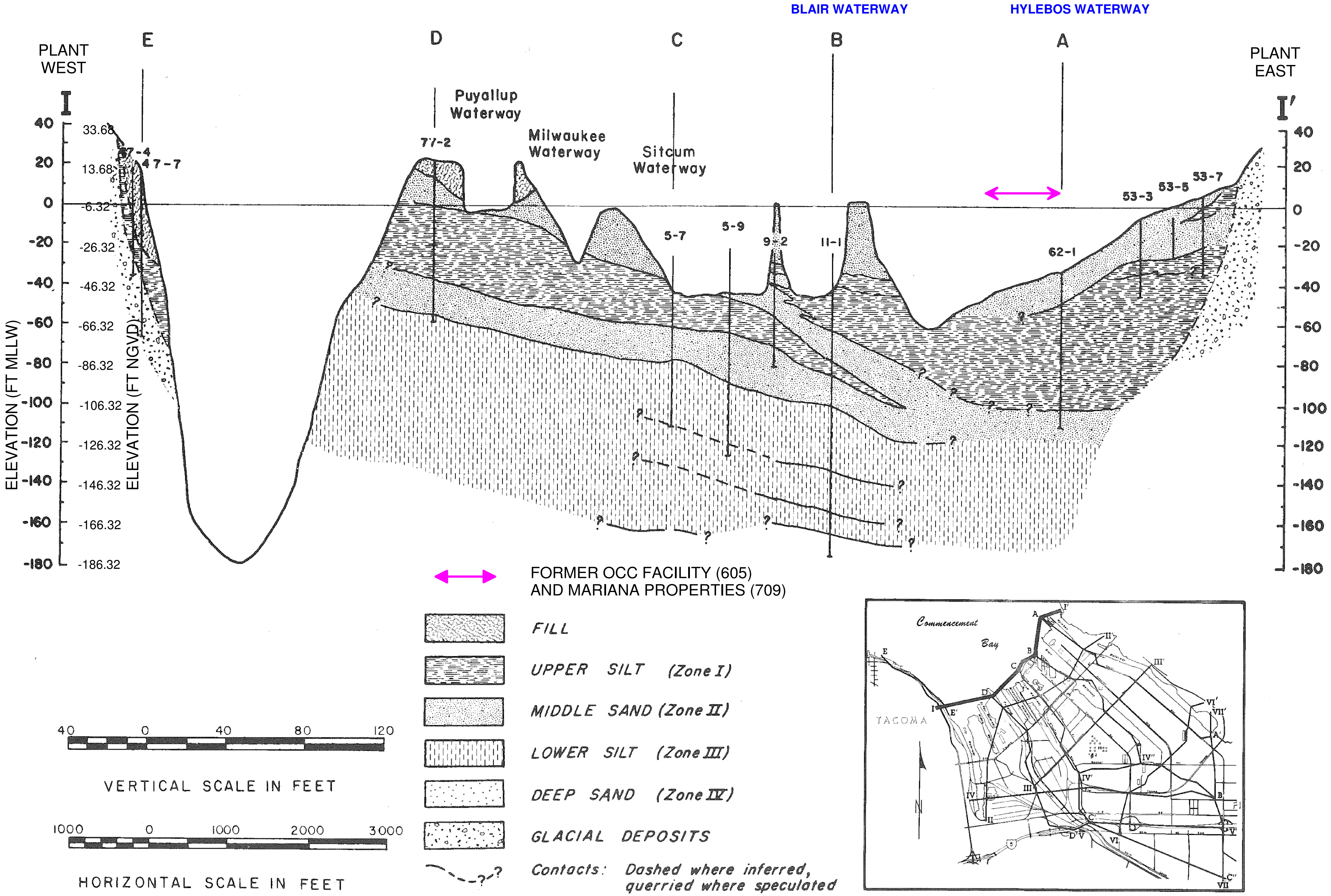


figure A.2

HART CROWSER (1975) CROSS-SECTION I-I'

Occidental Chemical Corporation, Tacoma, Washington

SOURCE: HART CROWSER (1975)

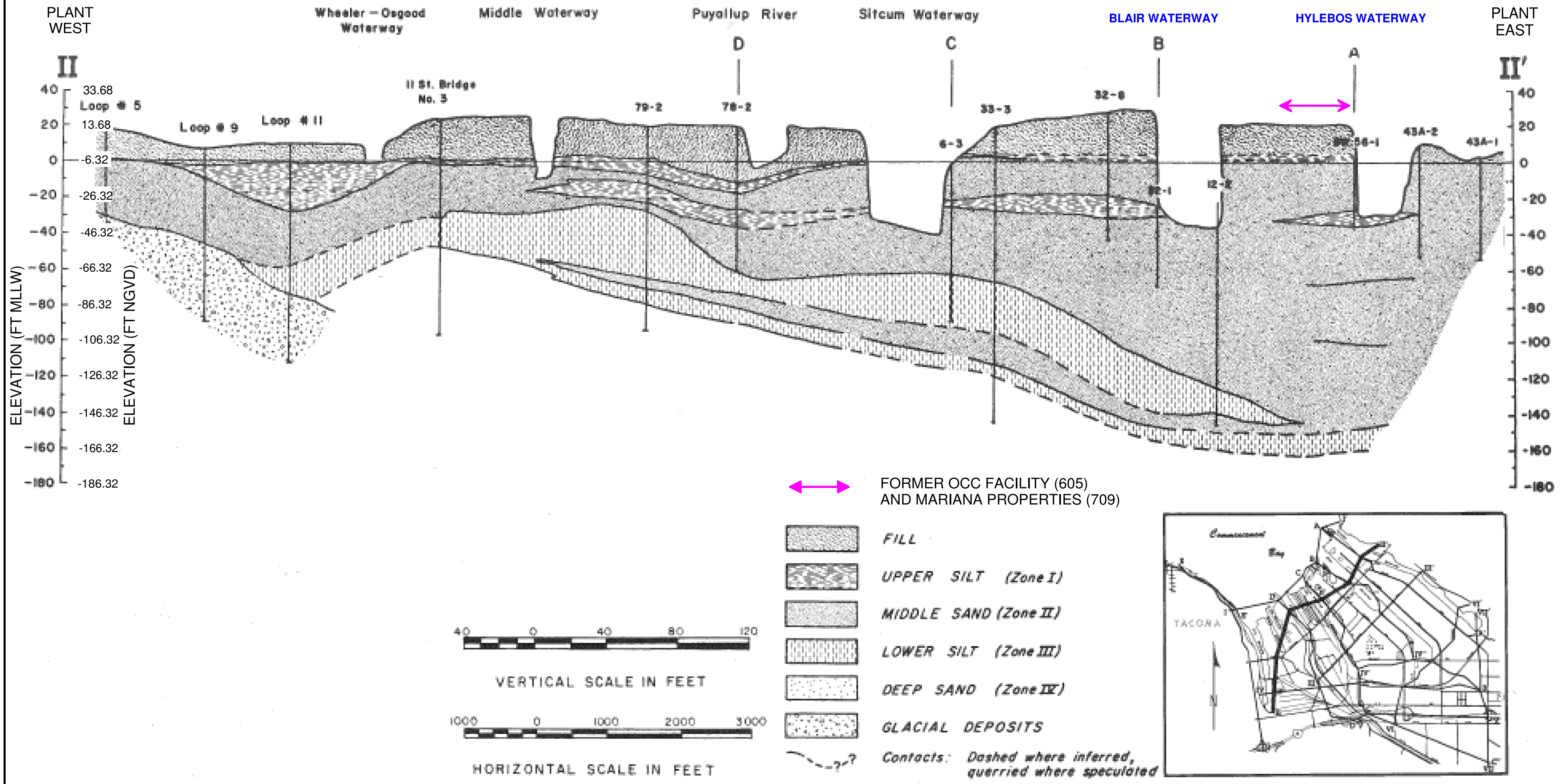


figure A.3

HART CROWSER (1975) CROSS-SECTION II-II'
Occidental Chemical Corporation, Tacoma, Washington

SOURCE: HART CROWSER (1975)

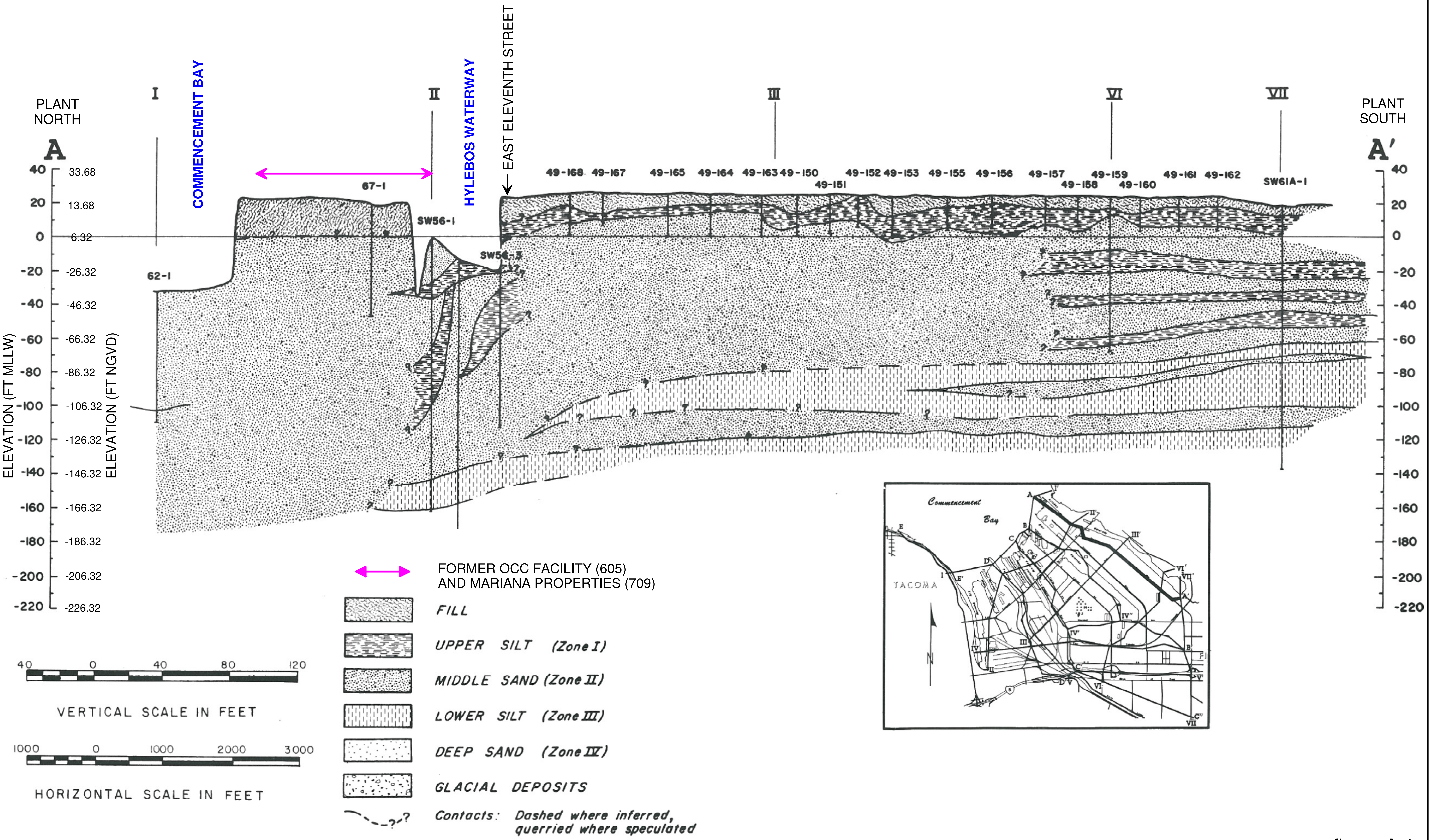


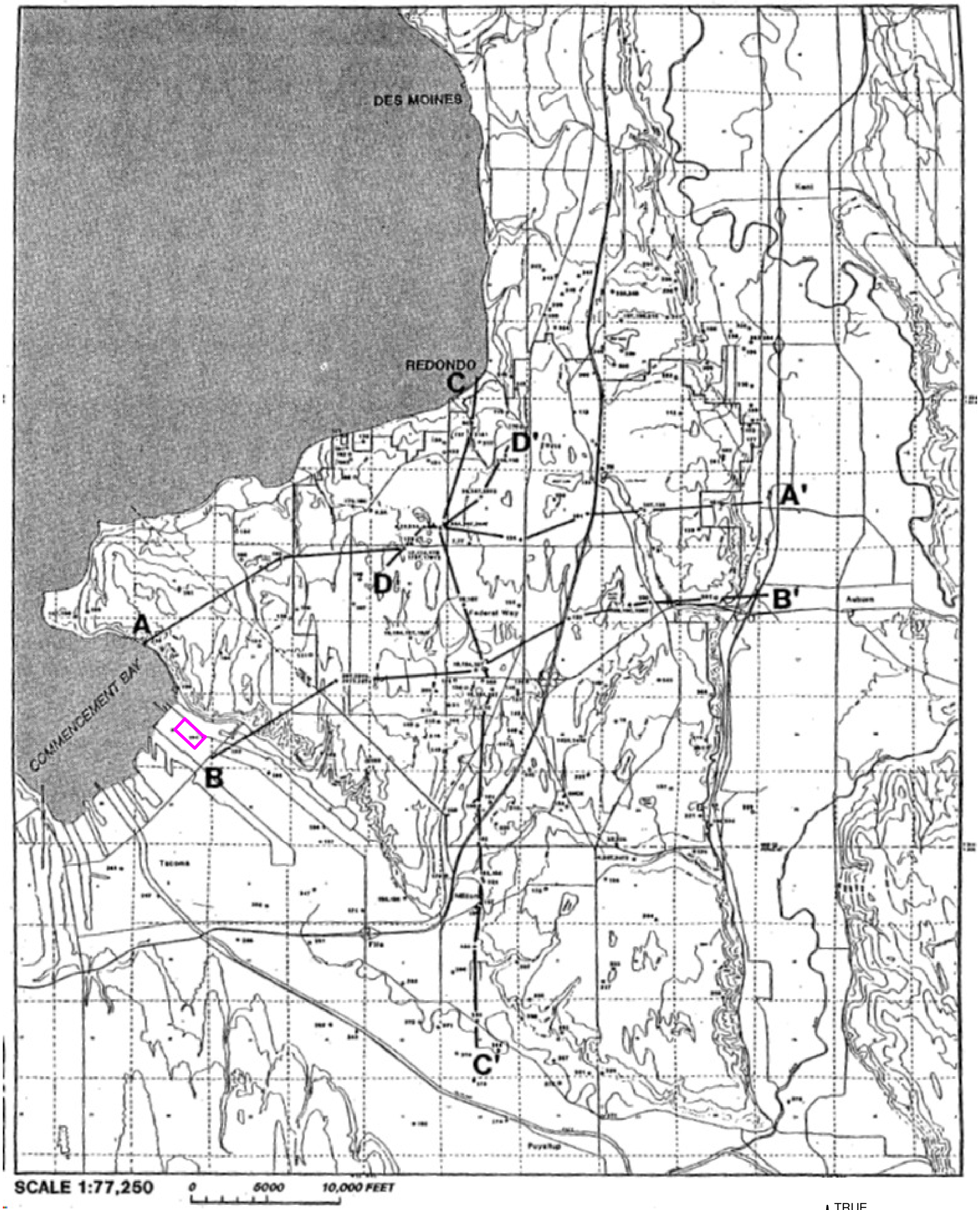
figure A.4

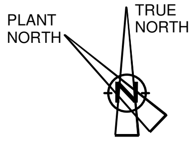
HART CROWSER (1975) CROSS-SECTION A-A'

Occidental Chemical Corporation, Tacoma, Washington

SOURCE: HART CROWSER (1975)

07843-A6(131)GN-WA-HYD (N:\HEG\07843\Report131-CSM-Aug-2013\Figures\Figure A.4.srf) JAN 17/2014





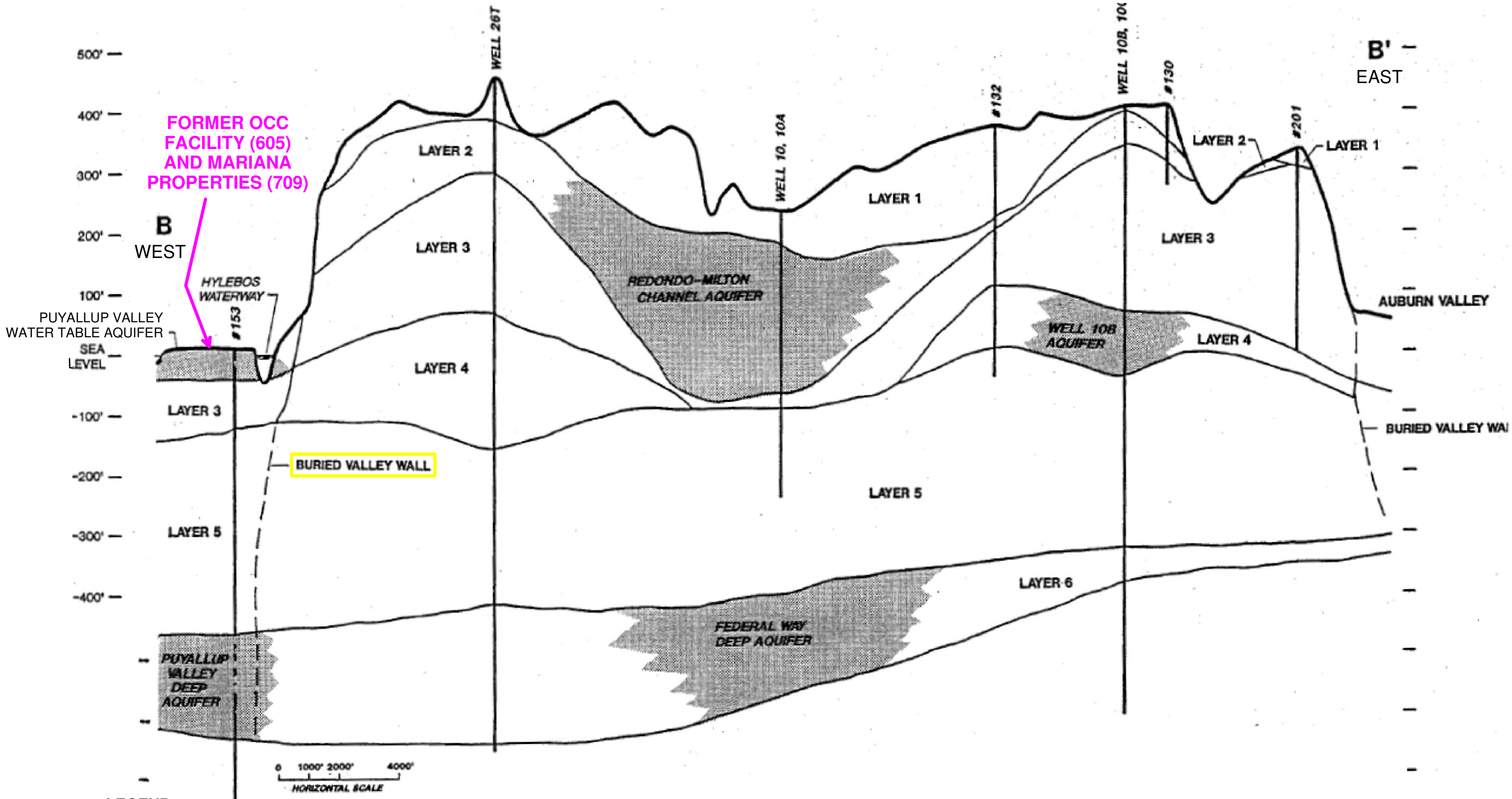
▭ FORMER OCC FACILITY (605)
AND MARIANA PROPERTIES (709)

SOURCE: ROBINSON & NOBLE, INC. (1992)

figure A.5

ROBINSON & NOBLE (1992) CROSS-SECTION LOCATIONS

Occidental Chemical Corporation, Tacoma, Washington



LEGEND

UPPER AQUIFER SYSTEM
LAYER 1: PERCHED AQUIFERS OF LIMITED AERIAL EXTENTS
LAYER 2: VASHON AQUIFER SYSTEM
LAYER 3: LOW PERMEABILITY AQUITARD SYSTEM

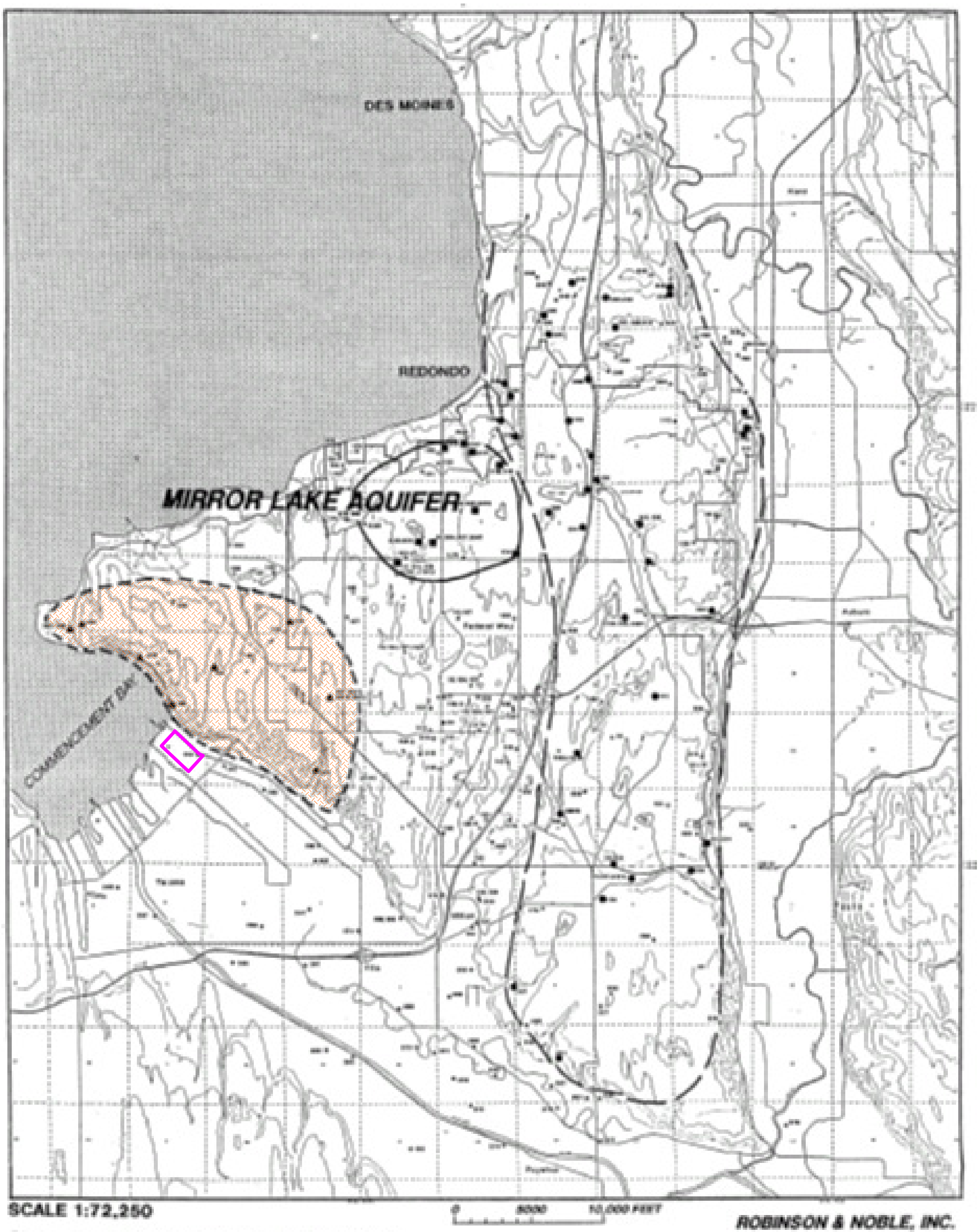
INTERMEDIATE AQUIFER SYSTEM
LAYER 4: RANDOMLY SPACED INTERMEDIATE AQUIFER SYSTEM WHERE AQUIFERS VARY GREATLY IN CHARACTER AND SIZE
LAYER 5: LOW PERMEABILITY AQUITARD SYSTEM

DEEP AQUIFER SYSTEM
LAYER 6: CONSISTS OF LOW PERMEABILITY STRATA WITH ISOLATED AQUIFERS

SOURCE: ROBINSON & NOBLE, INC. (1992)

figure A.6

ROBINSON & NOBLE (1992) CROSS-SECTION B-B'
Occidental Chemical Corporation, Tacoma, Washington



∼ MIRROR LAKE AQUIFER BOUNDARY

APPROXIMATE EDGE OF AREA CONTAINING NORTH SHORE AQUIFERS

∼ APPROXIMATE EDGE OF AREA CONTAINING EASTERN UPLAND AQUIFERS

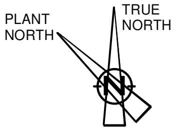
■ WELL COMPLETED IN MIRROR LAKE AQUIFER

▲ WELL COMPLETED IN NORTH SHORE AQUIFERS

● WELL COMPLETED IN EASTERN UPLAND AQUIFERS

▭ FORMER OCC FACILITY (605)
AND MARIANA PROPERTIES (709)

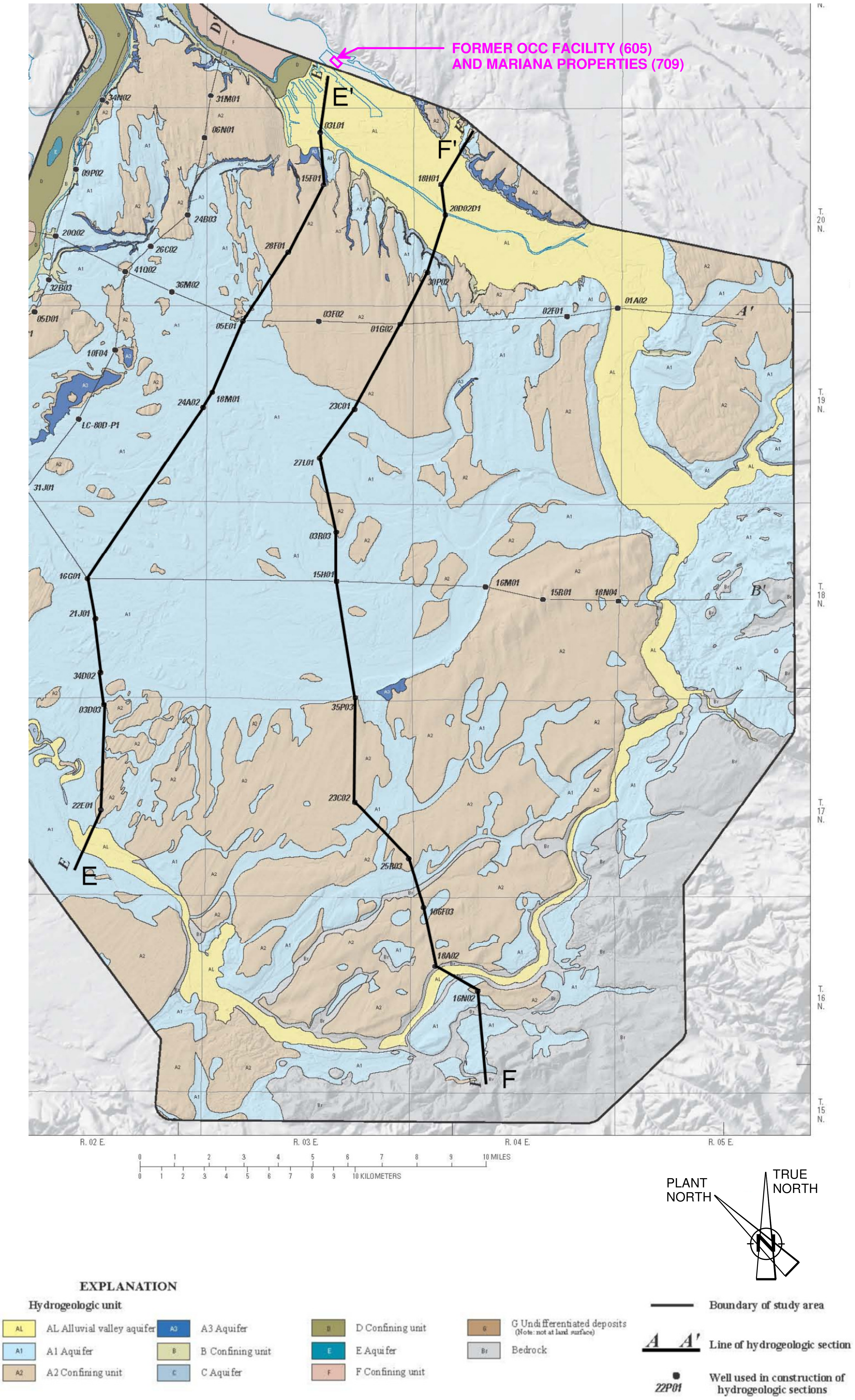
AQUIFERS IN LAYER 4



SOURCE: ROBINSON & NOBLE, INC. (1992)

figure A.7

LOCATION OF NORTH SHORE AQUIFERS UNDER BLUFFS
Occidental Chemical Corporation, Tacoma, Washington

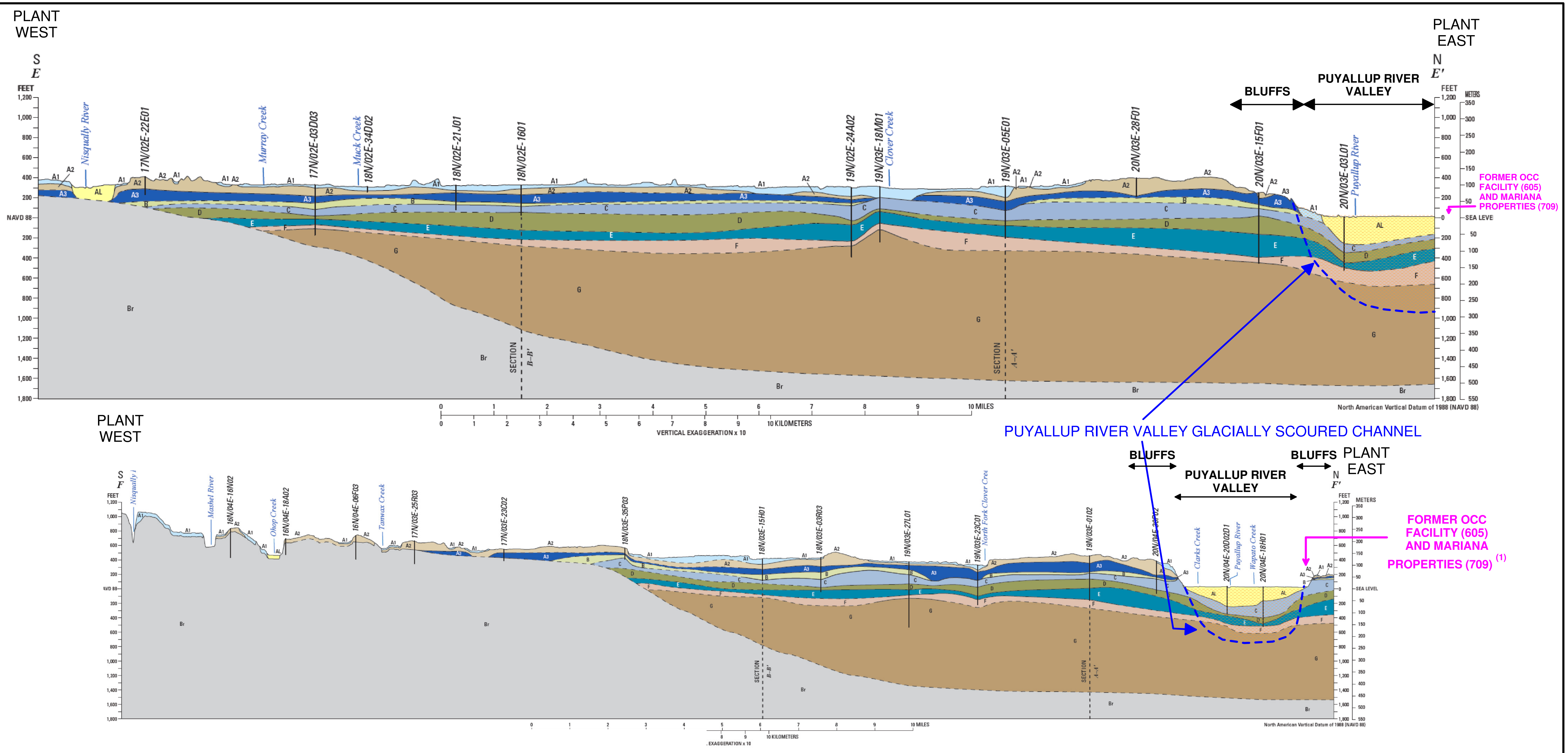


SOURCE: SAVOCA ET AL. (2010)

figure A.8

SAVOCA ET AL. (2010) CROSS-SECTION LOCATIONS

Occidental Chemical Corporation, Tacoma, Washington



EXPLANATION

Hydrogeologic unit

AL	AL Alluvial valley aquifer	A3	A3 Aquifer	D	D Confining unit	G	G Undifferentiated deposits (Note: not at land surface)
A1	A1 Aquifer	B	B Confining unit	E	E Aquifer	Br	Bedrock
A2	A2 Confining unit	C	C Aquifer	F	F Confining unit		

▨ PUYALLUP RIVER VALLEY GLACIALLY SCOURED CHANNEL IN-FILLED BY MELT-WATER SEDIMENTS AND DELTAIC DEPOSITS

Water Surface

Contact—approximately located, dashed where uncertain

21N/02E-34N02 Well No. (numbering system explained in text)

Well used in construction of section

SECTION A–A′ Intersection of two hydrogeologic sections

SOURCE: SAVOCA ET AL. (2010)

NOTE:
(1) LOCATED APPROXIMATELY 4 MILES PLANT-NORTH OF CROSS-SECTION F-F'.

figure A.9

SAVOCA ET AL. (2010) CROSS-SECTIONS E-E' AND F-F'

Occidental Chemical Corporation, Tacoma, Washington

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