SEPA[1] Environmental Checklist

Background

Find help answering background questions[2]

1. **Name of proposed project, if applicable:**

   Marine Carbon Dioxide Removal Pilot Project (Project Macoma)

2. **Name of applicant:**

3. Project Macoma, LLC **Address and phone number of applicant and contact person:**

   Applicant:

   Kyla Westphal
   Ebb Carbon
   950 Commercial Street
   San Carlos, California 94070
   Phone: (415) 307-9547
   Email: kyla@ebbcarbon.com

   Contact Person (Agent):

   Josh Jensen
   Anchor QEA
   1201 Third Avenue, Suite 2600
   Seattle, Washington 98117
   Phone: (206) 903-3374
   Email: jjensen@anchorqea.com

4. **Date checklist prepared:**

   February 26, 2024

5. **Agency requesting checklist:**

   Port of Port Angeles (Port)

6. **Proposed timing of schedule (including phasing, if applicable):**

   Construction of the pilot project would begin at Terminal 7 at the Port after issuance of appropriate permits and approvals and is expected to take approximately 4 months to complete. Project Macoma would run for approximately 1.5 years, beginning in summer 2024. The Project Description in Attachment 1 provides additional information about the pilot project's elements along with a description of construction and operational activities.

[1] https://ecology.wa.gov/Regulations-Permits/SEPA/Environmental-review/SEPA-guidance/Checklist-guidance
[2] https://ecology.wa.gov/Regulations-Permits/SEPA/Environmental-review/SEPA-guidance/SEPA-checklist-guidance/SEPA-Checklist-Section-A-Background

7. **Do you have any plans for future additions, expansion, or further activity related to or connected with this proposal? If yes, explain.**

   There are no plans for future additions, expansions, or further activity related to or connected with this proposal to deploy a pilot project sited at Terminal 7 of the Port.

   The scientific data gathered during Project Macoma will inform potential larger-scale future deployments of Ebb Carbon's marine carbon dioxide removal (mCDR) technology.

8. **List any environmental information you know about that has been prepared, or will be prepared, directly related to this proposal.**

   - Project Macoma Project Description (Attachment 1)
     - Project Macoma plan set (Attachment 1, Attachment 1-1)
   - Project Macoma Biological Assessment (Attachment 2)
     - Port Angeles mixing analyses (Attachment 2, Appendix A)
     - Project Macoma Ecological Safety Methodology (Attachment 2, Appendix B)
   - Project Macoma Environmentally Sensitive Areas Report (Attachment 3)

9. **Do you know whether applications are pending for governmental approvals of other proposals directly affecting the property covered by your proposal? If yes, explain.**

   Project Macoma, LLC, is not aware of any applications pending for governmental approvals of other proposals directly affecting the property covered by the pilot project.

10. **List any government approvals or permits that will be needed for your proposal, if known.**

    - U.S. Army Corps of Engineers (USACE) Letter of Permission and/or Nationwide Permit 7 for Outfall Structures and Associated Intake Structures
    - National Marine Fisheries Service and U.S. Fish and Wildlife Service (USFWS) Endangered Species Act Section 7 concurrence
    - Washington State Department of Archaeology and Historic Preservation National Historic Preservation Act (NHPA) Section 106 concurrence
    - Washington State Department of Ecology (Ecology) National Pollutant Discharge Elimination System (NPDES) and State Waste Discharge (SWD) Individual Permit
    - Ecology Coastal Zone Management Act Consistency Determination
    - Washington Department of Fish and Wildlife (WDFW) Hydraulic Project Approval
    - City of Port Angeles (City) Shoreline Substantial Development Permit (SSDP)
    - City Environmentally Sensitive Areas Ordinance compliance
    - City Waste Disposal Authorization
    - City building, grading, and other local permits for construction activities requiring City review

11. **Give brief, complete description of your proposal, including the proposed uses and the size of the project and site. There are several questions later in this checklist that ask you to describe certain aspects of your proposal. You do not need to repeat those answers on this page. (Lead agencies may modify this form to include additional specific information on project description.)**

    Project Macoma, LLC, is proposing a temporary pilot-scale mCDR project (Project Macoma) sited within Terminal 7 of the Port in Port Angeles, Washington. Ebb Carbon has developed an mCDR technology to remove CO_2 safely and permanently from the atmosphere while reducing seawater acidity locally. Ebb Carbon's technology removes acid from seawater, generating alkaline-enhanced seawater. The alkaline-enhanced seawater is returned to the ocean, which enables the ocean to draw down and store additional CO_2 from the atmosphere.

    The proposed pilot project, owned and operated by Project Macoma, LLC, would intake seawater via a barge moored at the Terminal 7 dock, pipe the seawater over the existing Terminal 7 pier structure to a modular treatment facility on land, and process and deacidify the seawater before returning it to Port Angeles Harbor via the barge-based outfall system. The purposes of the proposed pilot project are to operate Ebb Carbon's mCDR technology under real-world conditions, support scientific research through scientific and academic collaborations, and gather additional data to inform future deployments.

    Attachment 1 includes a complete Project Description and Plan Set.

12. **Location of the proposal. Give sufficient information for a person to understand the precise location of your proposed project, including a street address, if any, and section, township, and range, if known. If a proposal would occur over a range of area, provide the range or boundaries of the site(s). Provide a legal description, site plan, vicinity map, and topographic map, if reasonably available. While you should submit any plans required by the agency, you are not required to duplicate maps or detailed plans submitted with any permit applications related to this checklist.**

    The project site is at a portion of Terminal 7 of the Port-owned property on 1301 Marine Drive, Port Angeles, Washington. The terminal is a lay berth facility with a water depth of 30 feet mean lower low water located at 1433 Marine Drive in Port Angeles, Clallam County, Washington (Section 04, Township 31N, Range 06W). The pilot project is in tax Parcel No. 063000-50-5520. The legal description for the property is as follows:

    - TIDELANDS WEST TX#5949 BL 12-13-14 FOR REF ONLY VALUE 063000190090

    The pilot project will occur in the area depicted in the Plan Set included in Attachment 1.

Environmental Elements

1. Earth

Find help answering earth questions[3]

a. **General description of the site:**

Circle or highlight one: Flat, rolling, hilly, steep slopes, mountainous, other:

The pilot project site is generally flat, gently sloping towards the shoreline where a riprap slope extends to the substrate at an approximately 3:1 slope. The substrate slopes gently out into the harbor.

b. **What is the steepest slope on the site (approximate percent slope)?**

The steepest slope on the site is less than 5%.

c. **What general types of soils are found on the site (for example, clay, sand, gravel, peat, muck)? If you know the classification of agricultural soils, specify them, and note any agricultural land of long-term commercial significance and whether the proposal results in removing any of these soils.**

The subgrade soils are highly variable in the immediate vicinity of the pilot project site. There are no available soil data for the pilot project site in the Natural Resources Conservation Service Web Soil Survey because it is presumed to be primarily anthropogenic fill by previous users (USDA 2024). The near-surface subgrade soils contain a variable matrix of dredged sand, silt, and gravel; quarry spalls; cobbles; asphalt and brick debris; and geotextile fabric.

d. **Are there surface indications or history of unstable soils in the immediate vicinity? If so, describe.**

There are no surface indications or history of unstable soils in the immediate vicinity. Subgrade areas were determined to be stable enough to support typical log yard operations (AESI 2021). Ongoing operations have compacted soils at the site.

e. **Describe the purpose, type, total area, and approximate quantities and total affected area of any filling, excavation, and grading proposed. Indicate source of fill.**

Fill: Above-grade gravel fill would be used for the vehicle access paths and the areas where the containers are located. This excludes the existing electrical area, which would not receive fill. Based on the approximate area of 21,018 square feet, the pilot project would use 12 inches of aggregate base under trailers and for access area. These include approximately 950 cubic yards (cy) of hauled loose aggregate gravel and approximately 800 cy of compacted aggregate gravel, for a total of approximately 1,750 cy.

[3] https://ecology.wa.gov/regulations-permits/sepa/environmental-review/sepa-guidance/sepa-checklist-guidance/sepa-checklist-section-b-environmental-elements/environmental-elements-earth

Excavation: Elements of design that would involve potential trenching and/or excavation include the following:

- One to two copper ground rods (10 feet long and 3/4 inch in diameter) would be placed adjacent to each container/trailer corner, and two to four ground rods would be placed at each electrical building/shed. The ground rods would be driven vertically into the ground for site/system grounding. All ground cable and ground connections to equipment would be run above grade.
- An equipment pad would be constructed for the site electrical shed.
- Improvements to the existing utility main electrical room may include excavation of a conduit trench between the existing electrical room and the existing City utility transformer vault (on the northwest side of the utility vault). This conduit trench excavation may be avoided or minimized if an above-grade conduit is permitted by the City when the new transformer is installed.
- Excavation would be avoided for anchorage of trailers/containers/tanks for the electrical shed foundation and the utility vault building electrical area by laying down gravel and anchoring the trailers/containers/tanks to concrete blocks, if necessary.

f. Could erosion occur because of clearing, construction, or use? If so, generally describe.

The pilot project site would be used "as is" to the greatest extent possible. Some features would be modified or removed to accommodate equipment installation. If soil disturbance is necessary, applicable best management practices (BMPs) would be employed to minimize erosion on the site, as described in Section 1h.

g. About what percent of the site will be covered with impervious surfaces after project construction (for example, asphalt or buildings)?

The pilot project total area is approximately 21,488 square feet, with 20,618 square feet for treatment area, 200 square feet for barge transfer area, and 670 square feet of existing electrical area. Impermeable surfaces (trailers, tanks, structures) will cover 17% of the area. Permeable aggregate based road and access will cover 80% of the area. Existing electrical infrastructure will cover 3% of the area.

h. Proposed measures to reduce or control erosion, or other impacts to the earth, if any.

Measures to reduce and control erosion that may be used, as necessary, at the pilot project site include the following:

- Work would be performed according to the requirements and conditions of the project permits and approvals.
- Construction activities would be completed consistent with the Temporary Erosion and Sediment Control and stormwater site plans prepared for the project. Erosion control measures may include installing a stabilized construction access; construction road stabilization; installing mulching, nets, and blankets; applying surface roughing, gradient terraces, interceptor dikes, and swales; dust

control; material delivery storage and containment; outlet protection; and installing waffles, filter berms, or silt fencing.

- A Contaminated Materials Management Plan would be prepared and implemented during construction to address potential issues if contaminated soils are encountered.
- The contractor would be required to develop and implement a Spill Prevention, Control, and Countermeasure Plan to be used for the duration of the pilot Project to safeguard against unintentional release of fuel, lubricants, or hydraulic fluid from construction equipment.
- The contractor would be required to properly maintain construction equipment and vehicles to prevent them from leaking fuel or lubricants; if there is evidence of leakage, the further use of such equipment would be suspended until the deficiency has been satisfactorily corrected.

2. Air

Find help answering air questions[4]

a. What types of emissions to the air would result from the proposal during construction, operation, and maintenance when the project is completed? If any, generally describe and give approximate quantities if known.

During construction and decommissioning phases, emissions would be typical of construction sites in general: particulate matter and vehicle emissions. During operations, the primary emissions are oxygen and hydrogen gas. These are at ambient pressure and diluted with air below 25% of the lower explosive limit. The total emitted hydrogen is estimated at less than 1 metric ton per year.

b. Are there any off-site sources of emissions or odor that may affect your proposal? If so, generally describe.

No off-site source of emissions or odor are anticipated to affect the proposed pilot project.

c. Proposed measures to reduce or control emissions or other impacts to air, if any:

Construction equipment used on the pilot project would be maintained in good working order to minimize airborne emissions. Dust control measures, such as application of water, would be employed during construction, as necessary. A cover would be installed over the acid neutralization equipment to prevent dust from leaving the facility during operations. As mentioned in the Project Description (Attachment 1), the alkaline-enhanced seawater generated and returned to the ocean during operations is

[4] https://ecology.wa.gov/Regulations-Permits/SEPA/Environmental-review/SEPA-guidance/SEPA-checklist-guidance/SEPA-Checklist-Section-B-Environmental-elements/Environmental-elements-Air

expected to improve air quality by enabling the ocean to draw down and store additional CO_2 from the atmosphere.

3. Water

Find help answering water questions[5]

a. Surface:

Find help answering surface water questions[6]

1. **Is there any surface water body on or in the immediate vicinity of the site (including year-round and seasonal streams, saltwater, lakes, ponds, wetlands)? If yes, describe type and provide names. If appropriate, state what stream or river it flows into.**

   The pilot project would be located on Port Angeles Harbor, adjacent to the Strait of Juan de Fuca.

2. **Will the project require any work over, in, or adjacent to (within 200 feet) the described waters? If yes, please describe and attach available plans.**

   The pilot project would include moorage of an overwater barge and affixing an intake and outfall system at the existing berth at the Port's Terminal 7. The intake would consist of a pipe that is attached to the barge, equipped with screening and mesh. The outfall would be a 50-foot-long pipe with perforation holes pointing upward to diffuse the discharged seawater back into the harbor. The outfall pipe would be connected to the outside of the barge and submerged 2 meters below the water surface. Seawater would be taken in at the intake, run through the upland mCDR facility, and discharged from the outfall structure on the barge. The piping connecting this system to the upland mCDR facility would be installed over an existing pier structure. Most of the process equipment would be located onshore within 200 feet of the shoreline in standard shipping containers as machine housing. In total, there would be 10 shipping containers, six mobile tanks, two utility sheds, and one office trailer.

   A Plan Set is included with a detailed Project Description in Attachment 1.

3. **Estimate the amount of fill and dredge material that would be placed in or removed from surface water or wetlands and indicate the area of the site that would be affected. Indicate the source of fill material.**

   No dredge or fill material would be placed or removed from surface waters.

4. **Will the proposal require surface water withdrawals or diversions? Give a general description, purpose, and approximate quantities if known.**

[5] https://ecology.wa.gov/Regulations-Permits/SEPA/Environmental-review/SEPA-guidance/SEPA-checklist-guidance/SEPA-Checklist-Section-B-Environmental-elements/Environmental-elements-3-Water
[6] https://ecology.wa.gov/Regulations-Permits/SEPA/Environmental-review/SEPA-guidance/SEPA-checklist-guidance/SEPA-Checklist-Section-B-Environmental-elements/Environmental-elements-3-Water/Environmental-elements-Surface-water

Ebb Carbon's mCDR technology removes acid from seawater, generating alkaline-enhanced seawater in the process. The alkaline-enhanced seawater is returned to the ocean, which enables the ocean to draw down and store additional CO_2 from the atmosphere.

Project Macoma, LLC, proposes to treat marine seawater pumped from Port Angeles Harbor at an intake on a moored barge. The seawater would be conveyed to the onshore process area and run through the mCDR facility to remove acid from the seawater. The seawater would be returned with a higher alkalinity back to the harbor, where it would mix with the surrounding waters.

Approximately 97,000 gallons of seawater per day would be processed and returned to the harbor under an NPDES/SWD permit.

5. **Does the proposal lie within a 100-year floodplain? If so, note location on the site plan.**

   The upland portion of the pilot project site is not within the 100-year floodplain. The pier and barge would be located within a Zone AE floodplain, which is subject to inundation by a 1% annual chance flood event (FEMA 2023). This area's base flood elevation is 13 feet North American Vertical Datum of 1988 (NAVD88).

6. **Does the proposal involve any discharges of waste materials to surface waters? If so, describe the type of waste and anticipated volume of discharge.**

   The pilot project does not propose the discharge of waste materials to surface waters. All discharges to surface waters would be compliant with an NPDES/SWD permit.

b. Ground:

Find help answering ground water questions[7]

1. **Will groundwater be withdrawn from a well for drinking water or other purposes? If so, give a general description of the well, proposed uses and approximate quantities withdrawn from the well. Will water be discharged to groundwater? Give a general description, purpose, and approximate quantities if known.**

   No groundwater withdrawals or discharge would occur from the pilot project.

2. **Describe waste material that will be discharged into the ground from septic tanks or other sources, if any (domestic sewage; industrial, containing the following chemicals…; agricultural; etc.). Describe the general size of the system, the number of such systems, the number of houses to be served (if applicable), or the number of animals or humans the system(s) are expected to serve.**

[7] https://ecology.wa.gov/Regulations-Permits/SEPA/Environmental-review/SEPA-guidance/SEPA-checklist-guidance/SEPA-Checklist-Section-B-Environmental-elements/Environmental-elements-3-Water/Environmental-elements-Groundwater

No waste materials would be discharged to the ground. Employees would have restroom facilities in an office trailer with self-contained holding tanks that would be pumped on an as-needed basis.

c. Water Runoff (including stormwater):

1. Describe the source of runoff (including storm water) and method of collection and disposal, if any (include quantities, if known). Where will this water flow? Will this water flow into other waters? If so, describe.

Stormwater is the only source of runoff expected at the pilot project site. The pilot project would rely on the Port's existing stormwater system at Terminal 7. The area was previously graded to slope away from the shore to a collection point where it is captured and treated by the Port's stormwater system.

2. Could waste materials enter ground or surface waters? If so, generally describe.

The chemicals that would be used at the pilot project site include sulfuric acid, hydrochloric acid, sodium hydroxide, sodium chloride, deionized water, and hydrogen gas. Materials with hazardous characteristics would be processed in closed/impermeable containers and stored with secondary containment of the full volume or greater. Material would be contained and protected from rain and wind to prevent ground or surface water contamination.

In the event of an accidental release of material, liquid collection is expected to go to the site low point, which feeds into an existing and permitted stormwater treatment facility. Notification of the release would be made to the Port to prevent discharge of their system until remediation.

3. Does the proposal alter or otherwise affect drainage patterns in the vicinity of the site? If so, describe.

The proposed pilot project would not affect drainage patterns at the site. Runoff would continue to flow toward and be treated by the Port's existing stormwater system.

d. Proposed measures to reduce or control surface, ground, and runoff water, and drainage pattern impacts, if any:

Due to the pilot project's proximity to nearby surface waters, the BMPs listed in Section 1.h. would also be implemented to reduce surface, ground, and runoff water and drainage pattern impacts. Additional BMPs would be implemented as follows:

- No uncured concrete would be in contact with surface waters.
- Project Macoma, LLC, would implement a Stormwater Pollution Prevention Plan (SWPPP) that specifies BMPs and measures to minimize impacts to surface, ground, and stormwater water and drainage pattern impacts.
- Project Macoma, LLC, would develop, maintain, and implement a chemical management (See section 7, Environmental Health, for more information).

4. Plants

[Find help answering plants questions]

a. Check the types of vegetation found on the site:

☐ **deciduous tree: alder, maple, aspen, other**

☐ **evergreen tree: fir, cedar, pine, other**

☐ **shrubs**

☒ **grass**

☐ **pasture**

☐ **crop or grain**

☐ **orchards, vineyards, or other permanent crops.**

☐ **wet soil plants: cattail, buttercup, bullrush, skunk cabbage, other**

☒ **water plants: water lily, eelgrass, milfoil, other**

☒ **other types of vegetation**

The pilot project area is an industrial log yard that has been cleared and is primarily unvegetated. Plant species have grown through cracks in the pavement and riprap along the shoreline and mostly include weedy grass and shrub species such as Himalayan blackberry (*Rubus armeniacus*), Scotch broom (*Cytisus scoparius*), and common dandelion (*Taraxacum officinale*). The Port Angeles Harbor is mapped with fringe (patchy) kelp in the nearshore environment (WDNR 2024).

b. What kind and amount of vegetation will be removed or altered?

No vegetation will be removed or altered with the exception of limited weedy species that may be covered by fill or equipment in the upland portion of the site.

c. List threatened and endangered species known to be on or near the site.

There are no federally listed plant species at or near the site.

d. Proposed landscaping, use of native plants, or other measures to preserve or enhance vegetation on the site, if any.

No landscaping is proposed for the project site.

e. List all noxious weeds and invasive species known to be on or near the site.

Noxious weeds that could be expected in the immediate vicinity of the project site (WISC 2024) include the following:

- Common tansy (*Tanacetum vulgare*; Class B)
- Poison hemlock (*Conium maculatum*; Class B)
- Scotch broom (Class B)
- Himalayan blackberry (Class C)

5. Animals

Find help answering animal questions[8]

a. List any birds and other animals that have been observed on or near the site or are known to be on or near the site.

Examples include:

- **Birds: hawk, heron, eagle, songbirds, other: see description**
- **Mammals: deer, bear, elk, beaver, other:** Harbor seal (*Phoca vitulina*), sea lion (*Zalophus californianus*)
- **Fish: bass, salmon, trout, herring, shellfish, other:** forage fish

The pilot project site has no trees and limited vegetation that would provide habitat for birds or other animals. Ediz Hook provides a refuge point for a variety of bird species. Local sighting data indicate that over 200 bird species have been observed in the area, including seabirds such as sandpiper (*Calidris ptilocnemis*), turnstone (*Arenaria melanocephala*), tern (*Sterna hirundo*), and gull *(Larus occidentalis)*(eBird 2024).

Salmonid species that have been documented utilizing the nearby Tumwater Creek, Valley Creek, and Peabody Creek, which connect to Port Angeles Harbor, include fall chum salmon (*Oncorhynchus keta),* resident coastal cutthroat trout (*O. clarkii clarkii*), summer and winter steelhead (*O. mykiss*), and coho salmon (*O. kisutch)* (WDFW 2024). WDFW Priority Habitats and Species (PHS) data also document the following species to occur within the marine environment of the greater area of Port Angeles Harbor, outside of the project area:

- Hardshell clam (*Mercenaria mercenaria*)
- Subtidal hardshell clam
- Pandalid shrimp
- Dungeness crab (*Cancer magister*)
- Surf smelt (*Hypomesus pretiosus*)
- Shorebird concentrations
- Harlequin duck (*Histrionicus histrionicus*)
- Pacific sand lance

b. List any threatened and endangered species known to be on or near the site.

Given the history of use at the pilot project site, the presence of terrestrial threatened or endangered species is considered unlikely. To identify listed threatened and endangered species that could be near the project site, both the USFWS Information for

[8] https://ecology.wa.gov/Regulations-Permits/SEPA/Environmental-review/SEPA-guidance/SEPA-checklist-guidance/SEPA-Checklist-Section-B-Environmental-elements/Environmental-elements-5-Animals

Planning and Consultation (IPaC) and WDFW PHS tools were used. The species identified include the following:

- Killer whale (*Orcinus orca*)
- Humpback whale (*Megapterus novaeangliae*)
- Puget Sound Chinook salmon (*Oncorhynchus tshawytscha*)
- Puget Sound steelhead (*Oncorhynchus mykiss*)
- Bull trout (*Salvelinus confluentus*)
- Bocaccio (*Sebastes paucispinis*)
- Yelloweye rockfish (*Sebastes ruberrimus*)
- Pacific eulachon (*Thaleichthys pacificus*)
- Green sturgeon (*Acipenser medirostris*)
- Leatherback sea turtle (*Dermochelys coriacea*)
- Sunflower sea star (*Pycnopodia helianthoides*)
- Marbled murrelet (*Brachyramphus marmoratus*)
- Northern spotted owl (*Strix occidentalis*)
- Short-tailed albatross (*Phoebastria albatrus*)
- Streaked Horned Lark (*Eremophila alpestris strigata*)
- Yellow-billed cuckoo (*Coccyzus americanus*)
- Western pond turtle (*Actinemys marmorata*)
- Taylor's checkerspot (*Euphydryas editha taylori*)

A Biological Assessment has been prepared identifying threatened and endangered species presence in the area; refer to Attachment 2.

c. Is the site part of a migration route? If so, explain.

The pilot project is located within the Pacific Flyway, a north-south corridor that extends from Alaska to Patagonia for migratory birds. The area also may serve as a nearshore migratory corridor for juvenile salmonids leaving nearby streams to the Pacific Ocean.

d. Proposed measures to preserve or enhance wildlife, if any.

The measures listed in Sections 1.h. and 3.d. would be implemented to avoid or minimize potential impacts on wildlife. An Ecological Safety Methodology framework (Attachment 2, Appendix B) has been developed to understand the beneficial effects of the pilot project and actively monitor and adaptively manage operations to avoid or minimize potential adverse impacts to species and habitats in the vicinity of the pilot project.

e. List any invasive animal species known to be on or near the site.

Aquatic invasive species known to be on or near the pilot project site are as follows:

- **European Green Crab:** Has not been found in Port Angeles, but has been found in other locations near the Salish Sea (e.g., Lummi Bay, Makah Bay, Sooke Basin on southern Vancouver Island)
- **Purple Varnish Clam**: Has not been reported in Port Angeles, but has been reported in northern Puget Sound

- **Tunicates**: *Ciona savignyi, Styela clava,* and *Didemnum* spp have not been reported in Port Angeles but are present in Hood Canal and the Puget Sound.

Insect invasive species known to be on or near the project site are as follows:

- **Apple Maggot:** Clallam County is within the area under quarantine for apple maggot.

6. Energy and natural resources

Find help answering energy and natural resource questions[9]

a. What kinds of energy (electric, natural gas, oil, wood stove, solar) will be used to meet the completed project's energy needs? Describe whether it will be used for heating, manufacturing, etc.

The pilot project will use electric energy for the process, as well as for office functions (heating, lights, equipment). This mCDR process is reliant on low-carbon electricity to reach its goal of being a net-negative carbon emissions technology. The preliminary design requires a 1,500-kilovolt-amperes (kVA) transformer to meet peak loads. The system will operate on a duty cycle such that operation should be about 700 kVA. There is no need for industrial heating.

b. Would your project affect the potential use of solar energy by adjacent properties? If so, generally describe.

The pilot project would not impact the use of solar energy by adjacent properties.

c. What kinds of energy conservation features are included in the plans of this proposal? List other proposed measures to reduce or control energy impacts, if any.

The completed project does not include energy conservation features. Project Macoma, LLC, is intentionally siting the pilot project in an area that relies on renewable energy resources to supply the power grid (i.e., hydropower).

During construction, practices that encourage efficient energy use, such as limited idling of equipment, encouraging carpooling of workers, and locating staging areas near work areas, would be implemented as practicable.

[9] https://ecology.wa.gov/Regulations-Permits/SEPA/Environmental-review/SEPA-guidance/SEPA-checklist-guidance/SEPA-Checklist-Section-B-Environmental-elements/Environmental-elements-6-Energy-natural-resou

7. Environmental health

Health Find help with answering environmental health questions[10]

a. **Are there any environmental health hazards, including exposure to toxic chemicals, risk of fire and explosion, spill, or hazardous waste, that could occur because of this proposal? If so, describe.**

1. **Describe any known or possible contamination at the site from present or past uses.**

   The pilot project is located within an uplands area of Terminal 7 that is a part of Agreed Order DE 21560 and within a portion of Western Port Angeles Harbor that is under Agreed Order DE 9781, both issued under the Washington State Model Toxics Control Act. The site of the pilot project is also in the vicinity of sediments that are a part of the Rayonier Mill Cleanup Site.

   Since the early 1900s, effluents have been discharged into the area from industrial facilities operating in Port Angeles Harbor. The distribution of hazardous substances corresponds with the locations of historical industrial activities and wastewater discharge sites identified within Port Angeles Harbor. Discharges resulted in harbor sediments contaminated by petrochemicals, polychlorinated biphenyls (PCBs), dioxins, and heavy metals (NOAA 2023).

   The resulting contamination is in intertidal and subtidal sediments over the entirety of Port Angeles Harbor. Eleven sediment studies between 2002 and 2013 revealed hazardous substances at concentrations above state and federal standards, indicating potential injuries to benthic organisms, fish, shellfish, and birds (NOAA 2023).

   The pilot project is designed to be temporary and modular to allow future cleanup activities to occur, if and as required.

2. **Describe existing hazardous chemicals/conditions that might affect project development and design. This includes underground hazardous liquid and gas transmission pipelines located within the project area and in the vicinity.**

   No existing hazardous chemicals/conditions or underground hazardous liquid and gas transmission pipelines within the pilot project area have been identified that might affect project development and design.

3. **Describe any toxic or hazardous chemicals that might be stored, used, or produced during the project's development or construction, or at any time during the operating life of the project.**

   There would be small volumes of hazardous chemicals for maintenance: PVC cement, household cleaners, and solvents. Additional hazardous chemicals would be present for analysis and calibration including pH buffers, calibration gases, and dilute

[10] https://ecology.wa.gov/Regulations-Permits/SEPA/Environmental-review/SEPA-guidance/SEPA-checklist-guidance/SEPA-Checklist-Section-B-Environmental-elements/Environmental-elements-7-Environmental-health

mercuric chloride. The main chemicals produced by the mCDR technology would be base and acid.

All chemicals would be stored in compatible containers and with secondary containment in accordance with a site chemical management plan that would be prepared for implementation during facility operations.

4. **Describe special emergency services that might be required.**

   Emergency response, if necessary, would be by conventional emergency services (e.g., fire, medical, law enforcement).

5. **Proposed measures to reduce or control environmental health hazards, if any.**

   Some of the chemicals used in the process, if not managed properly, could result in environmental health hazards. Project Macoma, LLC, would develop, maintain, and implement a chemical management plan that includes specific procedures for procurement, delivery, transfer, storage, inventory, use, spill prevention and cleanup, emergency response, and disposal. All employees and contractors would receive chemical management training within 1 month of hiring and annually after. The pilot project would be implemented consistent with the SWPPP to supplement preparedness and response procedures.

b. Noise

1. **What types of noise exist in the area which may affect your project (for example: traffic, equipment, operation, other)?**

   The pilot project is located within an industrial area within the Port that has noise levels typical of active ports. These types and levels of noise would not affect the pilot project.

2. **What types and levels of noise would be created by or associated with the project on a short-term or a long-term basis (for example: traffic, construction, operation, other)? Indicate what hours noise would come from the site)?**

   Noise would be emitted from the pilot project site in the short term for construction and in the long term from traffic and operation of the mCDR facility. Construction noise levels would be typical of other industrial process equipment currently operating at the site.

   During operation, periodic noise increases would occur from transportation of materials to and from the site and, when required, maintenance work. The sustained noise levels from the mCDR process outside the structures is expected to be comparable to an advanced water treatment facility (approximately 25 A-weighted decibels). This noise level would be sustained up to 24 hours per day, 7 days per week.

   Other sources of noise include the barge-based pump system that would be used to convey water to and from the facility. Noise attenuation measures would be implemented if required to maintain noise from the pump system at or below background noise levels in the area.

Noise levels from construction and operation of the facility are not expected to be detectable at the nearest residence, located 0.2 mile from the pilot project site. The noise level from the proposed pilot project is expected to be less than the noise level of the site's current use as a log yard.

3. **Proposed measures to reduce or control noise impacts, if any:**

   Construction activities would occur during daylight hours and primarily on weekdays, to the extent practicable. During operations, vehicle traffic would be scheduled during Port business hours to the extent practicable to limit potential noise impacts.

8. Land and shoreline use

Find help answering land and shoreline use questions[11]

a. **What is the current use of the site and adjacent properties? Will the proposal affect current land uses on nearby or adjacent properties? If so, describe.**

   The property is currently used as a log yard. The Port will modify its use of the log yard to accommodate the pilot project's operations. A portion of the site is currently unused by the logging process and is available for lease by the Port. The proposed pilot project would not affect current uses on nearby or adjacent property. The site and adjacent land to the west is zoned industrial, which is consistent with the proposed pilot project. To the east of the project site is the Port Angeles Yacht Club marina. Port Angeles Harbor is directly to the north of the property. The pier structure and berth area are currently used for moorage of an oil response vessel. Port Angeles Harbor is used by commercial and recreational watercraft.

   To the south and west of the property is Tse-whit-zen, an ancestral village and cemetery of the Lower Elwha Klallam Tribe. Tse-whit-zen is a village of continuous uninterrupted use by the Klallam, extending back for more than 2,700 years. The village was used extensively as a year-round place of habitation, as well as for traditional practices of sea mammal hunting, shellfish harvesting, and open marine water fishing. A large cemetery and numerous burials are associated with the village. The Lower Elwha Klallam Tribe continues to maintain a cemetery at the site.

b. **Has the project site been used as working farmlands or working forest lands? If so, describe. How much agricultural or forest land of long-term commercial significance will be converted to other uses because of the proposal, if any? If resource lands have not been designated, how many acres in farmland or forest land tax status will be converted to nonfarm or nonforest use?**

   The property has not been used for working farmlands or working forest lands.

[11] https://ecology.wa.gov/Regulations-Permits/SEPA/Environmental-review/SEPA-guidance/SEPA-checklist-guidance/SEPA-Checklist-Section-B-Environmental-elements/Environmental-elements-8-Land-shoreline-use

1. **Will the proposal affect or be affected by surrounding working farm or forest land normal business operations, such as oversize equipment access, the application of pesticides, tilling, and harvesting? If so, how?**

   The pilot project will not affect or be affected by surrounding working farm or forest land normal business operations.

c. **Describe any structures on the site.**

There are three existing structures on the site, as follows:

- The first structure is a two-room building. The larger room is an uninsulated space with walls made up of a combination of concrete, masonry, and wood framing. The wood-framed walls have metal siding and door openings. The roof is supported by wood framing.
- The second structure is a 16-inch-thick concrete retaining wall extending north from the building. The wall is about 16 feet high and 75 feet long.
- The third structure is a dock that extends from the property and connects to the wharf that was used to moor ships while loading logs. The dock includes relic wood chip conveyor infrastructure that was used for past wood chip transfer activities. The wood chip conveyor is currently not in operation.

d. **Will any structures be demolished? If so, what?**

No structures will be demolished as part of the pilot project.

e. **What is the current zoning classification of the site?**

The project site is zoned “17.34 Industrial Heavy” on the City of Port Angeles Department of Community and Economic Development Zoning Map – Ordinance # 280 (DCED 2024).

f. **What is the current comprehensive plan designation of the site?**

The Port is designated as an Urban Growth Zone in the Clallam County Comprehensive Plan. Ports are required to comply with Revised Code of Washington 53.20.010, which requires a Comprehensive Scheme of Harbor Improvements instead of Comprehensive Plans (POPA 2023).

g. **If applicable, what is the current shoreline master program designation of the site?**

The current City of Port Angeles Shoreline Master Program (SMP) designates the area encompassing the pilot project site as High-Intensity Industrial environment (City of Port Angeles 2021)

h. **Has any part of the site been classified as a critical area by the city or county? If so, specify.**

The City regulates environmentally sensitive areas per Port Angeles Municipal Code Chapter 15.20. The pilot project is located within fish and wildlife habitat conservation areas, frequently flooded areas, and critical aquifer recharge areas. Attachment 3 includes an Environmentally Sensitive Areas Report prepared for the pilot project.

i. **Approximately how many people would reside or work in the completed project?**

No one would reside in the pilot project site. It is expected that a small team of operations employees (one to three) would work at the completed project site to monitor and maintain the mCDR system. There would also be periodic teams of visiting researchers and local partners to assess the process and ocean monitoring systems.

j. **Approximately how many people would the completed project displace?**

The pilot project would not displace any people.

k. **Proposed measures to avoid or reduce displacement impacts, if any.**

No measures are needed to avoid or reduce displacement impacts because no displacement impacts are expected. Local contractors would be engaged in establishing the pilot project at the site.

l. **Proposed measures to ensure the proposal is compatible with existing and projected land uses and plans, if any.**

Ebb Carbon has worked closely with the Port to ensure consistency with Port plans and requirements, including the City of Port Angeles SMP and Harbor Resources Management Plan. Proposed measures consist of continuing to work closely with the Port, City, and Lower Elwha Klallam Tribe through the installation, operation, and decommissioning phases of the pilot project.

m. **Proposed measures to reduce or control impacts to agricultural and forest lands of long-term commercial significance, if any:**

No impacts to agricultural or forest lands have been identified or are expected; therefore, no measures would be necessary to reduce impacts.

9. Housing

Find help answering housing questions[12]

a. **Approximately how many units would be provided, if any? Indicate whether high, middle, or low-income housing.**

The pilot project would not provide any housing units.

b. **Approximately how many units, if any, would be eliminated? Indicate whether high, middle, or low-income housing.**

The pilot project would not eliminate any housing units.

c. **Proposed measures to reduce or control housing impacts, if any:**

The pilot project would not impact housing. Therefore, no measures to reduce or control housing impacts are proposed.

[12] https://ecology.wa.gov/Regulations-Permits/SEPA/Environmental-review/SEPA-guidance/SEPA-checklist-guidance/SEPA-Checklist-Section-B-Environmental-elements/Environmental-elements-9-Housing

10. Aesthetics

Find help answering aesthetics questions[13]

a. What is the tallest height of any proposed structure(s), not including antennas; what is the principal exterior building material(s) proposed?

The tallest height of proposed equipment at the site would be mobile tanks at approximately 11 feet high and the 16-foot-tall retaining wall. The principal material of the tanks would be steel or similar metal.

b. What views in the immediate vicinity would be altered or obstructed?

The temporary presence of containers, tanks, and a barge at the site would be consistent with surrounding land uses and would have negligible impacts to views in the immediate vicinity.

c. Proposed measures to reduce or control aesthetic impacts, if any:

Existing views would not be altered or obstructed by the pilot project.

11. Light and glare

Find help answering light and glare questions[14]

a. What type of light or glare will the proposal produce? What time of day would it mainly occur?

During construction, temporary lighting could be used by contractors during early morning hours (before 8:00 a.m.) or late afternoon hours (after 4:00 p.m.) for visibility and safety. The lights not required for safety purposes would be turned off at the end of each workday.

b. Could light or glare from the finished project be a safety hazard or interfere with views?

No. The finished pilot project would not produce light or glare that would be a safety hazard or interfere with views.

c. What existing off-site sources of light or glare may affect your proposal?

No existing off-site sources of light or glare would affect the pilot project.

d. Proposed measures to reduce or control light and glare impacts, if any:

During construction and operation, lights would only be used when necessary and would be turned off at the end of each workday. Use of lights would adhere to applicable City regulations.

[13] https://ecology.wa.gov/Regulations-Permits/SEPA/Environmental-review/SEPA-guidance/SEPA-checklist-guidance/SEPA-Checklist-Section-B-Environmental-elements/Environmental-elements-10-Aesthetics
[14] https://ecology.wa.gov/Regulations-Permits/SEPA/Environmental-review/SEPA-guidance/SEPA-checklist-guidance/SEPA-Checklist-Section-B-Environmental-elements/Environmental-elements-11-Light-glare

12. Recreation

Find help answering recreation questions

a. **What designated and informal recreational opportunities are in the immediate vicinity?**

The Port Angeles Yacht Club is located on the eastern property adjacent to the pilot project area. Port Angeles Harbor is used for recreational watercraft. There are no immediate recreation opportunities in the upland portion of the pilot project area due to its active use as a log yard.

b. **Would the proposed project displace any existing recreational uses? If so, describe.**

The completed pilot project would not displace any existing recreational uses. The placement of in-water pipes or nets in the project area has the potential to restrict some in-water recreational uses during construction and operation. "Do Not Enter" signs around the upland and in-water project areas may be needed.

c. **Proposed measures to reduce or control impacts on recreation, including recreation opportunities to be provided by the project or applicant, if any:**

Because there are no proposed impacts, no measures are proposed to reduce or control impacts on recreation. The proposed project would not provide opportunities for recreation.

13. Historic and cultural preservation

Find help answering historic and cultural preservation questions[15]

a. **Are there any buildings, structures, or sites, located on or near the site that are over 45 years old listed in or eligible for listing in national, state, or local preservation registers? If so, specifically describe.**

One archaeological site listed in the National Register of Historic Places (NRHP) is immediately adjacent to the project site: 45CA523 (Tse-whit-zen). Tse-whit-zen is an ancestral village and cemetery of the Lower Elwha Klallam Tribe. Tse-whit-zen is a village of continuous uninterrupted use by the Klallam, extending back for more than 2,700 years. The village was used extensively as a year-round place of habitation, as well as for traditional practices of sea mammal hunting, shellfish harvesting, and open marine water fishing. A large cemetery and numerous burials are associated with the village. The Lower Elwha Klallam Tribe continues to maintain a cemetery at the site. Tse-whit-zen holds traditional cultural significance to the Lower Elwha Klallam Tribe, and it was listed in the NRHP under Criterion D in 2014.(LEKT 2023; Mapes 2009; White 2013. Under Criterion D, a property is eligible because it has or has had information to contribute to our understanding of human history or prehistory, and such information is considered important.

[15] https://ecology.wa.gov/Regulations-Permits/SEPA/Environmental-review/SEPA-guidance/SEPA-checklist-guidance/SEPA-Checklist-Section-B-Environmental-elements/Environmental-elements-13-Historic-cultural-p

There are no other buildings, structures, or sites located on or near the site that are over 45 years old and listed in, or eligible for listing in, national, state, or local preservation registers.

b. Are there any landmarks, features, or other evidence of Indian or historic use or occupation? This may include human burials or old cemeteries. Are there any material evidence, artifacts, or areas of cultural importance on or near the site? Please list any professional studies conducted at the site to identify such resources.

There have been prior archaeological studies performed on the Port's log yard, some of which overlap the pilot project site and Terminal 7 (Allen et al. 2023; Boersema 2016; Colón et al. 2021; Ferris 2019; Ferris and Scott 2019; Wessen 2006, 2009). Cascadia Archaeology performed monitoring during excavations for the Port's stormwater infiltration pond and outflow trench in 2016 (Boersema 2016). This prior work is within the pilot project site. The 2016 excavation reached a maximum depth of 3 feet, during which no cultural resources were observed.

Tse-Whit-Zen

The most extensive subsurface survey in the Port's log yard was performed in 2020 by Cardno, during which the boundary of Tse-whit-zen within the confines of the Port's stormwater project was delineated. 169 test pits were mechanically excavated (Colón et al. 2021); eight of these test pits overlap the pilot project site (Allen and Ferris 2023). No anthropogenic sediments or cultural deposits were observed in these eight test pits, which terminated at depths between 15.7 inches and 29.5 inches.

In July 2023, HDR monitored ground water well installation and bank soil sampling for the Port along the shoreline (Allen et al. 2023). Four soil borings were placed in proximity to the pilot project site. These soil borings were excavated to between 15 and 20 feet deep. The soil borings revealed reworked beach and dredge material to at least 15 feet below surface, and no anthropogenic sediments or cultural deposits were observed.

Dive inspection of Terminal 7 was performed in 2008, which revealed a steeply sloping surface just beyond the outer edge of the terminal, suggesting disturbance to the seabed from either deliberate dredging or inadvertent scouring (Wessen 2009). The area inspected overlaps with the pilot project site, and no potentially significant cultural materials were observed during the dive inspection.

Extensive studies were performed between 2003 and 2009 on the former Washington State Department of Transportation (WSDOT) graving dock site, which is adjacent to the Port's log yard. The graving dock is where Tse-whit-zen (45CA523) was documented (Gill 2005; Hartmann 2003; Lewarch et al. 2005; Schumacher 2003; Schumacher and Gill 2005; White 2009).

Based on the results of Cardno's 2020 investigations, the closest point of Tse-whit-zen to the pilot project site is about 20 feet to the southwest (Colón et al. 2021). The cultural materials at this nearest portion of Tse-whit-zen consist of disturbed shell midden. The Cardno 2020 investigation revealed that intact cultural deposits are located about 500 feet west of the project site (Colón et al. 2021).

Twentieth Century Industrial Mills

Historic materials related to the twentieth century industrial mills may be located within the pilot project site. However, these materials are expected to be within disturbed contexts because of the extensive reworking and import of fill and dredge materials beginning in 1958. As documented in Wegmann et al. (2010), the shoreline largely consists of imported fill and dredge materials reaching a maximum depth of 26.1 feet (8 meters).

Three historic archaeological sites have been previously documented in the Port's log yard outside the pilot project site by Cardno, including 45CA773 (railroad spur), 45CA796 (railroad spur), and 45CA797 (kiln stack/historic debris scatter) (Colón et al. 2021; Ferris and Scott 2019). All three sites were previously recommended not eligible for listing in the NRHP because they lack historic integrity and are not significant under any of the NRHP Criteria for Evaluation.

In 1914, the first sawmill, known as Big Mill, and a rail line were constructed near the pilot project site to support logging operations in the vicinity; the Big Mill operated until the Great Depression in the 1930s. In 1918, after World War I, a boxboard mill, known as the Crescent Boxboard Company, was developed near the pilot project site within what is the log yard today. The mill produced carton and paper packaging and was later renamed Fiberboard Products.

The following year, a pulp mill was constructed next to the Crescent Boxboard Company site and operated until 1921 under the name Washington Pulp and Paper Corporation and later as Crown Zellerbach. The boxboard mill continued operations as a fiberboard mill until the end of 1970. The property was subsequently sold to M&R Lumber, who demolished most of the boxboard mill buildings and operated a new planer mill and log yard. Daishowa America Company then purchased the property in 1988 for wood chip loading and storage. Nippon Paper purchased Daishowa America Company in 1991, and in 2004, Nippon Paper sold the property to the Port, which currently operates a log yard on the property.

Marine Terminal

A historic commercial marine terminal, Terminal 7, is within the pilot project site. Terminal 7 was built between 1925 and 1930 and measures 40 feet wide and 335 feet in length (excluding the mooring dolphins). The terminal formerly functioned in conjunction with Fiberboard Paper and Cardboard Mill, and later as a wood chip export facility for Daishowa America Company, but is no longer in use (Artifacts Consulting 2014). The terminal was documented by Artifacts Consulting (2013) on a historic property inventory form and subsequently determined not eligible for the NRHP by USACE in consultation with the Washington State Department of Archaeology and Historic Preservation (DAHP) in 2015 (Artifacts Consulting 2014). Terminal 7 is not eligible for the NRHP due to its diminished integrity resulting from previous alterations and additions to the terminal.

c. **Describe the methods used to assess the potential impacts to cultural and historic resources on or near the project site. Examples include consultation with tribes and the department of archeology and historic preservation, archaeological surveys, historic maps, GIS data, etc.**

The potential impacts to cultural and historic resources on or near the pilot project site were evaluated by consulting with the Lower Elwha Klallam Tribe, reviewing previously prepared reports available in the Washington Information System for Architectural and Archeological Records Data (WISAARD), and reviewing the results of prior studies and proposed project construction methods. The Lower Elwha Klallam Tribe and the project team met in person on December 1, 2023, to discuss the pilot project and walk through the pilot project site. The Lower Elwha Klallam Tribe and the project team have exchanged numerous emails regarding the pilot project's design and potential impacts to cultural resources.

As noted previously, Tse-whit-zen was extensively studied in 2004 as part of the WSDOT graving yard and dock to support replacement and refurbishment of Hood Canal Bridge concrete pontoons (Gill 2005; Hartmann 2003; Lewarch et al. 2005; Schumacher 2003; Schumacher and Gill 2005; White 2009). Tse-whit-zen was further studied in 2017 and 2020 as part of the Port's stormwater project (Colón et al. 2021; Ferris 2019; Ferris and Scott 2019). Previous surveys and/or monitoring with boundaries that overlap the pilot project site have also been performed (Allen and Ferris 2023; Allen et al. 2023; Boersema 2016; Colón et al. 2021; Wessen 2009).

The historic shoreline was studied and reported on by Wengler (2009), who compiled early and more recent maps of the Port Angeles shoreline and produced a series of nine geo-rectified maps of this area ranging from 1864 to 2007. Additionally, Wegmann et al. (2010, 2012) performed a geomorphology study of the Port Angeles waterfront and assessed the coastal landscape for archaeological sensitivity, including the vicinity of the project site.

d. **Proposed measures to avoid, minimize, or compensate for loss, changes to, and disturbance to resources. Please include plans for the above and any permits that may be required.**

The pilot project's engineering design and construction plans and methods have been refined to avoid physically impacting Tse-whit-zen. No cultural resources have been identified in the pilot project site, and no measures are proposed because no impacts are anticipated.

Based on prior investigations, the pilot project site is located on an artificially formed shoreline through the deposition and reworking of imported fill and dredge materials during the 20th century. The pilot project site is outside the known boundary of Tse-whit-zen. Accordingly, an Archaeological Site Alteration and Excavation Permit from DAHP is not required.

The pilot project is also being reviewed under Section 106 of the NHPA by USACE due to federal permitting requirements. As part of the Section 106 review process, the project team is preparing a cultural resources review (Allen and Ferris 2024) that will be shared with the Lower Elwha Klallam Tribe and submitted to USACE to support Section 106 consultation. Additionally, the project team anticipates preparing a Monitoring and Inadvertent Discovery Plan (MIDP) for use during pilot project construction and having an HDR professional archaeologist on-site to monitor all ground-disturbing activities. The MIDP will outline the Tribal notification and monitoring protocols, as well as the steps to follow in the event of an inadvertent discovery.

14. Transportation

Find help with answering transportation questions[16]

a. Identify public streets and highways serving the site or affected geographic area and describe proposed access to the existing street system. Show on site plans, if any.

State Route 1010 would be the main highway used to access Port Angeles. Marine View Drive would be the public street used to access the site during both construction and operation. The main entrance to the log yard on Marine View Drive would be used as the primary entrance. The secondary entrance would be the site entrance near the boat launch to the east.

b. Is the site or affected geographic area currently served by public transit? If so, generally describe. If not, what is the approximate distance to the nearest transit stop?

Port Angeles is served by public transit. Clallam Transit Route 26 serves the area near the site. Transit stops are located within approximately 0.5 mile of the site to the west and east of Marine View Drive.

c. Will the proposal require any new or improvements to existing roads, streets, pedestrian, bicycle, or state transportation facilities, not including driveways? If so, generally describe (indicate whether public or private).

The pilot project would not require any new or improvements to existing roads, streets, pedestrian, bicycle, or state transportation facilities.

d. Will the project or proposal use (or occur in the immediate vicinity of) water, rail, or air transportation? If so, generally describe.

The pilot project may use barges to ship aggregate material during operations, utilizing existing Port infrastructure near the pilot project site. Rail and air transportation are not anticipated to support the pilot project.

e. How many vehicular trips per day would be generated by the completed project or proposal? If known, indicate when peak volumes would occur and what percentage of the volume would be trucks (such as commercial and nonpassenger vehicles). What data or transportation models were used to make these estimates?

[16] https://ecology.wa.gov/Regulations-Permits/SEPA/Environmental-review/SEPA-guidance/SEPA-checklist-guidance/SEPA-Checklist-Section-B-Environmental-elements/Environmental-elements-14-Transportation

It is expected that commercial truck vehicles would deliver or remove aggregate approximately once per week. Truck transportation to remove acid by-product would occur more infrequently. On-site staff may drive private vehicles to the site.

f. **Will the proposal interfere with, affect, or be affected by the movement of agricultural and forest products on roads or streets in the area? If so, generally describe.**

The pilot project would not interfere with, affect, or be affected by the movement of agriculture and forest products on roads or streets in the area.

g. **Proposed measures to reduce or control transportation impacts, if any:**

Operation of the pilot project would minimize commercial deliveries during operation to the extent practicable. Staff would utilize existing on-site parking areas.

15. Public services

Find help answering public service questions[17]

a. **Would the project result in an increased need for public services (for example: fire protection, police protection, public transit, health care, schools, other)? If so, generally describe.**

The project would not result in the need for additional public services.

b. **Proposed measures to reduce or control direct impacts on public services, if any.**

No measures are proposed to reduce or control impacts on public services.

16. Utilities

Find help answering utilities questions[18]

a. **Circle utilities currently available at the site: electricity, natural gas, water, refuse service, telephone, sanitary sewer, septic system, other:**

b. **Describe the utilities that are proposed for the project, the utility providing the service, and the general construction activities on the site or in the immediate vicinity which might be needed.**

Electricity: Port Angeles Public Utilities

Electrical lines are currently routed from the utility to an existing electrical structure. Project Macoma, LLC, would need to route additional lines and upgrade the electrical panel to distribute the electricity to the shipping containers.

Project Macoma, LLC, is planning to route the electrical distribution lines by attaching them to existing structures, and across the roofs of the containers.

[17] https://ecology.wa.gov/regulations-permits/sepa/environmental-review/sepa-guidance/sepa-checklist-guidance/sepa-checklist-section-b-environmental-elements/environmental-elements-15-public-services
[18] https://ecology.wa.gov/regulations-permits/sepa/environmental-review/sepa-guidance/sepa-checklist-guidance/sepa-checklist-section-b-environmental-elements/environmental-elements-16-utilities

Signature

Find help about who should sign[19]

The above answers are true and complete to the best of my knowledge. I understand that the lead agency is relying on them to make its decision.

Type name of signee: Kyla Westphal

Position and agency/organization: VP, External Affairs / Ebb Carbon

Date submitted: 02/26/24

[19] https://ecology.wa.gov/Regulations-Permits/SEPA/Environmental-review/SEPA-guidance/SEPA-checklist-guidance/SEPA-Checklist-Section-C-Signature

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Attachment 1
Project Description

Project Description

Project Macoma, LLC, a wholly owned subsidiary of Ebb Carbon, is proposing a temporary pilot-scale marine carbon dioxide removal (mCDR) project (pilot project or Project Macoma) sited at Terminal 7 of the Port of Port Angeles (Port) in Port Angeles, Washington (see Attachment 1-1, Drawing C-001). Ebb Carbon has developed an mCDR technology to safely and permanently remove carbon dioxide (CO_2) from the atmosphere while reducing seawater acidity locally. Ebb Carbon's mCDR technology removes acid from seawater, generating alkaline-enhanced seawater in the process. The alkaline-enhanced seawater is returned to the ocean, which enables the ocean to draw down and store additional CO_2 from the atmosphere.

The proposed pilot project, owned and operated by Project Macoma, LLC, would intake seawater via a barge moored at the Terminal 7 dock, pipe the seawater over the existing Terminal 7 pier structure to a modular treatment facility on land, and process and deacidify the seawater before returning it to Port Angeles Harbor via the barge-based outfall system (see Attachment 1-1, Drawings C-101 and C-800). The purposes of the proposed pilot project are to operate Ebb Carbon's mCDR technology under real-world conditions, support scientific research through scientific and academic collaborations, and gather additional data to inform future deployments. This field trial is conservatively designed to remove 500 net tons of CO_2 from the atmosphere per year and reduce ocean acidification locally. Project Macoma, LLC, plans to undertake this pilot project with Pacific Northwest National Laboratory, the University of Washington, and other agency and scientific partners. Project Macoma, LLC, and the Lower Elwha Klallam Tribe are discussing the potential for partnership on this pilot project. The proposed pilot project would run for approximately 1.5 years, beginning in summer 2024.

This section provides additional information about the pilot project's elements along with a description of construction and operational activities.

1 Project Elements

As a pilot project, the proposed project elements would be installed as temporary features. The main elements consist of the following:

- A moored barge at the Terminal 7 pier with pumps and pipes that are used to intake, transport, and discharge seawater to the Port Angeles Harbor, adjacent to the Strait of Juan de Fuca.
- Onshore modular water treatment equipment that is used to filter and soften the water and create a concentrated brine.
- Onshore electrochemical processing equipment that is used to deacidify the seawater.
- Onshore equipment used to neutralize the acidic byproduct.

For safety, control, and research purposes, the project design also includes sensing and monitoring equipment that will be located at the site and throughout the harbor.

The proposed project footprint would roughly occupy 275 feet by 93 feet onshore, with the barge occupying roughly 30 feet by 80 feet adjacent to the Terminal 7 dock. The onshore area is located on Port-owned property and is currently being used as a log yard. Access and parking would be provided by existing infrastructure at the Port. The in-water portion of the site is located on state-owned aquatic lands that are leased by the Port under a Port Management Agreement.

1.1 Onshore Elements

A majority of the process equipment would be located onshore and would utilize shipping containers (up to 9.5 feet high with 2 additional feet for electrical lines) as machine housing. The treatment equipment would be procured from a combination of third-party manufacturers and assembled by Ebb Carbon. The treatment equipment and process are described in greater detail in Section 2.3 and Attachment 1-1, Drawing C-201.

In total, there would be 10 shipping containers, six mobile tanks, two utility sheds, and one office trailer, which would be used for the following functions:

- The shipping containers would contain seawater processing equipment. Plastic pipelines would connect the treatment facilities to and from the barge intake and outfall structures.
- Alkaline minerals and the equipment used for acid neutralization would be stored on site in lined containers with weather coverings.
- The mobile tanks would be used to store pumped seawater and the acid and base extracted from the brine. The mobile tanks would contain approximately 8,000 to 21,000 gallons and be 10 feet high with 2 additional feet for electrical lines. Any hazardous chemicals would be stored with appropriate secondary containment following best management practices (BMPs). All tanks would have containment suitable for minor leaks.
- Two of the utility sheds would house electrical equipment, providing required electrical protective measures consistent with City of Port Angeles (City) requirements. The third would be for storage and maintenance operations.

The office trailer would be for staff operations. The pilot project would rely on the Port’s existing stormwater system at Terminal 7 for stormwater runoff. The area was previously graded to slope away from the shore to a collection point where water is captured and treated by the Port’s stormwater system.

1.2 In-Water Elements

The in-water elements of the proposed pilot project include the barge, which would be equipped with intake and outfall infrastructure, water pumps, and water quality monitoring equipment.

The barge would be an approximately 30- by 80-foot platform (2,400 square feet) that houses the intake and outfall structures and pumps. The barge would also house some utilities and monitoring equipment. The intake would consist of a pipe that is attached to the barge, equipped with fish screening and mesh that complies with state and federal requirements. The outfall would be an approximately 4-inch-diameter and 50-foot-long pipe that is affixed to and runs the length of the barge, with half-inch perforation holes spaced approximately 2 feet apart and pointing toward the surface across the pipes to diffuse the discharged alkaline-enhanced seawater back into the harbor. The pipe would be submerged approximately 2 meters below the water surface (approximately 28 to 35 feet from the substrate at low to high tide levels, respectively).

Scientific monitoring would occur in the receiving waters throughout operations. Water quality sensors would be attached to existing piers to collect regular measurements. Ebb Carbon would use these measurements to adaptively manage operations, if needed, and to monitor environmental health and benefits.

2 Construction

Project construction is anticipated to begin in 2024. Construction activities would involve site preparation, construction, and assembly of onshore structures (i.e., electrical equipment enclosures); deployment of the barge; and assembly of intake/outfall and monitoring equipment. No existing structures would be demolished. All activities would be conducted in a manner appropriate to minimize the potential for erosion or spills consistent with applicable regulations and required permits and approvals. All ground-disturbing activities are expected to be conducted outside sensitive cultural resource areas.

Site preparation is anticipated to require minimal ground disturbance, mainly in the form of targeted areas of excavation required for the electrical equipment (i.e., not for larger structures). Elements of design that would involve potential onshore ground disturbance include the following:

- One to two copper ground rods (10 feet long and 3/4 inch in diameter) would be placed adjacent to each container/trailer corner, and two to four ground rods would be placed at each electrical building/shed. The ground rods would be driven vertically into the ground for site/system grounding. All ground cable and ground connections to equipment would be run above grade.
- An equipment pad would be constructed for the site electrical shed.
- Improvements to the existing utility main electrical room may include excavation of a conduit trench between the existing electrical room and the existing City utility transformer vault (on the northwest side of the utility vault). This conduit trench excavation may be avoided or minimized if an above-grade conduit is permitted by the City when the new transformer is installed.

- Excavation would be avoided for anchorage of trailers/containers/tanks for the electrical shed foundation and the utility vault building electrical area by laying down gravel and anchoring the trailers/containers/tanks to concrete blocks, if necessary.

Above-grade gravel fill would be used for access paths and the areas where the containers are located. This excludes the existing electrical area, which would not receive fill. Based on the approximate area of 21,018 square feet, the pilot project would use 12 inches of aggregate base under trailers and for access area. These include approximately 950 cubic yards of hauled loose aggregate gravel and approximately 800 cubic yards of compacted aggregate gravel, for a total of approximately 1,750 cubic yards.

Ebb Carbon would also prepare and implement a Contaminated Materials Management Plan (CMMP) to address potential issues if contaminated sediments are encountered. Although the level of ground disturbance would be minimal, the CMMP would help to ensure potential concerns are adequately addressed. The CMMP would include testing and appropriate disposal of excavated materials. Ebb Carbon also expects to develop a Monitoring and Inadvertent Discovery Plan for cultural resources.

The intake and outfall piping, screens, flexible connections, and other components would be prefabricated and connected to pump skids, which would be mounted on the barge. The barge would be moored on the north side of the existing dock. The pre-assembled pipelines and intake and outfall structures would then be mounted to the barge using small hoists. Scientific monitoring equipment would also be installed on the barge and to existing piers.

2.1 Bunker Building and Electrical Equipment

The existing bunker building would receive various architectural, mechanical, and electrical updates and improvements. The building updates include adding insulation to the interior walls and ceiling. The existing door would be replaced with a larger door meeting equipment access and egress requirements. The space would be conditioned with a new mechanical HVAC system to maintain proper humidity and temperature for the new electrical equipment.

The existing electrical service and associated equipment would be removed and upgraded as part of the proposed pilot project. A larger electrical utility transformer would be installed in place of the existing service due to the increased electrical demands of the pilot project. This new transformer would supply power to new electrical distribution equipment installed within the bunker building, including lighting and convenience receptacles. Existing electrical gear that is to remain in service would be connected to the new equipment being procured and installed.

All modifications and improvements would be done per local, state, and federal codes and guidelines.

3 Operation

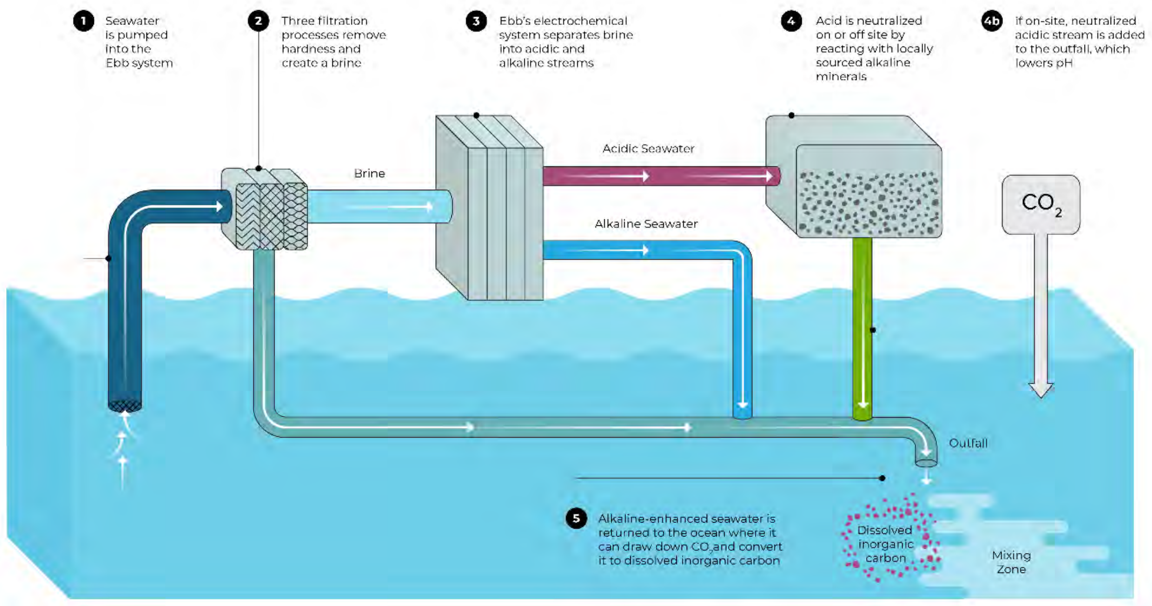
The pilot project's nameplate capacity is for 500 net tons of CO_2 removal per year from the atmosphere. The intake and outfall infrastructure would intake and return approximately 97,000 gallons per day (372,000 liters per day) of seawater from Port Angeles Harbor. Proposed pilot project operations are expected to last approximately 1.5 years post-construction (through 2025 and into 2026). If operations are extended, it would be in coordination with the Port, Lower Elwha Klallam Tribe, and review agencies. Monitoring is expected to occur after operations have concluded to gather post-operational data for review.

Operational activities include pilot-scale water treatment to deacidify seawater to support CO_2 removal from the atmosphere, possible sale and/or transport of acidic byproduct off site, transport on- and off site of alkaline minerals for acid neutralization, and monitoring and data collection activities. This section describes these aspects.

3.1 Water Treatment Process

A schematic of the treatment process is shown in Figure 1.

Figure 1
Schematic of Water Treatment Process



The main steps of the water treatment process include the following:

1. **Water Intake :** Water intake would occur at the barge.
2. **Water Pretreatment:** Once pumped onshore, the seawater would undergo pretreatment, which includes particulate filtration (to remove solids), nanofiltration (to remove hardness, calcium, and magnesium ions), and reverse osmosis to create a brine and permeate that will undergo electrochemical processing.
3. **Electrochemical Processing:** After pretreatment, the brine stream would be consumed electrochemically. Ebb Carbon's electrochemical technology uses low-carbon electricity to pass the brine through a series of ion-exchange membranes that separates the brine into two solutions: a base (sodium hydroxide [NaOH]) and an acid (hydrochloric acid [HCl]). The electrochemical process produces oxygen and hydrogen gases at ambient pressures that will be diluted below lower explosive limits and vented to the atmosphere following all applicable standards. The site generation rate of these are low, at 10 and 20 standard liters per minute undiluted, respectively.
4. **Acid Neutralization:** The acid produced from the brine may be neutralized at the site, so it does not return to the ocean. This would be done by reacting the acidic solution with alkaline materials such as ultramafic rocks, limestone, or unhardened concrete. If reacted on site, alkaline minerals would be transported to the site via truck and/or boat approximately once per week. The aqueous neutralized stream would then be filtered to remove solids and trace metals below acceptable limits before being recombined with the pretreated seawater and alkaline stream. Once combined, the streams would be pumped to the barge for outfall. Another option would be to remove and transport the acid off site rather than neutralizing on site.
5. **Discharge and Monitoring:** After processing on land, the combined streams (pretreated seawater, alkaline stream, and, if applicable, the neutralized stream) form an alkaline-enhanced seawater that would be pumped to the barge-based outfall. The outfalled alkaline-enhanced seawater would mix with ambient seawater to remove CO_2 gas from the air and store it as dissolved inorganic carbon, primarily bicarbonate ions—a safe and naturally abundant form of carbon storage in the ocean.
    a. The discharge is designed to be continuous for multiple hours per day throughout the pilot study with different discharge scenarios occurring to provide additional scientific information. Discharge may stop if monitors indicate that certain thresholds have been met.
    b. Although no new constituents would be added (e.g., no metals or organic compounds), the pH of the water could be altered from approximately 8 to 13.5 pH for short periods of time (a single tidal cycle). Preliminary mixing analyses indicate that surrounding pH would return to ambient within the nearfield mixing zone, approximately 21 feet from the discharge point at the barge. Water quality would return to ambient approximately 40 feet around the discharge, well within the allowable chronic mixing zone. During

operations, the mixing zone will be maintained within permitted limits. The standard Washington State Department of Ecology required mixing zone distance is 207 feet from the point of discharge. Water quality monitoring and ecological monitoring would be conducted within both zones to ensure safe operations of the pilot study and to collect data to help inform further development and deployment of this technology. Water quality monitoring would occur to assess for potential acute and chronic mixing zone exceedances at proposed distances of 15 and 150 feet, respectively.

3.2 Acid Byproduct Removal and Handling

When combined with the pretreated seawater and alkaline stream, the acidic byproduct would lower the pH of the alkaline-enhanced seawater, resulting in a final product with a pH that is similar to the receiving waters. There is also a potential that the HCl could be separated from the influent stream and used off site for other processes (e.g., in cement manufacturing or laboratory research). While on site, acid byproduct would be handled, stored, and transported consistent with applicable local, state, and federal regulations. It is assumed that entities receiving the acid would also adhere to required standards and regulations. Truck traffic to transport acid byproducts would occur approximately once per month.

3.3 Water Quality Monitoring

Water quality monitoring would be accomplished by attaching sensors to existing piers to collect regular measurements of water temperature, salinity, dissolved oxygen, turbidity and suspended solids, chlorophyll, pH, and the partial pressure of CO_2. Less frequent seawater samples would be collected and analyzed for total alkalinity and dissolved inorganic carbon.

3.4 Best Management Practices

BMPs would be implemented during construction to avoid or minimize potential impacts to the environment. BMPs would include, but not be limited to, the following:

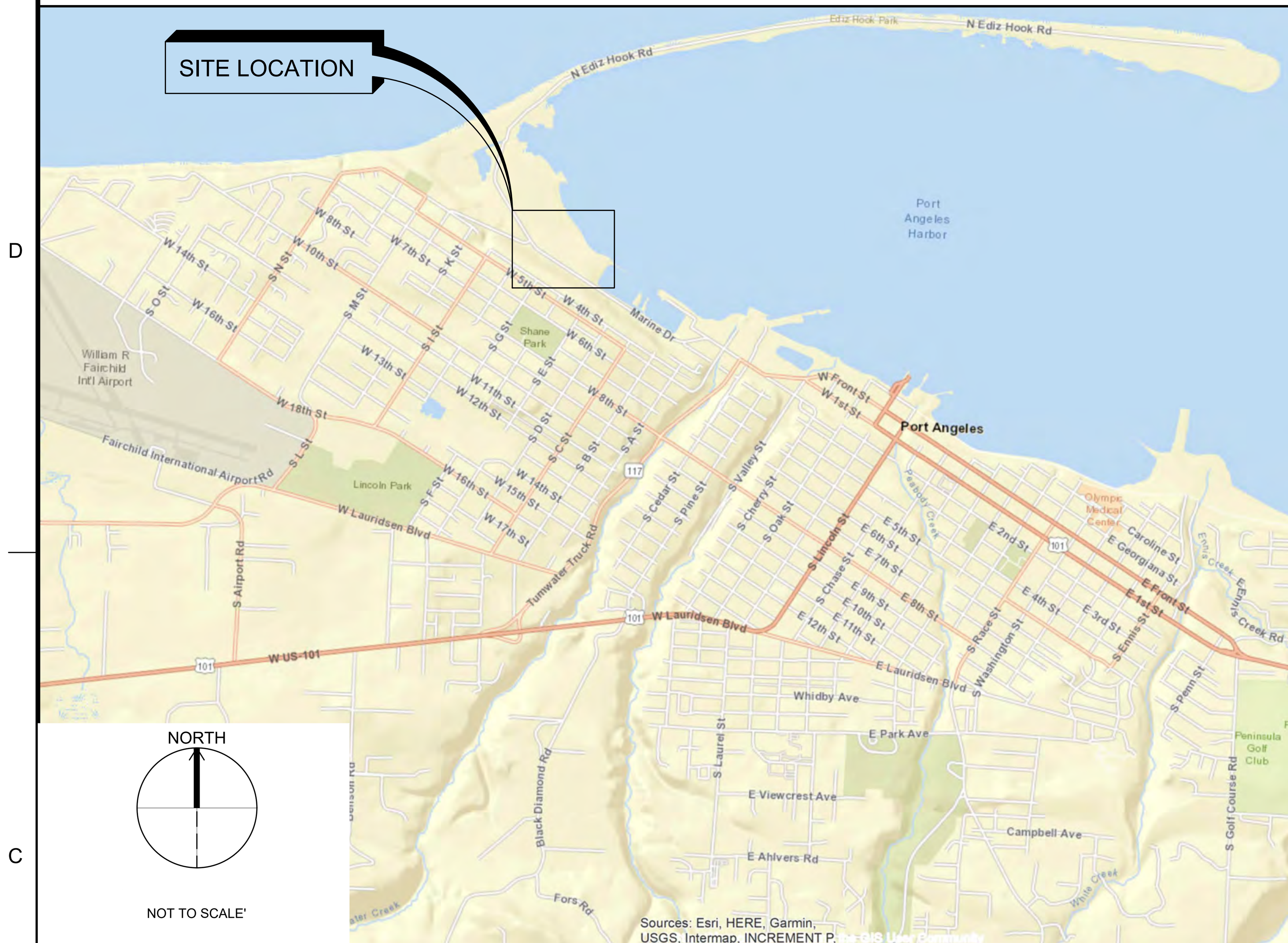
- Work would be performed according to the requirements and conditions of the project permits and approvals.
- Construction activities would be completed consistent with the Temporary Erosion and Sediment Control and stormwater site plans prepared for the project. Erosion control measures may include installing a stabilized construction access; construction road stabilization; installing mulching, nets, and blankets; applying surface roughing, gradient terraces, interceptor dikes, and swales; dust control; material delivery storage and containment; outlet protection; and installing waffles, filter berms, or silt fencing.
- A CMMP would be prepared and implemented during construction to address potential issues if contaminated soils are encountered.

- The contractor would be required to develop and implement a Spill Prevention, Control, and Countermeasure Plan to be used for the duration of the project to safeguard against unintentional release of fuel, lubricants, or hydraulic fluid from construction equipment.
- Construction equipment used on the project would be maintained in good working order to minimize airborne emissions.
- Dust control measures, such as application of water, would be employed during construction, as necessary.
- No uncured concrete would be in contact with surface waters.
- The contractor would be required to properly maintain construction equipment and vehicles to prevent them from leaking fuel or lubricants; if there is evidence of leakage, the further use of such equipment would be suspended until the deficiency has been satisfactorily corrected.
- Excess or waste materials would not be disposed of or abandoned in Port Angeles Harbor or allowed to enter waters of the state.
- Project Macoma, LLC, would adopt and implement the Port's Storm Water Pollution Prevention Plan (SWPPP) that specifies measures to avoid and minimize impacts to surface, ground, and stormwater water and drainage pattern impacts.
- Project Macoma, LLC, would develop, maintain, and implement a chemical management plan that includes specific procedures for procurement, delivery, transfer, storage, inventory, use, spill prevention and cleanup, emergency response, and disposal. All employees and contractors would receive chemical management training within 1 month of hiring and annually thereafter.
- New light fixtures for overwater structures would be directed away from the water to the extent practicable to minimize impacts on aquatic species.
- The intake screen would be designed to screen fish from entering the intake facilities in compliance with current fish screening guidelines from the Washington Department of Fish and Wildlife and the National Marine Fisheries Service.
- A Monitoring and Inadvertent Discovery Plan for cultural resources would be prepared and implemented during project construction.

Attachment 1-1

Plan Set

VICINITY PLAN:



PORT OF PORT ANGELES CULTURAL RESOURCE NOTES:

1. SUBSURFACE CULTURAL RESOURCES ARE KNOWN TO EXIST AT THE SITE.
2. PROPOSED IMPROVEMENT DESIGN IS INTENDED TO PROVIDE GENERAL FILL CONDITIONS ONLY. ANY EXCAVATION OR BELOW GRADE SOIL DISTURBANCE SHALL BE REVIEWED BY THE PORT OF PORT ANGELES.
3. AN ARCHAEOLOGIST UNDER CONTRACT WITH THE PORT WILL BE ONSITE DURING GROUND DISTURBING ACTIVITIES TO OVERSEE THE WORK.
4. FOR ALL PROJECT EXCAVATIONS, THE CONTRACTOR SHALL ENSURE THE ARCHEOLOGIST IS ONSITE PRIOR TO STARTING WORK.
5. IF CULTURAL RESOURCES (E.G., REMAINS, ARTIFACTS, ETC.) ARE UNCOVERED DURING EXCAVATION, THE CONTRACTOR SHALL STOP WORK AND NOTIFY AND CONSULT WITH THE ARCHEOLOGIST AND PORT PRIOR TO RECOMMENCING WORK.

PARCEL INFORMATION:

SITE OWNER: PORT OF PORT ANGELES

ADDRESS: 1433 MARINE DRIVE, PORT ANGELES, WA

PROPERTY ID/PARCEL NUMBER: 61350/063000505520

ABBREVIATIONS:

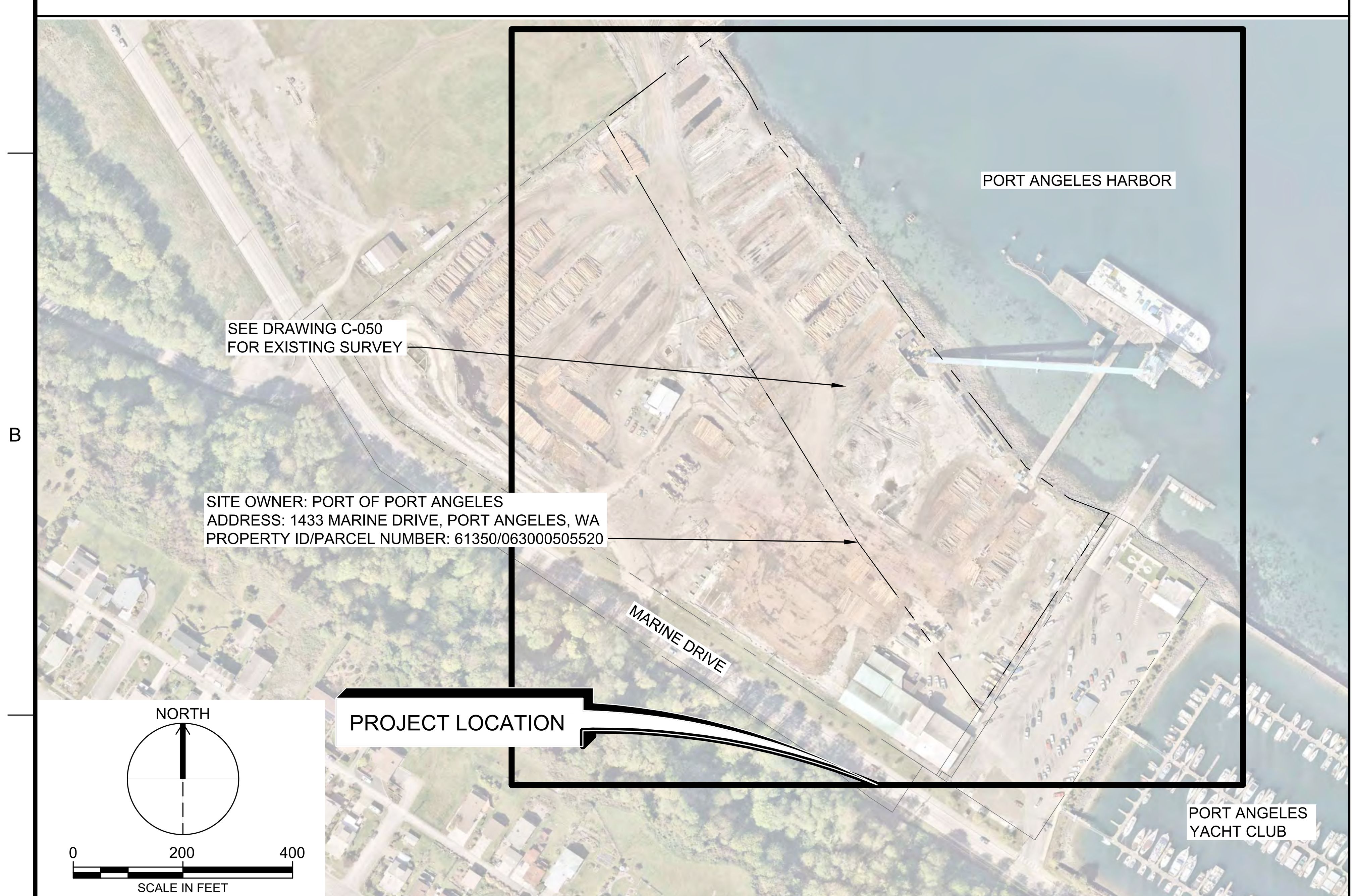
&	AND
±	APPROXIMATELY
℄	CENTERLINE
°	DEGREES
Ø	DIAMETER
'	FOOT
"	INCH
#	NUMBER
AC	ACRE, ASPHALT CONCRETE
APPROX	APPROXIMATE
BLDG	BUILDING
CB	CATCH BASIN
CF	CUBIC FEET
CFS	CUBIC FEET PER SECOND
CITY	CITY OF PORT ANGELES
CMP	CORRUGATED METAL PIPE
CONC	CONCRETE
CONT	CONTINUATION
CSBC	CRUSHED SURFACE BASE COURSE
CSTC	CRUSHED SURFACE TOP COURSE
CTB	CEMENT TREATED BASE
CY	CUBIC YARDS
DR	DRIVE
DEMO	DEMOLISH
DEPT	DEPARTMENT
DET	DETAIL
DIA	DIAMETER
DWG	DRAWING
EG	EXISTING GRADE
EL	ELEVATION
E	EXISTING
FG	FINISHED GRADE
FT	FOOT
HORZ	HORIZONTAL
IE	INVERT ELEVATION
IN	INCHES
LF	LINEAR FEET
MAX	MAXIMUM
MH	MANHOLE
MIN	MINIMUM
N	NORTH
NAD	NORTH AMERICAN DATUM
NAVD	NORTH AMERICAN VERTICAL DATUM
NTS	NOT TO SCALE
PORT	PORT OF PORT ANGELES
PSI	POUNDS PER SQUARE INCH
PVC	POLYVINYL CHLORIDE
PVMT	PAVEMENT
SD	STORM DRAIN
SEC	SECTION
SHT	SHEET
SPEC	SPECIFICATION
SS	SANITARY SEWER
STD	STANDARD
TYP	TYPICAL
UG	UNDERGROUND
VERT	VERTICAL
W/	WITH
W/O	WITHOUT
WA	WASHINGTON
WSDOT	WASHINGTON STATE DEPARTMENT OF TRANSPORTATION

GENERAL NOTES:

1. EXISTING SITE CONDITIONS AND TOPOGRAPHY ARE BASED ON SURVEY CONDUCTED BY WENGLER SURVEYING & MAPPING CO. (www.wenglersurveying.com) FROM FEBRUARY 2024 AND SUPPLEMENTED BY ZENOVIC AND ASSOCIATES SURVEY FROM 2012. SEE SHEET C-050 FOR EXISTING CONDITIONS.
2. HORIZONTAL DATUM = WASHINGTON STATE PLANE COORDINATE SYSTEM - NORTH ZONE, NAD 1983 (FEET).
3. VERTICAL DATUM = 1988 NAVD.
4. PORT ANGELES HARBOR IS IN THIS AREA DESIGNATED AS AN AE FLOODPLAIN WITH A BASE FLOOD ELEVATION OF 13 FEET, NAVD (FEMA PANEL PENDING, 2023). FLOODPLAIN EXTENTS ARE APPROXIMATE.
5. CITY OF PORT ANGELES SHORELINE MASTER PLAN'S SHORELINE DESIGNATION FOR SITE IS HIGH INTENSITY - INDUSTRIAL (HI-I). EXTENTS ARE APPROXIMATE. SHOWN FOR REFERENCE.
6. PARCEL BOUNDARIES ARE APPROXIMATE AND WERE OBTAINED FROM CLALLAM COUNTY GIS PORTAL.
7. FOR BENCHMARKS SEE DRAWING C-050.
8. TIDE LEVELS (BASIS OF SURVEY NOTE 5 ON DRAWING C-050).

TIDE LEVELS		MLLW	NAD88
EHW	EXTREME HIGH WATER	10.50	10.09
HTL	HIGH TIDAL LINE	8.82	8.40
MHHW	MEAN HIGHER-HIGH WATER	7.06	6.64
MHW	MEAN HIGH WATER	6.52	6.10
MLW	MEAN LOW WATER	1.92	1.50
MLLW	MEAN LOWER-LOW WATER	0.00	-0.42
ELW	EXTREME LOW WATER	-4.84	-5.26

LOCATION MAP:



REFERENCE **APPLICANT:** PORT OF PORT ANGELES **LOCATION:** 1433 MARINE DRIVE, PORT ANGELES, WA 98362 **ADJACENT PROPERTY OWNERS:** PORT OF PORT ANGELES LOWER ELWHA KLALLAM TRIBE	**NAME:** MARINE CARBON DIOXIDE REMOVAL PILOT PROJECT (PROJECT MACOMA) **PROPOSED:** TEMPORARY PILOT PROJECT INCLUDING A WATER TREATMENT FACILITY AND BARGE-BASED INTAKE AND OUTFALL SYSTEM. **PURPOSE:** OPERATE AND STUDY MARINE CARBON DIOXIDE REMOVAL PILOT PROJECT.	**LATITUDE:** 48.128749 N **LONGITUDE:** -123.458501 W **S-T-R:** 04-31N-06W **IN:** PORT OF PORT ANGELES, TERMINAL 7 **NEAR/AT:** PORT ANGELES **COUNTY:** CLALLAM **STATE:** WASHINGTON **DATE:** FEBRUARY 2024

Brown AND Caldwell
701 PIKE STREET SUITE 1300
SEATTLE, WA 98101

NOT FOR CONSTRUCTION

ISSUED FOR PERMIT

ebb carbon

PROJECT MACOMA LLC
PORT ANGELES, WA

REVISIONS

REV	DATE	DESCRIPTION

LINE IS 2 INCHES AT FULL SIZE

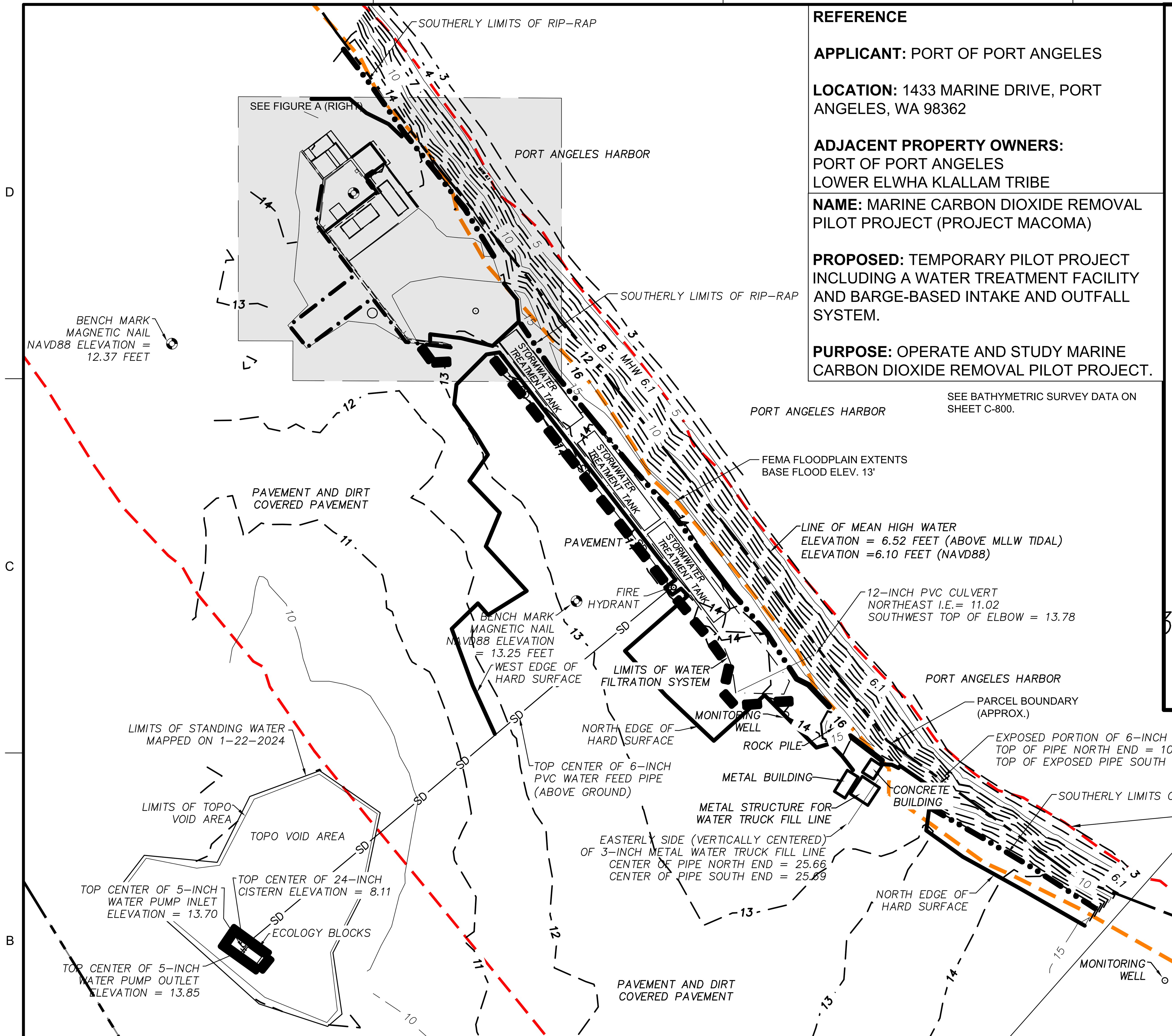
DESIGNED: R. MATTUCCI
DRAWN: R. JOHNSON
CHECKED: R. MATTUCCI
CHECKED: R. RHODES
APPROVED:

FILENAME
C-001_JARPA.dwg
BC PROJECT NUMBER
159812
CLIENT PROJECT NUMBER

CIVIL

PROJECT LOCATION, NOTES, AND ABBREVIATIONS

DRAWING NUMBER
C-001



REFERENCE

APPLICANT: PORT OF PORT ANGELES

LOCATION: 1433 MARINE DRIVE, PORT ANGELES, WA 98362

ADJACENT PROPERTY OWNERS:
PORT OF PORT ANGELES
LOWER ELWHA KLALLAM TRIBE

NAME: MARINE CARBON DIOXIDE REMOVAL PILOT PROJECT (PROJECT MACOMA)

PROPOSED: TEMPORARY PILOT PROJECT INCLUDING A WATER TREATMENT FACILITY AND BARGE-BASED INTAKE AND OUTFALL SYSTEM.

PURPOSE: OPERATE AND STUDY MARINE CARBON DIOXIDE REMOVAL PILOT PROJECT.

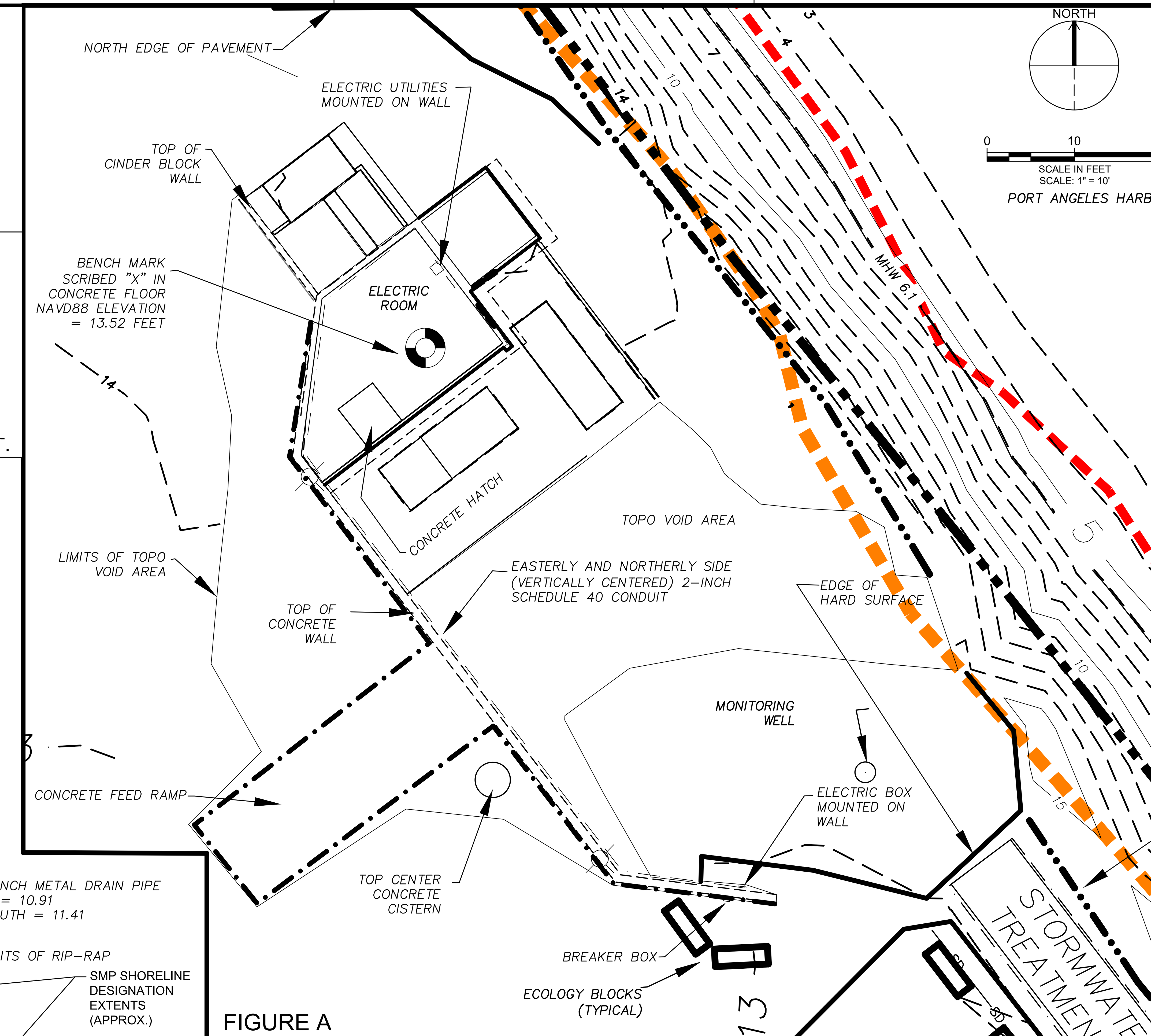


FIGURE A

GENERAL NOTES:

1. EXISTING SITE CONDITIONS AND TOPOGRAPHY ARE BASED ON SURVEY CONDUCTED BY WENGLER SURVEYING & MAPPING CO. (www.wenglersurveying.com) FROM FEBRUARY 2024 AND SUPPLEMENTED BY ZENOVIC AND ASSOCIATES SURVEY FROM 2012.
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MHW	MEAN HIGH WATER	6.52	6.10
MLW	MEAN LOW WATER	1.92	1.50
MLLW	MEAN LOWER-LOW WATER	0.00	-0.42
ELW	EXTREME LOW WATER	-4.84	-5.26

LOCATION OF STORM DRAIN MAN HOLE PER DRAWING BY OTHERS

NORTH

0 30 60
SCALE IN FEET
SCALE: 1" = 30'

LATITUDE: 48.128749 N
LONGITUDE: -123.458501 W
S-T-R: 04-31N-06W

IN: PORT OF PORT ANGELES, TERMINAL 7
NEAR/AT: PORT ANGELES
COUNTY: CLALLAM
STATE: WASHINGTON

DATE: FEBRUARY 2024

BASIS OF SURVEY NOTES:

1.) THIS SURVEY IS BASED UPON THE WASHINGTON COORDINATE SYSTEM GRID, NORTH ZONE, NORTH AMERICAN DATUM OF 1983, 1991 ADJUSTMENT (NAD83/91). SAID DATUM WAS DERIVED FROM TERRESTRIAL TIES BETWEEN NATIONAL GEODETIC (NGS) CONTROL MONUMENT "L467", VM NUMBER 1112, PID NUMBER TR0790 AND NATIONAL OCEAN SURVEY (NOS) CONTROL MONUMENT "4090A 1981", VM NUMBER 1118, PID NUMBER TR2551.

IN ADDITION CITY OF PORT ANGELES GEODETIC CONTROL MONUMENTS 06313360P (C11-3-1), 06300381P (F13-3-1), 06300380P (G13-1-1)AND 06300482P (G11-1-2) AS SHOWN ON BOOK 34 OF SURVEYS, PAGE 22 AND BOOK 48 OF SURVEYS, PAGE 84 RECORDS OF CLALLAM COUNTY, WASHINGTON WERE ORIGINALLY INCORPORATED INTO THIS CONTROL NETWORK.

MEASURED DISTANCES WERE REDUCED USING A COMBINED SCALE AND ELEVATION FACTOR. THE AVERAGE SCALE FACTOR IS 0.99994227. THE AVERAGE ELEVATION FACTOR IS 1.00000249. THE AVERAGE COMBINED FACTOR IS 0.99994475. TO OBTAIN GROUND DISTANCES MULTIPLY BY 1.00005525.

THE CONVERGENCE ANGLE AT THE MONUMENT OCCUPYING (NGS) CONTROL MONUMENT "L467" IS -1°56'42.93"

2.) THE VERTICAL DATUM USED FOR THIS SURVEY IS THE NORTH AMERICAN VERTICAL DATUM OF 1988 (NAVD88) AS DERIVED FROM TRIGONOMETRIC TIES BETWEEN NATIONAL GEODETIC (NGS) CONTROL MONUMENT "L467",VM NUMBER 1112, PID NUMBER TR0709, NATIONAL OCEAN SURVEY (NOS) CONTROL MONUMENT "4090A 1981", VM NUMBER 1118, PID NUMBER TR2551 AND "4090B 1981", VM NUMBER 1119.

IN ADDITION CITY OF PORT ANGELES GEODETIC CONTROL MONUMENTS 06313360P (C11-3-1), 06300381P (F13-3-1), 06300380P (G13-1-1) AND 06300482P (G11-1-2) AS SHOWN ON BOOK 34 OF SURVEYS, PAGE 22 AND BOOK 48 OF SURVEYS, PAGE 84 RECORDS OF CLALLAM COUNTY, WASHINGTON WERE ORIGINALLY INCORPORATED INTO THIS CONTROL NETWORK.

THE TOPOGRAPHIC ELEMENTS SHOWN HEREON WERE DETERMINED FROM DIRECT FIELD TRIGONOMETRIC MEASUREMENTS PERFORMED BETWEEN 1-11-2024 AND 2-1-2024. THE ACCURACY OF THE CONTOURS ARE 0.5 FEET VERTICALLY.

3.) THIS SURVEY WAS PERFORMED BY FIELD TRAVERSE USING A 5 SECOND TOTAL STATION. EDM EQUIPMENT WAS CALIBRATED ON 5-9-2023 AT THE NGS BASELINE IN PORT ANGELES.

4.) NO UNDERGROUND UTILITY LOCATES WERE PERFORMED DURING THE COURSE OF THIS SURVEY. CALL 1-800-424-5555 BEFORE YOU DIG.

5.) THE LINE OF MEAN HIGH WATER (MHW) AS SHOWN HEREON FALLS ALONG A LINE OF RIP RAP ALONG THE PORT ANGELES HARBOR AND IS SHOWN RELATIVE TO THE NORTH AMERICAN VERTICAL DATUM OF 1988 (NAVD88). TIDAL DATUM IS BASED ON THE U.S. DEPARTMENT OF COMMERCE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION (NOAA) TIDAL STATION 9444090. THE PUBLISHED TIDAL ELEVATION OF MHW FOR PORT ANGELES IS 6.52 FEET ABOVE MEAN LOWER LOW WATER (MLLW). THE PUBLISHED TIDAL ELEVATION FOR THE NAVD88 ABOVE MLLW IS 0.42 FEET. TO CONVERT FROM NAVD88 TO TIDAL DATUM ADD 0.42 FEET TO THE NAVD88 ELEVATIONS SHOWN HEREON.

LEGEND:

- SOUTHERLY LIMITS OF RIP-RAP
- LIMITS OF HARD SURFACE
- BUILDING LINE
- LIMITS OF WATER FILTRATION SYSTEM
- TOP CENTER OF 6-INCH PVC WATER FEED PIPE (ABOVE GROUND)
- LIMITS OF ROCK PILE
- INSIDE CEILING LINE
- INSIDE FLOOR LINE
- TOP CINDER BLOCK WALL
- TOE CINDER BLOCK WALL
- TOE CONCRETE WALL
- TOP CONCRETE WALL
- EDGE OF CONCRETE PADS
- EAVE LINE
- EASTERLY AND NORTHERLY SIDE (VERTICALLY CENTERED) 2-INCH SCHEDULE 40 CONDUIT
- TOP OF DOOR
- EXISTING MAJOR CONTOUR
- EXISTING MINOR CONTOUR
- 6' X 2' X 2' CONCRETE ECOLOGY BLOCK
- FIRE HYDRANT
- MONITORING WELL
- SOUTH FACE OF LIGHT POLE

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PROJECT MACOMA LLC
PORT ANGELES, WA

REVISIONS

REV	DATE	DESCRIPTION

LINE IS 2 INCHES AT FULL SIZE

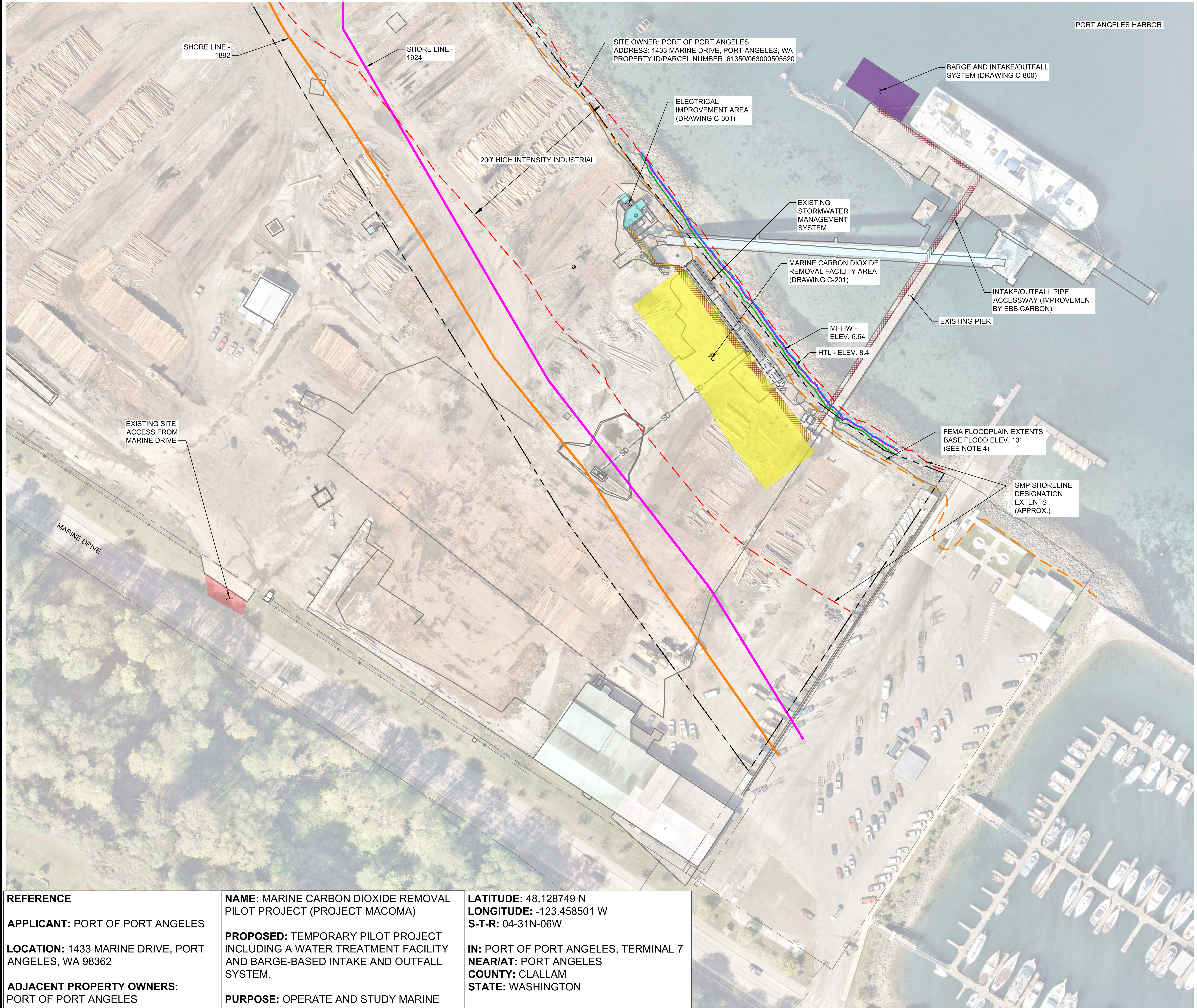
DESIGNED: R. MATTUCCI
DRAWN: R. JOHNSON
CHECKED: R. MATTUCCI
CHECKED: R. RHODES
APPROVED:

FILENAME
C-050_JARPA.dwg
BC PROJECT NUMBER
159812
CLIENT PROJECT NUMBER

CIVIL

EXISTING CONDITIONS

DRAWING NUMBER
C-050



REFERENCE **APPLICANT:** PORT OF PORT ANGELES **LOCATION:** 1433 MARINE DRIVE, PORT ANGELES, WA 98362 **ADJACENT PROPERTY OWNERS:** PORT OF PORT ANGELES LOWER ELWHA KLALLAM TRIBE	**NAME:** MARINE CARBON DIOXIDE REMOVAL PILOT PROJECT (PROJECT MACOMA) **PROPOSED:** TEMPORARY PILOT PROJECT INCLUDING A WATER TREATMENT FACILITY AND BARGE-BASED INTAKE AND OUTFALL SYSTEM. **PURPOSE:** OPERATE AND STUDY MARINE CARBON DIOXIDE REMOVAL PILOT PROJECT.
LATITUDE: 48.128749 N **LONGITUDE:** -123.458501 W **S-T-R:** 04-31N-06W **IN:** PORT OF PORT ANGELES, TERMINAL 7 **NEAR/AT:** PORT ANGELES **COUNTY:** CLALLAM **STATE:** WASHINGTON **DATE:** FEBRUARY 2024	

GENERAL NOTES:

1. BASED ON SURVEY CONDUCTED BY WENGLER SURVEYING & MAPPING CO. (www.wenglersurveying.com) FEBRUARY 2024 AND SUPPLEMENTED BY ZENOVIC AND ASSOCIATES SURVEY FROM 2012.
2. HORIZONTAL DATUM = WASHINGTON STATE PLANE COORDINATE SYSTEM - NORTH ZONE, NAD 1983 (FEET).
3. VERTICAL DATUM = 1988 NAVD.
4. PORT ANGELES HARBOR IS IN THIS AREA DESIGNATED AS AN AE FLOODPLAIN WITH A BASE FLOOD ELEVATION OF 13 FEET, NAVD (FEMA PANEL PENDING, 2023). FLOODPLAIN EXTENTS ARE APPROXIMATE.
5. SHORE MASTER PLAN - SHORELINE DESIGNATION FOR SITE IS HIGH INTENSITY - INDUSTRIAL (HI-I). EXTENTS ARE APPROXIMATE.
6. PARCEL BOUNDARIES ARE APPROXIMATE.
7. FOR BENCHMARKS SEE DRAWING C-050.
8. TIDE LEVELS (BASIS OF SURVEY NOTE 5 ON DRAWING C-050).

TIDE LEVELS		MLLW	NAD88
EHW	EXTREME HIGH WATER	10.50	10.09
HTL	HIGH TIDAL LINE	8.82	8.40
MHHW	MEAN HIGHER-HIGH WATER	7.06	6.64
MHW	MEAN HIGH WATER	6.52	6.10
MLW	MEAN LOW WATER	1.92	1.50
MLLW	MEAN LOWER-LOW WATER	0.00	-0.42
ELW	EXTREME LOW WATER	-4.84	-5.26

9. PORT OF PORT ANGELES SHALL MAINTAIN CLEARANCE FOR FIRE ACCESS. EXISTING ACCESS PATHS SHALL NOT BE OBSTRUCTED SUCH THAT ACCESS FOR FIRE AND OTHER EMERGENCY VEHICLES TO THE ELECTRICAL IMPROVEMENT AREA AND CARBON REMOVAL FACILITY IS BLOCKED DURING CONSTRUCTION AND OPERATION.

PARCEL INFORMATION:

SITE OWNER: PORT OF PORT ANGELES

ADDRESS: 1433 MARINE DRIVE, PORT ANGELES, WA

PARCEL NUMBER: 063000505520

LEGEND:

- MARINE CARBON DIOXIDE REMOVAL FACILITY AREA
- ELECTRICAL IMPROVEMENT AREA
- BARGE AND INTAKE/OUTFALL SYSTEM
- INTAKE/OUTFALL PIPE ACCESSWAY
- SITE PARCEL BOUNDARY
- SURROUNDING PARCEL BOUNDARY
- 1892 SHORE LINE
- 1924 SHORE LINE
- FLOODPLAIN EXTENTS
- SMP SHORELINE DESIGNATION

NORTH

0 60 120
SCALE IN FEET
SCALE: 1" = 60'

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PORT ANGELES, WA

REVISIONS

REV	DATE	DESCRIPTION

LINE IS 2 INCHES AT FULL SIZE

DESIGNED: R. MATTUCCI
DRAWN: R. JOHNSON
CHECKED: R. MATTUCCI
CHECKED: R. RHODES
APPROVED:

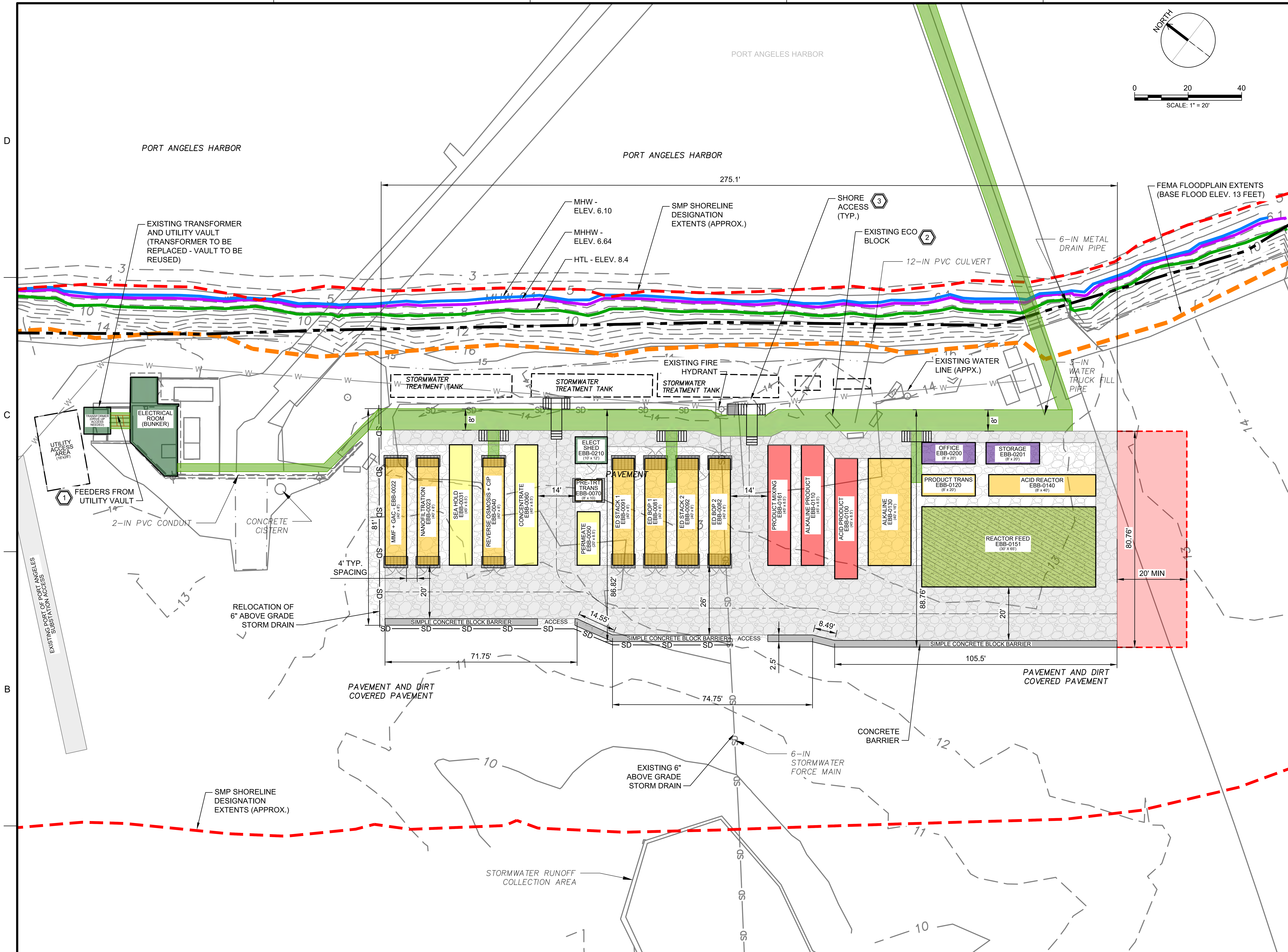
FILENAME
C-101_JARPA.dwg
BC PROJECT NUMBER
159812
CLIENT PROJECT NUMBER

CIVIL

OVERALL SITE PLAN

DRAWING NUMBER
C-101

Path: C:\USERS\PDRURY\BCPW\D3218318 FILENAME: C-101_JARPA.DWG PLOT DATE: 2/19/2024 11:47 AM CAD USER: PAIGE DRURY



GENERAL NOTES:

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5. SHORE MASTER PLAN - SHORELINE DESIGNATION FOR SITE IS HIGH INTENSITY - INDUSTRIAL (HI-I). EXTENTS ARE APPROXIMATE.
6. PARCEL BOUNDARIES ARE APPROXIMATE.
7. FOR BENCHMARKS SEE DRAWING C-050.
8. ESTIMATED SITE AREA: 23,690 SQUARE FEET.
9. TIDE LEVELS (BASIS OF SURVEY NOTE 5 ON DRAWING C-050).

TIDE LEVELS		MLLW	NAD88
EHW	EXTREME HIGH WATER	10.50	10.09
HTL	HIGH TIDAL LINE	8.82	8.40
MHHW	MEAN HIGHER-HIGH WATER	7.06	6.64
MHW	MEAN HIGH WATER	6.52	6.10
MLW	MEAN LOW WATER	1.92	1.50
MLLW	MEAN LOWER-LOW WATER	0.00	-0.42
ELW	EXTREME LOW WATER	-4.84	-5.26

KEY NOTES:

1. CONCRETE ENCASED DUCTS FROM EXISTING UTILITY TRANSFORMER VAULT TO EXISTING BUNKER BUILDING ELECTRICAL ROOM FOR NEW SECONDARY UTILITY POWER FEEDERS.
2. CONCRETE BLOCKS TO BE RE-LOCATED AS SOUTHWESTERN CONCRETE BLOCK BARRIERS EXCEPT AT PIPE OUTLETS.
3. SHORE ACCESS ABOVE PIPING CORRIDOR.

LEGEND:

- EXISTING MINOR CONTOURS
- EXISTING MAJOR CONTOURS
- SD — EXISTING STORM
- W — EXISTING WATER
- E — EXISTING ELECTRICAL
- SITE PARCEL BOUNDARY
- SMP SHORELINE DESIGNATION EXTENTS (APPROX.)
- FEMA FLOODPLAIN EXTENTS
- MEAN HIGH WATER
- MEAN HIGHER-HIGH WATER
- HIGH TIDAL LINE
- PROPOSED DOUBLE WALLED FRAC TANKS ON CONCRETE PAD
- PROPOSED SINGLE WALLED FRAC TANKS ON CONCRETE PAD
- PROPOSED PROCESS CONTAINER
- PROPOSED LINED MATERIAL MANAGEMENT
- PROPOSED OCCUPIED SPACE
- PROPOSED ELECTRICAL BUILDING
- PROPOSED UTILITY CORRIDOR
- PROPOSED CLASS II AGGREGATE (17,400 SF)
- PROPOSED CONCRETE
- FIRE ACCESS AREA

REFERENCE	NAME: MARINE CARBON DIOXIDE REMOVAL PILOT PROJECT (PROJECT MACOMA)	LATITUDE: 48.128749 N LONGITUDE: -123.458501 W S-T-R: 04-31N-06W
APPLICANT: PORT OF PORT ANGELES **LOCATION:** 1433 MARINE DRIVE, PORT ANGELES, WA 98362 **ADJACENT PROPERTY OWNERS:** PORT OF PORT ANGELES LOWER ELWHA KLALLAM TRIBE	**PROPOSED:** TEMPORARY PILOT PROJECT INCLUDING A WATER TREATMENT FACILITY AND BARGE-BASED INTAKE AND OUTFALL SYSTEM. **PURPOSE:** OPERATE AND STUDY MARINE CARBON DIOXIDE REMOVAL PILOT PROJECT.	**IN:** PORT OF PORT ANGELES, TERMINAL 7 **NEAR/AT:** PORT ANGELES **COUNTY:** CLALLAM **STATE:** WASHINGTON **DATE:** FEBRUARY 2024

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SEATTLE, WA 98101

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PROJECT MACOMA LLC
PORT ANGELES, WA

REVISIONS

REV	DATE	DESCRIPTION

LINE IS 2 INCHES AT FULL SIZE

DESIGNED: P. DRURY
DRAWN: P. DRURY
CHECKED: R. MATTUCCI
CHECKED: R. RHODES
APPROVED: A. MOLSEED

FILENAME
C-201-SHORE SITE PLAN_JARPA.dwg
BC PROJECT NUMBER
159812
CLIENT PROJECT NUMBER

CIVIL

SHORE SITE PLAN

DRAWING NUMBER
C-201

Path: C:\USERS\PDRURY\BCPW\D3218318 FILENAME: C-201-SHORE SITE PLAN_JARPA.DWG PLOT DATE: 2/19/2024 11:33 AM CAD USER: PAIGE DRURY

REFERENCE

APPLICANT: PORT OF PORT ANGELES

LOCATION: 1433 MARINE DRIVE, PORT ANGELES, WA 98362

ADJACENT PROPERTY OWNERS:
PORT OF PORT ANGELES
LOWER ELWHA KLALLAM TRIBE

NAME: MARINE CARBON DIOXIDE REMOVAL PILOT PROJECT (PROJECT MACOMA)

PROPOSED: TEMPORARY PILOT PROJECT INCLUDING A WATER TREATMENT FACILITY AND BARGE-BASED INTAKE AND OUTFALL SYSTEM.

PURPOSE: OPERATE AND STUDY MARINE CARBON DIOXIDE REMOVAL PILOT PROJECT.

LATITUDE: 48.128749 N
LONGITUDE: -123.458501 W
S-T-R: 04-31N-06W

IN: PORT OF PORT ANGELES, TERMINAL 7
NEAR/AT: PORT ANGELES
COUNTY: CLALLAM
STATE: WASHINGTON

DATE: FEBRUARY 2024

Point Table

Point #	Northing	Easting
1	422780.02	999420.07
2	422680.19	999473.90
3	422641.17	999423.74
4	422609.54	999476.23
5	422627.56	999522.87
6	422551.32	999519.44
7	422541.20	999528.44
8	422568.53	999564.20
9	422511.55	999544.81
10	422538.87	999580.57
11	422516.16	999590.37
12	422464.51	999629.84
13	422418.99	999583.44
14	422503.20	999519.10
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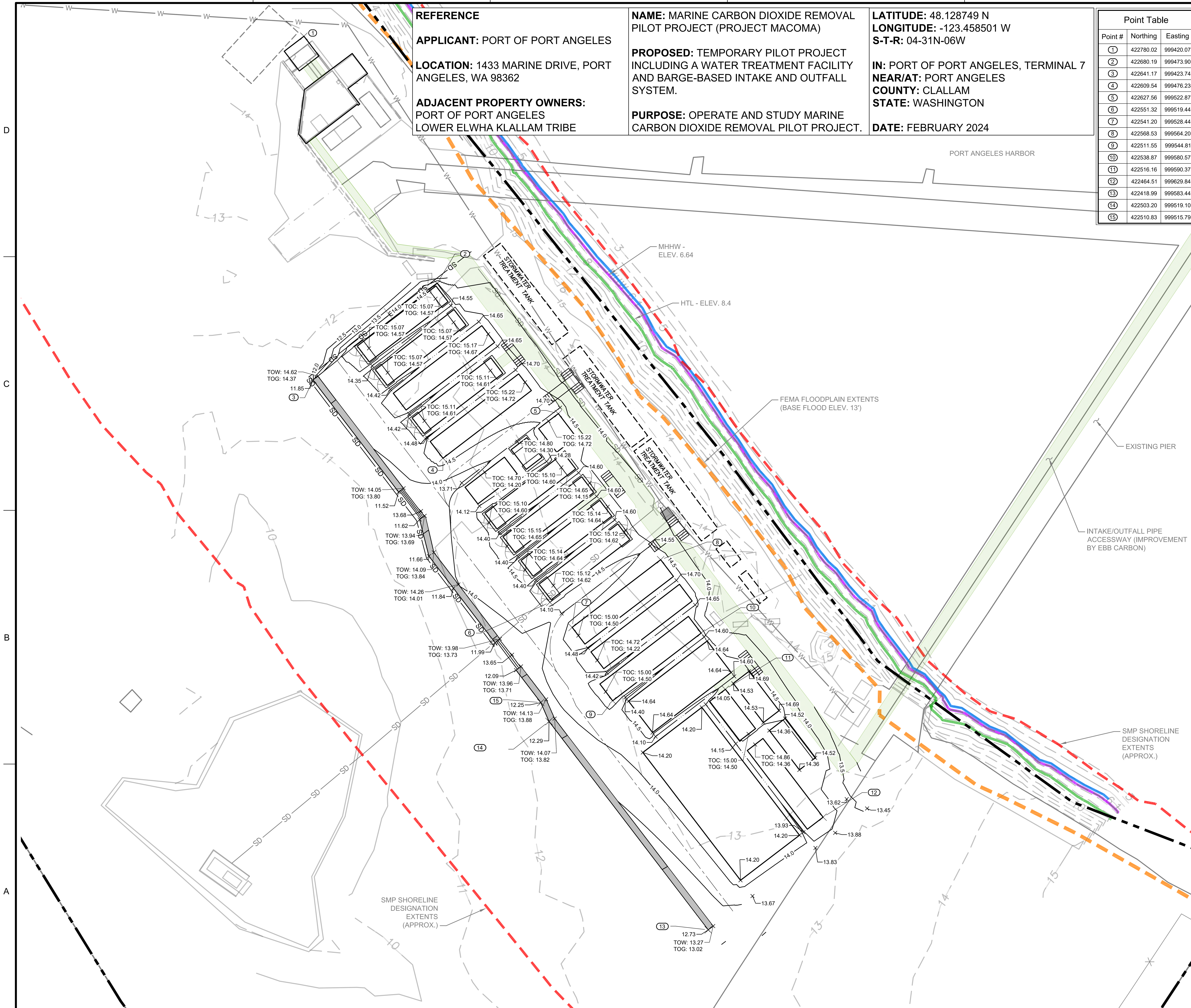

GENERAL NOTES:

1. BASED ON SURVEY CONDUCTED BY WENGLER SURVEYING & MAPPING CO. (www.wenglersurveying.com) FEBRUARY 2024 AND SUPPLEMENTED BY ZENOVIC AND ASSOCIATES SURVEY FROM 2012.
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5. SHORE MASTER PLAN - SHORELINE DESIGNATION FOR SITE IS HIGH INTENSITY - INDUSTRIAL (HI-I). EXTENTS ARE APPROXIMATE.
6. PARCEL BOUNDARIES ARE APPROXIMATE.
7. FOR BENCHMARKS SEE DRAWING C-050.
8. TIDE LEVELS (BASIS OF SURVEY NOTE 5 ON DRAWING C-050).

TIDE LEVELS		MLLW	NAD88
EHW	EXTREME HIGH WATER	10.50	10.09
HTL	HIGH TIDAL LINE	8.82	8.40
MHHW	MEAN HIGHER-HIGH WATER	7.06	6.64
MHW	MEAN HIGH WATER	6.52	6.10
MLW	MEAN LOW WATER	1.92	1.50
MLLW	MEAN LOWER-LOW WATER	0.00	-0.42
ELW	EXTREME LOW WATER	-4.84	-5.26

9. FINAL GRADES SHOWN ARE TOP OF GRAVEL. EDGE OF GRAVEL TO SLOPE TO MATCH EXISTING.

CUT/FILL SUMMARY	
CUT	0 CUBIC YARDS
FILL	2000 CUBIC YARDS

LEGEND:

- 14 — EXISTING MINOR CONTOURS
- 15 — EXISTING MAJOR CONTOURS
- SD — EXISTING STORM
- W — EXISTING WATER
- PROPOSED TREATMENT CONTAINER/TANK/SHED/TRAILER
- 15 — PROPOSED MAJOR CONTOUR
- 14 — PROPOSED MINOR CONTOUR
- SITE PARCEL BOUNDARY
- SD — RELOCATED 6" STORM DRAIN
- EXISTING STORMWATER TREATMENT (APPROX).
- SMP SHORELINE DESIGNATION EXTENTS (APPROX.)
- FEMA FLOODPLAIN EXTENTS (13 FEET)
- MEAN HIGH WATER (6.10 FEET)
- MEAN HIGHER-HIGH WATER (6.64 FEET)
- HIGH TIDAL LINE (8.4 FEET)
- PROPOSED UTILITY CORRIDOR

TOC TOP OF CONCRETE
TOG TOP OF GRAVEL

NORTH

0 20 40
SCALE IN FEET
SCALE: 1" = 20'

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PROJECT MACOMA LLC
PORT ANGELES, WA

REVISIONS

REV	DATE	DESCRIPTION

LINE IS 2 INCHES AT FULL SIZE

DESIGNED: R. MATTUCCI
DRAWN: P. DRURY
CHECKED: R. MATTUCCI
CHECKED: R. RHODES
APPROVED:

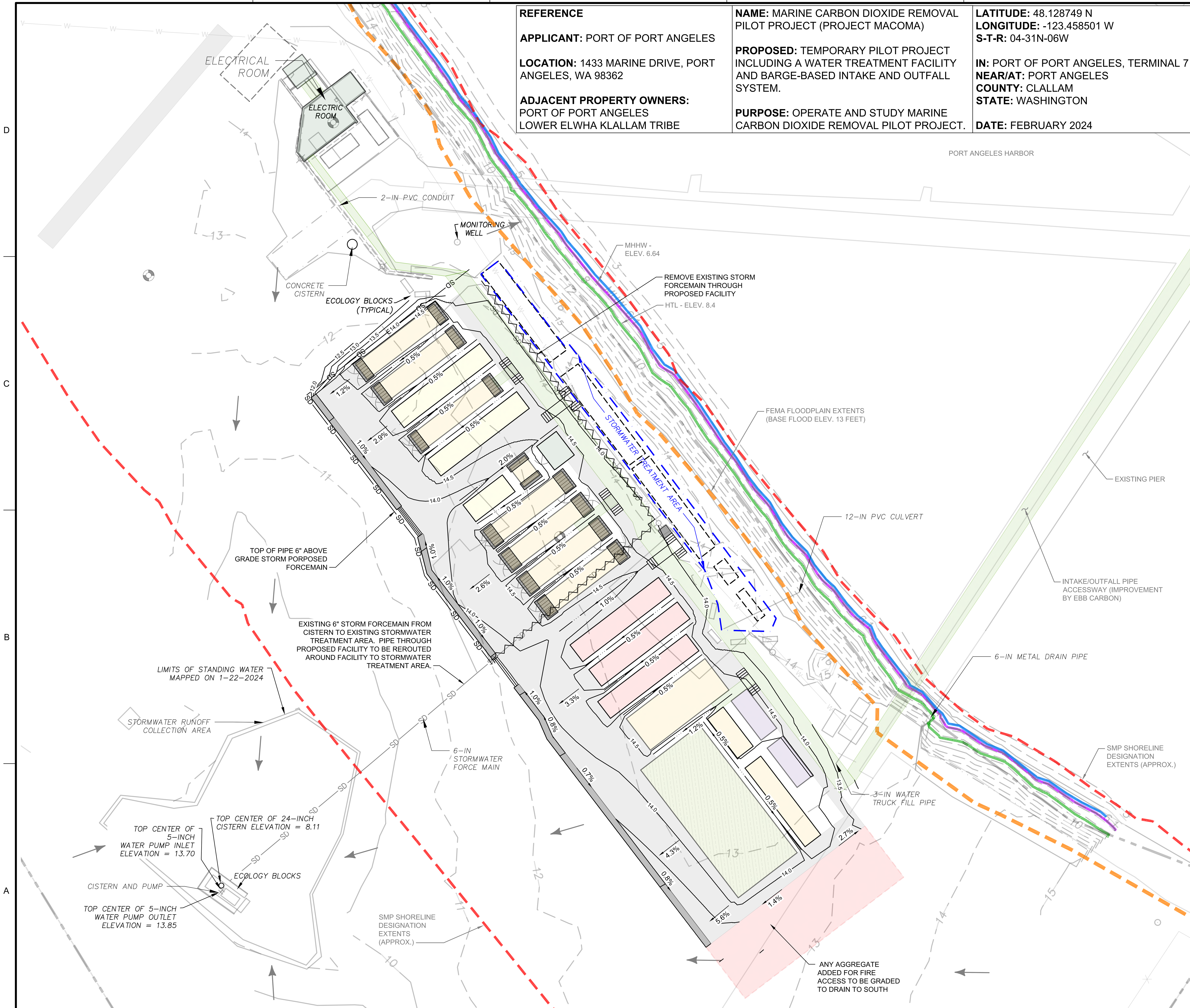
FILENAME
C-301-GRADING PLAN_JARPA.dwg
BC PROJECT NUMBER
159812
CLIENT PROJECT NUMBER

CIVIL

GRADING PLAN

DRAWING NUMBER
C-301

REFERENCE **APPLICANT:** PORT OF PORT ANGELES **LOCATION:** 1433 MARINE DRIVE, PORT ANGELES, WA 98362 **ADJACENT PROPERTY OWNERS:** PORT OF PORT ANGELES LOWER ELWHA KLALLAM TRIBE	**NAME:** MARINE CARBON DIOXIDE REMOVAL PILOT PROJECT (PROJECT MACOMA) **PROPOSED:** TEMPORARY PILOT PROJECT INCLUDING A WATER TREATMENT FACILITY AND BARGE-BASED INTAKE AND OUTFALL SYSTEM. **PURPOSE:** OPERATE AND STUDY MARINE CARBON DIOXIDE REMOVAL PILOT PROJECT.	**LATITUDE:** 48.128749 N **LONGITUDE:** -123.458501 W **S-T-R:** 04-31N-06W **IN:** PORT OF PORT ANGELES, TERMINAL 7 **NEAR/AT:** PORT ANGELES **COUNTY:** CLALLAM **STATE:** WASHINGTON **DATE:** FEBRUARY 2024



GENERAL NOTES:

1. BASED ON SURVEY CONDUCTED BY WENGLER SURVEYING & MAPPING CO. (WWW.WENGLERSURVEYING.COM) FEBRUARY 2024 AND SUPPLEMENTED BY ZENOVIC AND ASSOCIATES SURVEY FROM 2012.
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5. SHORE MASTER PLAN - SHORELINE DESIGNATION FOR SITE IS HIGH INTENSITY - INDUSTRIAL (HI-I). EXTENTS ARE APPROXIMATE.
6. PARCEL BOUNDARIES ARE APPROXIMATE.
7. FOR BENCHMARKS SEE DRAWING C-050.

STORMWATER MANAGEMENT NOTES:

1. ACCORDING TO SURVEY, ENTIRE SITE IS A MIXTURE OF ASPHALT AND CONCRETE. NO INCREASE IN IMPERVIOUS AREA IS PROPOSED.
2. EXISTING DRAINAGE PATTERN TO REMAIN. SITE WILL DRAIN SOUTH TO CISTERN AND BE ROUTED TO EXISTING STORMWATER TREATMENT AREA. EVENTUALLY TO DRAIN TO HARBOR.

LEGEND:

- EXISTING MINOR CONTOURS
- EXISTING MAJOR CONTOURS
- EXISTING STORM
- EXISTING WATER
- SITE PARCEL BOUNDARY
- RELOCATED 6" STORM DRAIN
- EXISTING STORMWATER TREATMENT EQUIPMENT (APPROX.)
- PROPOSED MAJOR CONTOUR
- PROPOSED MINOR CONTOUR
- SMP SHORELINE DESIGNATION EXTENTS (APPROX.)
- FEMA FLOODPLAIN EXTENTS (13 FEET)
- MEAN HIGH WATER (6.10 FEET)
- MEAN HIGHER-HIGH WATER (6.64 FEET)
- HIGH TIDAL LINE (8.4 FEET)
- EXISTING DRAINAGE FLOW
- PROPOSED DOUBLE WALLED FRAC TANKS
- PROPOSED SINGLE WALLED FRAC TANKS
- PROPOSED PROCESS CONTAINER
- PROPOSED MATERIAL MANAGEMENT
- PROPOSED OCCUPIED SPACE
- PROPOSED ELECTRICAL
- PROPOSED FIRE ACCESS
- PIPING/ELECTRICAL/FIBER CORRIDOR

NORTH

0 20 40
SCALE IN FEET
SCALE: 1" = 20'

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SEATTLE, WA 98101

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PROJECT MACOMA LLC
PORT ANGELES, WA

REVISIONS

REV	DATE	DESCRIPTION

LINE IS 2 INCHES AT FULL SIZE

DESIGNED: R. MATTUCCI
DRAWN: R. JOHNSON
CHECKED: R. MATTUCCI
CHECKED: R. RHODES
APPROVED:

FILENAME
C-302-STORMWATER MANAGEMENT PLAN_JARPA.dwg
BC PROJECT NUMBER
159812
CLIENT PROJECT NUMBER

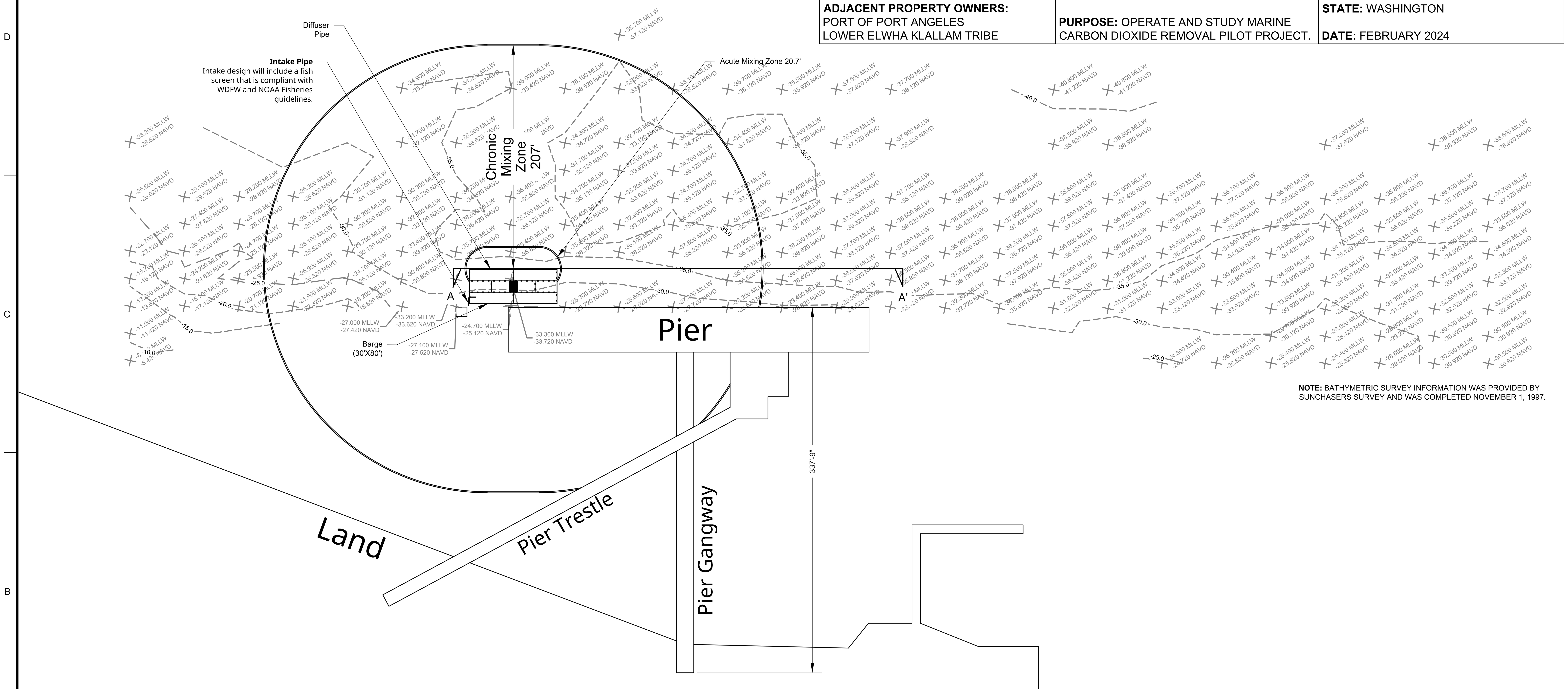
CIVIL

STORMWATER MANAGEMENT PLAN

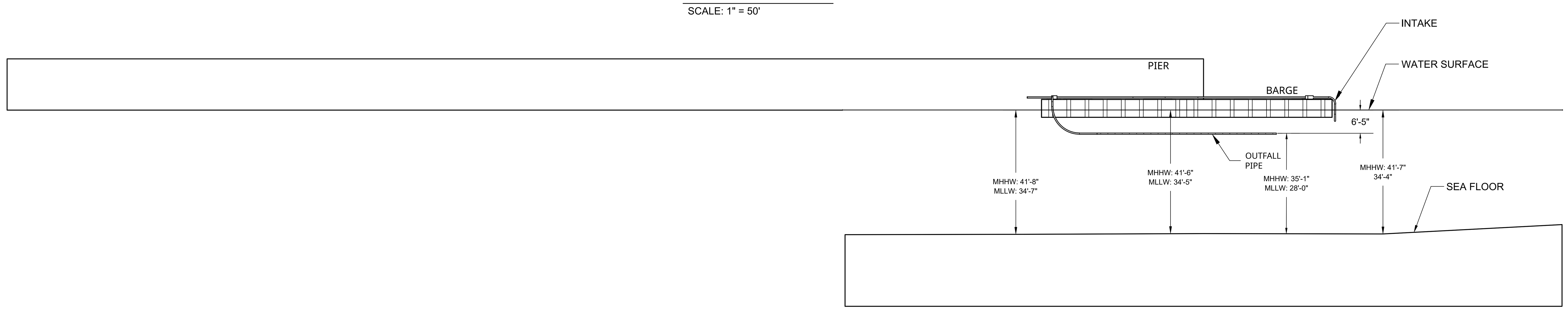
DRAWING NUMBER
C-302

Path: C:\USERS\PDRURY\BCPWD3218318 FILENAME: C-302-STORMWATER MANAGEMENT PLAN_JARPA.DWG PLOT DATE: 2/19/2024 11:31 AM CAD USER: PAIGE DRURY

REFERENCE **APPLICANT:** PORT OF PORT ANGELES **LOCATION:** 1433 MARINE DRIVE, PORT ANGELES, WA 98362 **ADJACENT PROPERTY OWNERS:** PORT OF PORT ANGELES LOWER ELWHA KLALLAM TRIBE	**NAME:** MARINE CARBON DIOXIDE REMOVAL PILOT PROJECT (PROJECT MACOMA) **PROPOSED:** TEMPORARY PILOT PROJECT INCLUDING A WATER TREATMENT FACILITY AND BARGE-BASED INTAKE AND OUTFALL SYSTEM. **PURPOSE:** OPERATE AND STUDY MARINE CARBON DIOXIDE REMOVAL PILOT PROJECT.	**LATITUDE:** 48.128749 N **LONGITUDE:** -123.458501 W **S-T-R:** 04-31N-06W **IN:** PORT OF PORT ANGELES, TERMINAL 7 **NEAR/AT:** PORT ANGELES **COUNTY:** CLALLAM **STATE:** WASHINGTON **DATE:** FEBRUARY 2024



OUTFALL PLAN
SCALE: 1" = 50'



OUTFALL SECTION A-A'
SCALE: 1" = 20'

NOTE: ALL BARGE DESIGN AND DEVELOPMENT BY EBB CARBON

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SEATTLE, WA 98101

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PORT ANGELES, WA

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DESIGNED: EBB CARBON
DRAWN: EBB CARBON
CHECKED:
CHECKED:
APPROVED:

FILENAME
C-800_JARPA.dwg
BC PROJECT NUMBER
159812
CLIENT PROJECT NUMBER

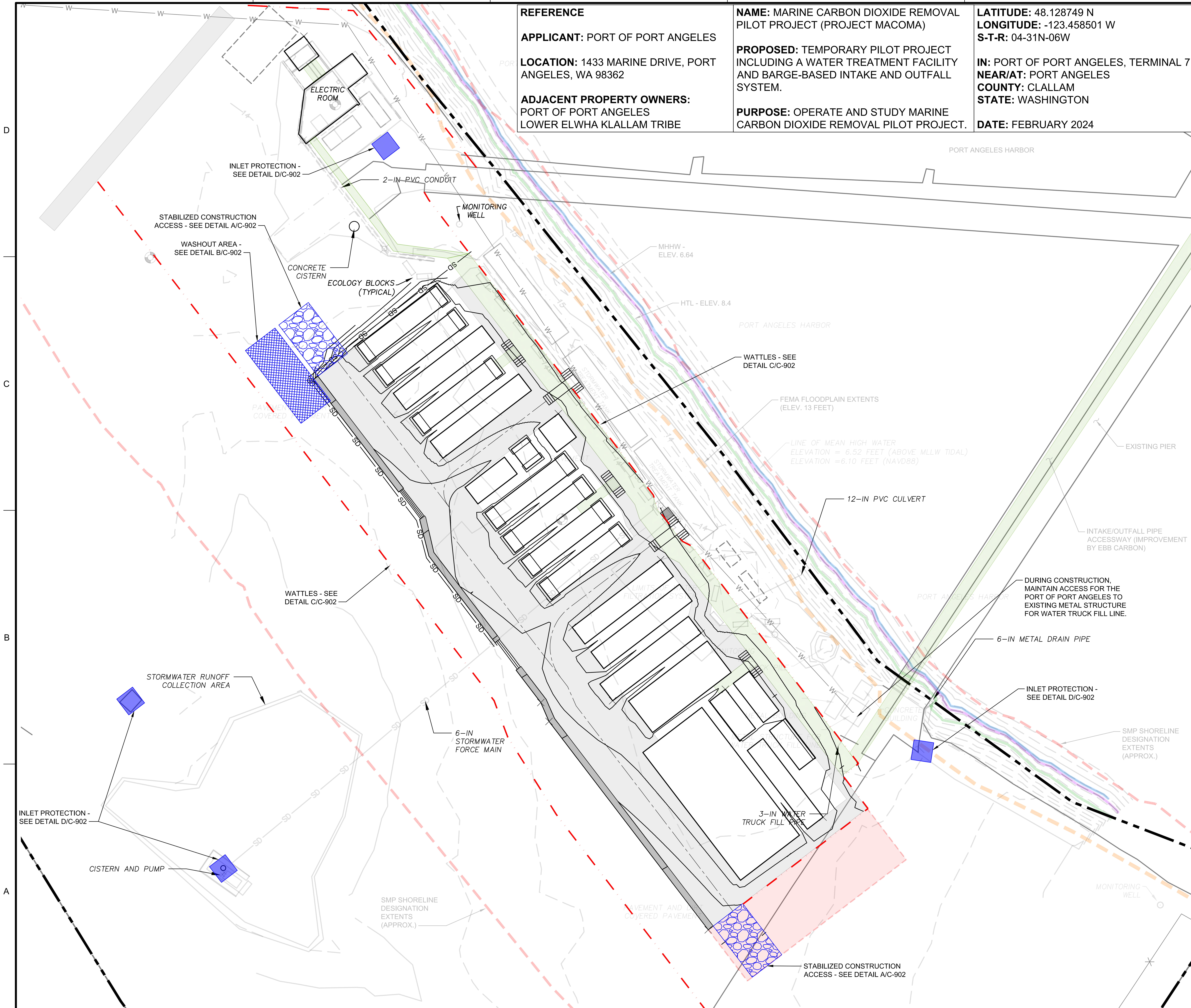
CIVIL

OUTFALL PLAN AND ELEVATION

DRAWING NUMBER
C-800

Path: C:\USERS\PDRURY\BCPWD3218318 FILENAME: C-800_JARPA.DWG PLOT DATE: 2/19/2024 10:06 AM CAD USER: PAIGE DRURY

REFERENCE **APPLICANT:** PORT OF PORT ANGELES **LOCATION:** 1433 MARINE DRIVE, PORT ANGELES, WA 98362 **ADJACENT PROPERTY OWNERS:** PORT OF PORT ANGELES LOWER ELWHA KLALLAM TRIBE	**NAME:** MARINE CARBON DIOXIDE REMOVAL PILOT PROJECT (PROJECT MACOMA) **PROPOSED:** TEMPORARY PILOT PROJECT INCLUDING A WATER TREATMENT FACILITY AND BARGE-BASED INTAKE AND OUTFALL SYSTEM. **PURPOSE:** OPERATE AND STUDY MARINE CARBON DIOXIDE REMOVAL PILOT PROJECT.	**LATITUDE:** 48.128749 N **LONGITUDE:** -123.458501 W **S-T-R:** 04-31N-06W **IN:** PORT OF PORT ANGELES, TERMINAL 7 **NEAR/AT:** PORT ANGELES **COUNTY:** CLALLAM **STATE:** WASHINGTON **DATE:** FEBRUARY 2024



GENERAL NOTES:

1. BASED ON SURVEY CONDUCTED BY WENGLER SURVEYING & MAPPING CO. (www.wenglersurveying.com) FEBRUARY 2024 AND SUPPLEMENTED BY ZENOVIC AND ASSOCIATES SURVEY FROM 2012.
2. HORIZONTAL DATUM = WASHINGTON STATE PLANE COORDINATE SYSTEM - NORTH ZONE, NAD 1983 (FEET).
3. VERTICAL DATUM = 1988 NAVD.
4. PORT ANGELES HARBOR IS IN THIS AREA DESIGNATED AS AN AE FLOODPLAIN WITH A BASE FLOOD ELEVATION OF 13 FEET, NAVD (FEMA PANEL PENDING, 2023). FLOODPLAIN EXTENTS ARE APPROXIMATE.
5. SHORE MASTER PLAN - SHORELINE DESIGNATION FOR SITE IS HIGH INTENSITY - INDUSTRIAL (HI-I). EXTENTS ARE APPROXIMATE.
6. PARCEL BOUNDARIES ARE APPROXIMATE.
7. FOR BENCHMARKS SEE DRAWING C-050.
8. TIDE LEVELS (BASIS OF SURVEY NOTE 5 ON DRAWING C-050),

TIDE LEVELS		MLLW	NAD88
EHW	EXTREME HIGH WATER	10.50	10.09
HTL	HIGH TIDAL LINE	8.82	8.40
MHHW	MEAN HIGHER-HIGH WATER	7.06	6.64
MHW	NEAN HIGH WATER	6.52	6.10
MLW	MEAN LOW WATER	1.92	1.50
MLLW	MEAN LOWER-LOW WATER	0.00	-0.42
ELW	EXTREME LOW WATER	-4.84	-5.26

LEGEND:

- EXISTING MINOR CONTOURS
- EXISTING MAJOR CONTOURS
- EXISTING STORM (SD)
- EXISTING WATER (W)
- PROPOSED TREATMENT CONTAINER/TANK/SHED/TRAILER
- PROPOSED MAJOR CONTOUR
- PROPOSED MINOR CONTOUR
- EXISTING STORMWATER TREATMENT (APPROX)
- RELOCATED 6" STORM DRAIN (SD)
- WATTLES (730 LF)
- FIRE ACCESS AREA
- STABILIZED CONSTRUCTION ACCESS (390 SF)
- CONCRETE WASHOUT AREA (560 SF)
- INLET PROTECTION (4 TOTAL)

NORTH

0 20 40
SCALE IN FEET
SCALE: 1" = 20'

Brown AND Caldwell
701 PIKE STREET SUITE 1300
SEATTLE, WA 98101

NOT FOR CONSTRUCTION

ISSUED FOR PERMIT

ebb carbon

PROJECT MACOMA LLC
PORT ANGELES, WA

REVISIONS

REV	DATE	DESCRIPTION

LINE IS 2 INCHES AT FULL SIZE

DESIGNED: R. MATTUCCI
DRAWN: P. DRURY
CHECKED: R. MATTUCCI
CHECKED: R. RHODES
APPROVED:

FILENAME
C-901-EC PLAN_JARPA.dwg
BC PROJECT NUMBER
159812
CLIENT PROJECT NUMBER

CIVIL

ENVIRONMENTAL CONTROLS PLAN

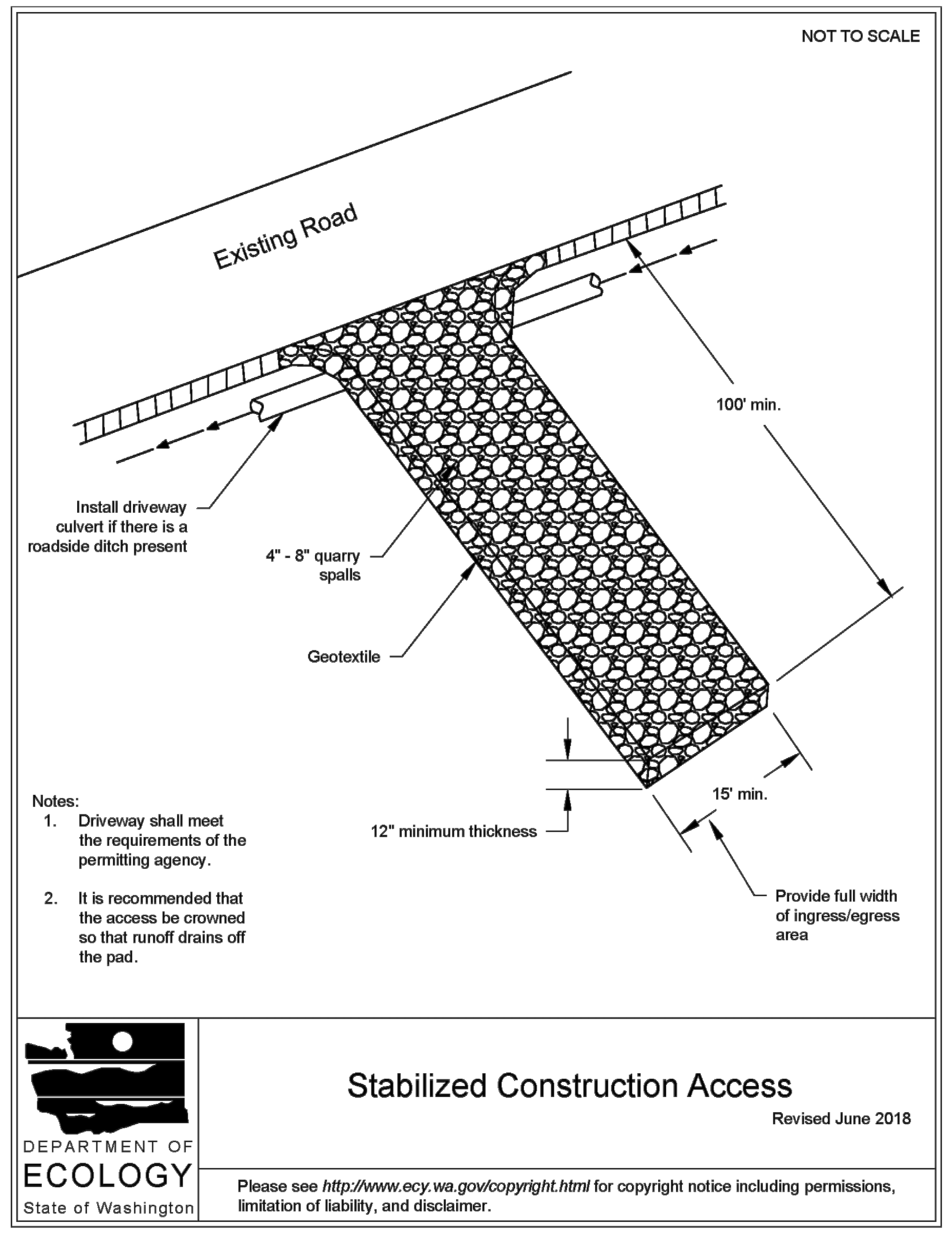
DRAWING NUMBER
C-901

Path: C:\USERS\PDRURY\BCPW\D3218318 FILENAME: C-901-EC PLAN_JARPA.DWG PLOT DATE: 2/19/2024 11:50 AM CAD USER: PAIGE DRURY

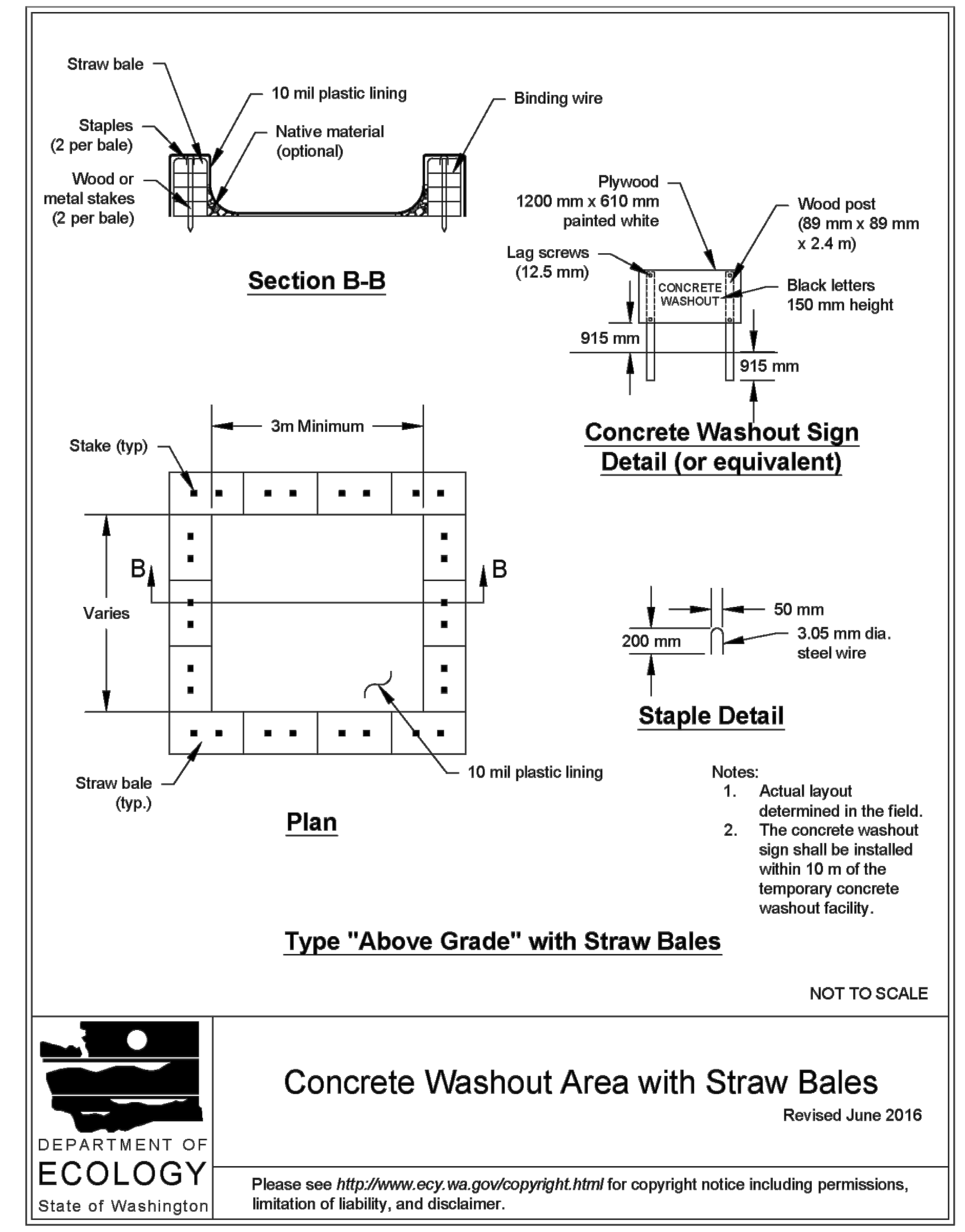
GENERAL ECP BMP NOTES:

1. ALL WORK SHALL BE DONE IN ACCORDANCE WITH THE STANDARDS AND SPECIFICATIONS FOR EROSION AND SEDIMENT CONTROL FROM THE "STORMWATER MANAGEMENT MANUAL FOR WESTERN WASHINGTON, (LATEST EDITION)".
2. APPROVAL OF THIS EROSION/SEDIMENTATION CONTROL (ESC) PLAN DOES NOT CONSTITUTE AN APPROVAL OF PERMANENT ROAD OR DRAINAGE DESIGN (E.G. SIZE AND LOCATION OF ROADS, PIPES, RESTRICTORS, CHANNELS, RETENTION ACILITIES, UTILITIES).
3. THE IMPLEMENTATION OF THIS ESC PLAN AND THE CONSTRUCTION, MAINTENANCE, REPLACEMENT, AND UPGRADING OF THESE ESC BMPS IS THE RESPONSIBILITY OF THE APPLICANT UNTIL ALL CONSTRUCTION IS COMPLETED AND APPROVED AND VEGETATION/LANDSCAPING IS ESTABLISHED.
4. ALL EROSION AND SEDIMENT CONTROL PRACTICES ARE TO BE INSTALLED PRIOR TO ANY MAJOR SOIL DISTURBANCE, OR IN THEIR PROPER SEQUENCE, AND MAINTAINED UNTIL PERMANENT PROTECTION IS ESTABLISHED.
5. CLEARLY FLAG THE BOUNDARIES OF THE CLEARING LIMITS SHOWN ON THIS PLAN IN THE FIELD PRIOR TO CONSTRUCTION. DURING THE CONSTRUCTION PERIOD, NO DISTURBANCE BEYOND THE FLAGGED CLEARING LIMITS SHALL BE PERMITTED. THE FLAGGING SHALL BE MAINTAINED BY THE APPLICANT FOR THE DURATION OF CONSTRUCTION.
6. CONSTRUCT THE ESC BMPS SHOWN ON THIS PLAN IN CONJUNCTION WITH ALL CLEARING AND GRADING ACTIVITIES, AND IN SUCH A MANNER AS TO ENSURE THAT SEDIMENT AND SEDIMENT LADEN WATER DO NOT ENTER THE DRAINAGE SYSTEM, ROADWAYS, OR VIOLATE APPLICABLE WATER STANDARDS.
7. THE ESC BMPS SHOWN ON THIS PLAN ARE THE MINIMUM REQUIREMENTS FOR ANTICIPATED SITE CONDITIONS. DURING THE CONSTRUCTION PERIOD, UPGRADE THESE ESC BMPS AS NEEDED FOR UNEXPECTED STORM EVENTS AND TO ENSURE THAT SEDIMENT AND SEDIMENT-LADEN WATER DO NOT LEAVE THE SITE.
8. THE APPLICANT SHALL INSPECT THE ESC BMPS DAILY AND MAINTAIN THEM AS NECESSARY TO ENSURE THEIR CONTINUED FUNCTIONING.
9. INSPECT AND MAINTAIN THE ESC BMPS ON INACTIVE SITES A MINIMUM OF ONCE A MONTH OR WITHIN THE 48 HOURS FOLLOWING A MAJOR STORM EVENT (I.E. A 24-HOUR STORM EVENT WITH A 10-YR OR GREATER RECURRENCE INTERVAL).
10. AT NO TIME SHALL THE SEDIMENT EXCEED 60-PERCENT OF THE SUMP DEPTH OR HAVE LESS THAN 6-INCHES OF CLEARANCE FROM THE SEDIMENT SURFACE TO THE INVERT OF THE LOWEST PIPE. ALL CATCH BASINS AND CONVEYANCE LINES SHALL BE CLEANED PRIOR TO PAVING. THE CLEANING OPERATION SHALL NOT FLUSH SEDIMENT LADEN WATER INTO THE DOWNSTREAM SYSTEM.
11. INSTALL STABILIZED CONSTRUCTION ENTRANCES AT THE BEGINNING OF CONSTRUCTION AND MAINTAINED FOR THE DURATION OF THE PROJECT. ADDITIONAL MEASURES MAY BE REQUIRED TO ENSURE THAT ALL PAVED AREAS ARE KEPT CLEAN FOR THE DURATION OF THE PROJECT.
12. CONTRACTOR SHALL DESIGNATE RESPONSIBILITY FOR THE ESC PLAN TO ONE INDIVIDUAL.
13. STOCKPILE AND STAGING LOCATIONS ESTABLISHED IN THE FIELD SHALL BE PLACED WITHIN THE LIMIT OF DISTURBANCE ACCORDING TO THE ESC PLAN.
14. CONTRACTOR AND SUB-CONTRACTOR PERSONNEL SHALL UNDERSTAND THE ESC PLAN AND, IF A GENERAL PERMIT FOR STORMWATER DISCHARGES FROM CONSTRUCTION ACTIVITY IS APPLICABLE, PERSONNEL SHALL SIGN THE CERTIFICATION STATEMENT REQUIRED BY PERMIT.

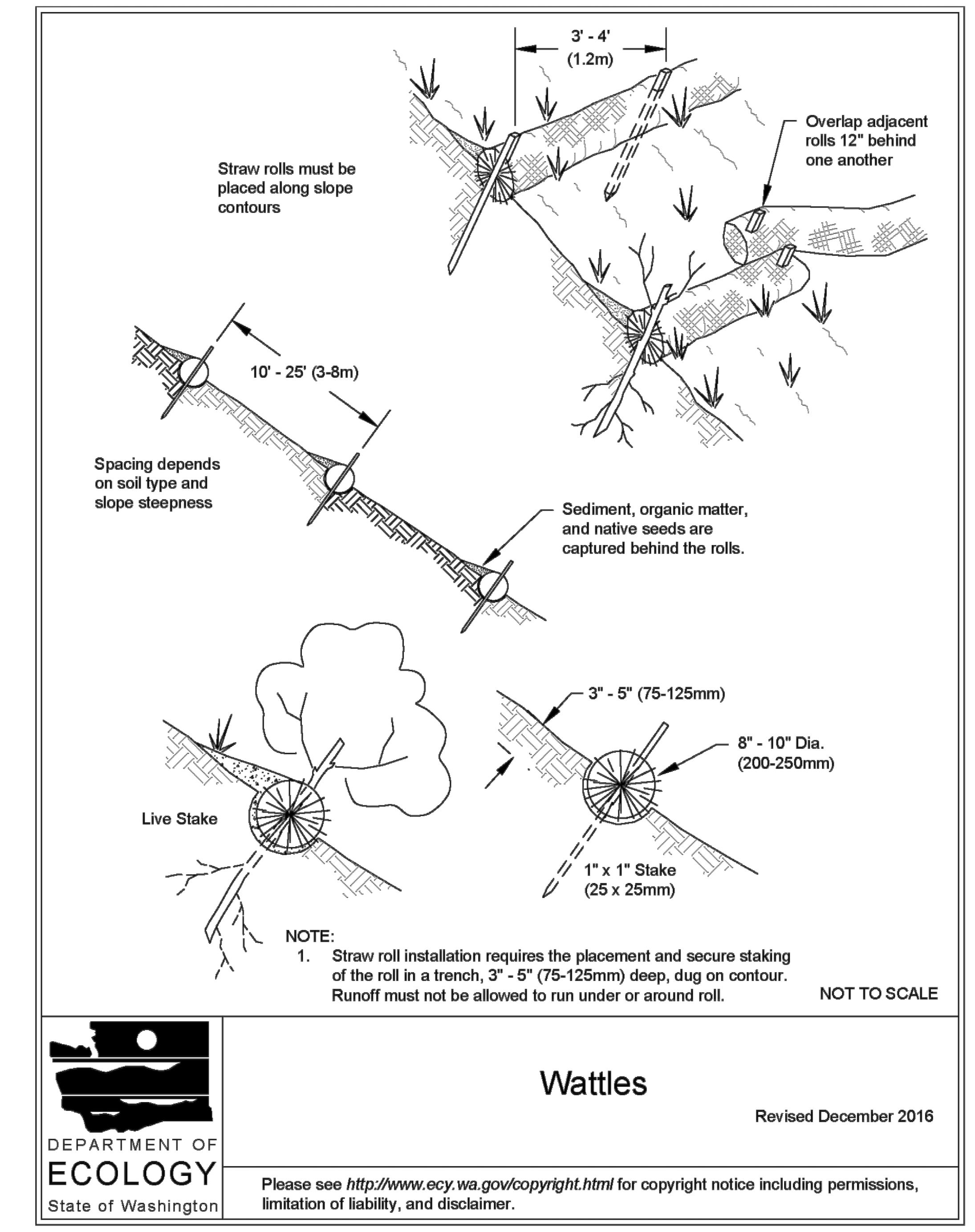
NOTE: DETAILS FROM THE "STORMWATER MANAGEMENT MANUAL FOR WESTERN WASHINGTON, (LATEST EDITION)"



A — STABILIZED CONTRUCTION ACCESS
NOT TO SCALE

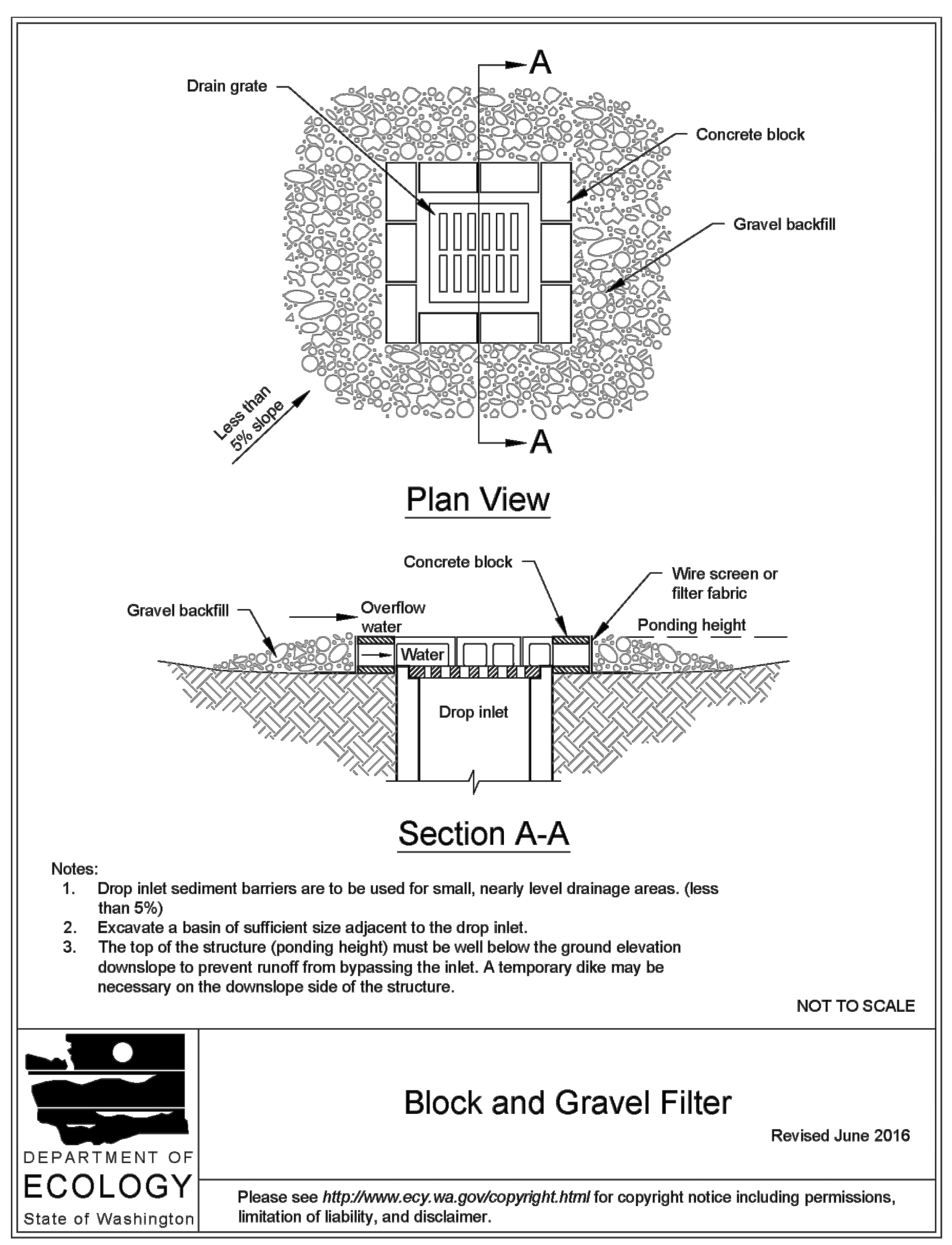


B — WASHOUT AREA WITH STRAW BALES
NOT TO SCALE



C — WATTLES
NOT TO SCALE

NOTE:
FILTER SOCK IS ACCEPTABLE ALTERNATIVE ON PAVEMENT
8" Ø ULTRATECH SEDIMENT REMOVAL SOCK OR EQUIVALENT



D — INLET PROTECTION
NOT TO SCALE

REFERENCE

APPLICANT: PORT OF PORT ANGELES

LOCATION: 1433 MARINE DRIVE, PORT ANGELES, WA 98362

ADJACENT PROPERTY OWNERS:
PORT OF PORT ANGELES
LOWER ELWHA KLALLAM TRIBE

NAME: MARINE CARBON DIOXIDE REMOVAL PILOT PROJECT (PROJECT MACOMA)

PROPOSED: TEMPORARY PILOT PROJECT INCLUDING A WATER TREATMENT FACILITY AND BARGE-BASED INTAKE AND OUTFALL SYSTEM.

PURPOSE: OPERATE AND STUDY MARINE CARBON DIOXIDE REMOVAL PILOT PROJECT.

LATITUDE: 48.128749 N
LONGITUDE: -123.458501 W
S-T-R: 04-31N-06W

IN: PORT OF PORT ANGELES, TERMINAL 7
NEAR/AT: PORT ANGELES
COUNTY: CLALLAM
STATE: WASHINGTON

DATE: FEBRUARY 2024

Brown AND Caldwell
701 PIKE STREET SUITE 1300
SEATTLE, WA 98101

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ebb carbon

PROJECT
MACOMA LLC
PORT ANGELES, WA

REVISIONS

REV	DATE	DESCRIPTION

LINE IS 2 INCHES AT FULL SIZE

DESIGNED: R. MATTUCCI
DRAWN: R. JOHNSON
CHECKED: R. MATTUCCI
CHECKED:
APPROVED:

FILENAME
C-902-ECP BMP DETAILS_JARPA.dwg
BC PROJECT NUMBER
159812
CLIENT PROJECT NUMBER

CIVIL

ECP BMP DETAILS

DRAWING NUMBER
C-902

Path: C:\BCPW\D3218318 FILENAME: C-902-ECP BMP DETAILS_JARPA.DWG PLOT DATE: 2/16/2024 5:45 PM CAD USER: RACHAEL RHODES

Attachment 2
Biological Assessment

February 2024
Marine Carbon Dioxide Removal Pilot Study (Project Macoma)

ANCHOR QEA

Biological Assessment

Prepared for Ebb Carbon

February 2024
Marine Carbon Dioxide Removal Pilot Study (Project Macoma)

Biological Assessment

Prepared for
Ebb Carbon
950 Commercial Street
San Carlos, CA 94070

Prepared by
Anchor QEA
6720 South Macadam Avenue, Suite 300
Portland, Oregon 97219

TABLE OF CONTENTS

TABLES

FIGURES

APPENDICES

ABBREVIATIONS

$CaCO_3$	calcium carbonate
CFR	Code of Federal Regulations
CMMP	contaminated materials management plan
CO_2	carbon dioxide
dBA	A-weighted decibels
DO	dissolved oxygen
DPS	Distinct Population Segment
Ecology	Washington State Department of Ecology
EFH	essential fish habitat
ESA	Endangered Species Act
ESU	Evolutionarily Significant Unit
FMO	foraging, migration, and overwintering area
FR	Federal Register
HAPC	Habitat Area of Particular Concern
HCl	hydrochloric acid
kg/m^3	kilograms per cubic meter
L/hr	liters per hour
Magnuson-Stevens Act	Magnuson-Stevens Fishery Conservation and Management Act
mCDR	marine carbon dioxide removal
mg/L	milligrams per liter
MHHW	mean higher high water
MLLW	mean lower low water
NaOH	sodium hydroxide
NLAA	not likely to adversely affect
NMFS	National Marine Fisheries Service
NTU	nephelometric turbidity unit
PAH	polycyclic aromatic hydrocarbon
PBF	physical and biological habitat feature
PCB	polychlorinated biphenyl
PNNL	Pacific Northwest National Laboratory
Port	Port of Port Angeles
RCW	Revised Code of Washington
RIWP	Remedial Investigation Work Plan
SU	standard unit
TMDL	Total Maximum Daily Load

Tribe	Lower Elwha Klallam Tribe
USFWS	U.S. Fish and Wildlife Service
WAC	Washington Administrative Code
WDFW	Washington Department of Fish and Wildlife
WDNR	Washington State Department of Natural Resources

1 Introduction

1.1 Project Overview

Project Macoma, LLC, a wholly owned subsidiary of Ebb Carbon, LLC, is proposing a temporary small-scale marine carbon dioxide removal (mCDR) pilot project sited at Terminal 7 of the Port of Port Angeles (Port) in Port Angeles, Washington ("Project Macoma") (Figure 1). Ebb Carbon has developed an mCDR technology to safely and permanently remove carbon dioxide from the atmosphere while reducing seawater acidity locally. Ebb Carbon's mCDR technology removes acid from seawater, generating alkaline-enhanced seawater in the process. The alkaline-enhanced seawater is returned to the ocean, which enables the ocean to draw down and store additional carbon dioxide (CO_2) from the atmosphere.

The proposed pilot project owned and operated by Project Macoma, LLC, would intake seawater via a barge moored at the Terminal 7 dock, pipe the seawater over the existing Terminal 7 pier structure to a modular treatment facility on land, and process and deacidify the seawater before returning it to Port Angeles Harbor via the barge-based outfall system (Figure 2). The purposes of the proposed pilot study are to operate Ebb Carbon's mCDR technology under real-world conditions, support scientific research through scientific and academic collaborations, and gather additional data to inform future deployments. Project Macoma, LLC, plans to assess the effects of this pilot study with local scientific and academic partners and is discussing the potential for partnership on this pilot project with the Lower Elwha Klallam Tribe (Tribe). The proposed pilot study would run for approximately 1.5 years, beginning in summer 2024.

1.2 Purpose

Excess CO_2 must be removed from the atmosphere to keep planetary warming to below 2°C above pre-industrial levels. The ocean, one of the largest carbon sinks on the planet and the single largest regulator and driver of our climate and weather systems, presents a potential solution. The earth regulates the chemistry of the ocean and draws CO_2 from the air through ocean alkalization, a process that happens naturally over millions of years. Ebb Carbon uses electrochemistry to accelerate this process so that atmospheric carbon can be safely removed fast enough to counteract climate change.

Ebb Carbon's mCDR technology also potentially reduces ocean acidification locally by deacidifying seawater. Project Macoma will study whether ocean acidification, primarily caused by human-generated excess CO_2 in the atmosphere, is reduced locally over the duration of the pilot project. Ocean acidification endangers ocean life and represents a stress on marine environments and marine-dependent communities. The Puget Sound and Pacific Northwest marine waters are particularly vulnerable to ocean acidification because of the location of these waters combined with global, natural, and human-driven factors (WSBRPOA 2012).

Ebb Carbon has partnered with Pacific Northwest National Laboratory (PNNL) – Sequim and the University of Washington to evaluate its mCDR technology in a laboratory setting and potential uses for acidic and alkaline process streams.

Project Macoma, LLC, proposes a small-scale pilot study to field test Ebb Carbon's technology and verify its effectiveness, benefits, and safety in the marine environment. The pilot-scale system will use electrochemical processes to remove acid from the ambient seawater of Port Angeles Harbor. The produced alkaline seawater that remains would be returned to the ocean where it can draw down CO_2 from the atmosphere and store it as bicarbonate—a safe and naturally abundant form of carbon storage in the ocean that does not acidify seawater. Numerous experiments would be performed in parallel to understand biological and toxicological impacts on target species, and Project Macoma, LLC, would continue to partner with local scientific and academic partners to validate the efficacy and safety of the system.

1.3 Endangered Species Act-Listed Species and Critical Habitats Potentially Present in the Action Area

Information on listed salmonid and marine species was obtained from the National Marine Fisheries Service (NMFS), and information on listed terrestrial species and bull trout (*Salvelinus confluentus*) was obtained from the U.S. Fish and Wildlife Service (USFWS) (NMFS 2023a; USFWS 2023a).

Listed species and designated critical habitat that may occur in the Action Area (described in Section 3) and the associated effect determinations are summarized in Table 1. Effects of Project Macoma that may occur during construction or operation include impacts to water quality (suspended sediment, turbidity, pH, temperature), entrainment, impacts to prey resources, and habitat modifications. Avoidance and minimization measures, as well as monitoring and adaptive management strategies, will be employed to avoid and minimize these effects. A detailed discussion of Project Macoma-related effects is provided in Section 6.

Table 1
Threatened and Endangered Species That May Occur in the Action Area and Effect Determinations

Species	Status	Agency	Effects Determination	Critical Habitat	Critical Habitat Effects Determination
Killer whale (*Orcinus orca*)	Endangered (Southern Resident DPS)	NMFS	NLAA	Designated	No Adverse Modification
Humpback whale (*Megapterus novaeangliae*)	Threatened (Mexico DPS); endangered (Central America DPS)	NMFS	NLAA	Designated, but not in Action Area	No Effect
Puget Sound Chinook salmon (*Oncorhynchus tshawytscha*)	Threatened (Puget Sound ESU)	NMFS	NLAA	Designated	No Adverse Modification
Puget Sound steelhead (*Oncorhynchus mykiss)*	Threatened (Puget Sound ESU)	NMFS	NLAA	Designated	No Effect
Hood Canal summer-run chum salmon (*Oncorhynchus keta)*	Threatened (Hood Canal ESU)	NMFS	NLAA	Designated, but not in Action Area	No Adverse Modification
Bull trout (*Salvelinus confluentus*)	Threatened (Coastal-Puget Sound ESU)	USFWS	NLAA	Designated	No Effect
Bocaccio (*Sebastes paucispinus)*	Endangered (Georgia Basin DPS)	NMFS	NLAA	Designated, but not in Action Area	No Adverse Modification
Yelloweye rockfish *(Sebastes ruberrimus)*	Threatened (Georgia Basin DPS)	NMFS	NLAA	Designated, but not in Action Area	No Effect
Sunflower sea star (*Pycnopodia helianthoides*)	Proposed Threatened	NMFS	No jeopardy	Not designated	Not applicable
Marbled murrelet *(Brachyramphus marmoratus*)	Threatened	USFWS	NLAA	Designated, but not in Action Area	No Effect

An additional nine species that occur in Washington are considered by NMFS or USFWS to potentially occur in the Action Area (as set forth in Section 3), but they are not addressed in this Biological Assessment because they are extremely unlikely to occur within the Action Area. Project

Macoma will have **no effect** on these species, which are listed as follows along with the rationale for eliminating them from this analysis:

- **Leatherback Sea Turtle *(Dermochelys coriacea)*:** Endangered
  - Rationale: Does not occur in Action Area; location is also outside of critical habitat. Leatherback sea turtles are occasionally sighted along the outer Washington coast; however, turtle nesting colonies are not present in Washington.
- **Pacific Eulachon/Smelt (*Thaleichthys pacificus*):** Southern Distinct Population Segment (DPS); Threatened
  - Rationale: Infrequent occurrences in coastal rivers and tributaries to Puget Sound; location is outside critical habitat (Willson et al. 2006; NOAA 2019). It is unlikely that eulachon would be found in the Action Area because there are no eulachon spawning rivers in proximity to or entering Port Angeles Harbor.
- **Green Sturgeon (*Acipenser medirostris*):** Southern DPS; Threatened
  - Rationale: Does not occur in Action Area; location is also outside of critical habitat. Observations of green sturgeon in Puget Sound are much less common compared to the other estuaries in Washington. Although two confirmed Southern DPS fish were detected there in 2006, the extent to which Southern DPS green sturgeon use Puget Sound remains uncertain, and very few green sturgeon have been observed there (74 Federal Register [FR] 52299; DeLacy et al. 1972; Miller and Borton 1980). In addition, Puget Sound does not appear to be part of the coastal migratory corridor that Southern DPS fish use to reach overwintering grounds north of Vancouver Island.
- **Northern Spotted Owl (*Strix occidentalis*):** Threatened
  - Rationale: Does not occur in Action Area; location is outside critical habitat (86 FR 62606; December 10, 2021) and does not contain suitable habitat (USFWS 2011). The northern spotted owl inhabits old-growth forests from southwest British Columbia through the Cascade Mountains and coastal ranges in Washington, Oregon, and California. The complex forests contain structures required for nesting, roosting, and foraging. The pilot study site does not contain old-growth forests, although suitable habitat is present within 3 miles of the pilot study site.
- **Short-Tailed Albatross (*Phoebastria albatrus*):** Endangered
  - Rationale: Does not occur in the Action Area due to lack of suitable habitat and does not have designated critical habitat. Short-tailed albatross require remote islands for breeding, nesting in open, treeless areas with low or no vegetation. They spend much of their time feeding in the open ocean along the continental shelf. Although the short-tailed albatross is occasionally observed along the outer coast of Washington on open beaches, the pilot study site is too far inland for short-tailed albatross and does not contain suitable resting habitat (USFWS 2008).

- **Streaked Horned Lark (*Eremophila alpestris strigata*):** Threatened
  - Rationale: Does not occur in Action Area; location is also outside of critical habitat (USFWS 2023b), and suitable habitat does not exist in the Action Area. The streaked horned lark is a subspecies of the horned lark and is endemic to the Pacific Northwest. They are small, ground-dwelling songbirds that nest in short-grass habitats, preferring large, open patches (i.e., 300 acres or more) with sparse trees. Their current range in Washington includes the south Puget Sound prairies, the Washington coast, and dredged material spoils sites along the Columbia River. The pilot study site does not contain suitable habitat.
- **Yellow-Billed Cuckoo (*Coccyzus americanus*):** Western DPS; Threatened
  - Rationale: Does not occur in Action Area; location is also outside of proposed critical habitat (USFWS 2023c), and suitable habitat does not exist in the Action Area. Yellow-billed cuckoos are migratory birds that breed in North America and winter in Central and South America. They nest within and use willow and cottonwood riparian forests with a dense closed canopy (Csuti et al. 2001). The pilot study site does not contain suitable habitat.
- **Western Pond Turtle (*Actinemys marmorata*):** Proposed Threatened
  - Rationale: Does not occur in Action Area; suitable habitat does not exist in the Action Area, and critical habitat has not been proposed. The western pond turtle occurs in two areas in Washington: along the Columbia River and in a restricted area near Puget Sound, which does not include the Action Area. They occur in large numbers in warm, shallow lakes; along larger rivers within their range near the banks or adjacent backwater habitats; and in slower moving streams where basking sites are available (WDFW 1993). The pilot study site does not contain suitable habitat.
- **Taylor's Checkerspot (*Euphydryas editha taylori*):** Endangered
  - Rationale: Does not occur in Action Area; location is also outside of proposed critical habitat (78 FR 61505; October 3, 2013), and suitable habitat does not exist in the Action Area. The Taylor's checkerspot inhabits prairies, meadows, coastal bluffs, and coastal beach deposits in the lowlands (USFWS 2022a). The Action Area is developed and contains no suitable prairie, meadow, or coastal beach habitat.

1.4 Site Background

Port Angeles Harbor is located along the northern coast of Washington's Olympic Peninsula in the Strait of Juan de Fuca (Figure 1). The harbor is the largest natural deepwater harbor on the west coast of the United States, with depths greater than 90 feet near the eastern extents (U.S. Department of the Interior 2024). Ediz Hook is a 2.5-mile-long jetty that protects the harbor from storms. The harbor and surrounding areas support diverse aquatic and upland habitats, as well as resources for fishing, shellfish harvesting, and many other aquatic uses.

The pilot study site and surrounding area have mixed land uses including industrial and commercial development. The upland portion of the site is within Terminal 7, an industrial property that has been used in the past for mill operations, wood processing, and log storage (Ecology 2023a). The Washington State Department of Ecology (Ecology) has finalized a legal agreement, Agreed Order DE 21560, with the Port to implement the Remedial Investigation Work Plan (RIWP) Phase I at Terminals 5, 6, and 7 Uplands. The Phase I investigation focuses on determining whether contaminated soil or groundwater is moving from the uplands into Port Angeles Harbor.

Beginning in 2008, Ecology conducted investigations of marine sediment in Western Port Angeles Harbor along sites in and adjacent to the Action Area. Per Agreed Order DE 9781, remedial actions are planned to clean up contaminated marine soils associated with industrial activities at the former M&R mill (1608 Marine Drive), Fiberboard mill (1313 Marine Drive), and NPIUSA paper mill (1805 Marine Drive), as well as the current and former locations of City of Port Angeles combined sewer overflow outfalls.

Based on environmental reports and information about these operations, investigations for hazardous chemicals present in soil and groundwater have been conducted in the study area. An initial site investigation has confirmed the presence of dioxins/furans, mercury, halogenated organics, and diesel petroleum in soil and/or groundwater, and ongoing remedial investigations will test for suspected arsenic, benzene, lead, other metals, non-halogenated organics, gasoline and other petroleum, phenolic compounds, polychlorinated biphenyls (PCBs), and polycyclic aromatic hydrocarbons (PAHs) (Ecology 2023b).

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ANCHOR QEA

0 2
Miles

Figure 1
Site Vicinity
Biological Assessment
Marine Carbon Dioxide Removal Pilot Project (Project Macoma)

2 Description of the Proposed Action

Project Macoma, LLC, is proposing to construct and operate a temporary pilot-scale mCDR project at a site within the Port's Terminal 7 (the Proposed Action). Ebb Carbon's mCDR technology removes acid from seawater, generating alkaline-enhanced seawater. Ebb Carbon returns the alkaline-enhanced seawater to the ocean, which enables the ocean to drawn down and store additional CO_2 from the atmosphere. Project Macoma would intake seawater via a barge moored at the Terminal 7 dock and convey the seawater through a pipe to a treatment facility that would process and remove acid from the seawater before returning the alkaline-enhanced seawater to Port Angeles Harbor.

Once pumped onshore, the seawater will undergo a series of process steps in a temporary modular facility. First, the seawater is pretreated to soften it and create a concentrated brine. The brine then undergoes an electrochemical process that separates the brine into acidic (hydrochloric acid [HCl]) and alkaline (sodium hydroxide [NaOH]) streams. The acidic stream is then neutralized through a reaction with locally sourced alkaline materials.

The process steps noted above result in the following three process streams:

1. **Alkaline Product Stream:** A saltwater solution with enhanced alkalinity produced via the electrochemical process
2. **Neutralized Acid Stream:** The aqueous stream that results from reacting the acidic stream produced by the electrochemical process with alkaline minerals
3. **Pretreatment Stream:** Saltwater that is filtered out during the initial filtration steps

Under routine operations, the three process streams would be discharged as a single combined flow through the outfall. See Table 2 for a description of operational scenarios. Under routine operations (Scenario 5a), the mCDR system would operate for 12 hours daily. Project Macoma anticipates that it would also conduct scientific operations in which one or two of the component flow streams are discharged for limited durations (on the order of a few times per month for single tidal cycles) for data collection and to further the understanding of potential impacts of the discharge to water chemistry/water quality. Project Macoma also anticipates conducting maintenance during which the characteristics of the discharge would vary. Brown and Caldwell (Appendix A) analyzed five release scenarios (and subscenarios) that reflect different proposed combinations of process flow streams. Predicted flow, pH, temperature, and density of the discharge (at the time of discharge) for the proposed operating scenarios are summarized in Table 2. Monitoring of impacts to water quality and aquatic organisms would occur during the pilot project.

Table 2
Effluent Flow and Water Quality Summary for Different Treatment Scenarios (Appendix A)

Scenario	Frequency	Duration	Discharge Flow (L/hr)	Temperature (°C)	Density (kg/m³)	pH (SU)
Scientific Operations						
Scenario 1b – Alkaline Product Only (13.5 pH)	A few times a month	Single tidal cycle	5,900	30.0	1,028	13.5
Scenario 5b – All Three Process Flows ($CaCO_3$) neutralization)[1]	1 to 2 times, total	Single tidal cycle	38,000	20.4	1,038	12.1
Maintenance Operations						
Scenario 2a – Neutralized Acid Only (with Olivine)	Weekly	<8 hours	5,900	30.0	1,020	2.3
Scenario 2b – Neutralized Acid Only (with $CaCO_3$)	Weekly	<8 hours	5,900	30.0	1,028	8.1
Scenario 3 – Pretreatment Reject Only	Weekly	<8 hours	27,000	17.0	1,042	7.1
Scenario 4a – Neutralized Acid (with Olivine) + Pretreatment Reject	Weekly	<8 hours	32,900	19.3	1,038	6.4
Scenario 4b – Neutralized Acid (with $CaCO_3$) + Pretreatment Reject	Weekly	<8 hours	32,900	19.3	1,039	6.8
Routine Operations						
Scenario 5a – All Three Process Flows (with olivine neutralization)1	Daily	Up to 12 hours	38,000	20.4	1,037	9.8

Note:
1. Scenarios 5a and 5b assume contribution of the alkaline product at a pH of 13.9 (Scenario 1a).

Project Macoma will run for approximately 2 years, beginning in summer 2024. The remainder of this section provides additional information about the pilot study's elements along with a description of construction and operational activities.

2.1 Project Elements

As a pilot study, Project Macoma's elements would be installed as temporary features.

The main elements consist of the following:

- A moored barge at the Terminal 7 pier with pumps and pipes that are used to intake, transport, and discharge seawater to the Port Angeles Harbor and Strait of Juan de Fuca

- Onshore modular water treatment equipment that is used to filter and soften the water and create a concentrated brine
- Onshore electrochemical processing equipment that is used to deacidify the seawater before its return to the Port Angeles Harbor
- Onshore equipment used to neutralize the acidic byproduct

For safety, control, and research purposes, the project design also includes sensing and monitoring equipment that will be located at the site and throughout the harbor.

Project Macoma's footprint would occupy approximately 275 feet by 93 feet (25,575 square feet) on shore with the barge occupying approximately 30 feet by 80 feet (2,400 square feet) adjacent to the Terminal 7 dock. Both areas would be on Port property. The onshore area is currently being used by the Port as a log yard, which the Port would relocate. Access and parking would be provided by existing infrastructure at the Port. The in-water portion of the site is located on state-owned aquatic lands that are leased by the Port under a Port Management Agreement with the Washington State Department of Natural Resources (WDNR).

2.1.1 Onshore

Most process and treatment equipment would be located onshore and housed in shipping containers (up to 9.5 feet high with 2 additional feet for electrical lines) as machine housing. The treatment equipment would be procured from a combination of third-party manufacturers and manufactured by Ebb Carbon. The treatment equipment and process are summarized as follows and described in greater detail in Section 2.3:

In total, there would be 10 shipping containers, six mobile tanks, three utility sheds, and one office trailer, which would be used for the following functions:

- The shipping containers would contain seawater processing equipment.
- Alkaline minerals and the equipment used for acid neutralization would be stored on site in lined containers with weather coverings.
- The mobile tanks would be used to store pumped seawater and the acid and base extracted from the brine. The mobile tanks would be approximately 8,300 to 21,000 gallons and be 11 feet high with 2 additional feet for electrical lines. Any hazardous chemicals would be stored with appropriate secondary containment following best management practices. All tanks would have containment suitable for minor leaks.
- The two utility sheds would house electrical equipment, providing required electrical protective measures consistent with City of Port Angeles requirements. The third would be for storage and maintenance operations.
- The office trailer would be used for staff operations.

Onshore elements would also consist of plastic pipelines connecting the treatment facility to the barge's intake and outfall structures. There would also be a barge transfer area at the Port that would be used to transfer the barge to its temporary moorage location on the north side of the dock.

Project Macoma would use the Port's existing stormwater system at Terminal 7 for stormwater runoff. The area was previously graded to slope away from the shore to a collection point where it is filtered by the Port's stormwater system.

2.1.2 In-Water

The in-water elements of Project Macoma include the barge, which would be equipped with intake and outfall infrastructure, and water quality monitoring equipment.

The barge would be an approximately 30- by 80-foot platform (2,400 square feet) that houses the intake and outfall structures and pumps. The barge would also house some utilities and monitoring equipment. The intake would consist of a pipe that is attached to the barge, equipped with fish screening and mesh that complies with state and federal requirements. The outfall would be an approximately 4-inch-diameter and 50-foot-long pipe that is affixed to and runs the length of the barge, with half-inch perforation holes spaced approximately 2 feet apart and pointing toward the surface across the pipes to diffuse the discharged alkaline-enhanced seawater back into the harbor. The pipe would be submerged approximately 2 meters below the water surface (approximately 28 to 35 feet from the substrate at low to high tide levels, respectively).

Scientific monitoring would occur in the receiving waters throughout operations. Water quality sensors would be attached to existing piers to collect regular measurements at various locations and distances from the outfall to be determined based on coordination with partners. Ebb Carbon would use these measurements to adaptively manage operations, if needed, and to monitor environmental health and benefits.

2.2 Construction

Project construction is anticipated to begin in 2024. Construction activities would involve site preparation, installation, and assembly of onshore structures (i.e., electrical equipment enclosures); deployment of the barge; and assembly of intake/outfall and monitoring equipment. No existing structures would be demolished. All activities are expected to be conducted in a manner appropriate to minimize the potential for erosion or spills consistent with applicable regulations and required permits and approvals, and ground-disturbing activities are expected to be conducted outside sensitive cultural resource areas.

2.2.1 Upland

Site preparation is anticipated to require minimal ground disturbance, mainly in the form of targeted areas of excavation required for the electrical equipment (i.e., not for larger structures). Excavation may be required for the electrical shed, the existing utility vault's main electrical room, and to provide a conduit trench between the existing City of Port Angeles utility transformer vault and the electrical room. As stated, any excavation areas are expected to be located outside culturally sensitive areas.

Grading of the existing soil is not anticipated. Instead, gravel would be used to create a flat area for the new structures and as needed to improve access roadways. Installation of the shipping containers and office trailers would also require 10-foot-long, 3/4-inch-diameter copper ground rods adjacent to each corner, and up to four ground rods at each electrical building/shed. All cable and connections to equipment would be above grade.

Project Macoma, LLC, will also prepare and implement a Contaminated Materials Management Plan (CMMP) to address potential issues if contaminated soils are encountered. Although the level of ground disturbance would be minimal, the CMMP would help to ensure potential concerns are adequately addressed. Project Macoma, LLC, also expects to develop a Monitoring and Inadvertent Discovery Plan for cultural resources.

2.2.2 In-Water

In-water construction would be minimized to assembling and installing intake and outfall pipes along existing infrastructure and the barge. The barge would be moored on the north side of the existing dock. The pre-assembled pipelines and intake and outfall structures would then be mounted to the barge. Monitoring equipment would also be installed on the barge and to existing piers. No large equipment would be involved in in-water work.

2.3 Operation

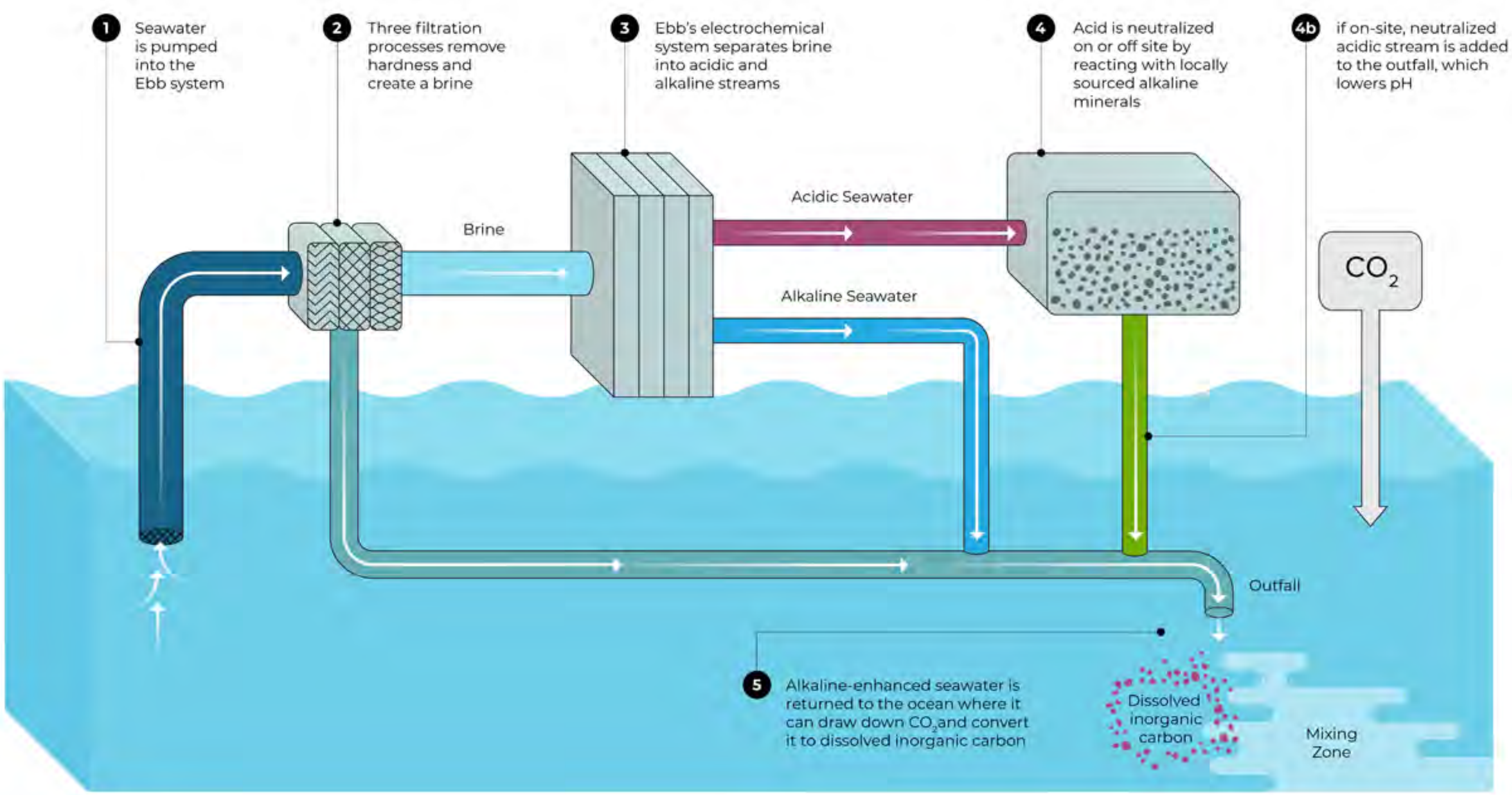
The intake and outfall infrastructure would intake and return approximately 97,000 gallons per day (367,000 liters per day) of seawater from Port Angeles Harbor. Project Macoma's operations are expected to last approximately 2 years post-construction.

Operational activities would include pilot-scale upland water treatment to deacidify seawater to support carbon capture, possible sale and/or transport of acidic byproduct off site, and transport on and off site of alkaline minerals for acid neutralization. This section describes these aspects. Monitoring and data collection activities are discussed in Section 2.5.

2.3.1 *Water Treatment Process*

A schematic of the treatment process is shown in Figure 2, and the main steps of the water treatment process include the following:

Figure 2
Water Treatment Process Diagram



1. **Water Intake:** Water intake would occur at the barge.
2. **Water Pretreatment:** Once pumped onshore, the seawater would undergo pretreatment, which includes particulate filtration (to remove solids), nanofiltration (to remove hardness, calcium and magnesium ions), and reverse osmosis to create a brine and permeate that will undergo electrochemical processing.
3. **Electrochemical Processing:** After pretreatment, the brine stream would be consumed electrochemically. Ebb Carbon's electrochemical technology uses low-carbon electricity to pass the brine through a series of ion-exchange membranes that separates the brine into two solutions: a base (NaOH) and an acid (HCl). The electrochemical process produces oxygen and hydrogen gases at ambient pressures that will be diluted below lower explosive limits and vented to the atmosphere following all applicable standards. The site generation rate of these are low, at 10 and 20 standard liters per minute undiluted, respectively.
4. **Acid Neutralization:** The acid produced from the brine may be neutralized at the site, so it does not return to the ocean. This would be done by reacting the acidic solution with alkaline materials such as ultramafic rocks, limestone, or unhardened concrete. If reacted on site, alkaline minerals would be transported to the site via truck and/or boat approximately once per week. The aqueous neutralized stream would then be filtered to remove solids and trace metals below acceptable limits before being recombined with the pretreated seawater and alkaline stream. Once combined, the streams would be pumped to the barge for outfall. Another option would be to remove and transport the acid off site rather than neutralizing on site, as discussed in Section 2.3.2.
5. **Discharge and Monitoring:** After processing on land, the combined streams (pretreated seawater, alkaline stream and, if applicable, the neutralized stream) form an alkaline-enhanced seawater that would be pumped to the barge-based outfall. The outfalled alkaline-enhanced seawater would mix with ambient seawater to remove CO_2 gas from the air and store it as dissolved inorganic carbon, primarily bicarbonate ions—a safe and naturally abundant form of carbon storage in the ocean.
    a. Discharge scenarios are outlined in Table 2. Discharge may stop if monitors indicate that certain thresholds have been met, as discussed further in Section 2.5.
    b. Although no new constituents would be added (e.g., no metals or organic compounds), the pH of the water could be altered from approximately 2.3 to 13.5 pH for short periods of time (a single tidal cycle). Preliminary mixing analyses indicate that surrounding pH would return to ambient within the nearfield mixing zone, approximately 21 feet from the discharge point at the barge (Appendix A). Water quality would return to ambient approximately 40 feet around the discharge, well within the allowable chronic mixing zone. During operations, the mixing zone will be maintained within permitted limits. The standard Ecology-required mixing zone distance is 207 feet from the point of discharge. Water quality monitoring and ecological monitoring would be conducted within both

zones to ensure safe operations of the pilot study and to collect data to help inform further development and deployment of this technology. Water quality monitoring would occur to assess for potential acute and chronic mixing zone exceedances at proposed distances of 15 and 150 feet, respectively.

2.3.2 Acid Byproduct Removal and Handling

When combined with the pretreated seawater and alkaline stream, the acidic byproduct would lower the pH of the alkaline-enhanced seawater, resulting in a final product with a pH that is similar to the receiving waters. There is also a potential that the HCl could be separated from the influent stream and used off site for other processes (e.g., in cement manufacturing or laboratory research). While on site, acid byproduct would be handled, stored, and transported consistent with applicable local, state, and federal regulations. It is assumed that entities receiving the acid would also adhere to required standards and regulations. Truck traffic to transport acid byproducts would occur approximately once per month.

2.4 Avoidance, Minimization, and Conservation Measures

The Proposed Action (set forth in Section 2) would minimize the amount of excavation conducted on the site, using the minimum necessary to establish utility access to the temporary structures. The structures would be placed on gravel to create a level grade rather than excavating the site. The existing slope would be graded away from the shoreline to direct stormwater to an existing collection point, where it would be managed by the Port's stormwater system that discharges to both freshwater and marine waterbodies.

A screen would be installed on the intake pipe that follows the Revised Code of Washington (RCW) 77.57.010 and RCW 77.57.070, as well as NMFS recommendations (NMFS 2022a), to prevent entrainment of juvenile salmonids.

2.5 Monitoring and Adaptive Management

The monitoring and adaptive management strategies are described in detail in the Ecological Safety Methodology (Appendix B).

2.5.1 Monitoring

Operation monitoring of pilot study effects would begin once project deployment occurs and would consist of water quality monitoring and biological monitoring, as detailed in the following subsections. Additional studies may be performed following discussions with partners, which may include the Tribe, PNNL-Sequim, and the University of Washington. The supplemental studies would investigate the beneficial impacts associated with the pilot project to determine if they are measurable and would be consulted separately.

2.5.1.1 Water Quality Monitoring

Water quality monitoring would be accomplished by attaching sensors to existing piers to collect regular measurements of water temperature, salinity, dissolved oxygen (DO), turbidity and suspended solids, chlorophyll, pH, and the partial pressure of CO_2 (pCO_2). Monitoring distances would be 15 and 150 feet from the outfall pipe, within the near- and far-field mixing zones. Water quality would be recorded prior to and during the release of each scenario to monitor for exceedances in water quality parameters. Less frequent seawater samples would be collected and analyzed for total alkalinity and dissolved inorganic carbon. Specific operational monitoring details will be prepared in coordination with the partners to meet desired study needs.

2.5.1.2 Biological Monitoring

Monitoring surveys could be periodically conducted to inform an understanding of pilot project effects. Areas for monitoring surveys would be identified during the baseline study, including areas with aquatic vegetation, rocky substrate, and shellfish beds. The observational studies would document presence/absence of species, delineate changes to aquatic vegetation boundaries, and otherwise note observable changes in habitat conditions. The periodic monitoring surveys would be analyzed by the partners and be used to identify when adaptive management strategies may be triggered and to track potential beneficial impacts related to the pilot project.

2.5.2 Adaptive Management

This section describes the initial adaptive management strategies that could be employed to adjust the pilot project's operations or monitoring based on results from ongoing monitoring efforts. Operations would be shut down within minutes of water quality or biological issues being observed or recorded. Table 3 addresses potential issues that may arise during operation and suggests actions to reduce adverse impacts.

It is expected that this protocol would also be developed with input from partners and stakeholders and would be included in documentation provided to NMFS and USFWS as part of the permitting process.

Table 3
Adaptive Management Strategies

Potential Issue	Indicator	Adaptive Management Strategy
Water quality parameter exceedances[1]	Remote monitoring from moored sensors indicates unanticipated changes from baseline levels (see Section 2.5.1.1 for parameters).	• Test and recalibrate moored sensors to ensure accurate readings. • Temporarily shut down operation to determine if all equipment is functioning properly. • Meet with partners to discuss changes to design prior to resuming operation.

Potential Issue	Indicator	Adaptive Management Strategy
Water quality parameter exceedances[1]	Weekly grab sample results document changes from baseline levels (see Section 2.5.1.1 for parameters).	• Follow monitoring plan to include duplicate samples for collection and laboratory quality assurance/quality control. • Resample to ensure accurate results and identify problem. • Temporarily shut down operation to determine if all equipment is functioning properly. • Meet with partners to discuss changes to design prior to resuming operation.
Observations of aquatic vegetation changes	Weekly visual inspections document algal growth or changes in visible aquatic vegetation compared to baseline assessment.	• Determine possible reason for observation and the role (if any) the Project Macoma operation had in development of algal growth or changes in visible aquatic vegetation. • Conduct additional water quality sampling to measure changes in nutrient levels and other water quality triggers to changes in aquatic vegetation. • Temporarily shut down operation to determine if all equipment is functioning properly. • Meet with partners to discuss changes to design prior to resuming operation.
Observations of aquatic organism behavioral changes (e.g., gill flaring, avoidance, or lack of startle response)	Collect additional water quality grab samples and review moored sensor readings leading up to and during observation.	• Determine possible reason for observation and the role (if any) Project Macoma operation played in the changes in behavior. • Temporarily shut down operation to determine if all equipment is functioning properly. • Meet with partners to discuss changes to design prior to resuming operation.
Observations of deceased aquatic organisms	Collect additional water quality grab samples and review moored sensor readings leading up to and during observation.	• Determine possible reason for observation and the role (if any) Project Macoma operation played in the die-off. • Temporarily shut down operation to determine if all equipment is functioning properly. • Meet with partners to discuss changes to design prior to resuming operation.

Note:

1. Washington State Marine Surface Waters, WAC 173-201A-210, WAC 173-201A-612.

2.6 Project Timing

Project Macoma, LLC, proposes to lease the property from the Port during the development and implementation of the Port's RIWP, which, along with the pilot study, would be completed prior to the Port's conducting remediation cleanup. While the RIWP is being prepared, the site has been leased to Project Macoma to use from April 2024 through June 2026. Project Macoma, LLC, aims to construct and begin operation in summer 2024 and operate until demobilizing in summer 2026, providing approximately 2 years of operation for the pilot study.

3 Action Area

The Action Area is defined as the area to be affected directly or indirectly by the federal action (50 Code of Federal Regulations [CFR] Section 402.04). This area is the geographic extent of the physical, chemical, and biological effects resulting from the Proposed Action. The Action Area boundary is thus set as the limits of the Proposed Action effects, as discussed in the following subsections.

3.1 Terrestrial Extent

Noise from construction equipment during minor excavation and placement of the temporary facilities is expected to be the pilot study impact with the most far-reaching terrestrial environmental effects. The Proposed Action would not generate in-air noise levels beyond the use of typical construction equipment and machinery, with the loudest equipment anticipated to be the use of an excavator, which generates in-air noise levels of 87 A-weighted decibels (dBA; WSDOT 2020). No nighttime work is expected to occur related to the construction of the upland facilities.

The pilot study setting is within an industrial area along the shoreline. There is no measured airborne noise data available to determine baseline sound levels. Based on the industrial setting and population density, 60 dBA was used as the ambient sound level.

Noise attenuates to ambient, or background, levels, as the distance from the source of the noise increases. In areas of hard ground cover, such as bare ground, concrete surfaces, or water, the standard reduction for point-source noise is 6.0 dBA for each doubling distance from the source. Using a 6.0-dBA reduction for each doubling distance (WSDOT 2020), in-air noise conditions were calculated for the distances at which they were expected to attenuate to ambient conditions using the spreading loss model.

Sound levels from the loudest anticipated construction activity would attenuate to background levels within approximately 1,119 feet (0.21 mile) from the Proposed Action footprint when an excavator is being used. Therefore, 1,119 feet (0.21 mile) from the Proposed Action footprint is used as the terrestrial extent of the Action Area (Figure 3).

3.2 Aquatic Extent

Operation of the Proposed Action would result in nearfield (acute) and far-field (diluted) changes to water quality extending from the diffuser ports that discharge the treated alkaline-enhanced seawater associated with Project Macoma. Based on modeling in the mixing zone analysis (Appendix A), the nearfield water quality changes are expected to dilute to meet Washington State marine surface water quality standards (Washington Administrative Code [WAC] 173-201A-210) within 40 feet (0.23 acre) for temperature, pH, and DO. Additional far-field water quality impacts are conservatively estimated to extend up to 207 feet in any horizontal direction of the diffuser ports and to include the entire vertical water column (Appendix A). With the 25 outfall ports spaced 2 feet apart (total outfall pipe length of 50 feet) and set 6 feet below the water surface along the offshore length of the barge, the aquatic extent of the Action Area representing the far-field water quality impacts encompasses 3.64 acres (Figure 3).

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ANCHOR QEA

Figure 3
Action Area
Biological Assessment
Marine Carbon Dioxide Removal Pilot Project (Project Macoma)

4 Environmental Baseline

4.1 Physical Conditions

Port Angeles Harbor is located along the northern coast of the Olympic Peninsula on the Strait of Juan de Fuca. The harbor is considered the largest natural deepwater harbor on the west coast of the United States, with water depths greater than 90 feet near the eastern end. Near the pilot study site, depths range from 25 feet at mean lower low water (MLLW) along the barge-mounted outfalls to 90 feet MLLW near the eastern end of Ediz Hook.

4.1.1 Shoreline Armoring, Substrate, and Slope

The existing upland component of the pilot study site has been cleared and is highly developed. The site is relatively flat with very little sloping. The shoreline is composed of fill material with a large boulder riprap wall preventing erosion. The WDNR Coastal Atlas map (WDNR 2024) classifies the geomorphology of the site as a "modified" slope stability, with no appreciable drift. The sediment of the harbor is documented as rock and gravel along the eastern portion and as a mix of mud and sand in the harbor's western portion, near the Action Area (NOAA 2024). Additionally, there are no rocky reefs documented within the harbor (NOAA 2024).

4.2 Chemical Conditions

4.2.1 Water Quality

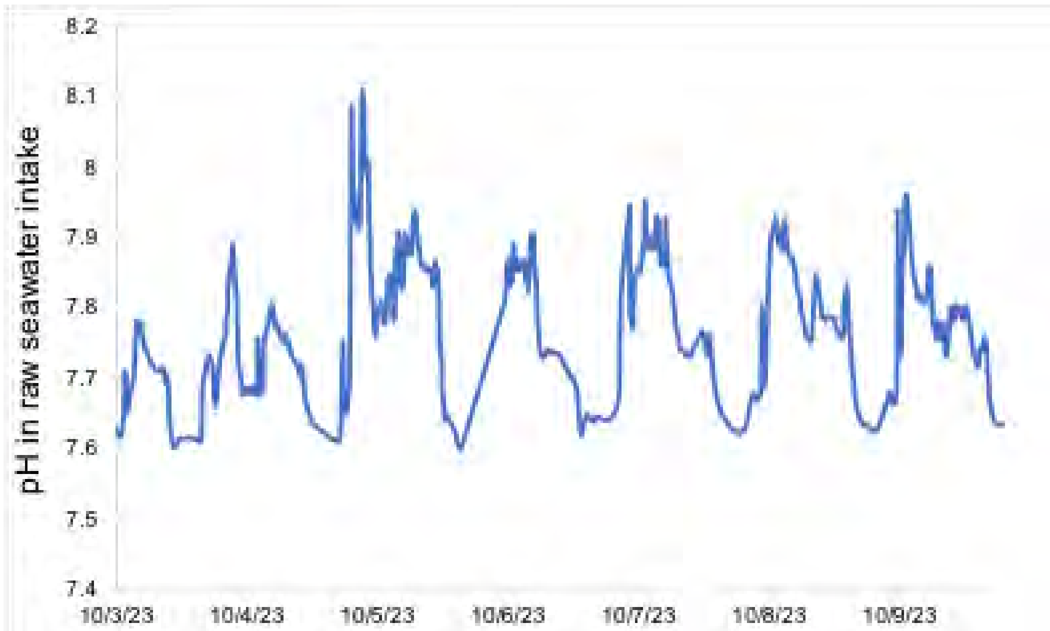
Ambient water quality parameters are provided in Table 4 and discussed in Appendix A.

Table 4
Ambient Water Quality Parameters

Water Quality Parameter	Ambient Conditions
pH	7.8 standard units
Temperature	10.0°C (October–April) 11.4°C (May–September)
DO	7.3 mg/L

The documented pH for Port Angeles Harbor and standard used for determining ambient conditions is 7.8 pH units; however, pH is variable, naturally fluctuating between 7.6 and 8.1 (Figure 4). The example of pH fluctuations in Figure 4 is provided for Sequim Harbor. Based on the proximity and similar conditions, it is anticipated that similar fluctuations in pH would be present in Port Angeles Harbor.

Figure 4
pH Fluctuations in Sequim Harbor



Turbidity and suspended sediment levels naturally fluctuate daily and seasonally in nearshore environments due to the interaction between wave and sandy substrate in intertidal areas and the amount of sunlight.

Ecology rated water quality in Port Angeles Harbor and surrounding areas as part of the State of Washington's most recent Water Quality Assessment. Waters within the pilot study area have been rated as Category 2 for coliform bacteria; PCBs; and 2,3,7,8-tetrachlorodibenzo-p-dioxin toxicity equivalence (Ecology 2024a). Category 2 listings are waters that have an indication of a potential water quality problem, but not enough evidence to require preparing a Total Maximum Daily Load (TMDL), associated with water quality improvement projects. There are no Category 5 water quality listings in Port Angeles Harbor, indicating waters impaired or threatened by pollutant(s) for one or more designated uses that require a TMDL.

4.2.2 Sediment Quality

Port Angeles Harbor has historically been used as a site for plywood, pulp, and paper manufacturing; marine shipping; boat building and refurbishing; fueling facilities; marinas; and commercial fishing, with subsequent stormwater, sewer, and process wastewater discharge. As a result, the direct discharge of petrochemicals, organic toxins, heavy metals, and other hazardous substances into the harbor has resulted in a legacy of contaminated sediments (PAHNRT 2021). The pilot study site has been identified as an Ecology cleanup site and lies within "Terminal 5, 6, and 7 Uplands" (Cleanup

Site and Facility Identifier 15440) under Ecology's Toxics Cleanup Program. Additionally, a Natural Resource Damage Assessment was completed for the cleanup site and submitted with a restoration plan (PAHNRT 2021). The existing site and adjacent locations will be remediated per Agreed Order DE 9781 for contaminated marine substrate in Western Port Angeles Harbor.

Ecology documents the following contaminants in the soil and groundwater at this cleanup site: petroleum hydrocarbons; dioxins/furans; and tris(2-carboxyethyl)phosphine, phencyclidine, and related compounds (Ecology 2024b). Ecology's Water Quality Atlas Map lists the marine sediments in the nearshore of the pilot study site as Category 4b for cadmium, high molecular weight PAHs, low molecular weight PAHs, mercury, phenol, PCBs, and zinc (Ecology 2024a). A Category 4b listing means that the site has a pollution control program, similar to a TMDL plan, that is expected to resolve the pollution problems.

4.3 Biological Habitat Conditions

4.3.1 Habitat Access and Refugia

The pilot project site is highly developed and currently used as an industrial logging yard, with no undisturbed habitats in the vicinity. The shoreline is composed of a boulder riprap wall and lacks the complexity necessary for a diverse shoreline microhabitat. There is no overhanging vegetative cover or woody debris present that would provide refugia for juvenile salmon and forage fish from predators and heat stress. No Habitat Areas of Particular Concern (HAPCs) are documented within the nearshore of the pilot study area. The nearest documented HAPCs are an estuary HAPC located approximately 0.6 mile northwest, in the lagoon west of Marine Drive, and a canopy kelp HAPC located approximately 2.6 miles southeast of the pilot study site, in the eastern portion of the harbor (NOAA 2024).

4.3.2 Shoreline Vegetation

The pilot study site is currently used as an industrial log yard and is highly modified. The riparian vegetation is sparse and limited to grass and incidental herbaceous species. There are no trees, riparian vegetation communities, or buffers located within or adjacent to the pilot study area.

4.3.3 Aquatic Vegetation

WDNR's Coastal Atlas map (WDNR 2024) documents patchy (fringe) kelp in the nearshore of the pilot study site. There is no eelgrass (*Zostera marina*) documented in the nearshore of the pilot study site, and the nearest known location is approximately 2.2 miles northeast of the pilot study site, off the shore of Ediz Hook. As discussed previously in Section 4.3.1, the National Oceanic and Atmospheric Administration's Marine Cadastre National Viewer also documents a canopy kelp HAPC in the eastern portion of the harbor, approximately 2.6 miles away from the pilot study area (NOAA 2024).

4.3.4 Forage Fish Spawning Habitat

According to the Washington Department of Fish and Wildlife (WDFW), there is no documented forage fish spawning habitat in the nearshore of the pilot study site. The nearest documented forage fish spawning habitat is located approximately 0.6 mile north of the pilot study site, on the shore of Ediz Hook, and is in the form of Pacific sand lance (*Ammodytes hexapterus*) and surf smelt (*Hypomesus pretiosus*) spawning habitat (WDFW 2024). The boulder riprap shoreline and the mud and sand sediment documented in the nearshore do not provide a suitable habitat for Pacific sand lance and surf smelt spawning. Surf smelt deposit eggs near the water's edge in water a few inches deep, typically around the time of the high-water slack tide and in areas with a mixture of coarse sand and pea gravel sediment. Sand lance deposit eggs in the upper intertidal zone on beaches that also have a mixture of coarse sand and pea gravel sediment but will also use pure sand beaches not used by surf smelt (Moulton and Penttila 2001).

The nearest documented Pacific herring (*Clupea pallasii*) spawning habitat is located in Dungeness Bay, approximately 12.8 miles east of the pilot study site (WDFW 2024). Pacific herring deposit eggs on submerged aquatic vegetation between the upper limits of high tide down to a depth of -40 feet MLLW, but most spawning takes place between 0 and -20 feet MLLW in tidal elevation (WDFW 2019). The documented patchy (fringe) kelp in the pilot study area's nearshore may provide potential habitat for Pacific herring spawning (WDNR 2024).

5 Species and Critical Habitats Potentially Present in Action Area

This section describes federally listed species and critical habitat in the Action Area.

5.1 Southern Resident Killer Whale

The Southern Resident killer whale (SRKW) DPS was listed as endangered on November 18, 2005 (70 FR 69903). The SRKW contains J pod, K pod, and L pod, and its population is estimated in the 70s (NMFS 2023b). The geographic distribution of SRKW is year-round in the coastal waters off Oregon, Washington, and Vancouver Island and off the coast of central California and the Queen Charlotte Islands (Center for Biological Diversity 2001). In the summer, SRKW are typically found in the Georgia Strait, Strait of Juan de Fuca, and the outer coastal waters of the continental shelf. In the fall, the J pod migrates into Puget Sound, while the rest of the population makes extended trips through the Strait of Juan de Fuca. In the winter, the K and L pods retreat from inland waters and are seldom detected in the core areas until late spring. The J pod generally remains in inland waterways throughout the winter, with most of their activity in Puget Sound. Other winter movements and range of SRKW are not well understood (NMFS 2023b).

SRKW use the entire water column, including regular access to the ocean surface to breathe and rest (Bateson 1974; Herman 1991). They remain underwater 95% of the time, with 60% to 70% of their time spent between the surface and a depth of 65 feet (20 meters), while diving regularly to depths of greater than 655 feet (200 meters; Baird 1994; Baird et al. 1998). SRKW spend less than 5% of their time between depths of 200 and 820 feet (60 and 250 meters; Center for Biological Diversity 2001). Time-depth recorder tagging studies of SRKW have documented that whales regularly dive to greater than 490 feet (150 meters) but that there is a trend toward a greater frequency of shallower dives in recent years (Baird and Hanson 2004).

SRKW primarily feed on salmon species (Balcomb et al. 1980; Bigg et al. 1987; NMFS 2008; Hanson et al. 2010). Chinook salmon dominate their diet (71.5%), followed by chum salmon (22.7%) and other salmon species or unidentifiable salmon species (Ford et al. 1998; Ford and Ellis 2006). Recent studies have indicated that while in their summer range (outside of the Action Area), Chinook salmon from the Fraser River basin accounted for 80% to 90% of the salmonid prey for SRKW, and fish originating in Puget Sound accounted for 6% to 14% (Hanson et al. 2010). Other species such as lingcod (*Ophiodon elongates*), halibut (*Hippoglossus stenolepis*), rockfish (*Sebastes* spp.), and Dover sole (*Microstomus pacificus*) were identified as additional prey species and may increasingly contribute to the diet as salmon populations decline (Center for Biological Diversity 2001; Hanson et al. 2010).

5.1.1 *Critical Habitat Presence in the Action Area*

Critical habitat was designated on November 29, 2006 (71 FR 69054) and revised on August 21, 2021 (86 FR 41668). Critical habitat for SRKW is designated for marine areas greater than 20 feet deep and overlaps with the Action Area (NMFS 2024). Critical habitat provides the physical and biological habitat features (PBFs) that are essential for the conservation of the species or that require special management considerations, as follows:

- **PBF 1:** Water quality to support growth and development
- **PBF 2:** Prey species of sufficient quantity, quality, and availability to support individual growth, reproduction, and development, as well as overall population growth
- **PBF 3:** Passage conditions to allow for migration, resting, and foraging

5.2 Humpback Whale

For the Marine Mammal Protection Act stock assessment reports (NOAA 2022a), the California-Oregon-Washington Stock is defined to include humpback whales that feed off the west coast of the United States, including animals from both the California-Oregon and Washington-southern British Columbia feeding groups. The Mexico humpback whale DPS feeds along the Washington coast and is listed as "threatened" under the Endangered Species Act (ESA; 81 FR 62259) and comprises 25% of humpback whales present in Washington. The Central America humpback whale DPS also is known to feed in the Washington-southern British Columbia area and is listed as "endangered" (81 FR 62259) and comprises 6% of the humpback whales in Washington. The Hawaii humpback whale DPS is not federally listed and comprises 69% of the humpback whales in Washington. A final humpback whale recovery plan was adopted in 1991 (NOAA 1991).

Humpback whales are baleen whales known for their long pectoral fins. They feed primarily on krill, plankton, and small fish, consuming up to 3,000 pounds per day. As with other baleen whales, the adult females are larger than adult males, with lengths reaching 60 feet. Humpbacks are grey in color, with significant variation such that the patterns on the undersides of the flukes can be used to identify individual whales.

Humpback whales have the longest migration of any mammal. Individuals of the Mexico DPS have been observed to make the 3,000-mile trip between Alaska and Hawaii in as little as 36 days. Humpbacks spend the warmer months in northern latitudes feeding and building fat stores; they migrate south during the winter for the breeding season (NOAA 2022b).

Humpback whales are found in coastal waters of Washington as they migrate from feeding grounds in Alaska to California to winter breeding grounds in Mexico. Humpbacks are historically only rare visitors to Puget Sound. In 1976 and 1978, two sightings were reported in Puget Sound, and one sighting was reported in 1986 (Osborne et al. 1988; Calambokidis and Steiger 1990;

Calambokidis and Baird 1994). More recently, sightings have increased, and, according to the Orca Network, humpbacks are regularly sighted in the Strait of Juan de Fuca, near the San Juan Islands and Whidbey Island, and in Puget Sound (Orca Network 2024).

5.2.1 Critical Habitat Presence in the Action Area

In Washington, the Central American DPS and Mexico DPS critical habitat includes coastal and nearshore waters beginning approximately 50 meters from MLLW, extending from the outer coast to include the Strait of Juan de Fuca to Angeles Point, approximately 5 miles west of the Action Area (86 FR 21082; May 21, 2021). Humpback whale critical habitat is present a few miles west of but not within the Action Area (NMFS 2024).

5.3 Puget Sound Chinook Salmon

The Puget Sound Chinook Salmon Evolutionarily Significant Unit (ESU) was listed as threatened on June 28, 2005, and updated on April 14, 2014 (79 FR 20802). The Puget Sound ESU of Chinook salmon includes all naturally spawned populations from rivers flowing into Puget Sound from the Elwha River (inclusive) eastward. This ESU also includes Chinook salmon from 25 different artificial propagation programs. Nearshore areas along the Strait of Juan de Fuca are considered a major migratory corridor for Chinook salmon (Shared Strategy 2007).

The Elwha River (approximately 6 miles west of the pilot study site) and the Dungeness River (approximately 14 miles east of the pilot study site) are used for spawning by Chinook salmon. Morse Creek, approximately 4 miles east of the pilot study site, is also used by Chinook salmon for spawning. Ennis Creek, approximately 1 mile east of the pilot study site, has documented Chinook salmon presence but no documented spawning (NWIFC 2023).

The recent 5-year status review of Puget Sound Chinook salmon indicates that although population abundance has been highly variable since the 1980s, there appears to be an overall decline in most wild spawning populations in recent years (NMFS 2015, 2017). The Dungeness and Elwha Chinook salmon populations have had very low adult returns in recent decades. Millions of hatchery Chinook salmon from indigenous stock have been released in both the Dungeness and Elwha rivers to support recovery (Shared Strategy 2007).

Chinook salmon typically migrate into freshwater spawning areas in the Dungeness River between May and July and spawn between August and October. After emerging as fry in the early spring, most of these Chinook salmon emigrate to rear in the Dungeness estuary during their first year, whereas others rear in the river for a year and emigrate as yearlings. Estuarine and nearshore habitat is therefore important for juvenile Chinook salmon from the Dungeness River (Shared Strategy 2007).

Prior to the removal of two dams from the Elwha River between 2011 and 2014, Chinook salmon had access to only the lower 5 miles of the river below Elwha Dam. Chinook salmon runs returned to the river from late spring through late September and spawned from late August through mid-October. Because of the lack of both freshwater and estuarine habitat, most juvenile Chinook salmon in the river migrated quickly into saltwater and spent most of their first year in the marine nearshore environment (Shared Strategy 2007). Since removal of the dams, the use of the Elwha River by Chinook salmon has been evolving, and studies are ongoing. Chinook salmon have moved into areas upstream of the former dam sites (Duda et al. 2021). However, hatchery-produced Chinook salmon are still dominant, and there is still no evidence of an increase in natural production of Chinook salmon in the river (Weinheimer et al. 2018). Based on recent modeling, it is thought that an increased diversity of stream temperature regimes in the river following dam removal may allow the emergence of more diverse life-history strategies, with some Chinook salmon juveniles potentially spending more time in the river before moving to the ocean (Liermann et al. 2023).

Adult Chinook salmon could be present in the Action Area in the summer months during their migration toward spawning areas. Juveniles could be present in the Action Area during out-migration in the spring. Juveniles would be expected to use shallower nearshore waters, whereas adults would be expected to use the deeper waters of the harbor.

5.3.1 Critical Habitat Presence in the Action Area

Critical habitat for Puget Sound Chinook salmon was designated on September 2, 2005 (70 FR 52698) and includes marine waters in the Action Area (NMFS 2024). The designation of critical habitat is based on the life history and habitat needs of Puget Sound Chinook salmon and includes six PBFs necessary for their conservation in freshwater, estuarine, and nearshore marine habitats. Project Macoma would not affect any PBFs related to freshwater spawning, rearing, or migration. In the Action Area, the following PBFs could be affected by the Proposed Action:

- **PBF 5:** Nearshore marine areas free of obstruction and excessive predation that meet the following criteria:
  - Water quality and quantity conditions and forage, including aquatic invertebrates and fishes, supporting growth and maturation
  - Natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, and side channels
- **PBF 6:** Offshore marine areas that meet the following criteria:
  - Water quality conditions and forage, including aquatic invertebrates and fishes, supporting growth and maturation

5.4 Puget Sound Steelhead

Puget Sound steelhead were listed as threatened on May 11, 2007 (72 FR 26722) and updated on April 14, 2014 (79 FR 20802). The Puget Sound DPS of steelhead includes all naturally spawned anadromous steelhead originating below natural and manufactured impassable barriers from rivers flowing into Puget Sound from the Elwha River (inclusive) eastward, as well as populations from five artificial propagation programs.

Steelhead are anadromous salmonids that, unlike most other Pacific salmon, are iteroparous (i.e., they can spawn several times), with spawning starting in their fourth or fifth year and continuing until reaching a maximum age of approximately 11 years (76 FR 1392; PSP 2017). Anadromous steelhead exhibit two major life-history strategies. Stream-maturing or summer-run steelhead enter freshwater at an early stage of maturation, usually from May to October; migrate to headwater areas; and hold for several months prior to spawning the following spring. Ocean-maturing or winter-run steelhead enter freshwater from November to April at an advanced stage of maturation, spawning from February through June. The winter run of steelhead is the predominant run timing in Puget Sound (Myers et al. 2015).

Steelhead have been documented in most of the streams in the pilot study vicinity that drain north to the Strait of Juan de Fuca or Port Angeles Harbor. Winter steelhead spawning is documented in several streams that empty into the strait (outside of Port Angeles Harbor), including the Elwha River, Ennis Creek, Morse Creek, Siebert Creek, McDonald Creek, and the Dungeness River (NWIFC 2023).

Winter-run juveniles would be out-migrating from freshwater during spring through midsummer and could be present in or near the Action Area during that time. Information on general steelhead life history suggests that few, if any, juvenile steelhead will be in the shallow nearshore areas at any time during the year. Burgner et al. (1992) reports that the majority of steelhead smolts migrate directly to the open ocean and do not rear extensively in the estuarine or coastal environments. In addition, by the time steelhead reach the marine waters, they would be much larger in size and tend to move rapidly to offshore habitat.

As previously discussed for Chinook salmon (Section 5.3), the use of the Elwha River by steelhead has been evolving since removal of the two dams. Steelhead have moved into previously inaccessible areas of the river, and their increased access to diverse habitats including cold-water tributary streams could allow the development of more diverse life-history strategies (Duda et al. 2021, Munsch et al. 2023).

5.4.1 Critical Habitat Presence in the Action Area

Critical habitat for steelhead was finalized on February 24, 2016 (81 FR 9252). In the pilot study vicinity, steelhead critical habitat includes the Elwha and Dungeness rivers and numerous smaller streams between the two rivers that drain north into the Strait of Juan de Fuca or Port Angeles Harbor. Tumwater and Valley creeks, both draining into the harbor, are the closest streams to the pilot study site that are included in critical habitat mapping for this species (NMFS 2024).

Project Macoma would not affect any steelhead PBFs related to freshwater spawning, rearing, or migration. Marine and estuarine PBFs for steelhead are the same as those discussed previously for Chinook salmon (Section 5.1.3.1).

5.5 Hood Canal Chum Salmon

Hood Canal summer-run chum salmon were listed as threatened on March 25, 1999 (64 FR 14508), and June 28, 2005 (70 FR 37159), and updated on April 14, 2014 (79 FR 20802). The Hood Canal summer-run ESU of chum salmon includes all naturally spawned populations of summer-run chum salmon in Hood Canal and its tributaries; populations in Olympic Peninsula rivers between Hood Canal and Dungeness Bay, Washington; and two artificial propagation programs: the Lilliwaup Creek Fish Hatchery and the Tahuya River Program. The nearest documented presence as well as spawning habitat is located in the Dungeness River, approximately 13 miles east of the Action Area (NWIFC 2023). Fall-run chum salmon, which are not federally listed, are present in small streams draining to the harbor and spawn in Frog Creek near the harbor mouth (NWIFC 2023).

Hood Canal summer-run chum salmon usually spawn from mid-August through October, and juveniles out-migrate immediately after emergence in spring, typically February through May (Haring 2000). Therefore, adults could be migrating through the deeper waters of the Action Area prior to and during this fall migration, and juveniles could use shallow mud substrate nearshore areas as they migrate and rear in the spring (Roni and Weitkamp 1996). However, no spawning or rearing streams for Hood Canal summer-run chum salmon are present in Port Angeles Harbor.

5.5.1 Critical Habitat Presence in the Action Area

Critical habitat for Hood Canal summer-run chum salmon was designated in 2005 (70 FR 52630). The closest mapped critical habitat is at Dungeness National Wildlife Refuge, approximately 13 miles east of the Action Area (NOAA Fisheries 2021).

5.6 Bull Trout

The U.S. lower 48 states (co-terminus) population of bull trout was listed as threatened on November 1, 1999 (64 FR 58910). The Coastal-Puget Sound DPS of bull trout includes all Pacific Coast drainages within the State of Washington.

Bull trout have specific cold-water requirements and are rarely found in waters with temperatures above 64°F (USFWS 2022b). They may also exhibit four different life-history types: anadromous, adfluvial, fluvial, and resident. Bull trout spawn from late summer through December, typically when water temperatures drop below 48°F (Wydoski and Whitney 2003). Juvenile bull trout feed on insects and then transition to small fish. Larger bull trout prey predominantly on fish. Anadromous bull trout use nearshore marine areas seasonally (spring and summer) and are typically present near their natal streams in shallow water (Hayes et al. 2011). Habitats used include shorelines adjacent to coastal deposits, sediment bluffs, and low bank areas with mixed substrate (Hayes et al. 2011).

Bull trout have been documented in the Dungeness and Elwha rivers. USFWS has identified two local populations of bull trout in the Dungeness watershed: one in the Dungeness River and one in the Gray Wolf tributary. The Elwha River is considered a core area for the species. Prior to removal of the two Elwha River dams, the river was thought to support both an "upper river" freshwater-only type and a "lower river" anadromous form of bull trout (Shared Strategy 2007). Following dam removal, bull trout moved into formerly inaccessible upstream areas, reaching the headwaters within 3 years, and moving between the river and its estuary (Brenkman et al. 2019).

Anadromous bull trout may occasionally be present in nearshore habitats in the Action Area. The low-elevation streams in the Action Area do not meet the cold-water spawning requirements of bull trout.

5.6.1 Critical Habitat Presence in the Action Area

Bull trout critical habitat was finalized on October 18, 2010 (75 FR 63898). It encompasses both freshwater streams and marine nearshore areas from mean higher high water (MHHW) offshore to depths of 33 feet. In the pilot study vicinity, bull trout critical habitat includes the Elwha and Dungeness rivers and numerous smaller streams between the two rivers that drain north into the Strait of Juan de Fuca or Port Angeles Harbor. The Action Area includes designated marine nearshore critical habitat. Valley Creek, which drains into Port Angeles Harbor, and Ennis Creek to the east of the harbor are the closest freshwater streams designated as critical habitat (USFWS 2024a).

The USFWS has designated several recovery units for bull trout. The Action Area is within the Coastal Recovery Unit, which includes the Olympic Peninsula, Puget Sound, and Lower Columbia River basin major geographic regions. The Olympic Peninsula region includes six core areas for bull trout recovery, which include the Elwha and Dungeness river watersheds. The Strait of Juan de Fuca is not considered a core area but is designated as a bull trout foraging, migration, and overwintering area (FMO). FMOs are defined as larger streams, mainstem rivers, estuaries, and nearshore environments used by subadult and adult migratory bull trout for foraging, migration, rearing, or overwintering (USFWS 2015a, 2015b).

The designation of critical habitat is based on the life history and habitat needs of Puget Sound bull trout and includes nine PBFs necessary for their conservation in freshwater, estuarine, and nearshore marine habitats. The PBFs relevant to Project Macoma include the following:

- **PBF-2:** Migration habitats with minimal physical, biological, or water quality impediments between spawning, rearing, overwintering, and freshwater and marine foraging habitats, including but not limited to permanent, partial, intermittent, or seasonal barriers
- **PBF-3:** An abundant food base, including terrestrial organisms of riparian origin, aquatic macroinvertebrates, and forage fish
- **PBF-4:** Complex river, stream, lake, reservoir, and marine shoreline aquatic environments and processes that establish and maintain these aquatic environments, with features such as large wood, side channels, pools, undercut banks, and unembedded substrates, to provide a variety of depths, gradients, velocities, and structure
- **PBF-8:** Sufficient water quality and quantity such that normal reproduction, growth, and survival are not inhibited
- **PBF-9:** Sufficiently low levels of occurrence of nonnative predatory (e.g., lake trout, walleye, northern pike, smallmouth bass), interbreeding (e.g., brook trout), or competing (e.g., brown trout) species that, if present, are adequately temporally and spatially isolated from bull trout

5.7 Bocaccio

The Puget Sound/Georgia Basin DPS of bocaccio was listed as threatened on April 28, 2010 (75 FR 22276). Bocaccio are large, long-lived rockfish that inhabit deep waters, from 160 to more than 800 feet (ranging as deep as 1,500 feet; 50 CFR 223-224). Rockfish are viviparous (i.e., their eggs are fertilized internally) and produce 1 million to 3 million larvae annually. The larvae are released in the spring and are distributed widely in surface water, floating with tides and currents. After 3 to 6 months as larvae, juveniles move into offshore or nearshore benthic habitats including rocky reefs, kelp canopies, and structures such as piers and oil platforms. Juveniles feed on zooplankton including the larvae of crustaceans, small fish, and invertebrates, and as they grow larger, typically move into deeper water and habitats with high roughness (i.e., rocky reefs). Adult bocaccio have a diverse diet including numerous fish species (e.g., juvenile salmon, forage fish, flatfish, pollock, and lingcod) and larger invertebrates such as crabs, and can be found associated with rocky or bouldery benthic habitats but have also been captured in soft-bottomed habitats (NMFS 2017).

Bocaccio are difficult to sample. Historically, they appear to have been most abundant in the South Sound and Main Basin of Puget Sound (Drake et al. 2010 and Williams et al. 2010, cited in NMFS 2017). Juveniles and subadults are more common than adults in shallower water, and bocaccio are known to school in nearshore waters as juveniles (McCall and He 2002). Adults are generally associated with rocky areas and outcrops (Drake et al. 2010), but some are also frequently found in areas lacking hard substrate (Washington 1977; Miller and Borton 1980).

Port Angeles Harbor lacks the rocky reefs, substrates, and deep waters typical of bocaccio rockfish habitat.

5.7.1 Critical Habitat Presence in the Action Area

Critical habitat for Puget Sound/Georgia Basin bocaccio was designated on November 13, 2014 (79 FR 68042). The nearest designated critical habitat to the Action Area is mapped approximately 7 miles east, near the outlet of Siebert Creek (NMFS 2024).

5.8 Yelloweye Rockfish

The Puget Sound/Georgia Basin DPS of yelloweye rockfish was listed as threatened on April 28, 2010 (75 FR 22276). Critical habitat was designated on November 13, 2014 (79 FR 68042). The nearest critical habitat to the Action Area is located offshore of Dungeness Spit.

Yelloweye rockfish are a large, long-lived rockfish most commonly occurring in deep water from 300 to 600 feet in depth. Rockfish are viviparous (i.e., their eggs are fertilized internally) and produce 1 million to 3 million larvae annually. The larvae are released in the spring and are distributed widely in surface water, floating with tides and currents. Juveniles use shallow waters and habitats including rocky reefs, kelp canopies, and structures such as piers and oil platforms. Juvenile yelloweye rockfish rarely occur in nearshore areas. Juveniles feed on zooplankton including the larvae of crustaceans and invertebrates, as well as small fish. Adult yelloweye rockfish feed on many species of fish and larger invertebrates such as crabs and are more associated with rough rocky benthic habitats than bocaccio (NMFS 2017).

Yelloweye rockfish occur in waters 80 to 1,560 feet deep (Orr et al. 2000) but are most commonly found between 300 to 590 feet in depth (Love et al. 2002). They are highly associated with high relief zones with crevices and complex rock habitats (Love et al. 1991; Richards 1986). Port Angeles Harbor is not ideal habitat for yelloweye rockfish due to its natural lack of rocky reefs or substrate and shallow depths. Juvenile yelloweye rockfish do not typically occupy shallow waters (Love et al. 1991) and are thus unlikely to be present in the Action Area where operations would occur. Yelloweye rockfish were recently sampled in low numbers in Puget Sound (NMFS 2017).

5.8.1 Critical Habitat Presence in the Action Area

Critical habitat for Puget Sound/Georgia Basin yelloweye rockfish was designated on November 13, 2014 (79 FR 68042). The nearest critical habitat to the Action Area is located approximately 10 miles to the northeast, offshore of Dungeness Spit (NMFS 2024).

5.9 Sunflower Sea Star

On August 18, 2021, the Center for Biological Diversity petitioned NMFS to list the sunflower sea star under the ESA. NMFS determined that the Proposed Action may be warranted (86 FR 73230; December 27, 2021) and began a full status review to evaluate the overall extinction risk for the species. NMFS determined that the sunflower sea star is likely to become endangered within the foreseeable future throughout its range. On March 16, 2023, NMFS published a proposed rule to list the sunflower sea star as a threatened species (88 FR 16212; March 16, 2023). NMFS did not propose to designate critical habitat (88 FR 16212; March 16, 2023).

Information on the status of the species was provided by NMFS (Vigil 2023). The sunflower sea star is a large (up to 1 meter in diameter), fast-moving (up to 160 centimeters per minute), many-armed (up to 24 rays) echinoderm native to the West Coast of North America. It occupies waters from the intertidal to at least 435 meters deep, but it is most common at depths less than 25 meters and rare in waters deeper than 120 meters. Sunflower sea stars occur over a broad array of soft-, mixed-, and hard-bottom habitats from the Aleutian Islands, Alaska, to Baja California, Mexico, but are most abundant in waters off eastern Alaska and British Columbia.

Prior to 2013, the global abundance of sunflower sea star was estimated at several billion animals; however, from 2013 to 2017, sea star wasting syndrome reached pandemic levels, killing an estimated 90% or more of the population. Declines in the northern portion of its range were less pronounced than in the southern portion but still exceeded 60%. Species-level impacts both during the pandemic and on an ongoing basis have been identified as the major threat affecting the long-term persistence of the sunflower sea star.

The species has separate sexes and is a broadcast spawner with a planktonic larval stage. Females can release a million eggs or more. Reproduction also occurs via larval cloning, enhancing potential reproductive output beyond female fecundity. Sea stars can regenerate lost rays/arms and parts of the central disc. Rays may detach when a sea star is injured or as a defense reaction when attacked by a predator. The longevity of the sunflower sea star in the wild is unknown, as is the age at first reproduction and the period over which a mature individual is capable of reproducing.

The sunflower sea star hunts a range of bivalves, gastropods, crustaceans, and other invertebrates using chemosensory stimuli and will dig for preferred prey in soft sediment. It preys on sea urchins and plays a key role in controlling sea urchin numbers in kelp forests. Although generally solitary, they are also known to seasonally aggregate, perhaps for spawning purposes.

5.9.1 Critical Habitat Presence in the Action Area

NMFS has not yet proposed to designate critical habitat for sunflower sea star (88 FR 16212; March 16, 2023).

5.10 Marbled Murrelet

The marbled murrelet was listed as threatened on October 1, 1992 (57 FR 45328). Marbled murrelets are small seabirds of the family Alcidae that occur along the north Pacific Coast from Alaska to California. They nest mainly in late-successional and old-growth coniferous forests and may fly up to 45 miles to marine areas to forage on small fish and large zooplankton (Ralph et al. 1995; Pearson et al. 2022). High-use areas for murrelets include upwelling areas, mouths of bays, areas over underwater sills, tidal rips, narrow passages between islands, shallow banks, and kelp beds. Field observations of murrelets in Puget Sound have suggested that foraging distribution is linked to tidal patterns that increase prey availability for the birds (Speich and Wahl 1995).

The USFWS Marbled Murrelet Recovery Plan designated six conservation zones spanning coastal areas from the U.S.-Canada border south to San Francisco Bay (USFWS 1997). The Northwest Forest Plan requires ongoing monitoring of marbled murrelet populations in the five northern conservation zones (U.S. Forest Service 2024), including Zone 1, where the Action Area is located. Overall, the Washington state marbled murrelet population has been declining over the past two decades (Pearson et al. 2022). Murrelet abundance in Zone 1 declined by approximately 5% per year between 2000 and 2018 (McIver et al. 2021). Recent summer marine surveys by WDFW found a density of approximately two marbled murrelets per square kilometer in the Strait of Juan de Fuca (Lance and Pearson 2021).

The Action Area does not provide suitable nesting habitat for this species, but such habitat is present within a few miles (see Section 5.1.10.1), increasing the likelihood of the species using marine habitat for foraging in the Action Area. The species has recently been observed from Ediz Hook (eBird 2023).

5.10.1 Critical Habitat Presence in the Action Area

Critical habitat for marbled murrelet includes terrestrial areas containing suitable nesting platforms, adequate canopy cover over the nest, landscape condition, and distance to the marine environment (81 FR 51348; August 4, 2016). The nearest mapped critical habitat to the Action Area is located approximately 3 miles south (USFWS 2024b).

6 Effects Analysis

6.1 Noise

The activities associated with the Proposed Action are not expected to create a noise impact on species listed as endangered, threatened, or proposed for listing under the ESA ("ESA-listed") species. Underwater sound pressure waves are known to affect fish and can lead to injury or death (CalTrans 2001; Longmuir and Lively 2001; Stotz and Colby 2001) through the mechanisms of ruptured swim bladder and internal hemorrhaging (CalTrans 2001; Abbott and Bing-Sawyer 2002). Marine mammals may experience temporary or permanent hearing threshold shifts associated with underwater noise (NOAA 2018), as well as behavioral disturbances such as disruption of rest and foraging behavior or changes in migration routes. Marbled murrelets may be affected by both in-air and underwater noise, with construction and operation noise associated with the Proposed Action potentially resulting in reduced foraging success (Smith et al. 2023).

All equipment used for constructing the necessary pilot study elements would be operated in and from the uplands in an industrial area. All in-water elements (intake and outfall pipes) would be pre-assembled upland and then installed on the barge at the pier. Underwater noise associated with installation would be minimal and conducted at low tide and would not require the use of large equipment. Therefore, underwater noise effects to listed aquatic species from the Proposed Action are expected to be discountable, and in-air noise impacts are expected to be localized and minimal in areas that do not contain suitable habitat for marbled murrelet nesting or foraging.

6.2 Water Quality

Water quality within Port Angeles south and west of a line bearing 152 degrees true from Buoy 2 at the tip of Ediz Hook is categorized as "excellent" for aquatic life use, recreational use, and harvest use (WAC 173-201A-612). The Proposed Action would not create water quality impacts associated with construction because in-water work would be minimal and related to mooring the barge and the installation of temporary intake and outfall pipes along the barge and existing infrastructure.

Water quality impacts are defined as short term (releases over limited hours) and long term (continuous repeated releases or releases over days). The operation of the mCDR facility will include variable treatment and discharge scenarios and will evaluate the impacts of potential short-term increases in turbidity, pH, and temperature and reduction in DO. A mixing zone study (Appendix A) was conducted to evaluate potential water quality impacts associated with operating Project Macoma. The analyses include hydrodynamic dilution modeling using Visual Plumes software and water quality/chemistry modeling using commercial OLI Systems software. Modeling analyses are supported by collected data, where available, and conservative assumptions. Ebb Carbon will validate model predictions from the mixing zone study using a dye test. This will include collection of site-specific current data. The combined results of the dilution and chemistry modeling indicate that, under routine operating conditions, Project Macoma will not exceed water quality criteria for turbidity, pH, temperature, or DO. Discharges that could occur under maintenance and scientific operating conditions also would not result in an exceedance of water quality criteria considering the limited duration of the discharge and Project Macoma, LLC's adherence to process controls described in the Ecological Safety Methodology (Appendix B).

6.2.1 Turbidity

The pilot project may increase turbidity after seawater treatment through the precipitation of elements associated with the treatment process. Elevated turbidity may affect marine organisms and aquatic wildlife during various life stages by reducing visibility and the ability to forage or avoid predators, altering movement patterns (due to avoidance of turbid waters) (DeYoung 2007), and reducing aquatic vegetation and habitat through loss of water clarity and light transmission. Although an aquatic vegetation survey has not been completed for the site, patchy (fringe) kelp has been mapped in the nearshore within the Action Area that may experience reduced growth and survival associated with elevated turbidity. Planktonic rockfish and sunflower sea star larvae may experience reduced growth and feeding rates when exposed to elevated turbidity; however, some turbidity may increase survival by reducing predation (Fiksen et al. 2002).

Turbidity is measured in nephelometric turbidity units (NTU). Per WAC 173-201A-210(1)(e), turbidity criteria for marine waters are based on deviations from ambient conditions: extraordinary and excellent quality is achieved with 5 NTU over background conditions when the background is 50 NTU or less, or a 10% increase in turbidity when the background turbidity is more than 50 NTU; and good or fair quality is achieved when turbidity is within 10 NTU of background conditions when background turbidity is 50 NTU or less, or a 20% increase in turbidity when the background turbidity is more than 50 NTU. Baseline monitoring conducted prior to pilot project operation would inform natural fluctuations in turbidity from which pilot project operation impacts could be measured.

The mixing zone study prepared for Project Macoma predicts that the dominant particulate that could precipitate during operations is calcite. Academic research around mCDR operations similar to Ebb Carbon's process indicates the potential for brucite and calcite formation above certain pH and saturation state thresholds (Ringham et al. [forthcoming]; Hartmann et al. [forthcoming]). Brucite formation in seawater following an alkalinity addition is primarily understood to readily dissolve under most mixing conditions. Site-specific data correlating calcite concentrations to turbidity values are not available; therefore, a conservative mixing equation was used to predict mixed turbidity following the completion of nearfield dilution. Assuming a worst-case dilution of 195:1 and an ambient turbidity of 2.0 NTU, a discharge turbidity of 100 NTU would increase ambient turbidity approximately 0.5 NTU within the nearfield. Similarly, a discharge turbidity of 500 NTU would increase ambient turbidity approximately 2.5 NTU within the nearfield. Both discharge turbidity values, which are considered cautiously high and unlikely for the pilot project, would meet applicable turbidity criteria.

An increase in turbidity above the Washington State water quality standards associated with pilot project operations would indicate that the mCDR system is not functioning efficiently and effectively. Turbidity, among other water quality parameters, would be continuously monitored with sensors mounted at various locations to document water quality conditions at various distances throughout the pilot project operation. If an increase in turbidity above the Washington State water quality standards attributable to the pilot project operations occurs, Project Macoma, LLC, would stop discharging alkaline-enhanced seawater within minutes of the exceedance and begin troubleshooting to determine the possible trigger and to correct the system to reduce turbidity consistent with the pilot project's Ecological Safety Methodology (Appendix B). Project Macoma, LLC, proposes to gather site-specific data to correlate precipitate concentrations to turbidity values and to follow process controls for pH to maintain turbidity values within applicable standards. Any exposure to elevated turbidity thus would be short-term and localized, resulting in insignificant impacts to ESA-listed aquatic species.

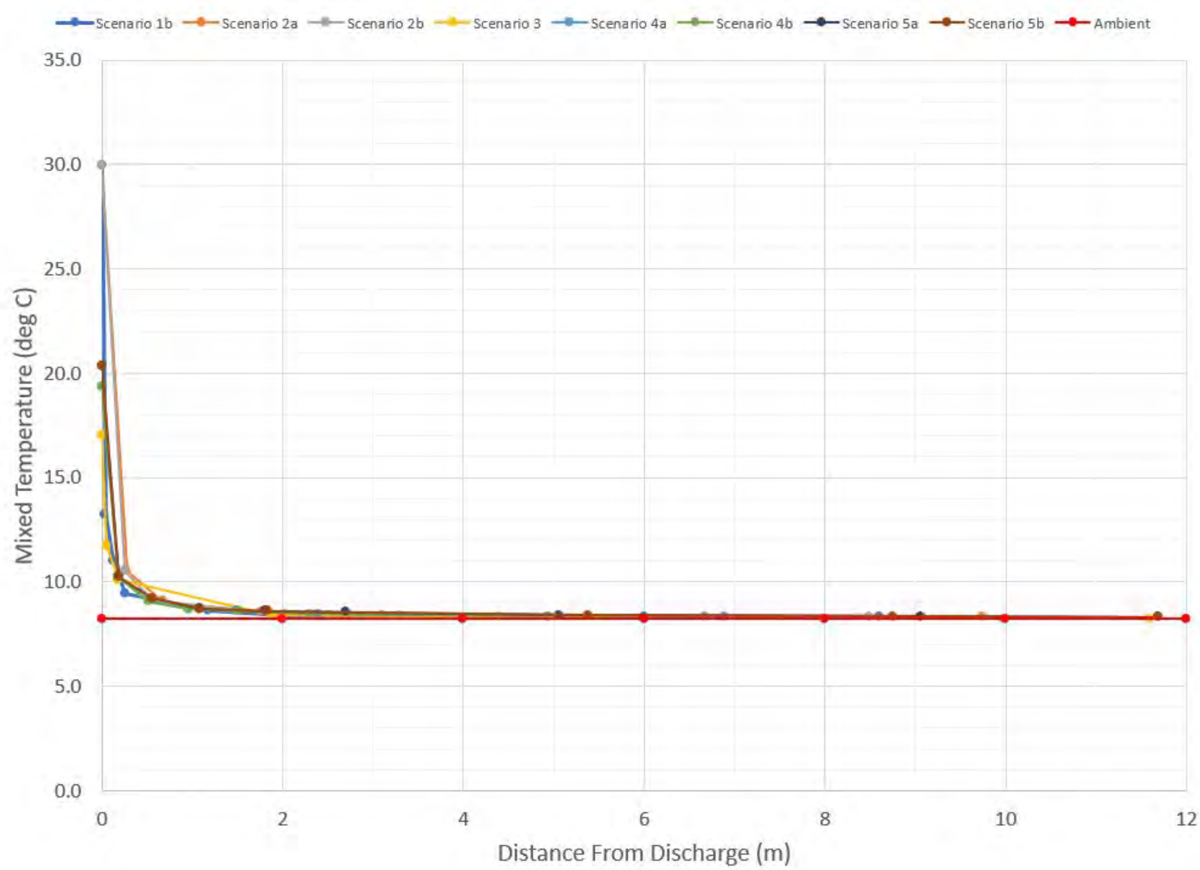
6.2.2 pH

Ocean acidification, which refers to a reduction in pH of the ocean over an extended period of time, is increasingly affecting marine life. Between 1950 and 2020, the global average pH of the world's oceans decreased from 8.15 to 8.05 (Terhaar et al. 2023). The purpose of Project Macoma is to increase the capacity of ocean CO_2 storage, increasing the pH of seawater and in turn reducing ocean acidification locally, and countering the anthropogenic-driven climate change impacts by accelerating the drawdown of additional CO_2 from the atmosphere.

Coastal ecosystems have particularly pronounced pH variability; the majority of 83 investigated coastal ecosystems displayed nonlinear trends, with seasonal and interannual variations exceeding 1 pH for some sites (Carstensen and Duarte 2019). In Port Angeles Harbor, pH is approximately 7.8, as described in Section 4.2.1, with a natural variation in nearby Sequim Bay between 7.6 and 8.1. Based on the proximity between harbors, it is likely that Port Angeles Harbor also experiences similar pH fluctuations.

Although Project Macoma is expected to have an overall beneficial impact on the environment and marine organisms during operations, changes in pH and higher pH can also impact aquatic species. The pH levels would be less differentiated from ambient with increasing distance from the discharge point (Figure 5). The range of pH levels released in the effluent would equilibrate into levels tolerable to aquatic life within less than 1 foot for acidic releases and less than 20 feet for alkaline releases. During the routine operations releases of 9.8 pH units, the pH level is modeled to increase to 10 pH units based on chemical reactions observed in laboratory conditions. This will be studied further during operations to evaluate how the discharge reacts in an open harbor environment.

Figure 5
pH Changes Modeled Over Distances From Outfall Pipe



Of the listed species addressed in this Biological Assessment, juvenile and adult salmonids (including bull trout), larval rockfish, and larval and adult sunflower sea stars could be affected by changes in pH that are likely to result from implementation of the Proposed Action. Impacts to juvenile and adult rockfish, humpback whales, and killer whales would be negligible due to the low likelihood of them entering Port Angeles Harbor, and marbled murrelets would similarly experience negligible impacts due to the limited and poor foraging habitat within the Action Area.

Per WAC 173-201-210(1)(f), pH within a range of 6.5 to 9.0 with a human-caused variation of less than 0.5 unit is fair quality; pH within a range of 7.0 to 8.5 with a human-caused variation of less than 0.5 unit is good to excellent quality; and a pH within the range of 7.0 to 8.5 with a human-caused variation of less than 0.2 unit is extraordinary quality. Because the pH of the discharge will be kept to below 13.5 under all operating conditions, pH would meet applicable water quality criteria and would be within 0.5 pH unit of ambient conditions (i.e., 7.8) within 12 meters. In the routine operating scenario (Scenario 5a), pH will be near ambient conditions within 2 meters.

Routine operations (with pH discharge of 9.8) will discharge alkaline-enhanced seawater to receiving waters for an anticipated 12 hours per day. Maintenance operations (Scenarios 2a, 2b, 3, 4a, and 4b) with pH discharges ranging from 2.3 to 8.1 will happen weekly for less than 8 hours. For scientific operations, Scenario 1b (with a pH discharge of 13.5) will be conducted a few times per month over a single tidal cycle, and Scenario 5b (with pH discharge of 12.1) will occur 1 to 2 times over the lifetime of the pilot project. Due to the frequency and duration of the pilot project's operations and the proportionally high dilution ratios (as described in Appendix A), the effects on water quality will be short term and would not result in a dead zone near the outfall.

Species have various preferences and tolerances to pH levels, with the optimal pH for most marine aquatic organisms between pH 6.5 to 8.5 (EPA 2023). Low, or acidic, pH can cause biological effects including damage to gill epithelium, increased mucus, decreased growth, reproductive failure, respiratory inhibition, ionoregulatory impacts, and mortality (EPA 2023). Most studies on the effects of pH on fish are from laboratory studies or closed systems, such as aquaculture facilities. These studies report that sudden changes in pH, even when within the range of tolerated pH levels, can be harmful, and pH higher than 9.5 can be lethal (Daye and Garside 1980; OpreX Analyzers 2020; Foldvik et al. 2022). Laboratory and field studies of ocean acidification impacts on salmon have documented olfactory disruptions and reduced avoidance responses when exposed to elevated CO_2 for 2 weeks; however, the responses returned to normal when in higher-pH waters for 6 hours (Williams et al. 2018).

Lowered pH significantly impacts survival, development, physiology, and growth in many benthic invertebrates (Dupont et al. 2013), such as the sunflower sea star. There are no specific studies of the impact of ocean acidification on sunflower sea stars, but it is considered a contributing factor that makes the sunflower sea star more vulnerable to wasting syndrome (NOAA Fisheries 2023). Planktonic larvae are particularly vulnerable to lower pH, which affects development and transition between life history stages, as well as increased mortality when exposed to more acidic pH (Dorey et al. 2022). Similar to salmon, low pH disrupts larvae chemosensation, altering behavioral choices and disrupting their response to potential predators (Pardo et al. 2021).

Short-term exposures of fish to high pH (approximately 9.5) are rarely lethal; however, prolonged exposure can damage outer surfaces such as gills, eyes, and skin (EPA 2023). Salmonids are mobile and are unlikely to spend extended periods within the nearfield zone. The intake and outfall pipes would be installed on an existing pier and barge. Studies on salmonid activity and presence in nearshore habitat show they avoid overwater structures in both fresh and marine waters

(Anchor QEA 2012), increasing the likelihood that their exposure would be short term as they migrate through the area.

Studies on other fish and invertebrate larvae were reviewed to determine potential effects to this life stage. Tests of increased pH on the success of the settlement stage of sea urchin (*Centrostephanus rodgersii*) larvae had little effect on morphological traits, but settlement was significantly reduced by 14% to 26% compared to ambient and low pH treatments (Mos et al. 2020). The design of the outfall ports is intended to direct the plume near the surface. The momentum of the discharge would push plankton away from the outfall and minimize potential exposure of planktonic rockfish larvae and sunflower sea star larvae. Although plankton have some mobility, they are generally subject to the movements of currents and tides; however, the nearest rockfish critical habitat is approximately 12 miles from the Action Area, and the current distribution of sunflower sea star within the Strait of Juan de Fuca has not been documented. The potential planktonic larval presence would represent a minute portion of the overall population.

The nearfield mixing zone, which extends 40 feet from the outfall ports, encompasses approximately 0.23 acre of nearshore habitat along an industrialized shoreline. Although juvenile salmonids migrate along the shoreline and would potentially be exposed to high/low pH within the mixing zone in the vicinity of the outfall during migration, the exposure would be short term and would not be likely to cause permanent physiological or behavioral changes. There are few suitable habitat features that would support rockfish or sunflower sea star presence. A sudden change of pH within the nearfield could have potentially harmful effects on fish and planktonic larvae; however, aquatic organism exposure within the boundary of the nearshore zone would be minimized due to tidal exchange within the mixing zone of a coastal environment.

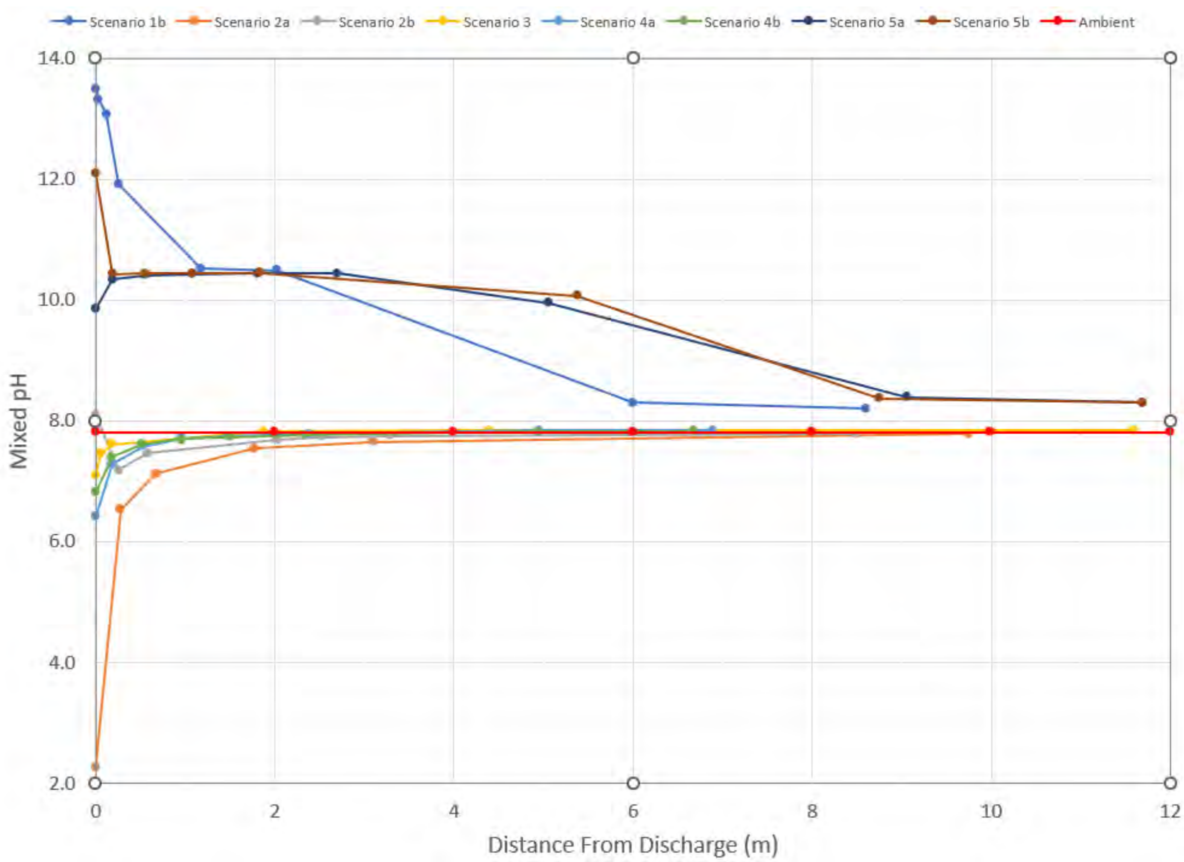
The larger far-field mixing zone, extending over 3.64 acres of nearshore and deeper water habitat within Port Angeles Harbor, represents a smaller change in pH (0.5 unit) that would have a minimal impact on aquatic organisms. Further deleterious impacts would be avoided by short residency in the affected area because the area lacks suitable rearing habitat and likely serves only as a migratory corridor for salmonids. Similarly, the nearshore habitat does not provide suitable settling habitat for rockfish larvae or sunflower sea star larvae. Exposures of these larvae would be limited to the few that may flow into the area.

The pH would be monitored at the site prior to and during release of each scenario. If an increase in pH in the near- and far-field mixing zones inconsistent with water quality criteria occurs, Project Macoma, LLC, would adjust its operations in accordance with the pilot project's Ecological Safety Methodology (Appendix B). Any exposure to pH outside of the acceptable range thus would be short term and localized, resulting in insignificant impacts to ESA-listed aquatic species. Per the monitoring and adaptive management strategies identified in the Ecological Safety Methodology, any observations of dead or dying aquatic organisms would trigger an immediate shutdown of operations (an action that can occur within seconds) to minimize the risk of lethal toxicity and prevent the creation of dead zones. Ebb Carbon is working with all regulatory agencies to meet requirements and requests for both information and measures to minimize potential harm to aquatic life.

6.2.3 Temperature

Ambient temperatures are approximately 10°C. Water temperatures at the time of discharge are expected to range from 17°C to 30°C. These temperatures are expected to reduce with distance away from the discharge locations. The incremental temperature increase within the nearfield mixing zone is predicted to be 0.1°C or less. For all operating scenarios, mixed temperature would be under 10°C within 0.5 meter (Figure 6).

Figure 6
Temperature Changes Modeled over Distances from Outfall Pipe



Per WAC 173-201A-210(1)(c), 1-day maximum aquatic temperatures classify as follows: 13°C is extraordinary quality, 16°C is excellent quality, 19°C is good quality, and 22°C is fair quality. The water temperatures above ambient conditions are expected to be categorized between fair and good quality per WAC 173-201A-210(1)(c).

The increase in temperature could affect salmonids, larval rockfish, and larval and adult sunflower sea star. As SRKW and humpback whales are not expected to be present in the area, they would not be directly affected by the increase in temperature. Similarly, because of the lack of suitable foraging habitat due to in-air and in-water disturbance associated with the industrialized shoreline and water uses, marbled murrelets are not expected to be present or affected by the increase in temperature.

There are extensive studies that document the impacts of increased freshwater temperatures on salmonids (Steel et al. 2014; Bowerman et al. 2021); however, few studies investigate the impact of sudden changes in marine temperatures on salmonids. Current research focuses on climate change-related increases in marine temperatures, documenting more dramatic impacts than changes in freshwater temperature increases to all species and populations (Crozier et al. 2021; Strøm et al. 2023). Increased ocean temperature will cause a reduction in salmonid productivity from a combination of bottom-up (a reduction in prey availability combined with an increase in metabolic needs) and top-down (increased predation and resource competition) trophic processes that jointly regulate growth and survival (Crozier et al. 2021; Strøm et al. 2023).

There are no specific studies of the impact of temperature on sunflower sea stars, but it is considered a contributing factor that makes the sunflower sea star more vulnerable to wasting syndrome (NOAA Fisheries 2023). Larval physiology is affected by an increase in temperature through impacts to metabolic rates, development, and settlement rate, reducing larval survival at higher temperatures (O'Connor et al. 2007; Marochi et al. 2022). Specifically in black rockfish (*Sebastes melanops*), dramatic increases in water temperature increase growth in the larval stage; however, without sufficient prey or with high predator abundance, extreme temperature fluctuations contribute to reduced survival (Fennie et al. 2023).

The increase in temperature above the Washington State water quality standards would extend up to 6 feet from the outfall pipe, affecting approximately 113.1 square feet of nearshore habitat before the temperature reduces to ambient levels below the state water quality standards. Salmonids potentially migrating through the area can avoid pockets of warmer water and thus are unlikely to sustain any short- or long-term physiological changes. Per WAC 173-201A-210(1)(c)(A), adult and juvenile salmonids are protected from acute lethality by discrete human actions in waters with a maximum daily temperature at or below 23°C. The lack of suitable rearing habitat in the pilot study area limits the potential for long-term exposure, and pilot study-related temperature increases are expected to remain below the 7-day maximum of 22°C. Similarly, sunflower sea stars can avoid the area of higher temperatures and are unlikely to be present due to the lack of suitable habitat features. Planktonic rockfish and sunflower sea star larvae may be affected by the increase in temperature; however, their exposure would be limited to one tidal cycle, and they would not be exposed for a prolonged period that could lead to adverse physiological effects.

Temperature would be monitored at the site. If an increase in temperature in the near- and far-field mixing zones inconsistent with water quality criteria occurs, Project Macoma, LLC, would adjust its operations in accordance with the pilot project's Ecological Safety Methodology (Appendix B). Any exposure to elevated temperature outside of the acceptable range thus would be short-term and localized, resulting in insignificant impacts to ESA-listed aquatic species.

6.2.4 Dissolved Oxygen

The proposed discharge is not anticipated to increase chemical and/or biological oxygen demand but may release discharge with DO less than ambient levels that may affect salmonids, rockfish, and sunflower sea star. Reductions in marine DO affects growth, alters behavior, increases mortality, and reduces reproduction of fish (Rose et al. 2019; Kim et al. 2023); increases sunflower sea star susceptibility to wasting disease (NMFS 2022b); and affects distribution and survival of larvae (Breitburg 1994).

The ambient DO levels (7.3 mg/L) are considered extraordinary per WAC 173-201A-210(1)(d). The minimum DO for all operating scenarios is estimated to be 7.0 mg/L based upon sample analyses of process streams at PNNL-Sequim. This concentration measured as a 1-day minimum is listed as extraordinary quality in WAC 173-201A-210(1)(d) above levels that would cause adverse impacts to listed aquatic species. Because the DO levels associated with discharge would remain in bounds of extraordinary quality levels in the marine environment, DO changes would have negligible impacts on salmonids, rockfish, and sunflower sea star. Moreover, DO would be monitored at the site. If a decrease in DO in the near- and far-field mixing zones inconsistent with water quality criteria occurs, Project Macoma, LLC, would adjust its operations in accordance with the pilot project's Ecological Safety Methodology (Appendix B). Any exposure to decreased DO outside of the acceptable range thus would be short-term and localized, resulting in insignificant impacts to ESA-listed aquatic species.

6.3 Entrainment

Intake pipes or other structures that draw in water for various reasons (e.g., irrigation, hydropower, and desalination) have the risk to entrain or impinge juvenile fish and larvae, causing injury and mortality (Barnthouse 2013; Zeug and Cavallo 2014; Mussen et al. 2015; Yao et al. 2023). A study that combined hydraulic modeling and hydroacoustic monitoring found that the risk of fish entrainment increased with increasing intake discharge amount and the number of intakes in the operation (Yao et al. 2023), and statistical modeling from another study identified a strong relationship between diversion rate and fish entrainment, recommending species-specific intake rates as a method for reducing entrainment of local species (Zeug and Cavallo 2014).

To minimize the risk of entrainment and impingement, the intake pipe would draw in seawater at a velocity of 3.48 feet per second for treatment under the Proposed Action, and the intake would be fitted with a screen. In the marine environment, juvenile salmonids should be large enough to avoid entrainment and impingement. Although the use of NMFS- and WDFW-recommended screening over the intake opening would not eliminate the risk of entrainment for rockfish and sunflower sea star larvae, the screens would minimize the risk of rockfish and sunflower sea star larval entrainment. All intake will go through multimedia filtration consisting of carbon filtration, sand filtration, and granular activated carbon filtration. All multimedia filters have to be backflushed daily, whereby trapped constituents like plankton will be returned to Port Angeles Harbor. Because of the lack of suitable rockfish and sunflower sea star habitat, combined with the distance to rockfish critical habitat, a large planktonic larval presence is not anticipated in the Action Area.

6.4 Invertebrate Prey Resources

The highly modified shoreline and industrial use of the upland area have reduced suitable habitat and recruitment for benthic invertebrates. The placement of the barge along the existing dock is within the existing mooring footprint in waters over 25 feet deep at MLLW, and there would be no construction or operation activities that affect shallow intertidal habitat. Therefore, impacts to benthic invertebrate prey for salmonids would be negligible.

6.5 Modification of Habitat

Project Macoma would result in habitat modifications that are expected to have short-term beneficial impacts (localized reduction in ocean acidification) as well as adverse impacts (barge presence shading aquatic vegetation) that extend for the duration of the pilot study (approximately 1.5 years). Eelgrass and other aquatic vegetation provide several important ecosystem functions, including foraging areas and shelter for young fish and invertebrates, food, and spawning surfaces. Aquatic vegetation also produces food and oxygen and improves water quality by filtering polluted runoff, absorbing excess nutrients, storing greenhouse gases, and protecting shoreline from erosion (NOAA 2014). Studies have also shown the value of eelgrass in providing nearshore foraging opportunities for juvenile salmonids and suggest that eelgrass habitat protection and restoration may provide critical support for growth, thereby easing the transition of juvenile salmonids from freshwater to the marine environment (Kennedy et al. 2018).

Eelgrass is documented around the tip, including the harbor-side edge, of Ediz Hook (Ecology 2024c). No documented eelgrass would be affected by overwater shading or short-term increases in turbidity; however, there may be fringe kelp present in the pilot study area. Furthermore, the placement of the barge is in deeper waters located at the edge of the photic zone.

7 Effects Determinations

For ESA-listed species and designated critical habitat, the range of conclusions that could result from the effects analysis for the effects determination include the following:

- **No effect** is the appropriate conclusion when the action agency determines that its Proposed Action will not affect listed species or critical habitat.
- **May affect, is not likely to adversely affect** is the appropriate conclusion when effects on listed species are expected to be discountable, insignificant, or completely beneficial. "Beneficial effects" are contemporaneous positive effects without any adverse effects to the species. "Insignificant effects" relate to the size of the impact and should never reach the scale where take occurs. "Discountable effects" are those extremely unlikely to occur. Based on best judgment, a person would not be able to meaningfully measure, detect, or evaluate insignificant effects and would not expect discountable effects to occur.
- **May affect, is likely to adversely affect** is the appropriate conclusion if any adverse effect to listed species may occur as a direct or indirect result of the Proposed Action or its interrelated or interdependent actions, and the effect is not discountable, insignificant, or beneficial (see definition of "may affect, is not likely to adversely affect").
- **Not likely to jeopardize** is the appropriate conclusion when effects on species proposed for listing are expected to be discountable, insignificant, or completely beneficial.

For ESA-listed species, a key factor in making an effects determination and distinguishing between a significant and insignificant effect is determining if the effect would be significant enough to cause a take. "Take," as defined by the ESA, includes such activities that harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or attempt to engage in any such conduct [ESA Section 3(19)]. "Harm" is further defined to include significant habitat modification or degradation that results in death or injury to ESA-listed species by significantly impairing behavioral patterns such as breeding, feeding, or sheltering; "harass" is further defined as actions that create the likelihood of injury to listed species to such an extent as to significantly disrupt normal behavior patterns that include, but are not limited to, breeding, feeding, or sheltering (50 CFR Section 17.3).

7.1 Southern Resident Killer Whale

Effects on SRKW were considered based on risk factors listed in the SRKW recovery plan (NMFS 2008). Potential pilot study effects include effects on SRKWs' food supply (primarily salmon) and water quality.

As discussed in Section 7.3, this Biological Assessment has determined that Project Macoma's potential effects to Puget Sound Chinook salmon, SRKW's favored and primary food source (78% of diet; NMFS 2008), are discountable, and it is reasonable to expect that Project Macoma would similarly not otherwise affect similar salmonid species using the area (coho and sockeye salmon, 2%

and 1% of typical SRKW diets, respectively; NMFS 2008). Some rockfish and herring could be present in the Action Area but compose such a small percentage of typical SRKW diets (NMFS 2008) that effects to SRKW via disturbance of these species can be considered insignificant.

There is a chance that other short-term water quality effects could occur related to pilot study operations; however, those impacts are localized and will achieve ambient conditions due to mixing with the surface water prior to reaching waters used by SRKW. These effects are therefore expected to be insignificant.

Based on the guidance and definitions provided within the context of ESA above and the previously discussed Project Macoma effects, the effect determination is that the pilot study **may affect, but is not likely to adversely affect SRKW.**

Project Macoma **may affect** SRKW because of the following:

- Pilot study operations will occur in marine aquatic habitat and have the potential to affect Chinook salmon, an important prey source.

Project Macoma **is not likely to adversely affect** SRKW because of the following:

- Water quality effects (turbidity, pH, temperature) are expected to be localized to within 207 feet of the discharge point and not where SRKW are expected to be. Water quality effects (turbidity, pH, temperature) are expected to reach ambient conditions within 40 feet of discharge. See Appendix B for monitoring and adaptive management strategies to further minimize potential impacts on listed species. As such, this potential impact to SRKW is expected to be insignificant.

The basis for this conclusion is that the likelihood of the potential effects can be discounted and/or their extent can be labeled as insignificant.

7.1.1 Critical Habitat Effects Determination

Critical habitat for SRKW is designated for areas containing the PBFs essential for the conservation of the species or that require special management considerations. PBFs include water quality, prey species, and passage conditions. Table 5 summarizes the PBFs applicable to this pilot study and the potential project effects on SRKW PBFs.

Table 5
Potential Project Effect on Southern Resident Killer Whale PBFs

SRKW PBFs Present	Effect from Proposed Action
PBF 1: Water quality to support growth and development	Increases in turbidity, pH, and temperature and a minor reduction in DO from extraordinary to excellent quality will have nearfield affects within 40 feet of the outfall ports. Water quality parameters are expected to achieve ambient conditions due to mixing 6 to 40 feet from the outfall pipe.
PBF 2: Prey species of sufficient quantity, quality, and availability to support individual growth, reproduction, and development, as well as overall population growth	Project Macoma may affect Chinook salmon, SRKW's favored food source. However, the pilot study is not anticipated to have significant water quality effects to Chinook salmon because they are able to avoid areas of changing water quality and, if present, would limit exposure by migrating through the area quickly.
PBF 3: Passage conditions to allow for migration, resting, and foraging	If present, SRKW passage within critical habitat is unlikely to be affected because whales are not anticipated to occur in the nearshore vicinity of the pilot study.

Based on the preceding analysis, the effect determination is that Project Macoma **will not adversely affect** SRKW designated critical habitat because of the following:

- Water quality impacts will achieve ambient conditions due to mixing prior to reaching waters used by SRKW.
- Project Macoma is expected to result in marine aquatic habitat benefits by decreasing seawater acidity during operations.

No significant long-term negative habitat effects to the previously mentioned PBFs will result from the pilot study.

7.2 Humpback Whale

Effects on humpback whales from Project Macoma were considered based on risk factors discussed in the humpback whale recovery plan (Humpback Whale Recovery Team 1991). Potential pilot study effects include those relating to water quality and prey species. Effects based on water quality were discussed in Section 7.1, related to SRKW, and would be expected to be similar for humpback whales. Also, because prey species of humpback whales are similar to the prey types for salmon and include juvenile salmon, effects to humpback prey species would be expected to be discountable or insignificant, aligned with prey effects to salmon (discussed in Section 7.3) and SRKW (which also prey on salmon).

Based on the guidance and definitions previously provided within the context of the ESA and the pilot study effects discussed in Section 6, the effect determination is that Project Macoma **may affect, but is not likely to adversely affect humpback whales** for the same reasons as listed for SRKW (Section 7.1). No critical habitat for the humpback whale is designated in the pilot study area.

7.3 Puget Sound Chinook Salmon

Based on the guidance and definitions previously provided within the context of the ESA and the pilot study effects discussed in Section 6, the effect determination is that Project Macoma **may affect, but is not likely to adversely affect Puget Sound Chinook salmon.**

Project Macoma **may affect** Chinook salmon because of the following:

- Chinook salmon could be affected by elevated turbidity, pH, and temperature and reduction in DO during the pilot project operation.
- Water quality changes may affect Chinook salmon prey, including Pacific herring.

Project Macoma is **not likely to adversely affect** Chinook salmon because of the following:

- There is no mapped eelgrass that would support Pacific herring (Chinook salmon prey) spawning in the Action Area, and there are no studies that confirm the presence of Pacific herring.
- Juvenile and adult Chinook salmon are able to avoid the area or move through quickly, so exposure to changes in water quality are temporary. Chinook salmon do not spawn in marine waters.
- Nearfield water quality impacts are limited to a 40-foot boundary around the outfall ports in disturbed habitat that provides minimal habitat for juvenile and adult salmonids. This area is a small portion of the overall area within Port Angeles Harbor available for juvenile and adult salmonids to migrate. See Appendix B for monitoring and adaptive management strategies to further minimize potential impacts on listed species.
- The use of an approved screen on the pipe intake will minimize potential entrainment of juvenile Chinook salmon.

The basis for this conclusion is that the potential effects are insignificant.

7.3.1 Critical Habitat Effects Determination

The designation of critical habitat is based on the life history and habitat needs of Puget Sound Chinook salmon and includes six PBFs necessary for their conservation in freshwater, estuarine, and nearshore marine habitats. In the Action Area PBFs 5 and 6 are present. Table 6 summarizes the PBFs applicable to Project Macoma and the potential project effects on Chinook salmon PBFs.

Table 6
Potential Project Effect on Chinook Salmon PBFs

Chinook Salmon PBFs Present	Effect from Proposed Action
PBF 5: Nearshore marine areas free of obstruction and excessive predation that meet the following criteria: • Water quality and quantity conditions and forage, including aquatic invertebrates and fishes, supporting growth and maturation • Natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, and side channels	Increases in turbidity, pH, and temperature and a minor reduction in DO will have nearfield affects within 40 feet of the outfall ports. Water quality parameters are expected to achieve ambient conditions 6 to 40 feet from the outfall and within 5 minutes under all scenarios due to mixing with the surface water. Project Macoma will use existing in-water infrastructure at the Port for the barge and placement of intake and outfall pipes and will not increase the amount of barriers to migration. The barge placement will be moored on the edge of the photic zone and will have minimal impacts on existing aquatic vegetation. Benthic invertebrates are not expected to experience adverse effects from operations because the discharge ports in the outfall are designed to maintain the effluent plume near the water surface, which promotes CO_2 absorption and maximizes dilution.
PBF 6: Offshore marine areas that meet the following criteria: • Water quality conditions and forage, including aquatic invertebrates and fishes, supporting growth and maturation	Increases in turbidity, pH, and temperature and a minor reduction in DO will have nearfield affects within 40 feet of the outfall ports. Water quality parameters are expected to achieve ambient conditions 6 to 40 feet from the outfall and within 5 minutes under all scenarios due to mixing with the surface water. Planktonic larvae (Chinook salmon prey) may be impacted by water quality changes; however, the area of impact is small compared to the available habitat and would represent a minute fraction of available prey.

Based on the preceding analysis, the effect determination is that Project Macoma **will not adversely affect** designated critical habitat because of the following:

- Water quality impacts will achieve ambient conditions due to mixing and will meet Washington water quality standards within 40 feet of the outfall ports. See Appendix B for monitoring and adaptive management strategies to further minimize potential impacts on listed species.
- Forage material, including benthic organisms, is not expected to experience adverse impacts associated with the change in water quality associated with the effluent releases.

No significant long-term negative habitat effects to the previously mentioned PBFs are expected to result from the pilot study.

7.4 Puget Sound Steelhead

Based on the guidance and definitions previously provided within the context of the ESA and the pilot study effects discussed in Section 6, the effect determination is that Project Macoma **may affect, but is not likely to adversely affect steelhead** and **will not adversely modify** designated critical habitat for the same reasons as listed for Chinook salmon (Section 7.3).

7.5 Hood Canal Chum Salmon

Based on the guidance and definitions previously provided within the context of the ESA and the pilot study effects discussed in Section 6, the effect determination is that Project Macoma **may affect, but is not likely to adversely affect Hood Canal chum salmon** and **will not adversely modify** designated critical habitat for the same reasons as listed for Chinook salmon (Section 7.3).

7.6 Bull Trout

Based on the guidance and definitions previously provided within the context of the ESA and the pilot study effects discussed in Section 6, the effect determination is that Project Macoma **may affect, but is not likely to adversely affect bull trout** and **will not adversely modify** designated critical habitat for the same reasons as listed for Chinook salmon (Section 7.3).

7.7 Bocaccio Rockfish

Based on the guidance and definitions previously provided within the context of ESA and the distribution information above, the effect determination is that Project Macoma **may affect, but is not likely to adversely affect the Georgia Basin DPS of bocaccio**.

Project Macoma **may affect** bocaccio because of the following:

- Bocaccio are present in various basins of Puget Sound. The level of use by adults or juveniles of these species in the Action Area is expected to be low year-round due to the lack of suitable rocky habitat in the Action Area.
- The possibility of some presence of larval, juvenile, or adult individuals from these species in the Action Area during operation cannot be discounted.

Project Macoma is **not likely to adversely affect** bocaccio because of the following:

- Due to depth, geographic, and habitat preferences, the likelihood that bocaccio would occur in the Action Area is low. Adult rockfish generally inhabit deep water associated with rock outcroppings or coarse substrate, which is not found in the Action Area. Although nearfield water quality impacts extending 40 feet from the outfall ports may occur, the discharge is expected to achieve ambient conditions due to mixing with surface water within 207 feet and 5 minutes before reaching habitat suitable for and more likely to be used by rockfish. See

Appendix B for monitoring and adaptive management strategies to further minimize potential impacts on listed species.

The basis for this conclusion is that the potential effects are insignificant. No critical habitat for bocaccio is designated in the pilot study area.

7.8 Yelloweye Rockfish

Based on the guidance and definitions previously provided within the context of the ESA and the pilot study effects discussed in Section 6, the effect determination is that Project Macoma **may affect, but is not likely to adversely affect yelloweye rockfish** for the same reasons as listed for bocaccio rockfish (Section 7.7). No critical habitat for yelloweye rockfish is designated in the pilot study area.

7.9 Sunflower Sea Star

The potential impacts to sunflower sea star from Project Macoma include increased turbidity, pH, and temperature and reduced DO associated with pilot project operations, all of which may increase the sunflower sea star susceptibility to wasting disease. The nearfield changes to water quality are minimized to a 40-foot radius around the outfall ports that dilutes to ambient conditions within 207 feet and 5 minutes under all scenarios. See Appendix B for monitoring and adaptive management strategies to further minimize potential impacts on listed species. Based on the limited number of sea stars that may be exposed to changes in water quality and the expected limited duration of that potential exposure, the Proposed Action is **not likely to jeopardize** the sunflower sea star. The basis for this conclusion is that the potential effects are insignificant, and the pilot study is not likely to jeopardize the continued existence of this proposed species.

Critical habitat has not been designated for the sunflower sea star.

7.10 Marbled Murrelet

Potential direct and indirect effects to marbled murrelets resulting from Project Macoma include temporary airborne noise effects attributable to construction. Elevated noise will be due to use of construction equipment in upland areas. These noise conditions have the potential to disturb marbled murrelets that may be present nearby.

The currently recognized noise-only harassment/injury threshold for marbled murrelet is based on a distance threshold that is based on noise measurements. Use of heavy construction equipment greater than 0.25-mile from a known occupied marbled murrelet nest tree or suitable nest tree during the nesting season of April 1 to September 21 is understood to have no effect on marbled murrelet (WSDOT 2021).

No critical habitat for the marbled murrelet is designated in the pilot study area. The project Action Area is approximately 3 miles away from the nearest marbled murrelet critical habitat, which is where nesting would be expected to occur. This determination is appropriate because marbled murrelets have not been observed in the Action Area, and the likelihood is very low that their presence would coincide with the small areas and periods when construction would occur.

Because construction will occur more 0.25 mile away from marbled murrelet critical habitat, Project Macoma will have **no effect** on marbled murrelet. The basis for this conclusion is that the likelihood of the effect causing take is very unlikely to occur.

8 Essential Fish Habitat Assessment

This document was also prepared as a resource document for concurrent essential fish habitat (EFH) consultation with NMFS for compliance with the Magnuson-Stevens Fishery Conservation and Management Act (Magnuson-Stevens Act) and the 1996 Sustainable Fisheries Act. EFH is defined by the Magnuson-Stevens Act in 50 CFR 600.905-930 as "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity." The objective of this assessment is to describe potential adverse effects to designated EFH for these federally managed fisheries species within the Action Area.

8.1 Essential Fish Habitat Presence in Action Area

The Action Area for Project Macoma includes the following mapped EFH (NOAA Fisheries 2024):

- **Pacific Coast Groundfish EFH**, which includes all waters and substrate within areas with a depth less than or equal to 3,500 meters (1,914 fathoms) shoreward to the MHHW level or the upriver extent of saltwater intrusion (defined as upstream and landward to where ocean-derived salts measure less than 0.5 part per thousand during the period of average annual low flow). Numerous benthic species are included under the groundfish EFH, such as rockfish, sole, flounder, cod, and others (PFMC 2023a).
- **Pacific Coast Salmon EFH**, which includes those waters and substrate necessary for salmon production needed to support a long-term sustainable salmon fishery and salmon contributions to a healthy ecosystem. In estuarine and marine areas, salmon EFH extends from the extreme high tide line in nearshore and tidal submerged environments within state territorial waters out to the full extent of the exclusive economic zone (200 nautical miles or 370.4 kilometers) offshore. Managed salmon stocks include Chinook, coho, and pink salmon (odd-numbered years only) and any salmon species listed under the ESA that is measurably impacted by Pacific Fishery Management Council fisheries (PFMC 2022).
- **Coast Pelagic Species EFH,** which includes the following (PFMC 2023b):
  - For finfish and market squid: All marine and estuarine waters from the shoreline offshore to the limits of the exclusive economic zone and above the thermocline where sea surface temperatures range between 10°C to 26°C
  - For krill: From the shoreline to the 1,000-fathom isobath and to a depth of 400 meters
- **Habitat Areas of Particular Concern (HAPC)** are types or areas of habitat within EFH that are identified based on one or more of the following considerations:
  - The importance of the ecological function provided by the habitat
  - The extent to which the habitat is sensitive to human-induced environmental degradation

- Whether, and to what extent, development activities are or will be stressing the habitat type
- The rarity of the habitat type

Six HAPCs have been identified for Pacific coast groundfish EFH (PFMC 2020), none of which are found in the Action Area.

8.2 Potential Effects of the Proposed Project

The assessment of potential impacts from Project Macoma to the species' EFH is based on the information in the documents listed in the reference section (NOAA 2022c; PFMC 2019, 2020, 2022). The specific elements of the pilot study that could impact groundfish, coastal pelagic species, and Pacific salmon EFH are changes in water quality parameters (turbidity, pH, temperature, DO).

Based on the preceding information, it is concluded that the effects of the Proposed Action **will adversely affect Pacific Coast Salmon EFH, Coastal Pelagic Species EFH, and Pacific Coast Groundfish EFH**. A "will adversely affect" determination is appropriate because the Proposed Action will have nearfield water quality impacts that reduce the quality of habitat within a 40-foot radius from the outfall ports.

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Appendix A
Port Angeles Mixing Analysis Technical Memorandum

2505 Fawcett Avenue
Tacoma, WA 98402

DRAFT Technical Memorandum

Prepared for: Ebb Carbon (EC)

Project Title: Ebb Carbon Preliminary Design

Project No.: 159812

Technical Memorandum

Subject: Port Angeles Mixing Analyses

Date: February 1, 2024

To: Todd Pelman (EC)

From: Matt DeBoer, Brown and Caldwell (BC)

Prepared by: ________________________________
Shubhashini Oza

Prepared by: ________________________________
Matt DeBoer

Reviewed by: ________________________________
Krystal Perez

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Section 1: Introduction

This Technical Memorandum (TM) evaluates potential water quality impacts of the Project Macoma, LLC marine carbon dioxide removal (mCDR) system proposed to be constructed and operated temporarily at Terminal 7 of the Port of Port Angeles in Port Angeles, Washington. Project Macoma, LLC is a wholly owned subsidiary of Ebb Carbon. Ebb Carbon has developed an mCDR technology to safely and permanently remove carbon dioxide (CO2) from the atmosphere while reducing seawater acidity locally. The pilot-scale system would use electrochemical processes to remove acid from the ambient seawater of Port Angeles Harbor. The produced alkaline seawater that remains would be returned to the ocean where it can absorb carbon dioxide (CO_2) from the atmosphere and store it as bicarbonate—a safe and naturally abundant form of carbon storage in the ocean that doesn't acidify seawater.

The proposed Project Macoma, LLC facility would include a barge-mounted seawater intake and discharge outfall connected to process equipment and storage at the shoreline. The preliminary site layout is as shown in Figure 1-1.

Figure 1-1. Preliminary Site Layout

Brown and Caldwell (BC) analyses include hydrodynamic dilution modeling using Visual Plumes software (https://www.epa.gov/ceam/visual-plumes) and water quality/chemistry modeling using commercial OLI Systems software (www.olisystems.com). Modeling analyses are supported by collected data, where available, and conservative assumptions. The combined results of the dilution and chemistry modeling support evaluation of compliance with applicable water quality standards.

Section 2: Previous Analyses

The proposed facility will be a pilot scale version of an mCDR system developed by Ebb Carbon that has been running since Summer 2023 at the Department of Energy's (DOE) Pacific Northwest National Laboratory (PNNL) in Sequim, Washington. The Sequim facility is currently discharging alkaline seawater produced by Ebb Carbon's system from their existing wastewater outfall. Ebb Carbon is currently sampling water quality at the intake and several locations within the pre-treatment and electrochemical processes. PNNL has requested 2024 funding for monitoring carbonate chemistry in Sequim Bay. Data collected would be used to support and/or confirm the analyses presented herein.

In addition to PNNL, Ebb Carbon has partnered with other research institutions including the National Oceanic and Atmospheric Administration (NOAA) and the University of Washington to evaluate how its system could work at-scale and potential uses for acidic and alkaline process streams. Numerous experiments are being performed in parallel to understand biological and toxicological impacts on target species and to model the alkaline plume in the farfield beyond the immediate nearfield evaluated herein. Project Macoma, LLC will continue to partner with local scientific and academic partners to validate the efficacy and safety of the system.

Section 3: Ambient Water Quality

Ambient water column density data was collected by Ecology in Port Angeles Harbor between 2001 and 2004 at Station PAH003. Ecology mapping shows Station PAH003 approximately 650 feet north of the proposed Project Macoma, LLC discharge location. During the data collection period, 29 water column profiles were collected, including density, salinity, and temperature, at 0.5-meter depth increments. Most profiles indicated some level of density stratification. For the dilution model analyses presented in Section 5, representative maximum (June 2004) and minimum (March 2004) stratification conditions were selected to evaluate potential critical dilution conditions. Table 3-1 summarizes water column density (kilograms per cubic meter (kg/m^3)) data through a depth of 10 meters for the selected representative stratification conditions.

Table 3-1. Water Column Density – Maximum and Minimum Stratification Conditions

	Maximum Stratification (June 2004)	Minimum Stratification (March 2004)
Depth (meters)	Density (sigma t, kg/m^3)	Density (sigma t, kg/m^3)
1.0		24.02
1.5	23.62	24.02
2.0	23.65	24.02
2.5	23.79	24.02
3.0	23.93	24.02
3.5	24.04	24.02
4.0	24.10	24.02
4.5	24.17	24.02
5.0	24.22	24.02
5.5	24.26	24.02
6.0	24.30	24.03
6.5	24.33	24.03

7.0	24.39	24.03
7.5	24.46	24.03
8.0	24.47	24.03
8.5	24.48	24.03
9.0	24.48	24.03
9.5	24.49	24.03
10.0	24.50	24.03

Additional ambient water quality samples were collected by Ebb Carbon at the proposed discharge location to characterize the specific chemical (cation and anion) distribution of the process intake water. Ambient samples were also collected to determine the presence of trace metals. Anion, cation, and trace metals data are provided in Attachment A.

Section 4: Effluent Flow and Water Quality

The proposed Project Macoma, LLC facility would produce three process streams, as shown schematically in Figure 4-1. Typically, the three process streams would be discharged as a combined flow through the outfall. However, Project Macoma, LLC may operate the pilot facility, for limited durations, discharging only one or two of the component flow streams. These atypical operational strategies would provide additional data to Project Macoma, LLC and further the understanding of potential impacts of the discharge to water chemistry/water quality. Each individual process stream is summarized as follows:

1. Outfall Stream 1 Alkaline Product – Saltwater solution with enhanced alkalinity produced via the bipolar electrodialysis (BPED) process.

2. Outfall Stream 2 Neutralized Acid – The acidic process stream produced via the BPED process is neutralized followed by post-neutralization settling and filtration. Neutralization may be achieved using mafic rocks (i.e., Olivine or basalt) or calcium carbonate ($CaCO_3$).

3. Outfall Stream 3 Pretreatment Reject – Saltwater reject from various filtration pretreatment steps. Most of this stream is comprised of nanofiltration (NF) membrane reject, but the process stream also includes flushes of other pretreatment processes as part of routine maintenance.

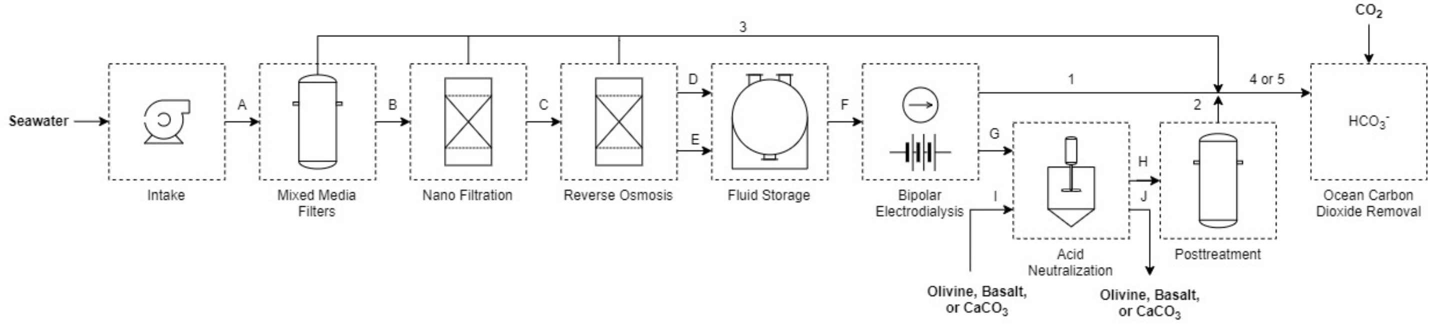

Figure 4-1. Process Flow Diagram

The dilution and water chemistry modeling discussed in this TM evaluated five discharge scenarios (and sub-scenarios) that reflect different combinations of process flow streams. Predicted effluent flow, pH, temperature, and density are summarized in Table 4-1 for the proposed scenarios. Table 4-1 also identifies anticipated frequency and duration for routine, maintenance, and scientific (targeted data collection) operating scenarios. These results and additional water chemistry data and assumptions specific to the water chemistry modeling are discussed in Section 6. Anion/cation and trace metals data for the effluent scenarios are provided in Attachment A. Trace metals data are based on samples collected in Port Angeles Harbor and from the Pretreatment Reject stream from the pilot at the PNNL facility.

Table 4-1. Effluent Flow and Water Quality Summary

Scenario	Frequency	Duration	Discharge Flow (L/hr.)	Temperature (deg C)	Density (kg/m³)	pH (s.u.)
Scientific Operations						
Scenario 1a – Alkaline Product Only (13.9 pH)	Not discharged – See Section 5.3		5,900	30.0	1,072	13.9
Scenario 1b – Alkaline Product Only (13.5 pH)	A few times per month	Single tidal cycle	5,900	30.0	1,028	13.5
Scenario 5b – All 3 Process Flows ($CaCO_3$ neutralization)[1]	1 or 2 times over project lifetime	Single tidal cycle	38,800	20.4	1,038	12.1
Maintenance Operations						
Scenario 2a – Neutralized Acid Only (with Olivine)	Weekly	< 8 hours	5,900	30.0	1,020	2.3
Scenario 2b – Neutralized Acid Only (with $CaCO_3$)	Weekly	< 8 hours	5,900	30.0	1,028	8.1
Scenario 3 – Pretreatment Reject Only	Weekly	< 8 hours	27,000	17.0	1,042	7.1
Scenario 4a – Neutralized Acid (with Olivine) + Pretreatment Reject	Weekly	< 8 hours	32,900	19.3	1,038	6.4
Scenario 4b – Neutralized Acid (with $CaCO_3$) + Pretreatment Reject	Weekly	< 8 hours	32,900	19.3	1,039	6.8
Routine Operations						
Scenario 5a – All 3 Process Flows (with Olivine neutralization)[1]	Daily	50% Operating Capacity	38,800	20.4	1,037	9.8

[1]Scenarios 5a and 5b assume contribution of the alkaline product at a pH of 13.9 (Scenario 1a).

L/hr. = liters per hour; deg C = degree Celsius; s.u = standard units

Section 5: Model Predicted Initial Dilution

BC evaluated predicted dilution using the outfall dilution model UM3, as included in the most recent release of the United States Environmental Protection Agency (USEPA)-supported Visual Plumes modeling package (https://www.epa.gov/ceam/visual-plumes). The model is applicable to submerged single and multi-port diffusers with both positively or negatively buoyant plumes. BC selected Visual Plumes for dilution modeling since it is well proven and widely used in Washington and is appropriate for the type of discharge and receiving water conditions. Model results provide predicted effluent plume dilution and effluent plume dimensions, including whether the plume rises to the surface or traps at neutral buoyancy within the water column.

5.1 General Plume Mixing Concepts

The mixing of effluent discharged from an outfall to receiving waters is typically described in two distinct phases: 1) rapid initial dilution in the nearfield, and 2) slower subsequent dilution in the farfield. Rapid initial dilution in the nearfield has two distinct physical components. The first component is turbulent jet mixing and entrainment resulting from the momentum of the discharge exiting the diffuser ports. The second component is turbulent mixing and entrainment resulting from the plume rising (or falling) in the water column due to the effluent buoyancy. When the jet momentum and buoyancy mixing forces dissipate, the slower process of subsequent dilution continues in the farfield. Mixing and dispersion in the farfield occurs along the boundaries of the plume, primarily in the horizontal plane laterally and longitudinally as the plume is carried by ambient currents. The dilution analysis in this section conservatively reports minimum initial dilution after completion of nearfield mixing.

5.2 Key Model Input Parameters

Input parameters to the UM3 model include the physical configuration of the proposed outfall discharge, and effluent and receiving water characteristics. Input parameters were selected consistent with the guidance provided in Ecology's Permit Writer's Manual (Ecology 2018).

5.2.1 Effluent Scenarios

BC performed dilution model analyses for the five scenarios and the discharge characteristics as shown in Table 4-1. The Project Macoma, LLC process is not influenced by seasonal conditions nor are flows anticipated to fluctuate significantly while process equipment is operational. The flows and effluent characteristics in Table 4-1 are conservatively representative of maximum daily and monthly conditions.

5.2.2 Ambient Conditions

Water column density, including representative maximum and minimum stratification conditions, are shown in Table 3-1. Model runs for each scenario were evaluated using both maximum and minimum stratification conditions.

Ambient current speed and direction data are not available for the proposed discharge location; however, current speed distribution was measured to support dilution analyses of the Port Angeles municipal wastewater treatment facility which discharges to Port Angeles Harbor near the Harbor mouth (Ecology 2016). Reported 10^{th} and 50^{th} percentile current speeds for Outfall 001 at the Harbor mouth are 5.6 centimeters per second (cm/s) and 15.5 cm/s, respectively. For the present analyses, current speeds are conservatively assumed to be lower within the Harbor (10^{th} percentile = 2 cm/s and 50^{th} percentile = 5 cm/s). Ambient current direction was conservatively assumed to be co-flowing with the effluent (cross current flows result in higher predicted dilution).

5.2.3 Discharge Parameters and Mixing Zone Dimensions

The proposed outfall discharge will be a barge-mounted multi-port diffuser located as shown in Figure 1-1. Water depth at the barge location, immediately adjacent to the pier, is approximately 25 feet mean lower low water (MLLW). Preliminary diffuser design parameters were selected to combine different momentum and negative buoyancy regimes to maintain the effluent plume near the water surface (promoting CO_2 absorption) and maximize dilution. Specifically, port depth and discharge angle, were used to generate initial plume trajectory upward through the water column before momentum dissipates and negative buoyancy draws the effluent plume downward prior to reaching equilibrium with ambient density. Input parameters used for model analyses include the following:

- Number of Ports = 25

- Port Diameter = 0.5 inches
- Port Spacing = 2 feet
- Port Discharge Angle = 45 degrees
- Port Depth = 2 meters

5.2.4 Mixing Zone Dimensions

Chronic water quality criteria apply at the boundary of an approved mixing zone. Applicable mixing zone dimensions are established in Washington Administrative Code (WAC) 173-201A-400. The analyses herein assume a designated chronic mixing zone of 207 feet in any horizontal direction of the diffuser ports and including the entire vertical water column. Acute water quality criteria apply within a smaller portion of the designated mixing zone, limited to 10 percent of the chronic mixing zone (20.7 feet), and including the entire vertical water column.

Figure 5-1 provides a plan view of the mixing zone with applicable dimensions scaled to the proposed outfall diffuser and in relationship to the existing pier and facility location.

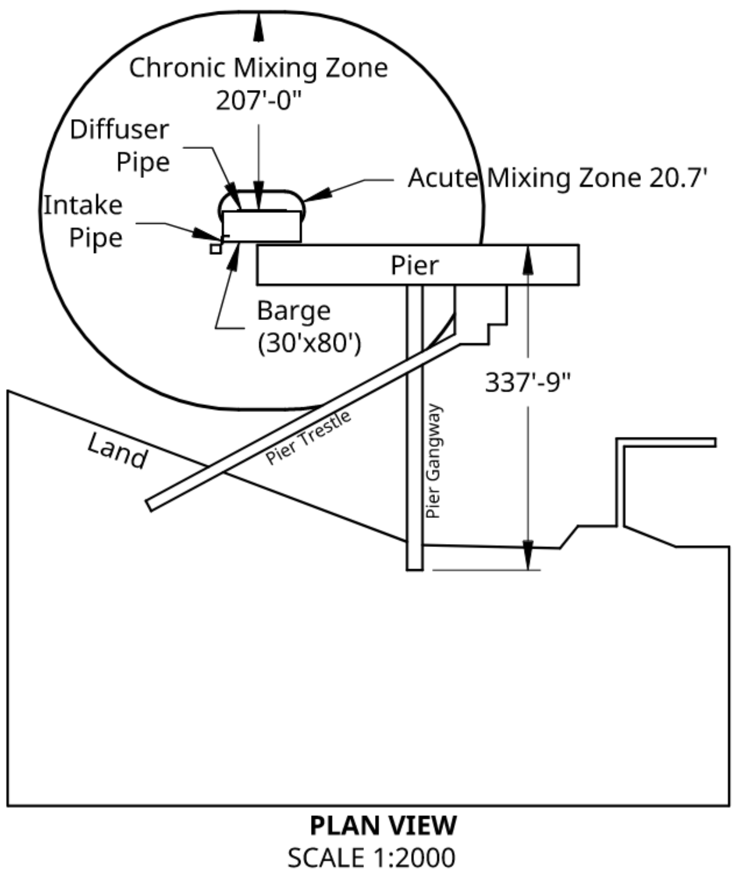

Figure 5-1. Mixing Zone Plan View

5.3 Model Results

Dilution model runs indicate that minimum dilutions occur for all scenarios using maximum stratification conditions. All model results presented herein conservatively assume maximum stratification conditions.

Under these stratification conditions, and based on the diffuser port design, the effluent plume trajectory is initially upward through the water column before momentum dissipates and negative buoyancy draws the effluent plume downward prior to reaching equilibrium with ambient density. For most scenarios, the effluent plume is generally bounded within the upper 3 meters of the water column, changing between minimum and maximum depths as the governing dynamics transition from momentum- to buoyancy-based driving forces. However, due to the high density of Scenario 1a, the effluent plume is predicted to quickly reach depths near or at the sea bottom at low current speeds (in the range of those assumed for acute conditions) prior to rising slightly and attaining neutral buoyancy. Because it is desirable for the effluent plume to be near the water surface to promote carbon dioxide absorption, Project Macoma, LLC would not operate at the identified Scenario 1a conditions. Project Macoma, LLC proposes to use 13.9 pH alkaline process stream waters when combined with other process streams (Scenarios 5a and 5b) but would control alkaline process stream pH at 13.5 or below if discharged alone (Scenario 1b).

For all proposed discharge scenarios, the effluent plume achieves neutral buoyancy with the ambient harbor waters within approximately 12 meters (40 feet) laterally from the multi-port diffuser at the assumed 50th percentile current speeds. The lateral distance to achieve neutral buoyancy decreases at lower current speeds. The UM3 model terminates at this neutral buoyancy (nearfield) location. Additional farfield dilution occurs within the chronic mixing zone, but at a much lower magnitude. The model results herein conservatively report minimum initial dilution at the acute mixing zone boundary and at completion of nearfield mixing. Minimum nearfield mixing is used for analyses at the chronic mixing zone in Section 7.

Table 5-1 summarizes dilution model results for the proposed effluent scenarios, including minimum acute and nearfield dilution, nearfield mixing distance, and range of effluent plume centerline depth. Minimum acute and nearfield dilutions assume 10th percentile and 50th percentile ambient current speeds, respectively. UM3 model input/output data are provided in Attachment B.

Table 5-1. Dilution Model Results Summary

Scenario	Minimum Acute Dilution[1]	Minimum Nearfield Dilution[2]	Nearfield Mixing Distance (m)	Effluent Plume Centerline Depth (m)
Scenario 1b – Alkaline Product Only (pH = 13.5)	240:1	580:1	8.6	1.8 – 2.8
Scenario 2a – Neutralized Acid Only (Olivine)	160:1	415:1	9.8	1.2 – 2.0
Scenario 2b – Neutralized Acid Only (CaCO3)	240:1	580:1	8.6	1.8 – 2.8
Scenario 3 – Pretreatment Reject Only	215:1	520:1	11.6	1.5 – 5.1
Scenario 4a – Neutralized Acid (Olivine) + Pretreatment Reject	160:1	415:1	10.9	1.3 – 4.1
Scenario 4b – Neutralized Acid (CaCO3) + Pretreatment Reject	170:1	430:1	11.1	1.3 – 4.4
Scenario 5a – All Process Flows (Olivine neutralization)	145:1	390:1	11.7	1.1 – 3.8
Scenario 5b – All Process Flows (CaCO3 neutralization)	150:1	395:1	11.4	1.2 – 4.0

1. Minimum acute dilution reported at the effluent plume centerline
2. Minimum nearfield dilution reported as the flux average dilution of the effluent plume.

Model predicted dilution ratios presented in Table 5-1 do not account for effluent reflux, the long-term buildup of effluent in tidally impacted areas. Reflux has not been quantified within Port Angeles Harbor. Ecology guidance in the Permit Writer's Manual conservatively recommends reducing measured/predicted dilution by a factor of two to account for unquantified tidal reflux. The water quality analyses in Section 7 address reflux and the impact on model predicted dilution using the conservative Ecology guidance.

Section 6: Water Chemistry Modeling

BC evaluated mixed water chemistry using the commercial water chemistry modeling software OLI Studio (www.olisystems.com). The software is an electrolytic water chemistry model based on first principles, that provides the predicted equilibrium composition of blended streams under variable conditions. Specific model outputs of interest were the mixed pH and the potential for solids formation within the mixed effluent plume.

6.1 Chemistry Model Input Data

Ebb Carbon provided the water quality data and ion concentrations for ambient Port Angeles Harbor waters and the three process streams generated onsite (see Section 4) to be used as modeling input. The chemistry model input data is tabulated in Attachment A, Table A-1 (ambient) and Table A-2 (process streams).

To conduct water chemistry modeling, the following assumptions were made:

- Ionic charge balance of the waste streams was performed by adjusting (adding or removing) chloride ions prior to the blending evaluation.
- The alkaline process stream in Scenarios 1a and 1b was assumed to be a pure stream of sodium hydroxide (NaOH) with a pH of 13.9 or 13.5, respectively. The solution strength of NaOH necessary to reach the target pH was generated in the model.

6.2 Water Chemistry Modeling

This section provides example dilution calculations used for the chemistry modeling and presents findings related to predicted pH trends and potential particulate formation.

6.2.1 Dilution Ratios

The process stream scenarios were modeled at various dilution ratios. The dilution ratio is calculated by dividing the total volume of process stream and harbor water with the incoming process stream volume. For example, a dilution ratio of 10 = (5,900 L/hr process stream+ 60,000 L/hr harbor)/5,900 L/hr process stream. The dilution ratios were simulated by using a fixed volume of process stream entering the Port Angeles Harbor waters and considering the addition of increasingly higher volumes of Port Angeles Harbor water. Examples of a few selected dilution ratio calculations are presented in Table 6-1. Model outputs, including mixed pH, ion concentrations and potential precipitation for each scenario, are summarized and presented in Attachment C.

Table 6-1. Blending Ratios Calculation Examples

Process stream volume L/hr	Port Angeles Harbor volume L/hr	Total volume L/hr	Dilution Ratio Ratio
5,900	761,100	767,000	130
5,900	1,410,100	1,416,000	240
5,900	1,646,100	1,652,000	580

6.2.2 pH Trends

For Scenarios 2 through 4, the process stream pH is near ambient pH (7.8) at the point of discharge and achieves a mixed pH equal to the ambient at dilutions less than 100:1. For Scenarios 1 and 5, the process stream pH is significantly higher than the ambient pH. For these scenarios, mixed pH initially decreases rapidly or after periods of steps where pH changes little with dilution (Figure 6-1). Mixed pH for Scenario 1b achieves a value within 0.5 standard units at a dilution of approximately 500:1. Mixed pH for Scenarios 5a and 5b achieve a value within 0.5 standard units at a dilution of approximately 200:1.

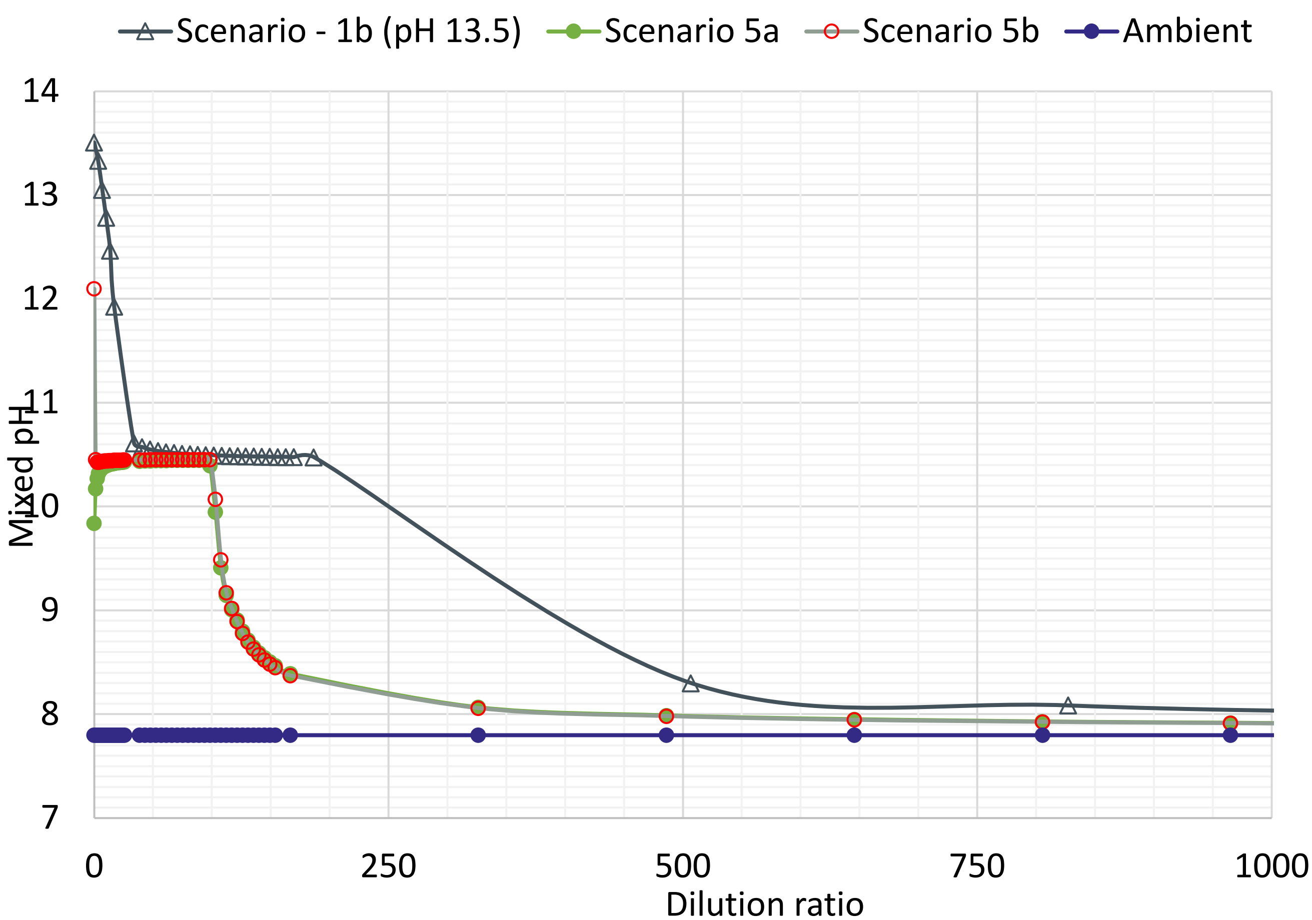

Figure 6-1. Chemistry Model Results – pH Trends

6.2.3 Potential for Particulate Formation

Solids precipitation in OLI Studio is calculated as a reaction taking place in a closed system and at equilibrium conditions (i.e., the reaction immediately going to completion). Therefore, the solids generation predicted in the model is conservative and may not occur in an open/dynamic system. Further, the model predicts all the solids that could potentially be formed based on thermodynamics of the system. However, all the solids predicted by the model may not actually form and depending on the system parameters such as pH, temperature, alkalinity, nucleation sites available, competing ions, etc., the dominant scaling compound would most likely be formed. The dominate particulate as predicted by the model is Calcite ($CaCO_3$). Particulate formation involving trace heavy metals is negligible even using the conservative model methodology.

Table 6-2 provides a conservative estimate of the solids that may be formed for the modeled scenarios at the minimum nearfield dilutions.

Table 6-2. Particulate Formation Summary			
Scenario	Chronic Dilution[1]	Mixed pH[2]	$CaCO_3$ (mg/L)
Scenario 1b – Alkaline Product Only (pH = 13.5)	290:1	9.2	225
Scenario 2a – Neutralized Acid Only (Olivine)	207:1	7.7	0
Scenario 2b – Neutralized Acid Only ($CaCO_3$)	290:1	7.8	4
Scenario 3 – Pretreatment Reject Only	260:1	7.8	1
Scenario 4a – Neutralized Acid (Olivine) + Pretreatment Reject	207:1	7.8	1
Scenario 4b – Neutralized Acid ($CaCO_3$) + Pretreatment Reject	215:1	7.8	2
Scenario 5a – All Process Flows (Olivine neutralization)	195:1	8.3	150
Scenario 5b – All Process Flows ($CaCO_3$ neutralization)	200:1	8.3	150

[1]Minimum nearfield dilution divided by two to account for tidal reflux.

[2]OLI model runs assume an ambient pH of 7.8.

Section 7: Water Quality Analyses

This section presents water quality analyses based on the supporting modeling discussed in Sections 5 and 6. Water quality analyses reference marine water quality standards identified in WAC 173-201A. Port Angeles Harbor is designated as 'Excellent Quality' for aquatic life uses. Input data for the analyses discussed in each section herein were selected consistent with the guidance provided in Ecology's Permit Writer's Manual.

7.1 Temperature

Compliance with temperature criteria was evaluated using Ecology's Reasonable Potential Analysis (RPA) methodology and supporting *PermitCalc* spreadsheets (see Attachment D). Input values for the calculations were conservatively selected as follows:

- Chronic Dilution Factor – The minimum nearfield dilution for all scenarios in Table 5-1 (390:1) was selected and divided by a factor of two to account for reflux. Temperature analyses assume a dilution factor of 195:1.
- Ambient Temperature – Ambient surface temperature data for the 29 sample dates at Ecology Station PAH003 were evaluated to develop 90th percentile values for May – September (11.4°C) and October – April (10.0°C).
- Effluent Temperature – The maximum effluent temperature for any discharge scenario is 30°C.

Using the above input values, there is no reasonable potential to exceed water quality criteria for temperature. The incremental temperature increase within the area of nearfield mixing is predicted to be 0.1°C or less. The values above combine worst case dilution and effluent conditions that are unlikely to occur simultaneously.

7.2 Dissolved Oxygen

The proposed discharge is not anticipated to contain chemical and/or biological oxygen demand. Therefore, compliance with dissolved oxygen (DO) criteria was evaluated using a volumetric mixing calculation. Input values for the calculation were conservatively selected as follows:

- Chronic Dilution Factor – The minimum nearfield dilution for all scenarios in Table 5-1 (390:1) was selected and divided by a factor of two to account for reflux. DO analyses assume a dilution factor of 195:1.
- Ambient DO – Ambient DO concentrations at the proposed discharge location are assumed to be 7.3 mg/L, based on the Ecology Fact Sheet analyses for the Port Angeles municipal wastewater treatment facility (Ecology 2016).
- Effluent DO – The minimum effluent DO for any discharge scenario is estimated to be 7.0 mg/L based upon sample analyses of process streams at the PNNL – Project Macoma, LLC facility.

The mixed DO concentration meets the applicable minimum water quality criteria (6.0 mg/L) and has a negligible DO concentration change with respect to background. The input values above combine worst case dilution and effluent conditions that are unlikely to occur simultaneously.

7.3 pH

The OLI model discussed in Section 6 was used to predict mixed pH at the predicted minimum nearfield dilution for each scenario. Table 7-1 summarizes the minimum dilution factor (accounting for reflux), effluent pH, mixed pH, and pH change for each scenario. As shown in Table 7-1, except for Scenario 1b, all discharge scenarios meet applicable pH water quality criteria with a pH between 7.0 and 8.5, and a 0.5 standard unit change (or less) with respect to background.

Table 7-1. pH Water Quality Analyses Summary

Scenario	Chronic Dilution[1]	Effluent pH	Mixed pH[2]	pH Change
Scenario 1b – Alkaline Product Only (pH = 13.5)	290:1	13.5	9.2	1.4
Scenario 2a – Neutralized Acid Only (Olivine)	207:1	2.3	7.7	-0.1
Scenario 2b – Neutralized Acid Only (CaCO3)	290:1	8.1	7.8	No Change
Scenario 3 – Pretreatment Reject Only	260:1	7.1	7.8	No Change
Scenario 4a – Neutralized Acid (Olivine) + Pretreatment Reject	207:1	6.4	7.8	No Change
Scenario 4b – Neutralized Acid (CaCO3) + Pretreatment Reject	215:1	6.8	7.8	No Change
Scenario 5a – All Process Flows (Olivine neutralization)	195:1	9.8	8.3	+0.5
Scenario 5b – All Process Flows (CaCO3 neutralization)	200:1	12.1	8.3	+0.5

1. Minimum nearfield dilution divided by two to account for tidal reflux.
2. OLI model runs assume an ambient pH of 7.8.

For Scenario 1b, the predicted mixed pH would be 8.2 at the nearfield mixing boundary assuming the predicted effluent dilution (580:1) without accounting for tidal reflux. Therefore, Scenario 1b would meet pH standards without reflux. As noted in Section 4, Scenario 1 discharge would be for a limited duration, likely on the order of several hours to collect pilot data. Under this scenario, tidal reflux is not significant and should not be applied to the dilution predictions. Should Project Macoma, LLC temporarily discharge the alkaline product only, process controls would be in place to limit effluent pH below 13.5.

7.4 Bacteria

The proposed discharge is not anticipated to contain pathogenic bacteria. Source water for the Project Macoma, LLC process is ambient Port Angeles Harbor water and the proposed process will not introduce human or animal wastes.

7.5 Turbidity

The potential for solids formation in the effluent plume of the proposed discharge is discussed in Section 6.2.3. The dominant particulate predicted by the model is calcite. For the typical discharge scenario, Scenario 5a , the chemistry model predicts worst case calcite concentrations near 150 mg/L in the nearfield. However, as discussed in Section 6, actual solids formation may be less in a dynamic condition versus model assumptions. Site-specific data that would correlate calcite concentrations to turbidity values are not available.

A basic mixing equation was used to predict mixed turbidity following the completion of nearfield dilution. While turbidity values may not respond linearly with dilution, and the relationship of potential calcite concentrations to turbidity is currently unknown, the analysis is informative for comparison to WAC criteria which allow for a 5 NTU increase above background when background is less than 50 NTU. Turbidity measured by Ecology in Sequim Bay (Station SEQ002) ranged between 0.5 and 2.0 NTU in 2014. Assuming a worst-case dilution of 195:1 and an ambient turbidity of 2.0 NTU, a discharge turbidity of 100 NTU would increase ambient turbidity approximately 0.5 NTU within the nearfield. Similarly, a discharge turbidity of 500 NTU would increase ambient turbidity approximately 2.5 NTU within the nearfield. Both discharge turbidity values would meet applicable turbidity criteria.

Project Macoma, LLC proposes targeted monitoring of turbidity within the nearfield, along with pH, during initial operation of the facility to assess the impact of the discharge on the receiving water. Modeled calcite concentrations are higher at high pH values. Therefore, effluent pH controls could potentially be used to maintain turbidity values within applicable standards, as needed. Because calcite formation decreases the efficiency of the proposed system with respect to CO_2 absorption, Project Macoma, LLC is actively developing methods to minimize the potential for calcite precipitation.

7.6 Toxics

Trace heavy metals data collected from Port Angeles Harbor and the PNNL pretreatment reject stream are either non-detect or below applicable acute water quality criteria at the point of discharge. The proposed process does not concentrate toxic parameters present in the ambient Port Angeles Harbor waters.

Section 8: Conclusions

The combined results of the dilution and chemistry modeling presented herein support the determination of compliance with applicable water quality standards based upon collected data, where available, and conservative assumptions. For most parameters, except for temperature, pH and turbidity, the proposed discharge would not be anticipated to be significantly changed from the process source waters (Port Angeles Harbor). Specific conclusions related to the mixing zone as well as the modeled mixing of temperature, pH and turbidity within the mixing zone are as follows:

- Dilution model analyses indicate nearfield dilution, the basis of the conservative water quality analyses herein, is complete within 12 meters (40 feet) laterally from the diffuser at the assumed 50th percentile current speeds. The entire WAC-defined mixing zone (207 feet) is not required to attain applicable water quality standards. Project Macoma, LLC proposes monitoring acute and chronic mixing zone dimensions at 15 and 150 feet, respectively, to account for potential nearfield conditions and process assumptions that differ from those modeled.
- Except for Scenario 1b, mixed pH for all scenarios will meet applicable standards within the mixing zone and accounting for reflux. For Scenario 1b, the predicted mixed pH would be 8.2 at the nearfield mixing boundary assuming the predicted effluent dilution (580:1) without accounting for tidal reflux. As noted in Section 4, Scenario 1 discharge would be for a limited duration, likely on the order of several hours to collect pilot data. Under this scenario, tidal reflux is not significant and should not be applied to the dilution predictions. Should Project Macoma, LLC temporarily discharge the alkaline product only, process controls would be in place to limit effluent pH at or below 13.5.
- Assuming a maximum effluent temperature (30°C) and worst-case modeled conditions, the incremental temperature increase within the area of nearfield mixing is predicted to be 0.1°C or less. Mixed temperature decreases rapidly from the point of discharge and approaches background temperature well within the proposed chronic mixing zone dimensions.
- For the typical discharge, Scenario 5a, the chemistry model predicts worst case calcite precipitate concentrations near 150 mg/L in the nearfield. Turbidity analyses are qualitative, because site-specific data that would correlate calcite concentrations to turbidity values are not currently available. However, using high effluent turbidity assumptions (up to 500 NTU) simple dilution calculations indicate that predicted mixed turbidity would be within the allowable range of increase above background (5 NTU). Project Macoma, LLC proposes targeted monitoring of turbidity within the nearfield, along with pH, during initial operation of the facility to assess the impact of the discharge on the receiving water.

References

Ecology 2016. National Pollutant Discharge Elimination System Permit No. WA0023973 and Fact Sheet. Ecology Water Quality Program. Effective February 2016.

Ecology 2018. Water Quality Program Permit Writer's Manual. Publication No. 92-109. Revised July 2018.

Frick, et al. 2003. Dilution Models for Effluent Discharges, 4th Edition (Visual Plumes). Environmental Research Division, USEPA. Athens, Georgia.

Attachment A: Ambient and Process Stream Water Quality Data

Table A-1. Port of port Angeles Water Quality Data		
Parameter	**Units**	**Value**
pH		7.78
Conductivity	µmhos/cm	47,000
Total sulfide	mg/L	< 0.05
Total dissolved solids	mg/L	34,000
Total suspended solids	mg/L	48.0
Bulk density	g/cm^3	1.002
Total organic carbon	mg/L as C	1.6
Total alkalinity	mg/L as $CaCO_3$	130
Carbonate alkalinity	mg/L as $CaCO_3$	< 2
Bicarbonate alkalinity	mg/L as $CaCO_3$	130
Bromide	mg/L	51.9
Chloride	mg/L	18,400
Fluoride	mg/L	< 5
Sulfate	mg/L	2,420
Calcium	mg/L	300
Potassium	mg/L	330
Magnesium	mg/L	460
Sodium	mg/L	8,570
Ammonia	mg/L as N	0.026
Nitrite	mg/L as N	< 0.5
Nitrate	mg/L as N	< 2.5
Orthophosphate	mg/L as P	0.04
Total phosphorus	mg/L as P	0.064
Aluminum	mg/L	< 0.30
Arsenic	mg/L	< 0.01
Barium	mg/L	< 0.01
Beryllium	mg/L	< 0.01
Cadmium	mg/L	< 0.005
Cobalt	mg/L	< 0.01
Chromium	mg/L	< 0.02
Copper	mg/L	< 0.01
Iron	mg/L	< 0.03

Table A-1. Port of port Angeles Water Quality Data		
Parameter	Units	Value
Mercury	mg/L	< 0.0001
Manganese	mg/L	< 0.01
Nickel	mg/L	< 0.01
Lead	mg/L	< 0.02
Antimony	mg/L	< 0.02
Silica	mg/L as SiO_2	1.40

Table A-2 Water Quality (Nominal) of various waste streams					
Parameter	Units	Alkaline Product	Acid with Olivine	Acid with Limestone	Pretreat Reject
Flow	L/hr	5,900	5,900	5,900	27,000
pH		13.93	2.26	8.10	8.00
Temperature	°C	30.0	30.0	30.0	17.0
Sodium	mg/L	--	--	--	12,500
Magnesium	mg/L	ND	7,379	198	4,631
Calcium	mg/L	ND	137.6	13,954	1,350
Iron	mg/L	ND	2.43	ND	ND
Nickel	mg/L	ND	18.13	0.001	ND
Cobalt	mg/L	ND	0.853	0.0003	ND
Silica	mg/L	ND	114.8	ND	ND
Aluminum	mg/L	ND	1.13	ND	ND
Phosphorus	mg/L	ND	0.133	ND	ND
Titanium	mg/L	ND	0.061	ND	ND
Chromium	mg/L	ND	0.051	ND	ND
Arsenic	mg/L	ND	ND	0.05	ND
Cadmium	mg/L	ND	ND	0.0002	ND
Mercury	mg/L	ND	ND	0.002	ND
Molybdenum	mg/L	ND	ND	0.0001	ND
Lead	mg/L	ND	ND	0.0025	ND
Selenium	mg/L	ND	ND	0.019	ND
Zinc	mg/L	ND	ND	0.0003	ND
Chloride	mg/L	--	22,055	26,300	27,203
Carbonate	mg/L	--	--	--	18.0
Bicarbonate	mg/L	--	--	172.26	216
Bromide	mg/L	--	--	--	53.0
Fluoride	mg/L	--	--	--	ND

Table A-2 Water Quality (Nominal) of various waste streams					
Parameter	Units	Alkaline Product	Acid with Olivine	Acid with Limestone	Pretreat Reject
Sulfate	mg/L	--	--	--	4,922
Carbon-dioxide	mg/L	--	--	0.42	--
CaHCO3+1	mg/L	--	--	92.8	--
Total dissolved solids	mg/L	--	30,629	41,033	50,893

Attachment B: Dilution Model Input/Output

Scenario 1b – Alkaline Product Only (pH=13.5)

Acute Conditions

Ambient Table:

Depth	Amb-cur	Amb-dir	Amb-den	Amb-tem	Amb-pol	Decay	Far-spd	Far-dir	Disprsn	Density
m	m/s	deg	psu	C	kg/kg	s-1	m/s	deg	m0.67/s2	sigma-T
0.0	0.020	90.00	30.95	11.20	0.0	0.0	-	-	0.0003	23.62000
3.000	0.020	90.00	31.17	10.35	0.0	0.0	-	-	0.0003	23.93000
6.000	0.020	90.00	31.16	9.690	0.0	0.0	-	-	0.0003	24.03000
9.000	0.020	90.00	31.68	9.440	0.0	0.0	-	-	0.0003	24.48000
12.00	0.020	90.00	31.76	9.340	0.0	0.0	-	-	0.0003	24.56000
15.00	0.020	90.00	31.87	9.220	0.0	0.0	-	-	0.0003	24.66000

Diffuser table:

P-dia	Ver angl	H-Angle	SourceX	SourceY	Ports	Spacing	MZ-dis	Isoplth	P-depth	Ttl-flo	Eff-den	Temp	Polutnt
(in)	(deg)	(deg)	(m)	(m)	()	(ft)	(ft)	(concent)	(m)	(m3/s)	(kg/m3)	(C)	(%)
0.5000	45.000	90.000	0.0	0.0	25.000	2.0000	200.00	0.0	2.0000	1.64E-3	1028.0	30.000	100.00

Simulation:

Froude No: -23.03; Strat No:-3.16E-4; Spcg No: 48.00; k: 25.89; eff den (sigmaT) 28.00000; eff vel 0.518(r

Step	Depth	Amb-cur	P-dia	Polutnt	Dilutn	CL-diln	x-posn	y-posn	Time	Iso dia	
	(m)	(cm/s)	(in)	(%)	()	()	(m)	(m)	(s)	(m)	
0	2.000	2.000	0.500	100.0	1.000	1.000	0.0	0.0	0.0	0.0127;	
50	1.962	2.000	1.346	36.10	2.770	1.385	0.000	0.0402	0.198	0.03418;	
100	1.885	2.000	3.389	13.94	7.173	3.586	0.000	0.144	1.354	0.08608;	
150	1.834	2.000	5.491	8.347	11.98	5.990	0.000	0.260	3.403	0.1395;	
200	1.815	2.000	6.968	6.329	15.80	7.901	0.000	0.372	5.917	0.1770;	
209	1.815	2.000	7.180	6.089	16.42	8.212	0.000	0.393	6.421	0.1824;	local maximum rise c
250	1.826	2.000	8.062	5.142	19.45	9.725	0.000	0.495	8.995	0.2048;	
300	1.888	2.000	10.09	3.535	28.29	14.15	0.000	0.667	13.92	0.2563;	
350	2.120	2.000	17.55	1.403	71.30	35.65	0.000	1.041	27.44	0.4458;	
376	2.286	2.000	24.01	0.838	119.3	59.66	0.000	1.304	38.51	0.6100;	merging;
400	2.498	2.000	32.43	0.528	189.3	103.8	0.000	1.702	56.41	0.8237;	
402	2.514	2.000	33.11	0.513	194.8	107.6	0.000	1.738	58.03	0.8409;	trap level;
450	2.722	2.000	43.05	0.368	271.7	169.5	0.000	2.371	87.55	1.0934;	
488	2.759	2.000	45.50	0.346	289.4	186.4	0.000	2.776	106.6	1.1557;	local maximum rise c
500	2.755	2.000	45.59	0.344	290.6	187.5	0.000	2.903	112.6	1.1580;	
549	2.505	2.000	51.26	0.278	359.4	239.6	0.000	3.998	164.5	1.3021;	trap level;

Horiz plane projections in effluent direction: radius(m): 0.0; CL(m): 3.9984

Chronic Conditions

Ambient Table:

Depth	Amb-cur	Amb-dir	Amb-den	Amb-tem	Amb-pol	Decay	Far-spd	Far-dir	Disprsn	Density
m	m/s	deg	psu	C	kg/kg	s-1	m/s	deg	m0.67/s2	sigma-T
0.0	0.050	90.00	30.95	11.20	0.0	0.0	-	-	0.0003	23.62000
3.000	0.050	90.00	31.17	10.35	0.0	0.0	-	-	0.0003	23.93000
6.000	0.050	90.00	31.16	9.690	0.0	0.0	-	-	0.0003	24.03000
9.000	0.050	90.00	31.68	9.440	0.0	0.0	-	-	0.0003	24.48000
12.00	0.050	90.00	31.76	9.340	0.0	0.0	-	-	0.0003	24.56000
15.00	0.050	90.00	31.87	9.220	0.0	0.0	-	-	0.0003	24.66000

Diffuser table:

P-dia	Ver angl	H-Angle	SourceX	SourceY	Ports	Spacing	MZ-dis	Isoplth	P-depth	Ttl-flo	Eff-den	Temp	Polutnt
(in)	(deg)	(deg)	(m)	(m)	()	(ft)	(ft)	(concent)	(m)	(m3/s)	(kg/m3)	(C)	(%)
0.5000	45.000	90.000	0.0	0.0	25.000	2.0000	200.00	0.0	2.0000	1.64E-3	1028.0	30.000	100.00

Simulation:

Froude No: -23.03; Strat No:-3.16E-4; Spcg No: 48.00; k: 10.36; eff den (sigmaT) 28.00000; eff vel 0.518(r

Step	Depth	Amb-cur	P-dia	Polutnt	Dilutn	CL-diln	x-posn	y-posn	Time	Iso dia	
	(m)	(cm/s)	(in)	(%)	()	()	(m)	(m)	(s)	(m)	
0	2.000	5.000	0.500	100.0	1.000	1.000	0.0	0.0	0.0	0.0127;	
50	1.965	5.000	1.296	36.17	2.765	1.382	0.000	0.039	0.177	0.03292;	
100	1.916	5.000	2.974	13.91	7.191	3.596	0.000	0.119	0.867	0.07555;	
150	1.872	5.000	5.259	6.473	15.45	7.725	0.000	0.258	2.639	0.1336;	
191	1.852	5.000	7.016	4.155	24.07	12.03	0.000	0.505	6.406	0.1782;	local maximum rise c
200	1.854	5.000	7.297	3.890	25.71	12.85	0.000	0.581	7.605	0.1854;	
250	1.943	5.000	11.87	1.631	61.32	30.66	0.000	1.167	17.65	0.3015;	
300	2.105	5.000	20.13	0.606	165.1	82.53	0.000	2.029	33.90	0.5113;	
318	2.184	5.000	24.24	0.424	235.7	117.9	0.000	2.530	43.62	0.6157;	merging;
334	2.282	5.000	28.79	0.309	323.6	170.3	0.000	3.277	58.22	0.7313;	trap level;
350	2.407	5.000	34.20	0.230	435.4	243.5	0.000	4.726	86.73	0.8686;	
361	2.433	5.000	35.67	0.215	466.9	265.2	0.000	5.787	107.7	0.9061;	local maximum rise c
382	2.272	5.000	40.65	0.172	581.6	351.8	0.000	8.609	163.4	1.0325;	trap level;

Horiz plane projections in effluent direction: radius(m): 0.0; CL(m): 8.6092

Scenario 2a – Neutralized Acid Only (Olivine)

Acute Conditions

```
Ambient Table:
     Depth   Amb-cur   Amb-dir   Amb-den   Amb-tem   Amb-pol     Decay   Far-spd   Far-dir   Disprsn   Density
         m       m/s       deg       psu         C     kg/kg       s-1       m/s       deg   m0.67/s2  sigma-T
       0.0     0.020     90.00     30.95     11.20       0.0       0.0         -         -    0.0003  23.62000
     3.000     0.020     90.00     31.17     10.35       0.0       0.0         -         -    0.0003  23.93000
     6.000     0.020     90.00     31.16     9.690       0.0       0.0         -         -    0.0003  24.03000
     9.000     0.020     90.00     31.68     9.440       0.0       0.0         -         -    0.0003  24.48000
     12.00     0.020     90.00     31.76     9.340       0.0       0.0         -         -    0.0003  24.56000
     15.00     0.020     90.00     31.87     9.220       0.0       0.0         -         -    0.0003  24.66000

Diffuser table:
   P-diaVer angl H-Angle SourceX SourceY   Ports Spacing  MZ-dis Isoplth P-depth Ttl-flo Eff-den    Temp Polutnt
    (in)   (deg)   (deg)     (m)     (m)      ()    (ft)    (ft)(concent)    (m)  (m3/s) (kg/m3)     (C)     (%)
  0.5000  45.000  90.000     0.0     0.0  25.000  2.0000  200.00      0.0  2.0000 1.64E-3  1020.0  30.000  100.00

Simulation:
Froude No:     23.95; Strat No: 3.44E-4; Spcg No:    48.00; k:    25.89; eff den (sigmaT)  20.00000; eff vel     0.518(r
        Depth  Amb-cur    P-dia  Polutnt   Dilutn  CL-diln   x-posn   y-posn     Time   Iso dia
Step      (m)   (cm/s)     (in)      (%)       ()       ()      (m)      (m)      (s)      (m)
   0    2.000    2.000    0.500    100.0    1.000    1.000      0.0      0.0      0.0   0.0127;
  50    1.962    2.000    1.331    36.27    2.757    1.379    0.000   0.0395    0.194   0.0338;
 100    1.875    2.000    3.328    13.48    7.416    3.708    0.000    0.141    1.332  0.08453;
 150    1.731    2.000    7.585    5.011    19.96    9.979    0.000    0.342    5.642   0.1927;
 200    1.537    2.000    15.40    1.862    53.72    26.86    0.000    0.696    17.42   0.3913;
 233    1.379    2.000    23.34    0.968    103.3    51.63    0.000    1.109    34.30   0.5927; trap level;
 236    1.364    2.000    24.17    0.914    109.4    54.68    0.000    1.160    36.47   0.6139; merging;
 250    1.298    2.000    27.64    0.740    135.2    70.25    0.000    1.419    47.83   0.7022;
 294    1.214    2.000    32.38    0.584    171.1    93.74    0.000    2.203    83.20   0.8224; local maximum rise c
 300    1.216    2.000    32.50    0.581    172.2    94.48    0.000    2.307    87.90   0.8255;
 334    1.371    2.000    37.57    0.453    220.8    128.6    0.000    3.425    139.2   0.9542; trap level;
 350    1.445    2.000    41.02    0.401    249.1    151.4    0.000    3.981    165.1   1.0420;
 367    1.459    2.000    41.99    0.389    256.8    158.0    0.000    4.349    182.4   1.0665; local maximum rise c
Horiz plane projections in effluent direction: radius(m):      0.0; CL(m):    4.3489
Lmz(m):    4.3489
```

Chronic Conditions

```
Ambient Table:
     Depth   Amb-cur   Amb-dir   Amb-den   Amb-tem   Amb-pol     Decay   Far-spd   Far-dir   Disprsn   Density
         m       m/s       deg       psu         C     kg/kg       s-1       m/s       deg   m0.67/s2  sigma-T
       0.0     0.050     90.00     30.95     11.20       0.0       0.0         -         -    0.0003  23.62000
     3.000     0.050     90.00     31.17     10.35       0.0       0.0         -         -    0.0003  23.93000
     6.000     0.050     90.00     31.16     9.690       0.0       0.0         -         -    0.0003  24.03000
     9.000     0.050     90.00     31.68     9.440       0.0       0.0         -         -    0.0003  24.48000
     12.00     0.050     90.00     31.76     9.340       0.0       0.0         -         -    0.0003  24.56000
     15.00     0.050     90.00     31.87     9.220       0.0       0.0         -         -    0.0003  24.66000

Diffuser table:
   P-diaVer angl H-Angle SourceX SourceY   Ports Spacing  MZ-dis Isoplth P-depth Ttl-flo Eff-den    Temp Polutnt
    (in)   (deg)   (deg)     (m)     (m)      ()    (ft)    (ft)(concent)    (m)  (m3/s) (kg/m3)     (C)     (%)
  0.5000  45.000  90.000     0.0     0.0  25.000  2.0000  200.00      0.0  2.0000 1.64E-3  1020.0  30.000  100.00

Simulation:
Froude No:     23.95; Strat No: 3.44E-4; Spcg No:    48.00; k:    10.36; eff den (sigmaT)  20.00000; eff vel     0.518(r
        Depth  Amb-cur    P-dia  Polutnt   Dilutn  CL-diln   x-posn   y-posn     Time   Iso dia
Step      (m)   (cm/s)     (in)      (%)       ()       ()      (m)      (m)      (s)      (m)
   0    2.000    5.000    0.500    100.0    1.000    1.000      0.0      0.0      0.0   0.0127;
  50    1.965    5.000    1.284    36.34    2.752    1.376    0.000   0.0384    0.174  0.03262;
 100    1.912    5.000    2.986    13.51    7.402    3.701    0.000    0.118    0.864  0.07585;
 150    1.844    5.000    6.084    5.020    19.92    9.960    0.000    0.278    3.012   0.1545;
 200    1.752    5.000    11.04    1.865    53.61    26.81    0.000    0.670    9.657   0.2804;
 250    1.608    5.000    18.87    0.693    144.3    72.15    0.000    1.769    30.25   0.4792;
 255    1.590    5.000    19.87    0.628    159.3    79.66    0.000    1.965    34.01   0.5047; trap level;
 274    1.515    5.000    24.17    0.431    232.1    116.0    0.000    3.089    55.79   0.6138; merging;
 285    1.484    5.000    26.45    0.364    274.6    140.9    0.000    4.568    84.69   0.6717; local maximum rise c
 300    1.571    5.000    29.75    0.293    341.2    181.5    0.000    7.071    133.7   0.7557;
 301    1.578    5.000    30.08    0.287 [illegible]  185.8    0.000    7.239    137.0   0.7641; trap level;
 313    1.638    5.000    33.31    0.241    414.7    229.6    0.000    9.752    186.5   0.8460; local maximum rise c
Horiz plane projections in effluent direction: radius(m):      0.0; CL(m):    9.7519
Lmz(m):    9.7519
```

Scenario 2b – Neutralized Acid Only (CaCO3)

Acute Conditions

```
Ambient Table:
     Depth   Amb-cur   Amb-dir   Amb-den   Amb-tem   Amb-pol     Decay   Far-spd   Far-dir   Disprsn   Density
         m       m/s       deg       psu         C     kg/kg       s-1       m/s       deg  m0.67/s2   sigma-T
       0.0     0.020     90.00     30.95     11.20       0.0       0.0         -         -    0.0003  23.62000
     3.000     0.020     90.00     31.17     10.35       0.0       0.0         -         -    0.0003  23.93000
     6.000     0.020     90.00     31.16     9.690       0.0       0.0         -         -    0.0003  24.03000
     9.000     0.020     90.00     31.68     9.440       0.0       0.0         -         -    0.0003  24.48000
     12.00     0.020     90.00     31.76     9.340       0.0       0.0         -         -    0.0003  24.56000
     15.00     0.020     90.00     31.87     9.220       0.0       0.0         -         -    0.0003  24.66000

Diffuser table:
   P-diaVer angl H-Angle SourceX SourceY   Ports Spacing  MZ-dis Isoplth P-depth Ttl-flo Eff-den    Temp Polutnt
    (in)   (deg)   (deg)     (m)     (m)     ()     (ft)    (ft)(concent)     (m)  (m3/s) (kg/m3)     (C)     (%)
  0.5000  45.000  90.000     0.0     0.0  25.000  2.0000  200.00     0.0  2.0000 1.64E-3  1028.0  30.000  100.00

Simulation:
Froude No:    -23.03; Strat No:-3.16E-4; Spcg No:    48.00; k:    25.89; eff den (sigmaT)  28.00000; eff vel     0.518(r
        Depth  Amb-cur     P-dia  Polutnt    Dilutn   CL-diln   x-posn    y-posn      Time   Iso dia
Step      (m)   (cm/s)      (in)      (%)        ()        ()      (m)       (m)       (s)       (m)
   0    2.000    2.000     0.500    100.0     1.000     1.000      0.0       0.0       0.0    0.0127;
  50    1.962    2.000     1.346    36.10     2.770     1.385    0.000    0.0402     0.198   0.03418;
 100    1.885    2.000     3.389    13.94     7.173     3.586    0.000     0.144     1.354   0.08608;
 150    1.834    2.000     5.491    8.347     11.98     5.990    0.000     0.260     3.403    0.1395;
 200    1.815    2.000     6.968    6.329     15.80     7.901    0.000     0.372     5.917    0.1770;
 209    1.815    2.000     7.180    6.089     16.42     8.212    0.000     0.393     6.421    0.1824; local maximum rise c
 250    1.826    2.000     8.062    5.142     19.45     9.725    0.000     0.495     8.995    0.2048;
 300    1.888    2.000     10.09    3.535     28.29     14.15    0.000     0.667     13.92    0.2563;
 350    2.120    2.000     17.55    1.403     71.30     35.65    0.000     1.041     27.44    0.4458;
 376    2.286    2.000     24.01    0.838     119.3     59.66    0.000     1.304     38.51    0.6100; merging;
 400    2.498    2.000     32.43    0.528     189.3     103.8    0.000     1.702     56.41    0.8237;
 402    2.514    2.000     33.11    0.513     194.8     107.6    0.000     1.738     58.03    0.8409; trap level;
 450    2.722    2.000     43.05    0.368     271.7     169.5    0.000     2.371     87.55    1.0934;
 488    2.759    2.000     45.50    0.346     289.4     186.4    0.000     2.776     106.6    1.1557; local maximum rise c
 500    2.755    2.000     45.59    0.344     290.6     197.5    0.000     2.903     112.6    1.1580;
 549    2.505    2.000     51.26    0.278     359.4     239.6    0.000     3.998     164.5    1.3021; trap level;
Horiz plane projections in effluent direction: radius(m):      0.0; CL(m):    3.9984
```

Chronic Conditions

```
Ambient Table:
     Depth   Amb-cur   Amb-dir   Amb-den   Amb-tem   Amb-pol     Decay   Far-spd   Far-dir   Disprsn   Density
         m       m/s       deg       psu         C     kg/kg       s-1       m/s       deg  m0.67/s2   sigma-T
       0.0     0.050     90.00     30.95     11.20       0.0       0.0         -         -    0.0003  23.62000
     3.000     0.050     90.00     31.17     10.35       0.0       0.0         -         -    0.0003  23.93000
     6.000     0.050     90.00     31.16     9.690       0.0       0.0         -         -    0.0003  24.03000
     9.000     0.050     90.00     31.68     9.440       0.0       0.0         -         -    0.0003  24.48000
     12.00     0.050     90.00     31.76     9.340       0.0       0.0         -         -    0.0003  24.56000
     15.00     0.050     90.00     31.87     9.220       0.0       0.0         -         -    0.0003  24.66000

Diffuser table:
   P-diaVer angl H-Angle SourceX SourceY   Ports Spacing  MZ-dis Isoplth P-depth Ttl-flo Eff-den    Temp Polutnt
    (in)   (deg)   (deg)     (m)     (m)     ()     (ft)    (ft)(concent)     (m)  (m3/s) (kg/m3)     (C)     (%)
  0.5000  45.000  90.000     0.0     0.0  25.000  2.0000  200.00     0.0  2.0000 1.64E-3  1028.0  30.000  100.00

Simulation:
Froude No:    -23.03; Strat No:-3.16E-4; Spcg No:    48.00; k:    10.36; eff den (sigmaT)  28.00000; eff vel     0.518(r
        Depth  Amb-cur     P-dia  Polutnt    Dilutn   CL-diln   x-posn    y-posn      Time   Iso dia
Step      (m)   (cm/s)      (in)      (%)        ()        ()      (m)       (m)       (s)       (m)
   0    2.000    5.000     0.500    100.0     1.000     1.000      0.0       0.0       0.0    0.0127;
  50    1.965    5.000     1.296    36.17     2.765     1.382    0.000     0.039     0.177   0.03292;
 100    1.916    5.000     2.974    13.91     7.191     3.596    0.000     0.119     0.867   0.07555;
 150    1.872    5.000     5.259    6.473     15.45     7.725    0.000     0.258     2.639    0.1336;
 191    1.852    5.000     7.016    4.155     24.07     12.03    0.000     0.505     6.406    0.1782; local maximum rise c
 200    1.854    5.000     7.297    3.890     25.71     12.85    0.000     0.581     7.605    0.1854;
 250    1.943    5.000     11.87    1.631     61.32     30.66    0.000     1.167     17.65    0.3015;
 300    2.105    5.000     20.13    0.606     165.1     82.53    0.000     2.029     33.90    0.5113;
 318    2.184    5.000     24.24    0.424     235.7     117.9    0.000     2.530     43.62    0.6157; merging;
 334    2.282    5.000     28.79    0.309     323.6     170.3    0.000     3.277     58.22    0.7313; trap level;
 350    2.407    5.000     34.20    0.230     435.4     243.5    0.000     4.726     86.73    0.8686;
 361    2.433    5.000     35.67    0.215     466.0     265.2    0.000     5.787     107.7    0.9061; local maximum rise c
 382    2.272    5.000     40.65    0.172     581.6     351.8    0.000     8.609     163.4    1.0325; trap level;
Horiz plane projections in effluent direction: radius(m):      0.0; CL(m):    8.6092
```

Scenario 3 – Pretreatment Reject Only

Acute Conditions

Depth	Amb-cur	Amb-dir	Amb-den	Amb-tem	Amb-pol	Decay	Far-spd	Far-dir	Disprsn	Density
m	m/s	deg	psu	C	kg/kg	s-1	m/s	deg	m0.67/s2	sigma-T
0.0	0.020	90.00	30.95	11.20	0.0	0.0	-	-	0.0003	23.62000
3.000	0.020	90.00	31.17	10.35	0.0	0.0	-	-	0.0003	23.93000
6.000	0.020	90.00	31.16	9.690	0.0	0.0	-	-	0.0003	24.03000
9.000	0.020	90.00	31.68	9.440	0.0	0.0	-	-	0.0003	24.48000
12.00	0.020	90.00	31.76	9.340	0.0	0.0	-	-	0.0003	24.56000
15.00	0.020	90.00	31.87	9.220	0.0	0.0	-	-	0.0003	24.66000

Diffuser table:

P-diaVer	angl	H-Angle	SourceX	SourceY	Ports	Spacing	MZ-dis	Isoplth	P-depth	Ttl-flo	Eff-den	Temp	Polutnt
(in)	(deg)	(deg)	(m)	(m)	()	(ft)	(ft)	(concent)	(m)	(m3/s)	(kg/m3)	(C)	(%)
0.5000	45.000	90.000	0.0	0.0	25.000	2.0000	200.00	0.0	2.0000	7.50E-3	1042.0	17.000	100.00

Simulation:
Froude No: -50.81; Strat No:-7.25E-5; Spcg No: 48.00; k: 118.4; eff den (sigmaT) 42.00000; eff vel 2.368(r

Step	Depth	Amb-cur	P-dia	Polutnt	Dilutn	CL-diln	x-posn	y-posn	Time	Iso dia	
	(m)	(cm/s)	(in)	(%)	()	()	(m)	(m)	(s)	(m)	
0	2.000	2.000	0.500	100.0	1.000	1.000	0.0	0.0	0.0	0.0127;	
50	1.951	2.000	1.594	30.73	3.255	1.627	0.000	0.0494	0.0626	0.04048;	
100	1.835	2.000	4.270	11.38	8.790	4.395	0.000	0.176	0.488	0.1085;	
150	1.614	2.000	10.36	4.746	21.07	10.53	0.000	0.483	2.822	0.2633;	
200	1.504	2.000	15.08	3.306	30.25	15.12	0.000	0.746	5.909	0.3830;	
250	1.473	2.000	18.31	2.694	37.12	18.56	0.000	0.964	9.036	0.4652;	
254	1.473	2.000	18.53	2.658	37.62	18.81	0.000	0.981	9.295	0.4706;	local maximum rise c
300	1.497	2.000	20.61	2.305	43.39	21.69	0.000	1.177	12.49	0.5235;	
350	1.592	2.000	22.82	1.923	52.00	26.00	0.000	1.423	16.92	0.5797;	
369	1.661	2.000	24.05	1.741	57.44	28.72	0.000	1.539	19.21	0.6109;	merging;
400	1.855	2.000	26.99	1.403	71.29	36.79	0.000	1.789	24.61	0.6855;	
450	3.090	2.000	45.55	0.656	152.5	98.31	0.000	2.838	54.07	1.1569;	
465	3.823	2.000	61.82	0.495	202.0	134.7	0.000	3.453	74.97	1.5703;	trap level;
500	4.588	2.000	91.73	0.383	261.2	174.1	0.000	4.256	104.4	2.3299;	
529	4.855	2.000	111.4	0.346	289.2	192.8	0.000	4.655	119.7	2.8294;	begin overlap;
550	4.974	2.000	122.8	0.331	302.5	201.7	0.000	4.897	129.1	3.1189;	
600	5.121	2.000	138.1	0.316	316.0	210.7	0.000	5.393	148.7	3.5086;	
632	5.142	2.000	141.1	0.314	318.2	212.2	0.000	5.680	160.0	3.5832;	local maximum rise c
650	5.134	2.000	140.8	0.314	318.6	212.4	0.000	5.840	166.3	3.5767;	
700	5.022	2.000	135.7	0.311	321.9	214.6	0.000	6.332	185.8	3.4465;	
726	4.873	2.000	131.8	0.305	327.9	218.6	0.000	6.672	199.3	3.3467;	end overlap;
750	4.576	2.000	129.7	0.292	342.1	228.1	0.000	7.171	219.2	3.2932;	
764	3.793	2.000	140.9	0.258	387.2	258.1	0.000	8.262	263.6	3.5789;	trap level;

Chronic Conditions

Ambient Table:

Depth	Amb-cur	Amb-dir	Amb-den	Amb-tem	Amb-pol	Decay	Far-spd	Far-dir	Disprsn	Density
m	m/s	deg	psu	C	kg/kg	s-1	m/s	deg	m0.67/s2	sigma-T
0.0	0.050	90.00	30.95	11.20	0.0	0.0	-	-	0.0003	23.62000
3.000	0.050	90.00	31.17	10.35	0.0	0.0	-	-	0.0003	23.93000
6.000	0.050	90.00	31.16	9.690	0.0	0.0	-	-	0.0003	24.03000
9.000	0.050	90.00	31.68	9.440	0.0	0.0	-	-	0.0003	24.48000
12.00	0.050	90.00	31.76	9.340	0.0	0.0	-	-	0.0003	24.56000
15.00	0.050	90.00	31.87	9.220	0.0	0.0	-	-	0.0003	24.66000

Diffuser table:

P-diaVer	angl	H-Angle	SourceX	SourceY	Ports	Spacing	MZ-dis	Isoplth	P-depth	Ttl-flo	Eff-den	Temp	Polutnt
(in)	(deg)	(deg)	(m)	(m)	()	(ft)	(ft)	(concent)	(m)	(m3/s)	(kg/m3)	(C)	(%)
0.5000	45.000	90.000	0.0	0.0	25.000	2.0000	200.00	0.0	2.0000	7.50E-3	1042.0	17.000	100.00

Simulation:
Froude No: -50.81; Strat No:-7.25E-5; Spcg No: 48.00; k: 47.36; eff den (sigmaT) 42.00000; eff vel 2.368(r

Step	Depth	Amb-cur	P-dia	Polutnt	Dilutn	CL-diln	x-posn	y-posn	Time	Iso dia	
	(m)	(cm/s)	(in)	(%)	()	()	(m)	(m)	(s)	(m)	
0	2.000	5.000	0.500	100.0	1.000	1.000	0.0	0.0	0.0	0.0127;	
50	1.952	5.000	1.576	30.78	3.249	1.625	0.000	0.0496	0.0613	0.04003;	
100	1.844	5.000	4.117	11.39	8.776	4.388	0.000	0.177	0.456	0.1046;	
150	1.666	5.000	9.618	4.565	21.90	10.95	0.000	0.465	2.258	0.2443;	
200	1.555	5.000	15.23	2.655	37.67	18.84	0.000	0.811	5.541	0.3869;	
239	1.525	5.000	18.46	2.062	48.49	24.24	0.000	1.138	9.255	0.4688;	local maximum rise c
250	1.528	5.000	19.22	1.945	51.42	25.71	0.000	1.241	10.49	0.4882;	
295	1.625	5.000	24.02	1.358	73.62	36.81	0.000	1.776	17.42	0.6101;	merging;
300	1.652	5.000	25.08	1.266	78.99	39.95	0.000	1.865	18.66	0.6369;	
350	2.377	5.000	47.13	0.491	203.8	134.2	0.000	3.545	45.55	1.1970;	
365	2.761	5.000	59.85	0.367	272.4	181.6	0.000	4.432	61.14	1.5201;	trap level;
400	3.203	5.000	80.08	0.274	365.6	243.7	0.000	5.908	87.90	2.0340;	
441	3.377	5.000	90.85	0.243	411.9	274.6	0.000	7.709	121.1	2.3077;	local maximum rise c
450	3.366	5.000	91.32	0.241	414.6	276.4	0.000	8.120	128.7	2.3195;	
494	2.708	5.000	108.5	0.191	522.6	348.4	0.000	11.63	194.3	2.7556;	trap level;

Horiz plane projections in effluent direction: radius(m): 0.0; CL(m): 11.633
Tmz(m): 11.633

Scenario 4a – Neutralized Acid (Olivine) + Pretreatment Reject

Acute Conditions

Ambient Table:

Depth	Amb-cur	Amb-dir	Amb-den	Amb-tem	Amb-pol	Decay	Far-spd	Far-dir	Disprsn	Density
m	m/s	deg	psu	C	kg/kg	s-1	m/s	deg	m0.67/s2	sigma-T
0.0	0.020	90.00	30.95	11.20	0.0	0.0	-	-	0.0003	23.62000
3.000	0.020	90.00	31.17	10.35	0.0	0.0	-	-	0.0003	23.93000
6.000	0.020	90.00	31.16	9.690	0.0	0.0	-	-	0.0003	24.03000
9.000	0.020	90.00	31.68	9.440	0.0	0.0	-	-	0.0003	24.48000
12.00	0.020	90.00	31.76	9.340	0.0	0.0	-	-	0.0003	24.56000
15.00	0.020	90.00	31.87	9.220	0.0	0.0	-	-	0.0003	24.66000

Diffuser table:

P-dia	Ver angl	H-Angle	SourceX	SourceY	Ports	Spacing	MZ-dis	Isoplth	P-depth	Ttl-flo	Eff-den	Temp	Polutnt
(in)	(deg)	(deg)	(m)	(m)	()	(ft)	(ft)	(concent)	(m)	(m3/s)	(kg/m3)	(C)	(%)
0.5000	45.000	90.000	0.0	0.0	25.000	2.0000	200.00	0.0	2.0000	9.10E-3	1038.0	19.300	100.00

Simulation:
Froude No: -69.68; Strat No:-9.29E-5; Spcg No: 48.00; k: 143.7; eff den (sigmaT) 38.00000; eff vel 2.873(r

Step	Depth	Amb-cur	P-dia	Polutnt	Dilutn	CL-diln	x-posn	y-posn	Time	Iso dia	
	(m)	(cm/s)	(in)	(%)	()	()	(m)	(m)	(s)	(m)	
0	2.000	2.000	0.500	100.0	1.000	1.000	0.0	0.0	0.0	0.0127;	
50	1.949	2.000	1.655	29.64	3.374	1.687	0.000	0.0517	0.0559	0.04203;	
100	1.828	2.000	4.424	10.98	9.105	4.553	0.000	0.181	0.433	0.1124;	
150	1.548	2.000	11.64	4.173	23.97	11.98	0.000	0.542	2.972	0.2956;	
200	1.358	2.000	18.75	2.621	38.16	19.08	0.000	0.931	7.524	0.4763;	
250	1.294	2.000	23.51	2.075	48.20	24.10	0.000	1.241	12.15	0.5971;	
257	1.292	2.000	24.05	2.022	49.47	24.73	0.000	1.282	12.81	0.6109;	merging;
265	1.291	2.000	24.62	1.968	50.80	25.56	0.000	1.328	13.58	0.6252;	local maximum rise c
300	1.310	2.000	26.59	1.785	56.02	28.79	0.000	1.536	17.15	0.6754;	
350	1.416	2.000	28.99	1.543	64.80	34.18	0.000	1.868	23.32	0.7363;	
400	1.726	2.000	33.30	1.198	83.48	46.22	0.000	2.357	33.57	0.8459;	
442	2.952	2.000	53.61	0.656	152.5	101.7	0.000	3.596	66.49	1.3617;	trap level;
450	3.167	2.000	60.31	0.603	165.8	110.5	0.000	3.819	73.31	1.5320;	
500	3.811	2.000	90.58	0.471	212.2	141.5	0.000	4.698	101.9	2.3007;	
523	3.946	2.000	101.6	0.444	225.5	150.3	0.000	4.988	111.8	2.5808;	begin overlap;
550	4.044	2.000	111.1	0.425	235.5	157.0	0.000	5.295	122.4	2.8218;	
599	4.106	2.000	118.1	0.413	242.2	161.4	0.000	5.807	140.4	3.0001;	local maximum rise c
600	4.106	2.000	118.1	0.413	242.2	161.5	0.000	5.817	140.7	3.0009;	
650	4.031	2.000	116.6	0.408	245.3	163.5	0.000	6.353	159.6	2.9609;	
671	3.944	2.000	115.0	0.402	248.7	165.8	0.000	6.621	169.1	2.9214;	end overlap;
700	3.710	2.000	113.3	0.387	258.3	172.2	0.000	7.116	186.8	2.8788;	
726	2.755	2.000	126.0	0.328	304.9	203.3	0.000	8.557	239.6	3.2008;	trap level;

Chronic Conditions

Ambient Table:

Depth	Amb-cur	Amb-dir	Amb-den	Amb-tem	Amb-pol	Decay	Far-spd	Far-dir	Disprsn	Density
m	m/s	deg	psu	C	kg/kg	s-1	m/s	deg	m0.67/s2	sigma-T
0.0	0.050	90.00	30.95	11.20	0.0	0.0	-	-	0.0003	23.62000
3.000	0.050	90.00	31.17	10.35	0.0	0.0	-	-	0.0003	23.93000
6.000	0.050	90.00	31.16	9.690	0.0	0.0	-	-	0.0003	24.03000
9.000	0.050	90.00	31.68	9.440	0.0	0.0	-	-	0.0003	24.48000
12.00	0.050	90.00	31.76	9.340	0.0	0.0	-	-	0.0003	24.56000
15.00	0.050	90.00	31.87	9.220	0.0	0.0	-	-	0.0003	24.66000

Diffuser table:

P-dia	Ver angl	H-Angle	SourceX	SourceY	Ports	Spacing	MZ-dis	Isoplth	P-depth	Ttl-flo	Eff-den	Temp	Polutnt
(in)	(deg)	(deg)	(m)	(m)	()	(ft)	(ft)	(concent)	(m)	(m3/s)	(kg/m3)	(C)	(%)
0.5000	45.000	90.000	0.0	0.0	25.000	2.0000	200.00	0.0	2.0000	9.10E-3	1038.0	19.300	100.00

Simulation:
Froude No: -69.68; Strat No:-9.29E-5; Spcg No: 48.00; k: 57.47; eff den (sigmaT) 38.00000; eff vel 2.873(r

Step	Depth	Amb-cur	P-dia	Polutnt	Dilutn	CL-diln	x-posn	y-posn	Time	Iso dia	
	(m)	(cm/s)	(in)	(%)	()	()	(m)	(m)	(s)	(m)	
0	2.000	5.000	0.500	100.0	1.000	1.000	0.0	0.0	0.0	0.0127;	
50	1.950	5.000	1.638	29.69	3.369	1.684	0.000	0.0519	0.0549	0.04161;	
100	1.835	5.000	4.289	11.00	9.091	4.546	0.000	0.183	0.409	0.1089;	
150	1.614	5.000	10.64	4.141	24.15	12.07	0.000	0.515	2.322	0.2703;	
200	1.439	5.000	18.60	2.149	46.53	23.26	0.000	0.973	6.598	0.4724;	
243	1.372	5.000	24.00	1.537	65.06	32.53	0.000	1.479	12.50	0.6097;	merging;
250	1.371	5.000	24.67	1.479	67.60	34.04	0.000	1.573	13.67	0.6265;	local maximum rise c
300	1.487	5.000	30.25	1.085	92.18	49.30	0.000	2.395	24.56	0.7684;	
350	2.346	5.000	56.17	0.461	217.0	144.7	0.000	4.656	59.98	1.4267;	
354	2.461	5.000	60.17	0.426	234.7	156.5	0.000	4.959	65.14	1.5284;	trap level;
400	2.953	5.000	83.97	0.308	324.3	216.2	0.000	6.894	99.03	2.1328;	
425	2.999	5.000	87.80	0.296	337.5	225.0	0.000	7.707	113.5	2.2302;	local maximum rise c
450	2.939	5.000	89.36	0.289	346.5	231.0	0.000	8.562	128.8	2.2698;	
478	2.426	5.000	102.6	0.240	416.6	277.7	0.000	10.90	171.1	2.6060;	trap level;

Horiz plane projections in effluent direction: radius(m): 0.0; CL(m): 10.902

Scenario 4b – Neutralized Acid ($CaCO_3$) + Pretreatment Reject

Acute Conditions

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Ambient Table:
     Depth   Amb-cur   Amb-dir   Amb-den   Amb-tem   Amb-pol     Decay   Far-spd   Far-dir   Disprsn   Density
         m       m/s       deg       psu         C     kg/kg       s-1       m/s       deg   m0.67/s2  sigma-T
       0.0     0.020     90.00     30.95     11.20       0.0       0.0         -         -    0.0003  23.62000
     3.000     0.020     90.00     31.17     10.35       0.0       0.0         -         -    0.0003  23.93000
     6.000     0.020     90.00     31.16     9.690       0.0       0.0         -         -    0.0003  24.03000
     9.000     0.020     90.00     31.68     9.440       0.0       0.0         -         -    0.0003  24.48000
     12.00     0.020     90.00     31.76     9.340       0.0       0.0         -         -    0.0003  24.56000
     15.00     0.020     90.00     31.87     9.220       0.0       0.0         -         -    0.0003  24.66000

Diffuser table:
   P-diaVer angl H-Angle SourceX SourceY   Ports Spacing  MZ-dis Isoplth P-depth Ttl-flo Eff-den    Temp Polutnt
    (in)   (deg)   (deg)     (m)     (m)     ()    (ft)    (ft)(concent)    (m)  (m3/s) (kg/m3)     (C)     (%)
  0.5000  45.000  90.000     0.0     0.0  25.000  2.0000  200.00     0.0  2.0000 9.10E-3  1039.0  19.300  100.00

Simulation:
Froude No:    -67.38; Strat No:-8.68E-5; Spcg No:    48.00; k:    143.7; eff den (sigmaT)  39.00000; eff vel     2.873(r
        Depth  Amb-cur    P-dia  Polutnt   Dilutn  CL-diln   x-posn   y-posn     Time   Iso dia
Step      (m)   (cm/s)     (in)      (%)       ()       ()      (m)      (m)      (s)       (m)
   0    2.000    2.000    0.500    100.0    1.000    1.000      0.0      0.0      0.0    0.0127;
  50    1.949    2.000    1.655    29.62    3.376    1.688    0.000   0.0517   0.0559   0.04204;
 100    1.828    2.000    4.427    10.98    9.111    4.556    0.000    0.181    0.434    0.1125;
 150    1.552    2.000    11.58    4.202    23.80    11.90    0.000    0.539    2.938    0.2943;
 200    1.373    2.000    18.38    2.684    37.26    18.63    0.000    0.911    7.233    0.4669;
 250    1.314    2.000    22.94    2.135    46.83    23.42    0.000    1.208    11.57    0.5827;
 264    1.312    2.000    23.96    2.031    49.23    24.61    0.000    1.286    12.83    0.6085; local maximum rise o
 265    1.312    2.000    24.03    2.025    49.39    24.70    0.000    1.292    12.92    0.6103; merging;
 300    1.331    2.000    25.98    1.832    54.59    27.87    0.000    1.490    16.27    0.6598;
 350    1.434    2.000    28.30    1.583    63.18    33.07    0.000    1.807    22.06    0.7189;
 400    1.729    2.000    32.35    1.234    81.06    44.39    0.000    2.268    31.57    0.8218;
 446    3.049    2.000    53.63    0.644    155.2    103.4    0.000    3.550    65.57    1.3622; trap level;
 450    3.184    2.000    57.50    0.612    163.3    108.9    0.000    3.682    69.59    1.4605;
 500    4.001    2.000    91.98    0.456    219.3    146.2    0.000    4.693    102.6    2.3362;
 526    4.175    2.000    105.9    0.424    236.0    157.4    0.000    5.036    114.4    2.6894; begin overlap;
 550    4.276    2.000    115.5    0.406    246.0    164.0    0.000    5.315    124.2    2.9347;
 600    4.361    2.000    124.7    0.393    254.1    169.4    0.000    5.841    142.9    3.1684;
 607    4.362    2.000    125.1    0.393    254.5    169.7    0.000    5.912    145.5    3.1767; local maximum rise o
 650    4.311    2.000    123.8    0.390    256.6    171.1    0.000    6.361    161.5    3.1454;
 685    4.171    2.000    120.8    0.382    261.7    174.5    0.000    6.799    177.2    3.0678; end overlap;
 700    4.060    2.000    119.6    0.376    266.3    177.5    0.000    7.042    186.0    3.0375;
 735    2.993    2.000    131.5    0.315    317.1    211.4    0.000    8.679    246.5    3.3404; trap level;
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Chronic Conditions

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Ambient Table:
     Depth   Amb-cur   Amb-dir   Amb-den   Amb-tem   Amb-pol     Decay   Far-spd   Far-dir   Disprsn   Density
         m       m/s       deg       psu         C     kg/kg       s-1       m/s       deg   m0.67/s2  sigma-T
       0.0     0.050     90.00     30.95     11.20       0.0       0.0         -         -    0.0003  23.62000
     3.000     0.050     90.00     31.17     10.35       0.0       0.0         -         -    0.0003  23.93000
     6.000     0.050     90.00     31.16     9.690       0.0       0.0         -         -    0.0003  24.03000
     9.000     0.050     90.00     31.68     9.440       0.0       0.0         -         -    0.0003  24.48000
     12.00     0.050     90.00     31.76     9.340       0.0       0.0         -         -    0.0003  24.56000
     15.00     0.050     90.00     31.87     9.220       0.0       0.0         -         -    0.0003  24.66000

Diffuser table:
   P-diaVer angl H-Angle SourceX SourceY   Ports Spacing  MZ-dis Isoplth P-depth Ttl-flo Eff-den    Temp Polutnt
    (in)   (deg)   (deg)     (m)     (m)     ()    (ft)    (ft)(concent)    (m)  (m3/s) (kg/m3)     (C)     (%)
  0.5000  45.000  90.000     0.0     0.0  25.000  2.0000  200.00     0.0  2.0000 9.10E-3  1039.0  19.300  100.00

Simulation:
Froude No:    -67.38; Strat No:-8.68E-5; Spcg No:    48.00; k:    57.47; eff den (sigmaT)  39.00000; eff vel     2.873(r
        Depth  Amb-cur    P-dia  Polutnt   Dilutn  CL-diln   x-posn   y-posn     Time   Iso dia
Step      (m)   (cm/s)     (in)      (%)       ()       ()      (m)      (m)      (s)       (m)
   0    2.000    5.000    0.500    100.0    1.000    1.000      0.0      0.0      0.0    0.0127;
  50    1.950    5.000    1.639    29.67    3.370    1.685    0.000   0.0519   0.0549   0.04162;
 100    1.835    5.000    4.291    10.99    9.097    4.549    0.000    0.183    0.410    0.1090;
 150    1.616    5.000    10.61    4.160    24.04    12.02    0.000    0.514    2.309    0.2696;
 200    1.448    5.000    18.28    2.202    45.42    22.71    0.000    0.958    6.415    0.4643;
 249    1.386    5.000    23.98    1.540    64.93    32.47    0.000    1.514    12.88    0.6090; local maximum rise o
 250    1.386    5.000    24.07    1.531    65.30    32.65    0.000    1.526    13.04    0.6114; merging;
 300    1.498    5.000    29.52    1.121    89.19    47.32    0.000    2.298    23.12    0.7499;
 350    2.314    5.000    53.66    0.484    206.8    137.9    0.000    4.372    55.31    1.3630;
 358    2.544    5.000    61.48    0.414    241.6    161.1    0.000    4.943    65.00    1.5615; trap level;
 400    3.015    5.000    84.28    0.306    327.0    218.0    0.000    6.667    95.25    2.1407;
 431    3.091    5.000    90.01    0.288    346.8    231.2    0.000    7.724    114.2    2.2864; local maximum rise o
 450    3.054    5.000    91.11    0.283    352.8    235.2    0.000    8.403    126.3    2.3141;
 486    2.467    5.000    106.2    0.231    432.8    288.5    0.000    11.12    175.5    2.6965; trap level;
Horiz plane projections in effluent direction: radius(m):      0.0; CL(m):    11.118
```

Scenario 5a – All Process Flows (Olivine neutralization)

Acute Conditions

Depth	Amb-cur	Amb-dir	Amb-den	Amb-tem	Amb-pol	Decay	Far-spd	Far-dir	Disprsn	Density
m	m/s	deg	psu	C	kg/kg	s-1	m/s	deg	m0.67/s2	sigma-T
0.0	0.020	90.00	30.95	11.20	0.0	0.0	-	-	0.0003	23.62000
3.000	0.020	90.00	31.17	10.35	0.0	0.0	-	-	0.0003	23.93000
6.000	0.020	90.00	31.16	9.690	0.0	0.0	-	-	0.0003	24.03000
9.000	0.020	90.00	31.68	9.440	0.0	0.0	-	-	0.0003	24.48000
12.00	0.020	90.00	31.76	9.340	0.0	0.0	-	-	0.0003	24.56000
15.00	0.020	90.00	31.87	9.220	0.0	0.0	-	-	0.0003	24.66000

Diffuser table:

P-dia	Ver angl	H-Angle	SourceX	SourceY	Ports	Spacing	MZ-dis	Isoplth	P-depth	Ttl-flo	Eff-den	Temp	Polutnt
(in)	(deg)	(deg)	(m)	(m)	()	(ft)	(ft)	(concent)	(m)	(m3/s)	(kg/m3)	(C)	(%)
0.5000	45.000	90.000	0.0	0.0	25.000	2.0000	200.00	0.0	2.0000	0.0108	1037.0	20.400	100.00

Simulation:
Froude No: -85.74; Strat No:-1.00E-4; Spcg No: 48.00; k: 170.5; eff den (sigmaT) 37.00000; eff vel   3.410(r

Step	Depth	Amb-cur	P-dia	Polutnt	Dilutn	CL-diln	x-posn	y-posn	Time	Iso dia	
	(m)	(cm/s)	(in)	(%)	()	()	(m)	(m)	(s)	(m)	
0	2.000	2.000	0.500	100.0	1.000	1.000	0.0	0.0	0.0	0.0127;	
50	1.946	2.000	1.721	28.52	3.506	1.753	0.000	0.0542	0.0512	0.0437;	
100	1.820	2.000	4.601	10.57	9.460	4.730	0.000	0.188	0.395	0.1169;	
150	1.510	2.000	12.31	3.926	25.47	12.74	0.000	0.571	2.825	0.3127;	
200	1.242	2.000	21.57	2.270	44.05	22.02	0.000	1.067	8.385	0.5479;	
218	1.195	2.000	24.01	2.041	48.99	24.49	0.000	1.211	10.39	0.6098;	merging;
250	1.149	2.000	27.36	1.796	55.68	28.85	0.000	1.449	13.99	0.6949;	
273	1.140	2.000	29.18	1.680	59.53	31.46	0.000	1.613	16.64	0.7412;	local maximum rise c
300	1.154	2.000	30.88	1.571	63.64	34.28	0.000	1.806	19.88	0.7844;	
350	1.263	2.000	33.44	1.385	72.18	40.02	0.000	2.197	26.91	0.8493;	
400	1.589	2.000	37.70	1.117	89.51	52.21	0.000	2.759	38.12	0.9576;	
439	2.790	2.000	57.17	0.674	148.4	98.95	0.000	4.071	70.41	1.4520;	trap level;
450	3.057	2.000	66.26	0.613	163.2	108.8	0.000	4.374	78.95	1.6831;	
500	3.565	2.000	93.42	0.508	196.9	131.3	0.000	5.152	102.2	2.3729;	
515	3.643	2.000	100.0	0.491	203.8	135.8	0.000	5.335	107.9	2.5401;	begin overlap;
550	3.754	2.000	110.7	0.468	213.6	142.4	0.000	5.725	120.3	2.8130;	
589	3.791	2.000	115.4	0.459	217.7	145.1	0.000	6.128	133.2	2.9310;	local maximum rise c
600	3.788	2.000	115.6	0.458	218.2	145.5	0.000	6.241	136.8	2.9370;	
650	3.681	2.000	113.4	0.451	222.0	148.0	0.000	6.792	154.6	2.8809;	
662	3.626	2.000	112.6	0.447	224.0	149.3	0.000	6.948	159.6	2.8593;	end overlap;
700	3.281	2.000	110.6	0.423	236.5	157.7	0.000	7.619	181.6	2.8102;	
720	2.519	2.000	119.7	0.373	268.3	178.9	0.000	8.704	218.3	3.0412;	trap level;

Horiz plane projections in effluent direction: radius(m):   0.0; CL(m):   8.7036

Chronic Conditions

Ambient Table:

Depth	Amb-cur	Amb-dir	Amb-den	Amb-tem	Amb-pol	Decay	Far-spd	Far-dir	Disprsn	Density
m	m/s	deg	psu	C	kg/kg	s-1	m/s	deg	m0.67/s2	sigma-T
0.0	0.050	90.00	30.95	11.20	0.0	0.0	-	-	0.0003	23.62000
3.000	0.050	90.00	31.17	10.35	0.0	0.0	-	-	0.0003	23.93000
6.000	0.050	90.00	31.16	9.690	0.0	0.0	-	-	0.0003	24.03000
9.000	0.050	90.00	31.68	9.440	0.0	0.0	-	-	0.0003	24.48000
12.00	0.050	90.00	31.76	9.340	0.0	0.0	-	-	0.0003	24.56000
15.00	0.050	90.00	31.87	9.220	0.0	0.0	-	-	0.0003	24.66000

Diffuser table:

P-dia	Ver angl	H-Angle	SourceX	SourceY	Ports	Spacing	MZ-dis	Isoplth	P-depth	Ttl-flo	Eff-den	Temp	Polutnt
(in)	(deg)	(deg)	(m)	(m)	()	(ft)	(ft)	(concent)	(m)	(m3/s)	(kg/m3)	(C)	(%)
0.5000	45.000	90.000	0.0	0.0	25.000	2.0000	200.00	0.0	2.0000	0.0108	1037.0	20.400	100.00

Simulation:
Froude No: -85.74; Strat No:-1.00E-4; Spcg No: 48.00; k: 68.20; eff den (sigmaT) 37.00000; eff vel   3.410(:

Step	Depth	Amb-cur	P-dia	Polutnt	Dilutn	CL-diln	x-posn	y-posn	Time	Iso dia	
	(m)	(cm/s)	(in)	(%)	()	()	(m)	(m)	(s)	(m)	
0	2.000	5.000	0.500	100.0	1.000	1.000	0.0	0.0	0.0	0.0127;	
50	1.947	5.000	1.705	28.56	3.501	1.750	0.000	0.0543	0.0504	0.04331;	
100	1.826	5.000	4.477	10.59	9.445	4.723	0.000	0.190	0.376	0.1137;	
150	1.575	5.000	11.32	3.932	25.43	12.72	0.000	0.548	2.262	0.2875;	
200	1.345	5.000	21.08	1.913	52.27	26.13	0.000	1.091	7.097	0.5353;	
217	1.294	5.000	24.15	1.612	62.04	31.02	0.000	1.305	9.438	0.6133;	merging;
250	1.240	5.000	28.45	1.312	76.24	39.97	0.000	1.795	15.26	0.7226;	
257	1.239	5.000	29.12	1.272	78.59	41.51	0.000	1.908	16.66	0.7397;	local maximum rise
300	1.333	5.000	33.75	1.029	97.14	54.06	0.000	2.708	26.99	0.8571;	
350	2.188	5.000	58.66	0.492	203.1	135.4	0.000	5.063	62.24	1.4900;	
355	2.348	5.000	64.17	0.446	224.0	149.4	0.000	5.480	69.07	1.6298;	trap level;
400	2.844	5.000	89.03	0.331	302.5	201.7	0.000	7.413	101.9	2.2614;	
426	2.894	5.000	93.43	0.317	315.4	210.2	0.000	8.259	116.5	2.3732;	local maximum rise
450	2.838	5.000	95.04	0.309	323.2	215.4	0.000	9.073	130.7	2.4140;	
481	2.252	5.000	110.4	0.255	392.0	261.3	0.000	11.68	176.5	2.8031;	trap level;

Horiz plane projections in effluent direction: radius(m):   0.0; CL(m):   11.676
Lmz(m):   11.676

Scenario 5b – All Process Flows ($CaCO_3$ neutralization)

Acute Conditions

Ambient Table:

Depth	Amb-cur	Amb-dir	Amb-den	Amb-tem	Amb-pol	Decay	Far-spd	Far-dir	Disprsn	Density
m	m/s	deg	psu	C	kg/kg	s-1	m/s	deg	m0.67/s2	sigma-T
0.0	0.020	90.00	30.95	11.20	0.0	0.0	-	-	0.0003	23.62000
3.000	0.020	90.00	31.17	10.35	0.0	0.0	-	-	0.0003	23.93000
6.000	0.020	90.00	31.16	9.690	0.0	0.0	-	-	0.0003	24.03000
9.000	0.020	90.00	31.68	9.440	0.0	0.0	-	-	0.0003	24.48000
12.00	0.020	90.00	31.76	9.340	0.0	0.0	-	-	0.0003	24.56000
15.00	0.020	90.00	31.87	9.220	0.0	0.0	-	-	0.0003	24.66000

Diffuser table:

P-dia	Ver angl	H-Angle	SourceX	SourceY	Ports	Spacing	MZ-dis	Isoplth	P-depth	Ttl-flo	Eff-den	Temp	Polutnt
(in)	(deg)	(deg)	(m)	(m)	()	(ft)	(ft)	(concent)	(m)	(m3/s)	(kg/m3)	(C)	(%)
0.5000	45.000	90.000	0.0	0.0	25.000	2.0000	200.00	0.0	2.0000	0.0108	1038.0	20.400	100.00

Simulation:

Froude No: -82.70; Strat No:-9.29E-5; Spcg No: 48.00; k: 170.5; eff den (sigmaT) 38.00000; eff vel 3.410(r

Step	Depth	Amb-cur	P-dia	Polutnt	Dilutn	CL-diln	x-posn	y-posn	Time	Iso dia	
	(m)	(cm/s)	(in)	(%)	()	()	(m)	(m)	(s)	(m)	
0	2.000	2.000	0.500	100.0	1.000	1.000	0.0	0.0	0.0	0.0127;	
50	1.946	2.000	1.721	28.51	3.508	1.754	0.000	0.0542	0.0512	0.04371;	
100	1.819	2.000	4.603	10.56	9.466	4.733	0.000	0.188	0.395	0.1169;	
150	1.512	2.000	12.32	3.930	25.44	12.72	0.000	0.571	2.824	0.3130;	
200	1.259	2.000	21.16	2.323	43.05	21.52	0.000	1.045	8.073	0.5375;	
223	1.206	2.000	24.08	2.043	48.94	24.47	0.000	1.220	10.48	0.6117;	merging;
250	1.173	2.000	26.76	1.841	54.31	27.96	0.000	1.411	13.34	0.6796;	
272	1.165	2.000	28.45	1.727	57.91	30.36	0.000	1.561	15.72	0.7226;	local maximum rise c
300	1.180	2.000	30.16	1.611	62.08	33.17	0.000	1.752	18.88	0.7661;	
350	1.286	2.000	32.62	1.420	70.43	38.69	0.000	2.127	25.50	0.8287;	
400	1.598	2.000	36.62	1.149	87.05	50.11	0.000	2.657	35.90	0.9301;	
443	2.895	2.000	57.08	0.664	150.5	100.4	0.000	4.020	69.34	1.4500;	trap level;
450	3.100	2.000	63.60	0.619	161.6	107.7	0.000	4.237	75.46	1.6154;	
500	3.745	2.000	94.40	0.495	202.1	134.7	0.000	5.132	102.3	2.3978;	
521	3.870	2.000	104.7	0.470	212.7	141.8	0.000	5.403	110.9	2.6582;	begin overlap;
550	3.976	2.000	114.9	0.451	222.0	148.0	0.000	5.740	121.7	2.9186;	
597	4.034	2.000	121.7	0.439	227.6	151.7	0.000	6.239	138.0	3.0914;	local maximum rise c
600	4.034	2.000	121.8	0.439	227.8	151.8	0.000	6.270	139.0	3.0941;	
650	3.953	2.000	120.1	0.433	230.7	153.8	0.000	6.816	156.8	3.0502;	
673	3.852	2.000	118.2	0.427	234.2	156.1	0.000	7.115	166.7	3.0031;	end overlap;
700	3.627	2.000	116.4	0.413	242.4	161.6	0.000	7.577	182.0	2.9565;	
729	2.640	2.000	126.9	0.353	282.9	188.6	0.000	9.004	230.7	3.2234;	trap level;

Chronic Conditions

Ambient Table:

Depth	Amb-cur	Amb-dir	Amb-den	Amb-tem	Amb-pol	Decay	Far-spd	Far-dir	Disprsn	Density
m	m/s	deg	psu	C	kg/kg	s-1	m/s	deg	m0.67/s2	sigma-T
0.0	0.050	90.00	30.95	11.20	0.0	0.0	-	-	0.0003	23.62000
3.000	0.050	90.00	31.17	10.35	0.0	0.0	-	-	0.0003	23.93000
6.000	0.050	90.00	31.16	9.690	0.0	0.0	-	-	0.0003	24.03000
9.000	0.050	90.00	31.68	9.440	0.0	0.0	-	-	0.0003	24.48000
12.00	0.050	90.00	31.76	9.340	0.0	0.0	-	-	0.0003	24.56000
15.00	0.050	90.00	31.87	9.220	0.0	0.0	-	-	0.0003	24.66000

Diffuser table:

P-dia	Ver angl	H-Angle	SourceX	SourceY	Ports	Spacing	MZ-dis	Isoplth	P-depth	Ttl-flo	Eff-den	Temp	Polutnt
(in)	(deg)	(deg)	(m)	(m)	()	(ft)	(ft)	(concent)	(m)	(m3/s)	(kg/m3)	(C)	(%)
0.5000	45.000	90.000	0.0	0.0	25.000	2.0000	200.00	0.0	2.0000	0.0108	1038.0	20.400	100.00

Simulation:

Froude No: -82.70; Strat No:-9.29E-5; Spcg No: 48.00; k: 68.20; eff den (sigmaT) 38.00000; eff vel 3.410(r

Step	Depth	Amb-cur	P-dia	Polutnt	Dilutn	CL-diln	x-posn	y-posn	Time	Iso dia	
	(m)	(cm/s)	(in)	(%)	()	()	(m)	(m)	(s)	(m)	
0	2.000	5.000	0.500	100.0	1.000	1.000	0.0	0.0	0.0	0.0127;	
50	1.947	5.000	1.705	28.55	3.502	1.751	0.000	0.0544	0.0504	0.04332;	
100	1.826	5.000	4.479	10.58	9.451	4.726	0.000	0.190	0.376	0.1138;	
150	1.576	5.000	11.32	3.934	25.42	12.71	0.000	0.548	2.263	0.2876;	
200	1.356	5.000	20.75	1.955	51.14	25.57	0.000	1.075	6.919	0.5270;	
220	1.300	5.000	24.15	1.615	61.91	30.96	0.000	1.319	9.570	0.6135;	merging;
250	1.258	5.000	27.81	1.352	73.97	38.51	0.000	1.744	14.58	0.7064;	
256	1.257	5.000	28.37	1.317	75.93	39.78	0.000	1.836	15.69	0.7206;	local maximum rise c
300	1.350	5.000	32.94	1.062	94.20	51.93	0.000	2.604	25.49	0.8367;	
350	2.155	5.000	55.87	0.518	193.2	128.8	0.000	4.755	57.34	1.4191;	
358	2.411	5.000	64.39	0.442	226.1	150.7	0.000	5.385	67.61	1.6354;	trap level;
400	2.914	5.000	89.18	0.328	304.4	203.0	0.000	7.175	97.99	2.2651;	
432	2.989	5.000	95.38	0.310	322.3	214.9	0.000	8.186	115.5	2.4226;	local maximum rise c
450	2.959	5.000	96.38	0.306	327.0	218.0	0.000	8.761	125.6	2.4480;	
488	2.368	5.000	111.0	0.253	395.0	263.4	0.000	11.44	172.8	2.8188;	trap level;

Horiz plane projections in effluent direction: radius(m): 0.0; CL(m): 11.437

Lmz(m): 11.437

Attachment C: Chemistry Model Output

Model Scenarios

Scenario No.		Streams	Flow Rate* (L/hr.)	Refernce Tab
Scenario 1		Alkaline product only	5,900	
		at pH 13.5		Scenario1_pH13-5
		at pH 13.9		Scenario1_pH13-9
Scenario 2		Reacted acid only	5,900	
	2A	Reacted acid with Olivine		Scenario2A
	2B	Reacted acid with CaCO3		Scenario2B
Scenario 3		Pretreat NF reject +IX waste	27,000	Scenario3
Scenario 4		Reacted acid+Pretreat reject waste	32,900	
	4A	Reacted acid with Olivine		Scenario4A
	4B	Reacted acid with CaCO3		Scenario4B
Scenario 5		Alkaline+Reacted acid+Pretreat reject waste	38,800	
	5A	Reacted acid with Olivine		Scenario5A
	5B	Reacted acid with CaCO3		Scenario5B

SCENARIO 1 at pH 13.5

Dilution Ratio	Volume - PoPA	Volume - Total	pH	Total Dissolved Solids	Temperature	Density - Total	Cl(-1) Liq1	Salinity	Si(+4)	Se(+4)	Sb(+5)	S(+6)	Pb(+2)
	L/hr	L/hr		mg/L	°C	kg/m3	mg/L	g/kg	mg/L	mg/L	mg/L	mg/L	mg/L
0	0	5,900	13.5	19,860	30.0	1,028	0	0	0	0	0	0	0
3	20,000	25,908	13.3	30,350	13.2	1,026	14,210	25.0	0.505	6.05E-04	0.008	624	0
7	40,000	45,927	13.1	31,748	11.0	1,025	16,033	28.2	0.125	6.82E-04	0.009	704	0
10	60,000	65,948	12.8	32,280	10.2	1,025	16,749	29.5	0.044	7.13E-04	0.009	735	0
14	80,000	85,969	12.5	32,322	9.71	1,025	17,131	30.2	0.017	7.29E-04	0.009	752	0
17	1.00E+05	1.06E+05	11.9	32,349	9.43	1,025	17,369	30.6	0.004	7.39E-04	0.009	763	0
34	2.00E+05	2.06E+05	10.6	32,929	8.87	1,025	17,869	31.5	0.000	7.60E-04	0.010	785	0
41	2.40E+05	2.46E+05	10.6	33,073	8.77	1,025	17,956	31.6	0.000	7.64E-04	0.010	788	0
47	2.80E+05	2.86E+05	10.6	33,191	8.70	1,025	18,018	31.7	0.000	7.67E-04	0.010	791	0
54	3.20E+05	3.26E+05	10.5	33,273	8.65	1,025	18,065	31.8	0.000	7.69E-04	0.010	793	0
61	3.60E+05	3.66E+05	10.5	33,325	8.61	1,025	18,102	31.9	0.000	7.70E-04	0.010	795	0
68	4.00E+05	4.06E+05	10.5	33,368	8.58	1,025	18,131	31.9	0.000	7.71E-04	0.010	796	0
75	4.40E+05	4.46E+05	10.5	33,409	8.55	1,025	18,155	32.0	0.000	7.72E-04	0.010	797	0
81	4.80E+05	4.86E+05	10.5	33,462	8.53	1,025	18,175	32.0	0.000	7.73E-04	0.010	798	0
88	5.20E+05	5.26E+05	10.5	33,473	8.51	1,025	18,192	32.1	0.000	7.74E-04	0.010	799	0
95	5.60E+05	5.66E+05	10.5	33,522	8.49	1,025	18,207	32.1	0.000	7.75E-04	0.010	799	0
102	6.00E+05	6.06E+05	10.5	33,538	8.48	1,025	18,220	32.1	0.000	7.75E-04	0.010	800	0
108	6.40E+05	6.46E+05	10.5	33,547	8.47	1,025	18,231	32.1	0.000	7.76E-04	0.010	800	0
115	6.80E+05	6.86E+05	10.5	33,553	8.46	1,025	18,241	32.1	0.000	7.76E-04	0.010	801	0
122	7.20E+05	7.26E+05	10.5	33,559	8.45	1,025	18,250	32.2	0.000	7.76E-04	0.010	801	0
129	7.60E+05	7.66E+05	10.5	33,564	8.44	1,025	18,257	32.2	0.000	7.77E-04	0.010	802	0
136	8.00E+05	8.06E+05	10.5	33,569	8.43	1,025	18,265	32.2	0.000	7.77E-04	0.010	802	0
142	8.40E+05	8.46E+05	10.5	33,573	8.42	1,025	18,271	32.2	0.000	7.77E-04	0.010	802	0
149	8.80E+05	8.86E+05	10.48	33,577	8.42	1,025	18,277	32.2	0.000	7.78E-04	0.010	802	0
156	9.20E+05	9.26E+05	10.48	33,580	8.41	1,025	18,282	32.2	0.000	7.78E-04	0.010	803	0
163	9.60E+05	9.66E+05	10.48	33,583	8.40	1,025	18,287	32.2	0.000	7.78E-04	0.010	803	0
169	1.00E+06	1.01E+06	10.48	33,586	8.40	1,025	18,292	32.2	0.000	7.78E-04	0.010	803	0
186	1.10E+06	1.11E+06	10.48	33,593	8.39	1,025	18,301	32.2	0.000	7.79E-04	0.010	803	0
507	2.99E+06	3.00E+06	8.30	33,657	8.31	1,026	18,364	32.3	0.653	7.81E-04	0.010	806	0
827	4.88E+06	4.89E+06	8.09	33,680	8.28	1,026	18,378	32.4	0.654	7.82E-04	0.010	807	0
1147	6.77E+06	6.78E+06	8.01	33,691	8.27	1,026	18,384	32.4	0.654	7.82E-04	0.010	807	0
1468	8.66E+06	8.67E+06	7.97	33,696	8.27	1,026	18,387	32.4	0.654	7.82E-04	0.010	807	0
1788	1.06E+07	1.06E+07	7.95	33,703	8.27	1,026	18,390	32.4	0.654	7.82E-04	0.010	807	0
2108	1.24E+07	1.24E+07	7.93	33,709	8.26	1,026	18,391	32.4	0.654	7.82E-04	0.010	807	0
2429	1.43E+07	1.43E+07	7.92	33,713	8.26	1,026	18,392	32.4	0.654	7.82E-04	0.010	807	0
2749	1.62E+07	1.62E+07	7.92	33,716	8.26	1,026	18,393	32.4	0.654	7.82E-04	0.010	808	0
3069	1.81E+07	1.81E+07	7.91	33,718	8.26	1,026	18,394	32.4	0.654	7.83E-04	0.010	808	0
3390	2.00E+07	2.00E+07	7.90	33,720	8.26	1,026	18,395	32.4	0.654	7.83E-04	0.010	808	0

Dilution Ratio	P(+5)	Ni(+2)	Na(+1)	N(-3)	N(+5)	N(+3)	Mn(+2)	Mg(+2)	K(+1)	Hg(+2)	Fe(+2)	F(-1)	Cu(+2)	Cr(+6)
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
0	0.000	0	17,434	0.000	0.000	0.000	0	0	0	0	0	0	0	0
3	0.002	0	13,054	0.016	0.218	0.059	0.004	0.001	254.86	2.70E-07	1.16E-02	1.93E+00	1.44E-03	9.77E-05
7	0.001	0	12,488	0.018	0.246	0.066	0.004	0.005	287.55	3.05E-07	1.31E-02	2.18E+00	1.62E-03	1.10E-04
10	0.001	0	12,265	0.018	0.257	0.069	0.005	0.013	300.39	3.19E-07	1.37E-02	2.28E+00	1.69E-03	1.15E-04
14	0.001	0	12,146	0.019	0.263	0.071	0.005	0.048	307.25	3.26E-07	1.23E-02	2.33E+00	1.73E-03	1.18E-04
17	0.001	0	12,072	0.019	0.267	0.072	0.005	0.500	311.51	3.30E-07	8.20E-03	2.36E+00	1.76E-03	1.19E-04
34	0.008	0	11,921	0.020	0.274	0.074	0.005	216.407	320.48	3.40E-07	1.46E-02	2.43E+00	1.25E-04	1.23E-04
41	0.009	0	11,894	0.020	0.276	0.074	0.005	261.486	322.03	3.42E-07	1.46E-02	2.44E+00	1.15E-04	1.23E-04
47	0.010	0	11,876	0.020	0.277	0.075	0.005	293.982	323.15	3.43E-07	1.47E-02	2.45E+00	1.10E-04	1.24E-04
54	0.011	0	11,862	0.020	0.277	0.075	0.005	318.514	323.99	3.44E-07	1.47E-02	2.45E+00	1.07E-04	1.24E-04
61	0.011	0	11,850	0.020	0.278	0.075	0.005	337.688	324.65	3.44E-07	1.48E-02	2.46E+00	1.04E-04	1.24E-04
68	0.011	0	11,842	0.020	0.278	0.075	0.005	353.086	325.17	3.45E-07	1.48E-02	2.46E+00	1.03E-04	1.25E-04
75	0.011	0	11,834	0.020	0.279	0.075	0.005	365.724	325.61	3.45E-07	1.48E-02	2.47E+00	1.01E-04	1.25E-04
81	0.012	0	11,828	0.020	0.279	0.075	0.005	376.282	325.97	3.46E-07	1.48E-02	2.47E+00	1.00E-04	1.25E-04
88	0.012	0	11,823	0.020	0.279	0.075	0.005	385.236	326.28	3.46E-07	1.48E-02	2.47E+00	9.94E-05	1.25E-04
95	0.012	0	11,819	0.020	0.279	0.075	0.005	392.924	326.54	3.46E-07	1.48E-02	2.47E+00	9.87E-05	1.25E-04
102	0.012	0	11,815	0.020	0.280	0.075	0.005	399.597	326.77	3.47E-07	1.49E-02	2.48E+00	9.80E-05	1.25E-04
108	0.012	0	11,811	0.020	0.280	0.075	0.005	405.444	326.97	3.47E-07	1.49E-02	2.48E+00	9.75E-05	1.25E-04
115	0.012	0	11,808	0.020	0.280	0.075	0.005	410.609	327.15	3.47E-07	1.49E-02	2.48E+00	9.71E-05	1.25E-04
122	0.012	0	11,806	0.020	0.280	0.075	0.005	415.206	327.30	3.47E-07	1.49E-02	2.48E+00	9.67E-05	1.25E-04
129	0.012	0	11,803	0.020	0.280	0.076	0.005	419.322	327.44	3.47E-07	1.49E-02	2.48E+00	9.63E-05	1.26E-04
136	0.012	0	11,801	0.020	0.280	0.076	0.005	423.030	327.57	3.47E-07	1.49E-02	2.48E+00	9.60E-05	1.26E-04
142	0.012	0	11,799	0.020	0.280	0.076	0.005	426.387	327.69	3.48E-07	1.49E-02	2.48E+00	9.58E-05	1.26E-04
149	0.013	0	11,798	0.020	0.280	0.076	0.005	429.441	327.79	3.48E-07	1.49E-02	2.48E+00	9.55E-05	1.26E-04
156	0.013	0	11,796	0.020	0.281	0.076	0.005	432.232	327.89	3.48E-07	1.49E-02	2.48E+00	9.53E-05	1.26E-04
163	0.013	0	11,794	0.020	0.281	0.076	0.005	434.791	327.97	3.48E-07	1.49E-02	2.48E+00	9.51E-05	1.26E-04
169	0.013	0	11,793	0.020	0.281	0.076	0.005	437.147	328.05	3.48E-07	1.49E-02	2.49E+00	9.49E-05	1.26E-04
186	0.013	0	11,790	0.020	0.281	0.076	0.005	442.291	328.23	3.48E-07	1.49E-02	2.49E+00	9.45E-05	1.26E-04
507	0.040	0	11,771	0.020	0.282	0.076	0.005	459.090	329.35	3.49E-07	1.50E-02	2.50E+00	1.86E-03	1.26E-04
827	0.040	0	11,767	0.020	0.282	0.076	0.005	459.442	329.60	3.50E-07	1.50E-02	2.50E+00	1.86E-03	1.26E-04
1147	0.040	0	11,765	0.020	0.282	0.076	0.005	459.598	329.71	3.50E-07	1.50E-02	2.50E+00	1.86E-03	1.26E-04
1468	0.040	0	11,764	0.020	0.282	0.076	0.005	459.685	329.77	3.50E-07	1.50E-02	2.50E+00	1.86E-03	1.26E-04
1788	0.040	0	11,763	0.020	0.282	0.076	0.005	459.742	329.82	3.50E-07	1.50E-02	2.50E+00	1.86E-03	1.26E-04
2108	0.040	0	11,763	0.020	0.282	0.076	0.005	459.781	329.84	3.50E-07	1.50E-02	2.50E+00	1.86E-03	1.26E-04
2429	0.040	0	11,762	0.020	0.282	0.076	0.005	459.810	329.86	3.50E-07	1.50E-02	2.50E+00	1.86E-03	1.26E-04
2749	0.040	0	11,762	0.020	0.282	0.076	0.005	459.832	329.88	3.50E-07	1.50E-02	2.50E+00	1.86E-03	1.26E-04
3069	0.040	0	11,762	0.020	0.282	0.076	0.005	459.849	329.89	3.50E-07	1.50E-02	2.50E+00	1.86E-03	1.26E-04
3390	0.040	0	11,762	0.020	0.282	0.076	0.005	459.864	329.90	3.50E-07	1.50E-02	2.50E+00	1.86E-03	1.26E-04

Dilution Ratio	Cr(+3)	Co(+2)	Zn(+2)	Cd(+2)	Ca(+2)	Br(-1)	Be(+2)	Ba(+2)	As(+5)	Al(+3)	NiCr2O4	NaAlCO3(OH)2 (Dawsonite) -	CoCr2O4 -	CaCO3 (Calcite) -
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0.0	0.0	4.94E-03	2.61E-05	1.53E+02	40.0827	0.004	0.004	0.0033	0.116	0	0.000	0.003	195.449
7	0	0.0	5.58E-03	2.95E-05	1.72E+02	45.2241	0.004	0.004	0.0037	0.131	0	0.000	0.003	222.677
10	0	0.0	5.83E-03	3.08E-05	1.80E+02	47.2432	0.005	0.005	0.0039	0.137	0	0.000	0.003	233.29
14	0	0.0	5.96E-03	3.15E-05	1.84E+02	48.3217	0.005	0.005	0.0040	0.140	0	0.000	0.003	238.93
17	0	0.0	6.04E-03	3.19E-05	1.86E+02	48.9927	0.005	0.005	0.0041	0.142	0	0.000	0.003	242.42
34	0	0.0	6.22E-03	3.28E-05	1.92E+02	50.4034	0.004	0.005	0.0042	0.081	0	0.000	0.004	248.37
41	0	0.0	6.25E-03	3.30E-05	1.93E+02	50.6469	0.004	0.005	0.0042	0.073	0	0.000	0.004	249.42
47	0	0.0	6.27E-03	3.31E-05	1.94E+02	50.8222	0.004	0.005	0.0042	0.069	0	0.000	0.004	250.19
54	0	0.0	6.28E-03	3.32E-05	1.94E+02	50.9546	0.004	0.005	0.0042	0.066	0	0.000	0.004	250.76
61	0	0.0	6.30E-03	3.33E-05	1.94E+02	51.058	0.004	0.005	0.0042	0.064	0	0.000	0.004	251.21
68	0	0.0	6.31E-03	3.33E-05	1.95E+02	51.141	0.004	0.005	0.0042	0.062	0	0.000	0.004	251.58
75	0	0.0	6.31E-03	3.34E-05	1.95E+02	51.2091	0.004	0.005	0.0042	0.061	0	0.000	0.004	251.88
81	0	0.0	6.32E-03	3.34E-05	1.95E+02	51.266	0.004	0.005	0.0043	0.060	0	0.000	0.004	252.13
88	0	0.0	6.33E-03	3.34E-05	1.96E+02	51.3142	0.004	0.005	0.0043	0.059	0	0.000	0.004	252.34
95	0	0.0	6.33E-03	3.34E-05	1.96E+02	51.3557	0.004	0.005	0.0043	0.059	0	0.000	0.004	252.52
102	0	0.0	6.34E-03	3.35E-05	1.96E+02	51.3916	0.004	0.005	0.0043	0.058	0	0.000	0.004	252.68
108	0	0.0	6.34E-03	3.35E-05	1.96E+02	51.4231	0.004	0.005	0.0043	0.058	0	0.000	0.004	252.82
115	0	0.0	6.34E-03	3.35E-05	1.96E+02	51.451	0.004	0.005	0.0043	0.057	0	0.000	0.004	252.94
122	0	0.0	6.35E-03	3.35E-05	1.96E+02	51.4757	0.004	0.005	0.0043	0.057	0	0.000	0.004	253.05
129	0	0.0	6.35E-03	3.35E-05	1.96E+02	51.4979	0.004	0.005	0.0043	0.057	0	0.000	0.004	253.15
136	0	0.0	6.35E-03	3.36E-05	1.96E+02	51.5179	0.004	0.005	0.0043	0.056	0	0.000	0.004	253.24
142	0	0.0	6.36E-03	3.36E-05	1.96E+02	51.536	0.004	0.005	0.0043	0.056	0	0.000	0.004	253.31
149	0	0.0	6.36E-03	3.36E-05	1.96E+02	51.5524	0.004	0.005	0.0043	0.056	0	0.000	0.004	253.39
156	0	0.0	6.36E-03	3.36E-05	1.97E+02	51.5674	0.005	0.005	0.0043	0.056	0	0.000	0.004	253.45
163	0	0.0	6.36E-03	3.36E-05	1.97E+02	51.5812	0.005	0.005	0.0043	0.056	0	0.000	0.004	253.51
169	0	0.0	6.36E-03	3.36E-05	1.97E+02	51.5939	0.005	0.005	0.0043	0.055	0	0.000	0.004	253.57
186	0	0.0	6.37E-03	3.36E-05	1.97E+02	51.6216	0.005	0.005	0.0043	0.055	0	0.000	0.004	253.69
507	0	0.0	6.39E-03	3.37E-05	2.41E+02	51.7973	0.005	0.005	0.0043	0.000	0	0.797	0.003	144.65
827	0	0.0	6.39E-03	3.38E-05	2.64E+02	5.18E+01	0.005	0.005	0.0043	0.000	0	0.799	0.003	88.6126
1147	0	0.0	6.39E-03	3.38E-05	2.74E+02	5.19E+01	0.005	0.005	0.0043	0.000	0	0.799	0.003	64.0244
1468	0	0.0	6.40E-03	3.38E-05	2.80E+02	5.19E+01	0.005	0.005	0.0043	0.000	0	0.800	0.003	50.2176
1788	0	0.0	6.40E-03	3.38E-05	2.83E+02	5.19E+01	0.005	0.005	0.0043	0.000	0	0.800	0.003	41.3772
2108	0	0.0	6.40E-03	3.38E-05	2.86E+02	5.19E+01	0.005	0.005	0.0043	0.000	0	0.800	0.003	35.2322
2429	0	0.0	6.40E-03	3.38E-05	2.88E+02	5.19E+01	0.005	0.005	0.0043	0.000	0	0.800	0.003	30.713
2749	0	0.0	6.40E-03	3.38E-05	2.89E+02	5.19E+01	0.005	0.005	0.0043	0.000	0	0.800	0.003	27.2499
3069	0	0.0	6.40E-03	3.38E-05	2.90E+02	5.19E+01	0.005	0.005	0.0043	0.000	0	0.800	0.003	24.5113
3390	0	0.0	6.40E-03	3.38E-05	2.91E+02	5.19E+01	0.005	0.005	0.0043	0.000	0	0.800	0.003	22.2915

SCENARIO 1 at pH 13.93

Dilution Ratio	Volume PoPA	Volume - Total	pH	Total Dissolved Solids	Temperature	Density	Cl(-1)	Salinity	Pb(+2)	P(+5)	Ni(+2)	Na(+1)	N(-3)	N(+5)	N(+3)	Mn(+2)	Mg(+2)	K(+1)	Hg(+2)	Fe(+2)	F(-1)	Cu(+2)	Cr(+6)	Cr(+3)	Co(+2)	Cd(+2)	Ca(+2)	Br(-1)	Be(+2)	Ba(+2)	As(+5)	Al(+3)	Zn(+2)	Si(+4)	Se(+4)	Sb(+5)	S(+6)	NiCr2O4	NaAlCO3(OH)2 (Dawsonite)	Mg3Si2O5(OH)4 (Poor-crystalline Antigorite)	Mg(OH)2 (Brucite)	Fe(OH)2 (Amakinite)	CuO	CoCr2O4	Co3(PO4) 2.8H2O	CaCO3 (Calcite)	Ca3(PO4)2	Ca(OH)2 (Portlandite)	Be2(OH)2 CO3	Al(OH)3 (Gibbsite)
	L/hr	L/hr		mg/L	°C	kg/m3	mg/L	g/kg	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
0	0	5,900	13.9	49,508	30.0	1,072	0	0.0	0	0	0	43,459	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	20,000	25,882	13.8	36,840	13.2	1,037	14,226	24.8	3.30E-05	0.018	5.03E-07	19,004	0.016	0.218	0.059	3.87E-03	0.000	255	2.71E-07	0.012	1.93	1.44E-03	9.78E-05	1.80E-07	3.19E-03	2.61E-05	63.8	40.1	0.0039	0.0039	0.0033	0.116	0.005	0.506	0.001	0.008	625	0.0011	0.0	0	853	0	0	0.0026	0	177	0.064	179	0	0
7	40,000	45,894	13.6	35,498	11.0	1,032	16,045	28.1	3.72E-05	0.002	4.69E-07	15,845	0.018	0.246	0.066	4.36E-03	0.001	288	3.05E-07	0.013	2.18	1.62E-03	1.10E-04	5.35E-08	3.59E-03	2.95E-05	173	45.3	0.0044	0.0044	0.0038	0.131	0.006	0.571	0.001	0.009	704	0.0012	0.0	0	962	0	0	0.0030	0	221	0.163	0	0	0
10	60,000	65,912	13.4	34,906	10.1	1,030	16,758	29.4	3.89E-05	0.002	4.47E-07	14,603	0.018	0.257	0.069	4.55E-03	0.002	301	3.19E-07	0.014	2.28	1.69E-03	1.15E-04	2.58E-08	3.75E-03	3.08E-05	180	47.3	0.0046	0.0046	0.0039	0.137	0.006	0.370	0.001	0.009	736	0.0013	0.0	1.11	1,005	0	0	0.0031	0	232	0.174	0	0	0
14	80,000	85,932	13.3	34,591	9.69	1,028	17,139	30.1	3.98E-05	0.001	4.36E-07	13,939	0.019	0.263	0.071	4.66E-03	0.003	307	3.26E-07	0.014	2.33	1.73E-03	1.18E-04	1.51E-08	3.84E-03	3.15E-05	184	48.3	0.0047	0.0047	0.0040	0.140	0.006	0.197	0.001	0.009	752	0.0013	0.0	2.04	1,027	0	0	0.0032	0	238	0.180	0	0	0
17	1.00E+05	1.06E+05	13.1	34,397	9.41	1,028	17,375	30.5	4.03E-05	0.001	4.37E-07	13,527	0.019	0.267	0.072	4.72E-03	0.004	312	3.31E-07	0.014	2.36	1.76E-03	1.19E-04	9.81E-09	3.89E-03	3.19E-05	186	49.0	0.0047	0.0047	0.0041	0.142	0.006	0.118	0.001	0.009	763	0.0013	0.0	2.47	1,041	0	0	0.0032	0	242	0.183	0	0	0
34	2.00E+05	2.06E+05	12.5	33,707	8.82	1,026	17,869	31.5	4.15E-05	0.001	9.77E-07	12,666	0.020	0.274	0.074	4.86E-03	0.048	320	3.40E-07	0.012	2.43	1.81E-03	1.23E-04	2.06E-09	4.00E-03	3.28E-05	191	50.4	0.0049	0.0049	0.0042	0.146	0.006	0.016	0.001	0.010	784	0.0014	0.0	3.06	1,070	3.55E-03	0	0.0033	0	249	0.189	0	0	0
41	2.40E+05	2.46E+05	12.1	33,504	8.72	1,026	17,954	31.6	4.17E-05	0.001	2.69E-06	12,517	0.020	0.276	0.074	4.88E-03	0.258	322	3.42E-07	0.008	2.44	1.81E-03	1.23E-04	1.21E-09	4.02E-03	3.30E-05	192	50.6	0.0049	0.0049	0.0042	0.146	0.006	0.006	0.001	0.010	788	0.0014	0.0	3.12	1,074	0.010	0	0.0033	0	251	0.190	0	0	0
47	2.80E+05	2.86E+05	11.2	33,396	8.65	1,026	18,015	31.7	4.18E-05	0.003	2.71E-05	12,411	0.020	0.276	0.075	4.90E-03	16.3	323	3.43E-07	0.015	2.45	4.27E-04	1.24E-04	8.09E-10	4.01E-03	3.31E-05	193	50.8	0.0049	0.0049	0.0042	0.147	0.006	0.001	0.001	0.010	791	0.0013	0.0	3.16	1,040	0	0.0017	0.0034	0	251	0.183	0	0	0
54	3.20E+05	3.26E+05	10.9	33,420	8.61	1,026	18,062	31.8	4.19E-05	0.005	5.99E-05	12,331	0.020	0.277	0.075	4.91E-03	71.4	324	3.44E-07	0.015	2.45	2.09E-04	1.24E-04	8.06E-10	3.99E-03	3.32E-05	194	50.9	0.0049	0.0049	0.0042	0.140	0.006	0.000	0.001	0.010	793	0.0012	0.0	3.17	910	0	0.0020	0.0036	0	252	0.173	0	0	0.020
61	3.60E+05	3.66E+05	10.8	33,445	8.57	1,026	18,099	31.9	4.20E-05	0.006	7.82E-05	12,269	0.020	0.278	0.075	4.92E-03	117	325	3.44E-07	0.015	2.46	1.66E-04	1.24E-04	8.13E-10	3.97E-03	3.32E-05	194	51.1	0.0045	0.0049	0.0042	0.109	0.006	0.000	0.001	0.010	795	0.0011	0.0	3.17	803	0	0.0021	0.0036	0	252	0.167	0	0.0028	0.111
68	4.00E+05	4.06E+05	10.7	33,466	8.54	1,026	18,129	31.9	4.21E-05	0.007	9.06E-05	12,218	0.020	0.278	0.075	4.93E-03	154	325	3.45E-07	0.015	2.46	1.47E-04	1.25E-04	8.19E-10	3.97E-03	3.33E-05	194	51.1	0.0042	0.0049	0.0042	0.095	0.006	0.000	0.001	0.010	796	0.0010	0.0	3.18	716	0	0.0021	0.0037	0	252	0.163	0	0.0042	0.153
75	4.40E+05	4.46E+05	10.7	33,484	8.52	1,026	18,153	32.0	4.21E-05	0.008	9.99E-05	12,177	0.020	0.279	0.075	4.93E-03	184	326	3.45E-07	0.015	2.47	1.35E-04	1.25E-04	8.23E-10	3.97E-03	3.33E-05	195	51.2	0.0042	0.0049	0.0042	0.086	0.006	0.000	0.001	0.010	797	0.0010	0.0	3.18	645	0	0.0021	0.0037	0	253	0.159	0	0.0047	0.178
81	4.80E+05	4.86E+05	10.6	33,498	8.50	1,026	18,174	32.0	4.22E-05	0.008	1.02E-04	12,143	0.020	0.279	0.075	4.94E-03	210	326	3.46E-07	0.015	2.47	1.28E-04	1.25E-04	8.49E-10	3.76E-03	3.34E-05	195	51.3	0.0042	0.0049	0.0042	0.081	0.006	0.000	0.001	0.010	798	0.0010	0.0	3.19	585	0	0.0021	0.0037	0.0006	253	0.156	0	0.0049	0.194
88	5.20E+05	5.26E+05	10.6	33,510	8.48	1,026	18,191	32.0	4.22E-05	0.009	9.81E-05	12,114	0.020	0.279	0.075	4.94E-03	231	326	3.46E-07	0.015	2.47	1.23E-04	1.25E-04	8.90E-10	3.44E-03	3.34E-05	195	51.3	0.0042	0.0049	0.0043	0.077	0.006	0.000	0.001	0.010	799	0.0010	0.0	3.19	534	0	0.0021	0.0037	0.0015	253	0.154	0	0.0049	0.206
95	5.60E+05	5.66E+05	10.6	33,532	8.47	1,026	18,206	32.1	4.22E-05	0.009	9.55E-05	12,089	0.020	0.279	0.075	4.95E-03	250	327	3.46E-07	0.015	2.47	1.19E-04	1.25E-04	9.23E-10	3.21E-03	3.34E-05	195	51.4	0.0042	0.0049	0.0043	0.074	0.006	0.000	0.001	0.010	799	0.0010	0.0	3.19	491	0	0.0022	0.0037	0.0022	253	0.152	0	0.0048	0.215
102	6.00E+05	6.06E+05	10.6	33,557	8.46	1,026	18,218	32.1	4.23E-05	0.009	9.34E-05	12,067	0.020	0.280	0.075	4.95E-03	266	327	3.47E-07	0.015	2.48	1.16E-04	1.25E-04	9.51E-10	3.04E-03	3.35E-05	196	51.4	0.0042	0.0050	0.0043	0.072	0.006	0.000	0.001	0.010	800	0.0010	0.0	3.20	453	0	0.0022	0.0037	0.0027	253	0.150	0	0.0048	0.223
108	6.40E+05	6.46E+05	10.6	33,579	8.44	1,026	18,230	32.1	4.23E-05	0.010	9.17E-05	12,048	0.020	0.280	0.075	4.95E-03	280	327	3.47E-07	0.015	2.48	1.13E-04	1.25E-04	9.75E-10	2.90E-03	3.35E-05	196	51.4	0.0042	0.0050	0.0043	0.070	0.006	0.000	0.001	0.010	800	0.0010	0.0	3.20	420	0	0.0022	0.0037	0.0031	253	0.148	0	0.0047	0.228
115	6.80E+05	6.86E+05	10.6	33,599	8.43	1,026	18,240	32.1	4.23E-05	0.010	9.04E-05	12,031	0.020	0.280	0.075	4.96E-03	292	327	3.47E-07	0.015	2.48	1.11E-04	1.25E-04	9.96E-10	2.79E-03	3.35E-05	196	51.4	0.0042	0.0050	0.0043	0.068	0.006	0.000	0.001	0.010	801	0.0011	0.0	3.20	390	0	0.0022	0.0037	0.0035	253	0.147	0	0.0046	0.233
122	7.20E+05	7.26E+05	10.6	33,616	8.43	1,026	18,248	32.1	4.23E-05	0.010	8.92E-05	12,016	0.020	0.280	0.075	4.96E-03	304	327	3.47E-07	0.015	2.48	1.10E-04	1.25E-04	1.01E-09	2.70E-03	3.35E-05	196	51.5	0.0042	0.0050	0.0043	0.067	0.006	0.000	0.001	0.010	801	0.0011	0.0	3.20	364	0	0.0022	0.0037	0.0037	253	0.146	0	0.0045	0.237
129	7.60E+05	7.66E+05	10.6	33,630	8.42	1,026	18,256	32.2	4.24E-05	0.010	8.82E-05	12,003	0.020	0.280	0.076	4.96E-03	314	327	3.47E-07	0.015	2.48	1.08E-04	1.26E-04	1.03E-09	2.63E-03	3.35E-05	196	51.5	0.0043	0.0050	0.0043	0.066	0.006	0.000	0.001	0.010	801	0.0011	0.0	3.20	341	0	0.0022	0.0037	0.0040	254	0.145	0	0.0044	0.240
136	8.00E+05	8.06E+05	10.5	33,639	8.41	1,026	18,264	32.2	4.24E-05	0.010	8.74E-05	11,991	0.020	0.280	0.076	4.96E-03	322	328	3.47E-07	0.015	2.48	1.07E-04	1.26E-04	1.04E-09	2.56E-03	3.35E-05	196	51.5	0.0043	0.0050	0.0043	0.065	0.006	0.000	0.001	0.010	802	0.0011	0.0	3.20	320	0	0.0022	0.0037	0.0042	254	0.144	0	0.0043	0.243
142	8.40E+05	8.46E+05	10.5	33,645	8.41	1,026	18,270	32.2	4.24E-05	0.011	8.67E-05	11,980	0.020	0.280	0.076	4.96E-03	331	328	3.48E-07	0.015	2.48	1.06E-04	1.26E-04	1.06E-09	2.51E-03	3.36E-05	196	51.5	0.0043	0.0050	0.0043	0.064	0.006	0.000	0.001	0.010	802	0.0011	0.0	3.20	301	0	0.0022	0.0037	0.0043	254	0.143	0	0.0042	0.246
149	8.80E+05	8.86E+05	10.5	33,650	8.40	1,026	18,276	32.2	4.24E-05	0.011	8.60E-05	11,970	0.020	0.280	0.076	4.97E-03	338	328	3.48E-07	0.015	2.48	1.05E-04	1.26E-04	1.07E-09	2.46E-03	3.36E-05	196	51.5	0.0043	0.0050	0.0043	0.063	0.006	0.000	0.001	0.010	802	0.0011	0.0	3.21	283	0	0.0022	0.0037	0.0045	254	0.142	0	0.0041	0.248
156	9.20E+05	9.26E+05	10.5	33,652	8.39	1,026	18,281	32.2	4.24E-05	0.011	8.55E-05	11,961	0.020	0.281	0.076	4.97E-03	345	328	3.48E-07	0.015	2.48	1.04E-04	1.26E-04	1.08E-09	2.42E-03	3.36E-05	196	51.6	0.0043	0.0050	0.0043	0.062	0.006	0.000	0.001	0.010	803	0.0011	0.0	3.21	268	0	0.0022	0.0037	0.0046	254	0.142	0	0.0040	0.250
163	9.60E+05	9.66E+05	10.5	33,655	8.39	1,026	18,286	32.2	4.24E-05	0.011	8.50E-05	11,953	0.020	0.281	0.076	4.97E-03	351	328	3.48E-07	0.015	2.48	1.03E-04	1.26E-04	1.09E-09	2.38E-03	3.36E-05	196	51.6	0.0043	0.0050	0.0043	0.062	0.006	0.000	0.001	0.010	803	0.0011	0.0	3.21	253	0	0.0022	0.0037	0.0047	254	0.141	0	0.0040	0.252
169	1.00E+06	1.01E+06	10.5	33,662	8.39	1,026	18,291	32.2	4.24E-05	0.011	8.45E-05	11,945	0.020	0.281	0.076	4.97E-03	357	328	3.48E-07	0.015	2.49	1.03E-04	1.26E-04	1.09E-09	2.35E-03	3.36E-05	197	51.6	0.0043	0.0050	0.0043	0.061	0.006	0.000	0.001	0.010	803	0.0011	0.0	3.21	240	0	0.0022	0.0037	0.0048	254	0.140	0	0.0039	0.254
186	1.10E+06	1.11E+06	10.5	33,677	8.38	1,026	18,301	32.2	4.25E-05	0.011	8.35E-05	11,928	0.020	0.281	0.076	4.97E-03	369	328	3.48E-07	0.015	2.49	1.01E-04	1.26E-04	1.11E-09	2.28E-03	3.36E-05	197	51.6	0.0044	0.0050	0.0043	0.060	0.006	0.000	0.001	0.010	803	0.0011	0.0	3.21	210	0	0.0022	0.0037	0.0050	254	0.139	0	0.0038	0.257
507	2.99E+06	3.00E+06	10.5	33,697	8.31	1,026	18,363	32.3	4.26E-05	0.013	7.84E-05	11,822	0.020	0.282	0.076	4.99E-03	448	329	3.49E-07	0.015	2.50	9.42E-05	1.26E-04	1.22E-09	1.93E-03	3.37E-05	197	51.8	0.0046	0.0050	0.0043	0.054	0.006	0.000	0.001	0.010	806	0.0011	0.0	3.22	25	0	0.0022	0.0037	0.0061	255	0.132	0	0.0027	0.275
827	4.88E+06	4.89E+06	8.87	33,686	8.30	1,026	18,378	32.4	4.26E-05	0.040	7.68E-05	11,798	0.020	0.282	0.076	4.99E-03	459	330	3.50E-07	0.015	2.50	7.71E-04	1.26E-04	3.12E-08	4.04E-03	3.38E-05	211	51.8	0.0050	0.0050	0.0043	0.001	0.006	0.654	0.001	0.010	807	0.0011	0.0	0	0	0	0.0014	0.0037	0	222	0	0	0	0.429
1147	6.77E+06	6.78E+06	8.37	33,694	8.28	1,026	18,384	32.4	4.27E-05	0.040	2.51E-05	11,788	0.020	0.282	0.076	5.00E-03	460	330	3.50E-07	0.015	2.50	1.86E-03	1.26E-04	1.83E-07	4.09E-03	3.38E-05	236	51.9	0.0050	0.0050	0.0043	0.000	0.006	0.654	0.001	0.010	807	0.0013	0.798	0	0	0	0	0.0035	0	160	0	0	0	0
1468	8.66E+06	8.67E+06	8.21	33,700	8.28	1,026	18,387	32.4	4.27E-05	0.040	1.75E-05	11,782	0.020	0.282	0.076	5.00E-03	460	330	3.50E-07	0.015	2.50	1.86E-03	1.26E-04	3.42E-07	4.10E-03	3.38E-05	250	51.9	0.0050	0.0050	0.0043	0.000	0.006	0.654	0.001	0.010	807	0.0013	0.799	0	0	0	0	0.0034	0	125	0	0	0	0
1788	1.06E+07	1.06E+07	8.13	33,703	8.27	1,026	18,390	32.4	4.27E-05	0.040	1.45E-05	11,778	0.020	0.282	0.076	5.00E-03	460	330	3.50E-07	0.015	2.50	1.86E-03	1.26E-04	4.88E-07	4.10E-03	3.38E-05	259	51.9	0.0050	0.0050	0.0043	0.000	0.006	0.654	0.001	0.010	807	0.0014	0.799	0	0	0	0	0.0034	0	102	0	0	0	0
2108	1.24E+07	1.24E+07	8.08	33,705	8.27	1,026	18,391	32.4	4.27E-05	0.040	1.30E-05	11,775	0.020	0.282	0.076	5.00E-03	460	330	3.50E-07	0.015	2.50	1.86E-03	1.26E-04	6.15E-07	4.11E-03	3.38E-05	265	51.9	0.0050	0.0050	0.0043	0.000	0.006	0.654	0.001	0.010	807	0.0014	0.799	0	0	0	0	0.0034	0	86.7	0	0	0	0
2429	1.43E+07	1.43E+07	8.04	33,707	8.27	1,026	18,392	32.4	4.27E-05	0.040	1.20E-05	11,773	0.020	0.282	0.076	5.00E-03	460	330	3.50E-07	0.015	2.50	1.86E-03	1.26E-04	7.24E-07	4.11E-03	3.38E-05	270	51.9	0.0050	0.0050	0.0043	0.000	0.006	0.654	0.001	0.010	807	0.0014	0.800	0	0	0	0	0.0034	0	75.3	0	0	0	0
2749	1.62E+07	1.62E+07	8.02	33,708	8.26	1,026	18,393	32.4	4.27E-05	0.040	1.13E-05	11,772	0.020	0.282	0.076	5.00E-03	460	330	3.50E-07	0.015	2.50	1.86E-03	1.26E-04	8.19E-07	4.11E-03	3.38E-05	273	51.9	0.0050	0.0050	0.0043	0.000	0.006	0.654	0.001	0.010	807	0.0014	0.800	0	0	0	0	0.0034	0	66.6	0	0	0	0
3069	1.81E+07	1.81E+07	8.00	33,709	8.26	1,026	18,394	32.4	4.27E-05	0.040	1.08E-05	11,770	0.020	0.282	0.076	5.00E-03	460	330	3.50E-07	0.015	2.50	1.86E-03	1.26E-04	9.01E-07	4.11E-03	3.38E-05	276	51.9	0.0050	0.0050	0.0043	0.000	0.006	0.654	0.001	0.010	808	0.0014	0.800	0	0	0	0	0.0034	0	59.7	0	0	0	0
3390	2.00E+07	2.00E+07	7.98	33,710	8.26	1,026	18,395	32.4	4.27E-05	0.040	1.05E-05	11,769	0.020	0.282	0.076	5.00E-03	460	330	3.50E-07	0.015	2.50	1.86E-03	1.26E-04	9.73E-07	4.11E-03	3.38E-05	278	51.9	0.0050	0.0050	0.0043	0.000	0.006	0.654	0.001	0.010	808	0.0014	0.800	0	0	0	0	0.0034	0	54.2	0	0	0	0

SCENARIO 2A

Dilution Ratio	Volume PoPA	Volume - Total	pH	Total Dissolved Solids	Temperature	Density - Total	Cl(-1)	Salinity	Si(+4)	S(+6)	Ni(+2)	Na(+1)	Mg(+2)	K(+1)	Fe(+3)	Cr(+3)	Co(+2)	Ca(+2)	Br(-1)	Al(+3)	Ti(+4)	TiO2 (Rutile)	SiO2 (lechatelierite)	NiFe2O4 (Trevorite)	NiCr2O4	NaAlCO3(OH)2 (Dawsonite)	CaCO3 (Calcite)
	L/hr	L/hr		mg/L	°C	kg/m3	mg/L	g/kg	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
0	0	5,900	2.26	28,755	30	1,020	22,041	39.0	53.6	0	18.1	0	7,379	0	2.43	0.05	0.853	138	0	1.13	0.002	0.098906	131	0	0	0	0
8	50,000	55,894	6.53	33,419	10.5	1,025	18,787	33.1	12.7	723	1.78	10,520	1,190	295	4.29E-08	1.07E-05	0.095	283	46.4	0.0099	0.001	8.41E-03	0	0.5379	0.016	1.300	0
17	1.00E+05	105,893	6.92	33,640	9.46	1,025	18,604	32.8	7.01	763	0.94	11,106	846	312	1.25E-08	1.28E-06	0.052	291	49.0	0.0008	0.001	3.31E-03	0	0.2839	0.011	1.088	0
25	1.50E+05	1.56E+05	7.12	33,500	9.07	1,025	18,539	32.7	4.97	777	0.64	11,315	722	318	7.48E-09	4.55E-07	0.037	294	49.9	0.0002	0.001	1.48E-03	0	0.1929	0.009	0.997	0
34	2.00E+05	2.06E+05	7.24	33,646	8.87	1,026	18,505	32.6	3.92	785	0.48	11,423	658	321	5.59E-09	2.37E-07	0.029	295	50.4	0.0001	0.001	5.36E-04	0	0.1460	0.008	0.950	0
42	2.50E+05	2.56E+05	7.34	33,735	8.75	1,026	18,485	32.6	3.29	789	0.39	11,489	620	322	4.63E-09	1.51E-07	0.025	296	50.7	7.60E-05	0.001	0	0	0.1175	0.007	0.921	0
51	3.00E+05	3.06E+05	7.40	33,794	8.67	1,026	18,471	32.5	2.86	792	0.32	11,533	593	324	4.07E-09	1.08E-07	0.021	297	50.9	5.95E-05	0.001	0	0	0.0983	0.007	0.901	0
59	3.50E+05	3.56E+05	7.46	33,837	8.61	1,026	18,461	32.5	2.55	794	0.28	11,565	575	325	3.71E-09	8.44E-08	0.019	297	51.0	5.16E-05	0.001	0	0	0.0845	0.007	0.887	0
68	4.00E+05	4.06E+05	7.50	33,870	8.56	1,026	18,453	32.5	2.31	796	0.24	11,589	561	325	3.47E-09	6.96E-08	0.017	298	51.1	4.75E-05	8.92E-04	0	0	0.0741	0.006	0.876	0
76	4.50E+05	4.56E+05	7.54	33,895	8.53	1,026	18,447	32.5	2.13	797	0.22	11,608	550	326	3.30E-09	5.98E-08	0.016	298	51.2	4.55E-05	7.94E-04	0	0	0.0660	0.006	0.868	0
85	5.00E+05	5.06E+05	7.57	33,884	8.50	1,026	18,443	32.5	1.99	798	0.20	11,623	541	326	3.17E-09	5.29E-08	0.015	298	51.3	4.44E-05	7.16E-04	0	0	0.0594	0.006	0.861	0
93	5.50E+05	5.56E+05	7.59	33,871	8.48	1,026	18,439	32.5	1.87	799	0.18	11,635	533	327	3.09E-09	4.80E-08	0.014	298	51.3	4.40E-05	6.52E-04	0	0	0.0541	0.006	0.856	0
102	6.00E+05	6.06E+05	7.62	33,861	8.46	1,026	18,436	32.5	1.77	800	0.16	11,646	527	327	3.02E-09	4.43E-08	0.013	298	51.4	4.39E-05	5.98E-04	0	0	0.0496	0.006	0.851	0
110	6.50E+05	6.56E+05	7.64	33,851	8.44	1,026	18,433	32.5	1.68	801	0.15	11,654	522	327	2.97E-09	4.15E-08	0.013	299	51.4	4.40E-05	5.52E-04	0	0	0.0458	0.006	0.847	0
119	7.00E+05	7.06E+05	7.65	33,849	8.43	1,026	18,431	32.5	1.61	801	0.14	11,662	518	327	2.94E-09	3.93E-08	0.012	299	51.5	4.43E-05	5.13E-04	0	0	0.0426	0.006	0.844	0
127	7.50E+05	7.56E+05	7.67	33,851	8.42	1,026	18,429	32.5	1.55	801	0.13	11,668	514	327	2.92E-09	3.76E-08	0.012	299	51.5	4.46E-05	4.79E-04	0	0	0.0398	0.006	0.841	0
136	8.00E+05	8.06E+05	7.68	33,853	8.41	1,026	18,427	32.5	1.49	802	0.12	11,674	511	328	2.90E-09	3.62E-08	0.011	299	51.5	4.49E-05	4.49E-04	0	0	0.0373	0.006	0.839	0
144	8.50E+05	8.56E+05	7.69	33,825	8.40	1,026	18,425	32.5	1.44	802	0.12	11,679	508	328	2.89E-09	3.50E-08	0.011	299	51.5	4.53E-05	4.23E-04	0	0	0.0351	0.006	0.836	0
153	9.00E+05	9.06E+05	7.70	33,856	8.39	1,026	18,424	32.5	1.40	803	0.11	11,684	505	328	2.89E-09	3.41E-08	0.011	299	51.6	4.56E-05	4.00E-04	0	0	0.0332	0.005	0.834	0
161	9.50E+05	9.56E+05	7.71	33,858	8.38	1,026	18,423	32.5	1.36	803	0.10	11,688	503	328	2.89E-09	3.33E-08	0.010	299	51.6	4.60E-05	3.79E-04	0	0	0.0315	0.005	0.833	0
169	1.00E+06	1.01E+06	7.72	33,813	8.38	1,026	18,422	32.4	1.32	803	0.10	11,691	501	328	2.89E-09	3.27E-08	0.010	299	51.6	4.64E-05	3.60E-04	0	0	0.0299	0.005	0.831	0
254	1.50E+06	1.51E+06	7.78	33,789	8.33	1,026	18,414	32.4	1.10	805	0.07	11,714	487	329	3.03E-09	3.02E-08	0.008	299	51.7	4.94E-05	2.40E-04	0	0	0.0200	0.005	0.821	0
330	1.95E+06	1.96E+06	7.81	33,777	8.32	1,026	18,411	32.4	1.00	805	0.05	11,725	481	329	3.21E-09	3.03E-08	0.008	300	51.7	5.12E-05	1.85E-04	0	0	0.0154	0.005	0.816	0
407	2.40E+06	2.41E+06	7.82	33,874	8.30	1,026	18,409	32.4	0.93	806	0.04	11,731	477	329	3.40E-09	3.11E-08	0.007	300	51.8	5.24E-05	1.51E-04	0	0	0.0125	0.005	0.813	0
483	2.85E+06	2.86E+06	7.84	33,876	8.29	1,026	18,408	32.4	0.89	806	0.03	11,736	474	329	3.60E-09	3.21E-08	0.007	300	51.8	5.33E-05	1.27E-04	0	0	0.0105	0.005	0.811	0
559	3.30E+06	3.31E+06	7.84	33,877	8.29	1,026	18,407	32.4	0.86	806	0.03	11,739	472	329	3.79E-09	3.33E-08	0.007	300	51.8	5.40E-05	1.10E-04	0	0	0.0091	0.005	0.810	0
636	3.75E+06	3.76E+06	7.85	33,878	8.28	1,026	18,406	32.4	0.83	807	0.03	11,742	471	329	3.98E-09	3.45E-08	0.006	300	51.8	5.45E-05	9.64E-05	0	0	0.0080	0.005	0.808	0
712	4.20E+06	4.21E+06	7.85	33,878	8.28	1,026	18,405	32.4	0.81	807	0.02	11,744	470	330	4.20E-09	3.64E-08	0.006	300	51.8	5.46E-05	8.61E-05	0	0	0.0071	0.005	0.808	0.096
788	4.65E+06	4.66E+06	7.85	33,879	8.28	1,026	18,405	32.4	0.80	807	0.02	11,745	469	330	4.43E-09	3.84E-08	0.006	300	51.8	5.46E-05	7.78E-05	0	0	0.0065	0.005	0.807	0.191
864	5.10E+06	5.11E+06	7.85	33,879	8.28	1,026	18,404	32.4	0.79	807	0.02	11,746	468	330	4.65E-09	4.03E-08	0.006	300	51.8	5.46E-05	7.09E-05	0	0	0.0059	0.005	0.806	0.269
941	5.55E+06	5.56E+06	7.85	33,880	8.27	1,026	18,404	32.4	0.78	807	0.02	11,748	467	330	4.85E-09	4.21E-08	0.006	300	51.8	5.46E-05	6.52E-05	0	0	0.0054	0.005	0.806	0.334
1017	6.00E+06	6.01E+06	7.85	33,880	8.27	1,026	18,404	32.4	0.77	807	0.02	11,749	467	330	5.06E-09	4.38E-08	0.006	300	51.8	5.46E-05	6.03E-05	0	0	0.0050	0.005	0.805	0.390
1102	6.50E+06	6.51E+06	7.85	33,881	8.27	1,026	18,403	32.4	0.76	807	0.01	11,749	466	330	5.27E-09	4.57E-08	0.006	300	51.9	5.46E-05	5.57E-05	0	0	0.0046	0.005	0.805	0.443

SCENARIO 2B

Dilution Ratio	Volume - Reconcile _PoPA_W O	Volume - Total	pH	Total Dissolved Solids	Temperat ure	Density - Total	Cl(-1)	Salinity	Si(+4)	Se(+4)	S(+6)	Pb(+2)	P(+5)	Ni(+2)	Na(+1)	N(-3)	Mo(+6)	Mg(+2)	K(+1)	Hg(+2)	Co(+2)	Zn(+2)	Cd(+2)	Ca(+2)	Br(-1)	As(+5)	NiCr2O4	NaAlCO3(OH)2 (Dawsonit e)	CoCr2O4	CaF2 (Fluorite)	CaCO3 (Calcite)
	L/hr	L/hr		mg/L	°C	kg/m3	mg/L	g/kg	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
0	0	5,901	8.10	39,282	30.0	1,028	25,165	44.2	0	0.0192	0	2.50E-03	0	1.00E-03	107	0	1.00E-04	198	0	2.00E-03	3.00E-04	3.00E-04	2.00E-04	13,805	0	0.100	0	0	0	0	463
8	50,000	55,892	7.18	34,511	10.5	1,026	19,117	33.7	0.585	0.0027	723	3.02E-04	0.036	2.02E-06	10,532	0.018	1.06E-05	432	295	2.11E-04	3.89E-03	5.76E-03	5.14E-05	1,718	46.4	0.014	0.0017	0.72	0.0024	0.09	67.1
17	#######	105,891	7.36	34,217	9.45	1,026	18,779	33.1	0.618	0.0018	763	1.80E-04	0.038	2.80E-06	11,112	0.019	5.57E-06	445	312	1.12E-04	3.98E-03	6.06E-03	4.31E-05	1,047	49.0	0.010	0.0015	0.76	0.0029	0	38.9
25	#######	#######	7.46	33,567	9.06	1,026	18,657	32.9	0.630	0.0015	777	1.36E-04	0.038	3.40E-06	11,320	0.019	3.78E-06	450	318	7.60E-05	4.02E-03	6.17E-03	4.01E-05	807	49.9	0.008	0.0015	0.77	0.0031	0	27.8
34	#######	#######	7.52	34,056	8.87	1,026	18,595	32.8	0.636	0.0013	785	1.13E-04	0.039	3.88E-06	11,427	0.020	2.87E-06	453	321	5.77E-05	4.04E-03	6.23E-03	3.86E-05	684	50.4	0.007	0.0015	0.78	0.0032	0	21.9
42	#######	#######	7.57	34,023	8.75	1,026	18,557	32.7	0.639	0.0012	789	9.94E-05	0.039	4.26E-06	11,492	0.020	2.31E-06	454	322	4.65E-05	4.06E-03	6.26E-03	3.76E-05	608	50.7	0.007	0.0015	0.78	0.0032	0	18.1
51	#######	#######	7.60	34,000	8.67	1,026	18,531	32.6	0.642	0.0011	792	9.01E-05	0.039	4.58E-06	11,536	0.020	1.93E-06	455	324	3.89E-05	4.07E-03	6.28E-03	3.70E-05	558	50.9	0.006	0.0014	0.78	0.0032	0	15.6
59	#######	#######	7.63	33,984	8.61	1,026	18,513	32.6	0.644	0.0011	794	8.34E-05	0.039	4.84E-06	11,567	0.020	1.66E-06	456	325	3.35E-05	4.07E-03	6.30E-03	3.66E-05	522	51.0	0.006	0.0014	0.79	0.0033	0	13.7
68	#######	#######	7.65	33,972	8.56	1,026	18,499	32.6	0.645	0.0011	796	7.84E-05	0.039	5.07E-06	11,591	0.020	1.45E-06	456	325	2.94E-05	4.08E-03	6.31E-03	3.62E-05	494	51.1	0.006	0.0014	0.79	0.0033	0	12.2
76	#######	#######	7.67	33,962	8.53	1,026	18,488	32.6	0.646	0.0010	797	7.45E-05	0.039	5.26E-06	11,610	0.020	1.29E-06	457	326	2.62E-05	4.08E-03	6.32E-03	3.60E-05	473	51.2	0.006	0.0014	0.79	0.0033	0	11.1
85	#######	#######	7.68	33,955	8.50	1,026	18,479	32.5	0.647	9.98E-04	798	7.14E-05	0.040	5.43E-06	11,624	0.020	1.17E-06	457	326	2.37E-05	4.09E-03	6.33E-03	3.57E-05	456	51.3	0.005	0.0014	0.79	0.0033	0	10.2
93	#######	#######	7.70	33,948	8.48	1,026	18,472	32.5	0.647	9.78E-04	799	6.88E-05	0.040	5.58E-06	11,637	0.020	1.06E-06	457	327	2.16E-05	4.09E-03	6.34E-03	3.56E-05	442	51.4	0.005	0.0014	0.79	0.0033	0	9.38
102	#######	#######	7.71	33,943	8.46	1,026	18,466	32.5	0.648	9.62E-04	800	6.66E-05	0.040	5.71E-06	11,647	0.020	9.74E-07	457	327	1.98E-05	4.09E-03	6.34E-03	3.54E-05	430	51.4	0.005	0.0014	0.79	0.0033	0	8.73
110	#######	#######	7.72	33,939	8.44	1,026	18,461	32.5	0.649	9.49E-04	801	6.48E-05	0.040	5.82E-06	11,655	0.020	8.99E-07	458	327	1.83E-05	4.09E-03	6.35E-03	3.53E-05	420	51.4	0.005	0.0014	0.79	0.0033	0	8.18
119	#######	#######	7.72	33,935	8.43	1,026	18,457	32.5	0.649	9.37E-04	801	6.32E-05	0.040	5.93E-06	11,663	0.020	8.36E-07	458	327	1.71E-05	4.09E-03	6.35E-03	3.52E-05	411	51.5	0.005	0.0014	0.79	0.0033	0	7.70
127	#######	#######	7.73	33,932	8.42	1,026	18,453	32.5	0.649	9.27E-04	802	6.19E-05	0.040	6.02E-06	11,669	0.020	7.80E-07	458	327	1.60E-05	4.10E-03	6.35E-03	3.51E-05	404	51.5	0.005	0.0014	0.79	0.0033	0	7.28
136	#######	#######	7.74	33,929	8.41	1,026	18,450	32.5	0.650	9.18E-04	802	6.07E-05	0.040	6.11E-06	11,675	0.020	7.32E-07	458	328	1.50E-05	4.10E-03	6.36E-03	3.50E-05	397	51.5	0.005	0.0014	0.79	0.0033	0	6.92
144	#######	#######	7.74	33,926	8.40	1,026	18,447	32.5	0.650	9.10E-04	802	5.96E-05	0.040	6.19E-06	11,680	0.020	6.89E-07	458	328	1.41E-05	4.10E-03	6.36E-03	3.49E-05	392	51.5	0.005	0.0014	0.79	0.0034	0	6.59
153	#######	#######	7.75	33,924	8.39	1,026	18,444	32.5	0.650	9.03E-04	803	5.87E-05	0.040	6.26E-06	11,684	0.020	6.51E-07	458	328	1.34E-05	4.10E-03	6.36E-03	3.49E-05	387	51.6	0.005	0.0014	0.80	0.0034	0	6.30
161	#######	#######	7.75	33,922	8.38	1,026	18,442	32.5	0.650	8.97E-04	803	5.79E-05	0.040	6.32E-06	11,688	0.020	6.17E-07	458	328	1.27E-05	4.10E-03	6.36E-03	3.48E-05	382	51.6	0.005	0.0014	0.80	0.0034	0	6.04
169	#######	#######	7.76	33,920	8.38	1,026	18,440	32.5	0.651	8.91E-04	803	5.71E-05	0.040	6.38E-06	11,692	0.020	5.86E-07	458	328	1.21E-05	4.10E-03	6.36E-03	3.48E-05	378	51.6	0.005	0.0014	0.80	0.0034	0	5.80
254	#######	#######	7.79	33,908	8.33	1,026	18,427	32.5	0.652	8.55E-04	805	5.23E-05	0.040	6.80E-06	11,714	0.020	3.92E-07	459	329	8.18E-06	4.10E-03	6.38E-03	3.45E-05	352	51.7	0.005	0.0014	0.80	0.0034	0	4.27
330	#######	#######	7.80	33,903	8.31	1,026	18,421	32.4	0.652	8.38E-04	805	5.01E-05	0.040	7.01E-06	11,725	0.020	3.02E-07	459	329	6.38E-06	4.11E-03	6.38E-03	3.43E-05	340	51.7	0.005	0.0014	0.80	0.0034	0	3.56
407	#######	#######	7.81	33,899	8.30	1,026	18,417	32.4	0.653	8.28E-04	806	4.87E-05	0.040	7.15E-06	11,732	0.020	2.45E-07	459	329	5.25E-06	4.11E-03	6.39E-03	3.42E-05	332	51.8	0.005	0.0014	0.80	0.0034	0	3.10
483	#######	#######	7.82	33,897	8.29	1,026	18,414	32.4	0.653	8.21E-04	806	4.78E-05	0.040	7.25E-06	11,736	0.020	2.07E-07	459	329	4.48E-06	4.11E-03	6.39E-03	3.41E-05	327	51.8	0.005	0.0014	0.80	0.0034	0	2.79
559	#######	#######	7.82	33,895	8.29	1,026	18,412	32.4	0.653	8.16E-04	806	4.71E-05	0.040	7.33E-06	11,739	0.020	1.78E-07	460	329	3.92E-06	4.11E-03	6.39E-03	3.41E-05	323	51.8	0.004	0.0014	0.80	0.0034	0	2.56
635	#######	#######	7.83	33,894	8.28	1,026	18,411	32.4	0.653	8.12E-04	807	4.66E-05	0.040	7.39E-06	11,742	0.020	1.57E-07	460	329	3.49E-06	4.11E-03	6.39E-03	3.41E-05	321	51.8	0.004	0.0014	0.80	0.0034	0	2.38
712	#######	#######	7.83	33,893	8.28	1,026	18,410	32.4	0.653	8.09E-04	807	4.61E-05	0.040	7.43E-06	11,744	0.020	1.40E-07	460	330	3.16E-06	4.11E-03	6.39E-03	3.40E-05	318	51.8	0.004	0.0014	0.80	0.0034	0	2.24
788	#######	#######	7.83	33,892	8.28	1,026	18,409	32.4	0.654	8.06E-04	807	4.58E-05	0.040	7.47E-06	11,745	0.020	1.27E-07	460	330	2.88E-06	4.11E-03	6.39E-03	3.40E-05	316	51.8	0.004	0.0014	0.80	0.0034	0	2.13
864	#######	#######	7.83	33,891	8.27	1,026	18,408	32.4	0.654	8.04E-04	807	4.55E-05	0.040	7.50E-06	11,747	0.020	1.16E-07	460	330	2.66E-06	4.11E-03	6.39E-03	3.40E-05	315	51.8	0.004	0.0014	0.80	0.0034	0	2.04
941	#######	#######	7.83	33,891	8.27	1,026	18,407	32.4	0.654	8.02E-04	807	4.53E-05	0.040	7.53E-06	11,748	0.020	1.06E-07	460	330	2.47E-06	4.11E-03	6.39E-03	3.40E-05	314	51.8	0.004	0.0014	0.80	0.0034	0	1.96
1017	#######	#######	7.84	33,890	8.27	1,026	18,407	32.4	0.654	8.01E-04	807	4.51E-05	0.040	7.55E-06	11,749	0.020	9.82E-08	460	330	2.31E-06	4.11E-03	6.39E-03	3.40E-05	313	51.8	0.004	0.0014	0.80	0.0034	0	1.90
1102	#######	#######	7.84	33,890	8.27	1,026	18,406	32.4	0.654	7.99E-04	807	4.49E-05	0.040	7.57E-06	11,750	0.020	9.07E-08	460	330	2.16E-06	4.11E-03	6.39E-03	3.40E-05	312	51.9	0.004	0.0014	0.80	0.0034	0	1.83
2158	#######	#######	7.85	33,887	8.26	1,026	18,403	32.4	0.654	7.91E-04	807	4.38E-05	0.040	7.71E-06	11,755	0.020	4.63E-08	460	330	1.28E-06	4.11E-03	6.40E-03	3.39E-05	306	51.9	0.004	0.0014	0.80	0.0034	0	1.46
3214	#######	#######	7.85	33,886	8.26	1,026	18,402	32.4	0.654	7.89E-04	808	4.35E-05	0.040	7.75E-06	11,756	0.020	3.11E-08	460	330	9.72E-07	4.11E-03	6.40E-03	3.39E-05	304	51.9	0.004	0.0014	0.80	0.0034	0	1.34
4270	#######	#######	7.85	33,886	8.26	1,026	18,402	32.4	0.654	7.87E-04	808	4.33E-05	0.040	7.78E-06	11,757	0.020	2.34E-08	460	330	8.18E-07	4.11E-03	6.40E-03	3.38E-05	303	51.9	0.004	0.0014	0.80	0.0034	0	1.27
5327	#######	#######	7.85	33,886	8.25	1,026	18,401	32.4	0.654	7.86E-04	808	4.32E-05	0.040	7.79E-06	11,758	0.020	1.88E-08	460	330	7.25E-07	4.11E-03	6.40E-03	3.38E-05	302	51.9	0.004	0.0014	0.80	0.0034	0	1.23
6383	#######	#######	7.85	33,885	8.25	1,026	18,401	32.4	0.654	7.86E-04	808	4.31E-05	0.040	7.80E-06	11,758	0.020	0	460	330	6.63E-07	4.11E-03	6.40E-03	3.38E-05	302	51.9	0.004	0.0014	0.80	0.0034	0	1.21
7439	#######	#######	7.85	33,885	8.25	1,026	18,401	32.4	0.654	7.85E-04	808	4.30E-05	0.040	7.81E-06	11,758	0.020	0	460	330	6.19E-07	4.11E-03	6.40E-03	3.38E-05	301	51.9	0.004	0.0014	0.80	0.0034	0	1.19
8496	#######	#######	7.85	33,885	8.25	1,026	18,401	32.4	0.654	7.85E-04	808	4.30E-05	0.040	7.81E-06	11,759	0.020	0	460	330	5.85E-07	4.11E-03	6.40E-03	3.38E-05	301	51.9	0.004	0.0014	0.80	0.0034	0	1.17
9552	#######	#######	7.85	33,885	8.25	1,026	18,401	32.4	0.654	7.85E-04	808	4.30E-05	0.040	7.82E-06	11,759	0.020	0	460	330	5.59E-07	4.11E-03	6.40E-03	3.38E-05	301	51.9	0.004	0.0014	0.80	0.0034	0	1.16
10608	#######	#######	7.85	33,885	8.25	1,026	18,401	32.4	0.654	7.85E-04	808	4.29E-05	0.040	7.82E-06	11,759	0.020	0	460	330	5.38E-07	4.11E-03	6.40E-03	3.38E-05	301	51.9	0.004	0.0014	0.80	0.0034	0	1.15
11665	#######	#######	7.85	33,885	8.25	1,026	18,401	32.4	0.654	7.84E-04	808	4.29E-05	0.040	7.82E-06	11,759	0.020	0	460	330	5.21E-07	4.11E-03	6.40E-03	3.38E-05	301	51.9	0.004	0.0014	0.80	0.0034	0	1.15
12721	#######	#######	7.85	33,885	8.25	1,026	18,401	32.4	0.654	7.84E-04	808	4.29E-05	0.040	7.82E-06	11,759	0.020	0	460	330	5.07E-07	4.11E-03	6.40E-03	3.38E-05	301	51.9	0.004	0.0014	0.80	0.0034	0	1.14
13777	#######	#######	7.85	33,885	8.25	1,026	18,401	32.4	0.654	7.84E-04	808	4.29E-05	0.040	7.83E-06	11,759	0.020	0	460	330	4.95E-07	4.11E-03	6.40E-03	3.38E-05	301	51.9	0.004	0.0014	0.80	0.0034	0	1.14
14834	#######	#######	7.85	33,885	8.25	1,026	18,401	32.4	0.654	7.84E-04	808	4.29E-05	0.040	7.83E-06	11,759	0.020	0	460	330	4.85E-07	4.11E-03	6.40E-03	3.38E-05	300	51.9	0.004	0.0014	0.80	0.0034	0	1.13
15890	#######	#######	7.85	33,885	8.25	1,026	18,400	32.4	0.654	7.84E-04	808	4.29E-05	0.040	7.83E-06	11,759	0.020	0	460	330	4.76E-07	4.11E-03	6.40E-03	3.38E-05	300	51.9	0.004	0.0014	0.80	0.0034	0	1.13
16946	#######	#######	7.85	33,885	8.25	1,026	18,400	32.4	0.654	7.84E-04	808	4.28E-05	0.040	7.83E-06	11,759	0.020	0	460	330	4.68E-07	4.11E-03	6.40E-03	3.38E-05	300	51.9	0.004	0.0014	0.80	0.0034	0	1.12

SCENARIO 3

Dilution Ratio	Volume - PoPA	Volume - Total	pH	Total Dissolved Solids	Temperature	Density - Total	Cl(-1)	Salinity	Si(+4)	Se(+4)	Sb(+5)	S(+6)	Pb(+2)	P(+5)	Ni(+2)	Na(+1)	N(-3)	N(+5)	N(+3)	Mn(+2)
	L/hr	L/hr		mg/L	°C	kg/m3	mg/L	g/kg	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
0	0	27,001	7.10	55,069	17.0	1,042	31,372	54.4	0	7.83E-04	0	1,643	0.003	0	1.26E-07	12,500	0	0	0	0
0.4	10,000	36,995	7.24	49,219	14.6	1,037	27,870	48.5	0.18	7.83E-04	0.003	1,417	0.002	0.011	4.22E-06	12,302	0.005	0.076	0.021	0.001
0.7	20,000	46,992	7.33	45,859	13.3	1,035	25,857	45.1	0.28	7.83E-04	0.004	1,288	0.001	0.017	5.05E-06	12,187	0.009	0.120	0.032	0.002
1.1	30,000	56,990	7.39	43,681	12.4	1,033	24,549	42.9	0.34	7.83E-04	0.005	1,204	0.001	0.021	5.40E-06	12,113	0.011	0.149	0.040	0.003
1.5	40,000	66,989	7.44	42,157	11.8	1,032	23,632	41.4	0.39	7.83E-04	0.006	1,145	0.001	0.024	5.63E-06	12,060	0.012	0.169	0.045	0.003
1.9	50,000	76,987	7.48	41,032	11.3	1,031	22,952	40.2	0.43	7.83E-04	0.006	1,101	9.05E-04	0.026	5.79E-06	12,022	0.013	0.183	0.049	0.003
2.2	60,000	86,987	7.51	40,463	10.9	1,031	22,429	39.3	0.45	7.83E-04	0.007	1,067	8.05E-04	0.028	5.92E-06	11,992	0.014	0.195	0.053	0.003
2.6	70,000	96,986	7.54	39,785	10.7	1,030	22,014	38.6	0.47	7.83E-04	0.007	1,040	7.27E-04	0.029	6.04E-06	11,968	0.015	0.204	0.055	0.004
3.0	80,000	1.07E+05	7.56	39,234	10.4	1,030	21,676	38.0	0.49	7.83E-04	0.007	1,019	6.63E-04	0.030	6.13E-06	11,948	0.015	0.211	0.057	0.004
3.3	90,000	1.17E+05	7.58	38,777	10.3	1,029	21,396	37.5	0.50	7.83E-04	0.008	1,001	6.10E-04	0.031	6.22E-06	11,932	0.016	0.217	0.059	0.004
3.7	1.00E+05	1.27E+05	7.60	38,392	10.1	1,029	21,160	37.1	0.52	7.83E-04	0.008	985	5.65E-04	0.031	6.29E-06	11,919	0.016	0.222	0.060	0.004
7	2.00E+05	2.27E+05	7.70	36,406	9.28	1,028	19,945	35.1	0.58	7.83E-04	0.009	907	3.35E-04	0.035	6.78E-06	11,849	0.018	0.249	0.067	0.004
44	1.18E+06	1.21E+06	7.82	34,359	8.44	1,026	18,691	32.9	0.64	7.83E-04	0.010	826	9.77E-05	0.039	7.58E-06	11,777	0.020	0.276	0.074	0.005
80	2.16E+06	2.19E+06	7.83	34,146	8.36	1,026	18,560	32.7	0.65	7.83E-04	0.010	818	7.30E-05	0.040	7.70E-06	11,769	0.020	0.279	0.075	0.005
116	3.14E+06	3.17E+06	7.84	34,065	8.32	1,026	18,511	32.6	0.65	7.83E-04	0.010	815	6.36E-05	0.040	7.74E-06	11,766	0.020	0.280	0.075	0.005
153	4.12E+06	4.15E+06	7.84	34,022	8.31	1,026	18,485	32.6	0.65	7.83E-04	0.010	813	5.87E-05	0.040	7.77E-06	11,765	0.020	0.281	0.076	0.005
189	5.10E+06	5.13E+06	7.85	33,996	8.30	1,026	18,468	32.5	0.65	7.83E-04	0.010	812	5.56E-05	0.040	7.78E-06	11,764	0.020	0.281	0.076	0.005
225	6.08E+06	6.11E+06	7.85	33,978	8.29	1,026	18,457	32.5	0.65	7.83E-04	0.010	811	5.36E-05	0.040	7.79E-06	11,763	0.020	0.281	0.076	0.005
261	7.06E+06	7.09E+06	7.85	33,965	8.28	1,026	18,450	32.5	0.65	7.83E-04	0.010	811	5.21E-05	0.040	7.80E-06	11,763	0.020	0.281	0.076	0.005
298	8.04E+06	8.07E+06	7.85	33,955	8.28	1,026	18,444	32.5	0.65	7.83E-04	0.010	811	5.09E-05	0.040	7.81E-06	11,763	0.020	0.281	0.076	0.005
334	9.02E+06	9.05E+06	7.85	33,948	8.28	1,026	18,439	32.5	0.65	7.83E-04	0.010	810	5.00E-05	0.040	7.81E-06	11,762	0.020	0.282	0.076	0.005
370	1.00E+07	1.00E+07	7.85	33,941	8.27	1,026	18,435	32.5	0.65	7.83E-04	0.010	810	4.93E-05	0.040	7.81E-06	11,762	0.020	0.282	0.076	0.005
37	1.00E+06	1.03E+06	7.81	34,442	8.48	1,026	18,741	33.0	0.64	7.83E-04	0.010	830	1.07E-04	0.039	7.54E-06	11,780	0.020	0.275	0.074	0.005
404	1.09E+07	1.09E+07	7.85	33,937	8.27	1,026	18,432	32.5	0.65	7.83E-04	0.010	810	4.88E-05	0.040	7.82E-06	11,762	0.020	0.282	0.076	0.005
770	2.08E+07	2.08E+07	7.85	33,912	8.26	1,026	18,417	32.4	0.65	7.83E-04	0.010	809	4.59E-05	0.040	7.83E-06	11,761	0.020	0.282	0.076	0.005
1137	3.07E+07	3.07E+07	7.85	33,903	8.26	1,026	18,411	32.4	0.65	7.83E-04	0.010	809	4.49E-05	0.040	7.84E-06	11,761	0.020	0.282	0.076	0.005
1504	4.06E+07	4.06E+07	7.85	33,898	8.26	1,026	18,409	32.4	0.65	7.83E-04	0.010	808	4.43E-05	0.040	7.84E-06	11,761	0.020	0.282	0.076	0.005
1870	5.05E+07	5.05E+07	7.85	33,896	8.25	1,026	18,407	32.4	0.65	7.83E-04	0.010	808	4.40E-05	0.040	7.84E-06	11,760	0.020	0.282	0.076	0.005
2237	6.04E+07	6.04E+07	7.85	33,894	8.25	1,026	18,406	32.4	0.65	7.83E-04	0.010	808	4.38E-05	0.040	7.84E-06	11,760	0.020	0.282	0.076	0.005
2604	7.03E+07	7.03E+07	7.85	33,893	8.25	1,026	18,405	32.4	0.65	7.83E-04	0.010	808	4.36E-05	0.040	7.84E-06	11,760	0.020	0.282	0.076	0.005
2970	8.02E+07	8.02E+07	7.85	33,892	8.25	1,026	18,404	32.4	0.65	7.83E-04	0.010	808	4.35E-05	0.040	7.84E-06	11,760	0.020	0.282	0.076	0.005
3337	9.01E+07	9.01E+07	7.85	33,891	8.25	1,026	18,404	32.4	0.65	7.83E-04	0.010	808	4.34E-05	0.040	7.84E-06	11,760	0.020	0.282	0.076	0.005
3704	1.00E+08	1.00E+08	7.85	33,890	8.25	1,026	18,404	32.4	0.65	7.83E-04	0.010	808	4.34E-05	0.040	7.85E-06	11,760	0.020	0.282	0.076	0.005

Dilution Ratio	Mg(+2)	Zn(+2)	K(+1)	Hg(+2)	Fe(+2)	F(-1)	Cu(+2)	Cr(+6)	Cr(+3)	Co(+2)	Cd(+2)	Ca(+2)	Br(-1)	Be(+2)	Ba(+2)	As(+5)	Al(+3)	NiCr2O4	NaAlCO3(OH)2 (Dawsonite)	CoCr2O4	CaCO3 (Calcite)
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
0	4,631	0.001	0	6.50E-08	0	0	3.74E-04	2.69E-04	7.82E-04	0	7.79E-05	1,328	53.0	0	0	3.26E-03	0	0.003	0	0	54.9
0.4	3,504	0.003	89.2	1.42E-07	0.004	0.68	7.76E-04	2.30E-04	6.36E-05	0.0008	6.60E-05	1,050	52.7	0.0014	0.0014	0.0035	3.84E-05	0.003	0.216	0.0020	39.7
0.7	2,857	0.004	140	1.86E-07	0.006	1.06	0.0010	2.08E-04	3.53E-05	0.0015	5.91E-05	891	52.5	0.0021	0.0021	0.0037	3.82E-05	0.002	0.341	0.0024	31.3
1.1	2,436	0.004	174	2.15E-07	0.008	1.32	0.0012	1.94E-04	2.39E-05	0.0020	5.47E-05	787	52.4	0.0026	0.0026	0.0038	3.84E-05	0.002	0.421	0.0026	25.9
1.5	2,141	0.004	197	2.35E-07	0.009	1.49	0.0013	1.84E-04	1.79E-05	0.0023	5.16E-05	714	52.4	0.0030	0.0030	0.0039	3.89E-05	0.002	0.478	0.0027	22.1
1.9	1,923	0.005	214	2.50E-07	0.010	1.62	0.0013	1.76E-04	1.43E-05	0.0025	4.93E-05	661	52.3	0.0032	0.0032	0.0039	3.94E-05	0.002	0.520	0.0028	19.4
2.2	1,755	0.005	228	2.62E-07	0.010	1.72	0.0014	1.71E-04	1.19E-05	0.0027	4.75E-05	619	52.2	0.0034	0.0034	0.0040	4.00E-05	0.002	0.552	0.0029	17.3
2.6	1,621	0.005	238	2.71E-07	0.011	1.80	0.0014	1.66E-04	1.02E-05	0.0029	4.61E-05	586	52.2	0.0036	0.0036	0.0040	4.05E-05	0.002	0.578	0.0029	15.6
3.0	1,513	0.005	247	2.78E-07	0.011	1.87	0.0015	1.62E-04	9.00E-06	0.0030	4.49E-05	559	52.2	0.0037	0.0037	0.0040	4.10E-05	0.002	0.598	0.0030	14.3
3.3	1,423	0.005	254	2.84E-07	0.012	1.92	0.0015	1.59E-04	8.07E-06	0.0031	4.40E-05	537	52.2	0.0038	0.0038	0.0041	4.15E-05	0.002	0.616	0.0030	13.1
3.7	1,347	0.005	260	2.89E-07	0.012	1.97	0.0015	1.57E-04	7.35E-06	0.0031	4.32E-05	518	52.1	0.0039	0.0039	0.0041	4.20E-05	0.002	0.630	0.0030	12.2
7	956	0.006	291	3.16E-07	0.013	2.20	0.0017	1.43E-04	4.36E-06	0.0036	3.90E-05	422	52.0	0.0044	0.0044	0.0042	4.55E-05	0.002	0.705	0.0032	7.32
44	553	0.006	323	3.44E-07	0.015	2.44	0.0018	1.30E-04	2.31E-06	0.0040	3.48E-05	323	51.9	0.0049	0.0049	0.0043	5.22E-05	0.001	0.782	0.0034	2.26
80	511	0.006	326	3.46E-07	0.015	2.47	0.0018	1.28E-04	2.14E-06	0.0041	3.43E-05	312	51.9	0.0049	0.0049	0.0043	5.31E-05	0.001	0.790	0.0034	1.73
116	496	0.006	327	3.48E-07	0.015	2.48	0.0018	1.28E-04	2.08E-06	0.0041	3.42E-05	308	51.9	0.0050	0.0050	0.0043	5.35E-05	0.001	0.793	0.0034	1.53
153	487	0.006	328	3.48E-07	0.015	2.48	0.0019	1.27E-04	2.05E-06	0.0041	3.41E-05	306	51.9	0.0050	0.0050	0.0043	5.38E-05	0.001	0.795	0.0034	1.42
189	482	0.006	328	3.49E-07	0.015	2.49	0.0019	1.27E-04	2.03E-06	0.0041	3.40E-05	305	51.9	0.0050	0.0050	0.0043	5.39E-05	0.001	0.796	0.0034	1.35
225	478	0.006	329	3.49E-07	0.015	2.49	0.0019	1.27E-04	2.02E-06	0.0041	3.40E-05	304	51.9	0.0050	0.0050	0.0043	5.40E-05	0.001	0.797	0.0034	1.31
261	476	0.006	329	3.49E-07	0.015	2.49	0.0019	1.27E-04	2.01E-06	0.0041	3.40E-05	303	51.9	0.0050	0.0050	0.0043	5.40E-05	0.001	0.797	0.0034	1.28
298	474	0.006	329	3.49E-07	0.015	2.49	0.0019	1.27E-04	2.00E-06	0.0041	3.39E-05	303	51.9	0.0050	0.0050	0.0043	5.41E-05	0.001	0.798	0.0034	1.25
334	472	0.006	329	3.49E-07	0.015	2.49	0.0019	1.27E-04	2.00E-06	0.0041	3.39E-05	303	51.9	0.0050	0.0050	0.0043	5.41E-05	0.001	0.798	0.0034	1.23
370	471	0.006	329	3.49E-07	0.015	2.49	0.0019	1.27E-04	1.99E-06	0.0041	3.39E-05	302	51.9	0.0050	0.0050	0.0043	5.42E-05	0.001	0.798	0.0034	1.22
37	570	0.006	321	3.43E-07	0.015	2.43	0.0018	1.30E-04	2.37E-06	0.0040	3.50E-05	327	51.9	0.0049	0.0049	0.0043	5.18E-05	0.001	0.779	0.0034	2.47
404	470	0.006	329	3.49E-07	0.015	2.49	0.0019	1.27E-04	1.99E-06	0.0041	3.39E-05	302	51.9	0.0050	0.0050	0.0043	5.42E-05	0.001	0.798	0.0034	1.21
770	465	0.006	330	3.50E-07	0.015	2.50	0.0019	1.27E-04	1.97E-06	0.0041	3.39E-05	301	51.9	0.0050	0.0050	0.0043	5.43E-05	0.001	0.799	0.0034	1.14
1137	464	0.006	330	3.50E-07	0.015	2.50	0.0019	1.27E-04	1.96E-06	0.0041	3.38E-05	300	51.9	0.0050	0.0050	0.0043	5.44E-05	0.001	0.800	0.0034	1.12
1504	463	0.006	330	3.50E-07	0.015	2.50	0.0019	1.27E-04	1.96E-06	0.0041	3.38E-05	300	51.9	0.0050	0.0050	0.0043	5.44E-05	0.001	0.800	0.0034	1.11
1870	462	0.006	330	3.50E-07	0.015	2.50	0.0019	1.27E-04	1.96E-06	0.0041	3.38E-05	300	51.9	0.0050	0.0050	0.0043	5.44E-05	0.001	0.800	0.0034	1.10
2237	462	0.006	330	3.50E-07	0.015	2.50	0.0019	1.27E-04	1.96E-06	0.0041	3.38E-05	300	51.9	0.0050	0.0050	0.0043	5.44E-05	0.001	0.800	0.0034	1.10
2604	462	0.006	330	3.50E-07	0.015	2.50	0.0019	1.27E-04	1.96E-06	0.0041	3.38E-05	300	51.9	0.0050	0.0050	0.0043	5.44E-05	0.001	0.800	0.0034	1.09
2970	461	0.006	330	3.50E-07	0.015	2.50	0.0019	1.27E-04	1.96E-06	0.0041	3.38E-05	300	51.9	0.0050	0.0050	0.0043	5.44E-05	0.001	0.800	0.0034	1.09
3337	461	0.006	330	3.50E-07	0.015	2.50	0.0019	1.27E-04	1.96E-06	0.0041	3.38E-05	300	51.9	0.0050	0.0050	0.0043	5.44E-05	0.001	0.800	0.0034	1.09
3704	461	0.006	330	3.50E-07	0.015	2.50	0.0019	1.27E-04	1.96E-06	0.0041	3.38E-05	300	51.9	0.0050	0.0050	0.0043	5.44E-05	0.001	0.800	0.0034	1.09

SCENARIO 4A

Dilution Ratio	Volume - PoPA	Volume - Total	pH	Total Dissolved Solid	Temperature	Density - Total	Cl(-1) Liq1	Salinity	Zn(+2) Liq1	Ti(+4) Liq1	Si(+4) Liq1	Se(+4) Liq1	Sb(+5) Liq1	S(+6) Liq1	Pb(+2) Liq1	P(+5) Liq1	Ni(+2) Liq1	Na(+1) Liq1	N(-3) Liq1	N(+5) Liq1	N(+3) Liq1	Mn(+2) Liq1
	L/hr	L/hr		mg/L	°C	kg/m3	mg/L	g/kg	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
0	0	32,900	6.40	50,390	19.3	1,038	29,699	51.7	0.0	1.43E-03	20.1064	0	#######	1,348	0.002	0	3.01722	10,258	0	0	0	0.000
2	50,000	82,883	6.92	40,246	12.6	1,031	22,889	40.1	0.00	1.43E-03	8.564	0	6.03E-03	1,023	0.001	0	1.197	11,166	0.012	0.170	0	0.003
3	#######	#######	7.14	37,717	11.0	1,029	21,200	37.2	0.01	1.44E-03	5.588	0	7.53E-03	942	0.001	0	0.746	11,390	0.015	0.213	0	0.004
5	#######	#######	7.28	36,875	10.2	1,028	20,435	35.9	0.01	1.44E-03	4.239	0	8.20E-03	905	0.000	0	0.542	11,491	0.017	0.232	0	0.004
6	#######	#######	7.37	36,233	9.80	1,027	19,998	35.2	0.01	1.44E-03	3.469	0	8.59E-03	884	0.000	0	0.426	11,549	0.017	0.243	0	0.004
8	#######	#######	7.44	35,591	9.53	1,027	19,716	34.7	0.01	1.28E-03	2.972	0	8.84E-03	871	0.000	0	0.350	11,586	0.018	0.250	0	0.004
9	#######	#######	7.49	35,528	9.34	1,027	19,518	34.3	0.01	1.09E-03	2.624	0	9.01E-03	861	0.000	0	0.297	11,613	0.018	0.254	0	0.005
11	#######	#######	7.54	35,313	9.19	1,027	19,372	34.1	0.01	9.46E-04	2.367	0	9.14E-03	854	0.000	0	0.258	11,632	0.018	0.258	0	0.005
12	#######	#######	7.57	35,148	9.08	1,027	19,260	33.9	0.01	8.37E-04	2.169	0	9.24E-03	849	0.000	0	0.229	11,647	0.019	0.261	0	0.005
14	#######	#######	7.60	35,018	9.00	1,027	19,171	33.7	0.01	7.50E-04	2.012	0	9.32E-03	845	0.000	0	0.205	11,658	0.019	0.263	0	0.005
15	#######	#######	7.62	34,678	8.93	1,026	19,099	33.6	0.01	6.80E-04	1.885	0	9.38E-03	841	0.000	0	0.185	11,668	0.019	0.265	0	0.005
17	#######	#######	7.64	34,628	8.87	1,026	19,039	33.5	0.01	6.21E-04	1.779	0	9.44E-03	838	0.000	0	0.169	11,676	0.019	0.266	0	0.005
18	#######	#######	7.66	34,587	8.82	1,026	18,988	33.4	0.01	5.72E-04	1.690	0	9.48E-03	836	0.000	0	0.156	11,682	0.019	0.268	0	0.005
20	#######	#######	7.68	34,551	8.78	1,026	18,945	33.4	0.01	5.30E-04	1.614	0	9.52E-03	834	0.000	0	0.145	11,688	0.019	0.269	0	0.005
21	#######	#######	7.69	34,520	8.74	1,026	18,908	33.3	0.01	4.94E-04	1.549	0	9.55E-03	832	0.000	0	0.135	11,693	0.019	0.270	0	0.005
23	#######	#######	7.70	34,493	8.71	1,026	18,875	33.2	0.01	4.63E-04	1.492	0	9.58E-03	831	0.000	0	0.126	11,697	0.019	0.271	0	0.005
24	#######	#######	7.71	34,470	8.68	1,026	18,847	33.2	0.01	4.35E-04	1.442	0	9.60E-03	829	0.000	0	0.118	11,701	0.019	0.271	0	0.005
26	#######	#######	7.72	34,449	8.66	1,026	18,822	33.1	0.01	4.10E-04	1.397	0	9.63E-03	828	0.000	0	0.112	11,704	0.019	0.272	0	0.005
27	#######	#######	7.73	34,471	8.64	1,026	18,799	33.1	0.01	3.88E-04	1.357	0	9.65E-03	827	0.000	0	0.106	11,707	0.019	0.272	0	0.005
29	#######	#######	7.74	34,414	8.62	1,026	18,779	33.1	0.01	3.68E-04	1.321	0	9.67E-03	826	0.000	0	0.100	11,710	0.020	0.273	0	0.005
30	#######	#######	7.75	34,398	8.60	1,026	18,760	33.0	0.01	3.51E-04	1.289	0	9.68E-03	825	0.000	0	0.095	11,713	0.020	0.273	0	0.005
46	#######	#######	7.79	34,301	8.49	1,026	18,643	32.8	0.01	2.36E-04	1.082	0	9.79E-03	819	0.000	0	0.064	11,728	0.020	0.276	0	0.005
59	#######	#######	7.82	34,191	8.43	1,026	18,588	32.7	0.01	1.83E-04	0.985	0	9.83E-03	817	0.000	0	0.049	11,735	0.020	0.278	0	0.005
73	#######	#######	7.83	34,109	8.40	1,026	18,553	32.7	0.01	1.49E-04	0.924	0	9.86E-03	815	0.000	0	0.040	11,740	0.020	0.279	0	0.005
87	#######	#######	7.84	34,074	8.38	1,026	18,529	32.6	0.01	1.26E-04	0.882	0	9.89E-03	814	0.000	0	0.034	11,743	0.020	0.279	0	0.005
100	#######	#######	7.84	34,049	8.36	1,026	18,512	32.6	0.01	1.09E-04	0.851	0	9.90E-03	813	0.000	0	0.029	11,745	0.020	0.280	0	0.005
114	#######	#######	7.84	34,029	8.35	1,026	18,498	32.6	0.01	9.57E-05	0.828	0	9.91E-03	813	0.000	0	0.025	11,747	0.020	0.280	0	0.005
128	#######	#######	7.84	34,014	8.34	1,026	18,488	32.6	0.01	8.56E-05	0.809	0	9.92E-03	812	0.000	0	0.023	11,748	0.020	0.280	0	0.005
141	#######	#######	7.84	34,001	8.33	1,026	18,480	32.5	0.01	7.73E-05	0.794	0	9.93E-03	812	0.000	0	0.020	11,750	0.020	0.280	0	0.005
155	#######	#######	7.84	33,991	8.32	1,026	18,473	32.5	0.01	7.06E-05	0.782	0	9.94E-03	811	0.000	0	0.018	11,751	0.020	0.281	0	0.005
169	#######	#######	7.84	33,982	8.31	1,026	18,467	32.5	0.01	6.49E-05	0.772	0	9.94E-03	811	0.000	0	0.017	11,751	0.020	0.281	0	0.005
182	#######	#######	7.85	33,975	8.31	1,026	18,462	32.5	0.01	6.00E-05	0.763	0	9.95E-03	811	0.000	0	0.016	11,752	0.020	0.281	0	0.005
198	#######	#######	7.85	33,968	8.31	1,026	18,457	32.5	0.01	5.54E-05	0.755	0	9.95E-03	811	0.000	0	0.014	11,753	0.020	0.281	0	0.005
482	#######	#######	7.85	33,919	8.27	1,026	18,423	32.5	0.01	2.28E-05	0.696	0	9.98E-03	809	0.000	0	0.005	11,757	0.020	0.282	0	0.005
766	#######	#######	7.85	33,906	8.26	1,026	18,415	32.4	0.01	1.44E-05	0.680	0	9.99E-03	809	0.000	0	0.003	11,758	0.020	0.282	0	0.005
1050	#######	#######	7.85	33,900	8.26	1,026	18,411	32.4	0.01	1.05E-05	0.673	0	9.99E-03	808	0.000	0	0.002	11,759	0.020	0.282	0	0.005
1334	#######	#######	7.85	33,897	8.26	1,026	18,409	32.4	0.01	8.24E-06	0.669	0	9.99E-03	808	0.000	0	0.001	11,759	0.020	0.282	0	0.005
1619	#######	#######	7.85	33,895	8.26	1,026	18,407	32.4	0.01	6.80E-06	0.667	0	9.99E-03	808	0.000	0	0.001	11,759	0.020	0.282	0	0.005
1903	#######	#######	7.85	33,893	8.26	1,026	18,406	32.4	0.01	5.78E-06	0.665	0	9.99E-03	808	0.000	0	0.001	11,759	0.020	0.282	0	0.005
2187	#######	#######	7.85	33,892	8.26	1,026	18,405	32.4	0.01	5.03E-06	0.664	0	9.99E-03	808	0.000	0	0.001	11,759	0.020	0.282	0	0.005
2471	#######	#######	7.85	33,891	8.25	1,026	18,405	32.4	0.01	4.45E-06	0.662	0	1.00E-02	808	0.000	0	0.000	11,759	0.020	0.282	0	0.005
2755	#######	#######	7.85	33,890	8.25	1,026	18,404	32.4	0.01	3.99E-06	0.662	0	1.00E-02	808	0.000	0	0.000	11,760	0.020	0.282	0	0.005
3040	#######	#######	7.85	33,890	8.25	1,026	18,404	32.4	0.01	3.62E-06	0.661	0	1.00E-02	808	0.000	0	0.000	11,760	0.020	0.282	0	0.005

Dilution Ratio	Mg(+2) Liq1	K(+1) Liq1	Hg(+2) Liq1	Fe(+3) Liq1	Fe(+2) Liq1	F(-1) Liq1	Cu(+2) Liq1	Cr(+6) Liq1	Cr(+3) Liq1	Co(+2) Liq1	Cd(+2) Liq1	Ca(+2) Liq1	Br(-1) Liq1	Be(+2) Liq1	Ba(+2) Liq1	As(+5) Liq1	Al(+3) Liq1	TiO2 (Rutile)	NiFe2O4 (Trevorite)	NiCr2O4	NaAlSi2.3O 6.6.4H2O (sodium aluminosili	NaAlCO3(OH)2 (Dawsonite)	CaCO3 (Calcite)
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
0	5123.84	0	5.33E-08	6.88E-08	0	0	3.07E-04	2.21E-04	1.21E-05	0.153	0	1,133	43.5	0.0	0	2.68E-03	0.005	0.016	0.914	0.024	2.141	0.00	0
2	2,311	199	2.32E-07	1.28E-08	0.009	1.51	0.0012	1.64E-04	9.05E-07	0.064	0	631	48.6	0.0	0.0030	0.0037	0.0004	4.90E-03	3.63E-01	0.012	0.0	0.91	0
3	1,615	248	2.77E-07	7.03E-09	0.011	1.88	0.0015	1.50E-04	3.03E-07	0.042	0	506	49.8	0.0	0.0038	0.0039	0.0001	2.15E-03	2.26E-01	0.010	0.0	0.87	0
5	1,299	271	2.97E-07	5.12E-09	0.012	2.05	0.0016	1.43E-04	1.59E-07	0.032	0	450	50.4	0.0	0.0041	0.0040	0.0001	9.08E-04	1.64E-01	0.008	0.0	0.85	0
6	1,119	283	3.08E-07	4.22E-09	0.013	2.15	0.0016	1.40E-04	1.04E-07	0.026	0	418	50.7	0.0	0.0043	0.0041	0.0001	1.98E-04	1.29E-01	0.007	0.0	0.84	0
8	1,002	292	3.16E-07	3.71E-09	0.013	2.21	0.0017	1.37E-04	7.70E-08	0.022	0	397	50.9	0.0	0.0044	0.0041	0.0000	#######	0.10629	0.007	0.0	0.83	0
9	921	297	3.21E-07	3.40E-09	0.014	2.25	0.0017	1.36E-04	6.18E-08	0.020	0	382	51.1	0.0	0.0045	0.0041	0.0000	#######	0.09032	0.007	0.0	0.83	0
11	861	302	3.25E-07	3.19E-09	0.014	2.29	0.0017	1.35E-04	5.24E-08	0.018	0	372	51.2	0.0	0.0046	0.0042	0.0000	#######	0.07853	0.006	0.0	0.82	0
12	814	305	3.27E-07	3.05E-09	0.014	2.31	0.0017	1.34E-04	4.62E-08	0.016	0	363	51.3	0.0	0.0046	0.0042	0.0000	#######	0.06946	0.006	0.0	0.82	0
14	778	308	3.30E-07	2.95E-09	0.014	2.33	0.0018	1.33E-04	4.18E-08	0.015	0	357	51.3	0.0	0.0047	0.0042	0.0000	#######	0.06227	0.006	0.0	0.82	0
15	748	310	3.32E-07	2.88E-09	0.014	2.35	0.0018	1.32E-04	3.87E-08	0.014	0	351	51.4	0.0	0.0047	0.0042	0.0000	#######	0.05642	0.006	0.0	0.82	0
17	723	311	3.33E-07	2.84E-09	0.014	2.36	0.0018	1.32E-04	3.63E-08	0.013	0	347	51.4	0.0	0.0047	0.0042	0.0000	#######	0.05158	0.006	0.0	0.82	0
18	702	313	3.35E-07	2.80E-09	0.014	2.37	0.0018	1.31E-04	3.45E-08	0.013	0	343	51.5	0.0	0.0047	0.0042	0.0000	#######	0.04751	0.006	0.0	0.81	0
20	685	314	3.36E-07	2.78E-09	0.014	2.38	0.0018	1.31E-04	3.31E-08	0.012	0	340	51.5	0.0	0.0048	0.0042	0.0000	#######	0.04403	0.006	0.0	0.81	0
21	669	315	3.37E-07	2.77E-09	0.014	2.39	0.0018	1.31E-04	3.20E-08	0.012	0	337	51.5	0.0	0.0048	0.0042	0.0000	#######	0.04103	0.006	0.0	0.81	0
23	656	316	3.38E-07	2.76E-09	0.014	2.40	0.0018	1.30E-04	3.12E-08	0.011	0	335	51.5	0.0	0.0048	0.0042	0.0000	#######	0.03841	0.006	0.0	0.81	0
24	644	317	3.38E-07	2.76E-09	0.014	2.40	0.0018	1.30E-04	3.05E-08	0.011	0	333	51.6	0.0	0.0048	0.0042	0.0000	#######	0.0361	0.006	0.0	0.81	0
26	634	318	3.39E-07	2.76E-09	0.014	2.41	0.0018	1.30E-04	2.99E-08	0.011	0	331	51.6	0.0	0.0048	0.0042	0.0000	#######	0.03406	0.006	0.0	0.81	0
27	624	318	3.40E-07	2.77E-09	0.014	2.41	0.0018	1.30E-04	2.95E-08	0.010	0	329	51.6	0.0	0.0048	0.0042	0.0000	#######	0.03223	0.005	0.0	0.81	0
29	616	319	3.40E-07	2.78E-09	0.014	2.42	0.0018	1.30E-04	2.91E-08	0.010	0	328	51.6	0.0	0.0048	0.0042	0.0000	#######	0.03059	0.005	0.0	0.81	0
30	609	319	3.41E-07	2.79E-09	0.015	2.42	0.0018	1.30E-04	2.88E-08	0.010	0	327	51.6	0.0	0.0048	0.0043	0.0000	#######	0.02911	0.005	0.0	0.81	0
46	560	323	3.44E-07	2.97E-09	0.015	2.45	0.0018	1.29E-04	2.81E-08	0.008	0	318	51.7	0.0	0.0049	0.0043	0.0001	#######	0.01961	0.005	0.0	0.81	0
59	537	325	3.45E-07	3.17E-09	0.015	2.46	0.0018	1.28E-04	2.88E-08	0.007	0	314	51.8	0.0	0.0049	0.0043	0.0001	#######	0.01516	0.005	0.0	0.80	0
73	523	326	3.46E-07	3.37E-09	0.015	2.47	0.0018	1.28E-04	2.99E-08	0.007	0	311	51.8	0.0	0.0049	0.0043	0.0001	#######	0.01236	0.005	0.0	0.80	0
87	513	326	3.47E-07	3.63E-09	0.015	2.47	0.0018	1.28E-04	3.20E-08	0.007	0	309	51.8	0.0	0.0049	0.0043	0.0001	#######	0.01043	0.005	0.0	0.80	0.15
100	506	327	3.47E-07	3.88E-09	0.015	2.48	0.0018	1.27E-04	3.42E-08	0.006	0	308	51.8	0.0	0.0050	0.0043	0.0001	#######	9.02E-03	0.005	0.0	0.80	0.27
114	501	327	3.47E-07	4.12E-09	0.015	2.48	0.0018	1.27E-04	3.62E-08	0.006	0	307	51.8	0.0	0.0050	0.0043	0.0001	#######	7.95E-03	0.005	0.0	0.80	0.37
128	496	327	3.48E-07	4.35E-09	0.015	2.48	0.0018	1.27E-04	3.82E-08	0.006	0	306	51.8	0.0	0.0050	0.0043	0.0001	#######	7.10E-03	0.005	0.0	0.80	0.44
141	493	328	3.48E-07	4.57E-09	0.015	2.48	0.0018	1.27E-04	4.00E-08	0.006	0	306	51.8	0.0	0.0050	0.0043	0.0001	#######	6.42E-03	0.005	0.0	0.80	0.50
155	490	328	3.48E-07	4.78E-09	0.015	2.48	0.0019	1.27E-04	4.18E-08	0.006	0	305	51.8	0.0	0.0050	0.0043	0.0001	#######	5.86E-03	0.005	0.0	0.80	0.55
169	487	328	3.48E-07	4.98E-09	0.015	2.49	0.0019	1.27E-04	4.36E-08	0.006	0	305	51.9	0.0	0.0050	0.0043	0.0001	#######	5.39E-03	0.005	0.0	0.80	0.60
182	485	328	3.48E-07	5.18E-09	0.015	2.49	0.0019	1.27E-04	4.53E-08	0.006	0	304	51.9	0.0	0.0050	0.0043	0.0001	#######	4.98E-03	0.005	0.0	0.80	0.63
198	483	328	3.49E-07	5.39E-09	0.015	2.49	0.0019	1.27E-04	4.71E-08	0.006	0	304	51.9	0.0	0.0050	0.0043	0.0001	#######	4.60E-03	0.005	0.0	0.80	0.67
482	470	329	3.49E-07	8.67E-09	0.015	2.49	0.0019	1.27E-04	7.55E-08	0.005	0	301	51.9	0.0	0.0050	0.0043	0.0001	#######	1.89E-03	0.005	0.0	0.80	0.91
766	466	330	3.50E-07	1.15E-08	0.015	2.50	0.0019	1.27E-04	9.96E-08	0.005	0	301	51.9	0.0	0.0050	0.0043	0.0001	#######	1.19E-03	0.005	0.0	0.80	0.97
1050	464	330	3.50E-07	1.42E-08	0.015	2.50	0.0019	1.27E-04	1.23E-07	0.005	0	300	51.9	0.0	0.0050	0.0043	0.0001	#######	8.69E-04	0.005	0.0	0.80	1.00
1334	463	330	3.50E-07	1.70E-08	0.015	2.50	0.0019	1.27E-04	1.48E-07	0.005	0	300	51.9	0.0	0.0050	0.0043	0.0001	#######	6.84E-04	0.005	0.0	0.80	1.01
1619	463	330	3.50E-07	2.01E-08	0.015	2.50	0.0019	1.27E-04	1.75E-07	0.005	0	300	51.9	0.0	0.0050	0.0043	0.0001	#######	5.64E-04	0.005	0.0	0.80	1.03
1903	462	330	3.50E-07	2.37E-08	0.015	2.50	0.0019	1.27E-04	2.06E-07	0.005	0	300	51.9	0.0	0.0050	0.0043	0.0001	#######	4.80E-04	0.005	0.0	0.80	1.03
2187	462	330	3.50E-07	2.81E-08	0.015	2.50	0.0019	1.27E-04	2.44E-07	0.005	0	300	51.9	0.0	0.0050	0.0043	0.0001	#######	4.18E-04	0.005	0.0	0.80	1.04
2471	462	330	3.50E-07	3.39E-08	0.015	2.50	0.0019	1.27E-04	2.95E-07	0.005	0	300	51.9	0.0	0.0050	0.0043	0.0001	#######	3.70E-04	0.005	0.0	0.80	1.04
2755	462	330	3.50E-07	4.25E-08	0.015	2.50	0.0019	1.27E-04	3.69E-07	0.005	0	300	51.9	0.0	0.0050	0.0043	0.0001	#######	3.31E-04	0.005	0.0	0.80	1.05
3040	462	330	3.50E-07	5.81E-08	0.015	2.50	0.0019	1.27E-04	5.05E-07	0.005	0	300	51.9	0.0	0.0050	0.0043	0.0001	#######	3.00E-04	0.005	0.0	0.80	1.05

SCENARIO 4B

Dilution Ratio	Volume - Reconcile _PoPA_W Q	Volume - Total	pH	Total Dissolved Solids, Rigorous	Temperat ure	Density - Total	Cl(-1) Liq1	Salinity	Si(+4) Liq1	Se(+4) Liq1	S(+6) Liq1	Pb(+2) Liq1	P(+5) Liq1	Ni(+2) Liq1	Na(+1) Liq1	N(-3) Liq1	Mo(+6) Liq1	Mg(+2) Liq1	K(+1) Liq1	Hg(+2) Liq1	Co(+2) Liq1	Zn(+2) Liq1	Cd(+2) Liq1	Ca(+2) Liq1	Br(-1) Liq1	As(+5) Liq1	NiCr2O4 - Sol	NaAlCO3(OH)2 (Dawsonit e) - Sol	CoCr2O4 - Sol	CaSO4.2 H2O (Gypsum)	CaCO3 (Calcite) - Sol
	L/hr	L/hr		mg/L	°C	kg/m3	mg/L	g/kg	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
0	0	32,905	6.81	50,547	19.3	1,039	30,269	52.6	0	0.0041	1,141	2.50E-03	0	1.05E-05	10,281	0	1.79E-05	3,837	0	3.59E-04	0.0000	0.0012	9.98E-05	3,301	43.5	0.0206	0.0032	0	0.0001	1,114	145
2	50,000	82,883	7.16	40,487	12.6	1,031	23,112	40.5	0.395	0.0021	1,023	1.02E-03	0.024	3.06E-06	11,174	0.0122	7.12E-06	1,800	199	1.43E-04	0.0025	0.0043	6.00E-05	1,591	48.6	0.0108	0.0021	0.48	0.0021	0	63.2
3	1.00E+05	1.33E+05	7.31	38,455	11.0	1,029	21,340	37.5	0.492	0.0016	942	6.51E-04	0.030	3.46E-06	11,395	0.0152	4.44E-06	1,296	248	8.91E-05	0.0031	0.0051	5.01E-05	1,105	49.8	0.0083	0.0019	0.60	0.0026	0	41.5
5	1.50E+05	1.83E+05	7.40	37,206	10.2	1,028	20,536	36.1	0.537	0.0014	905	4.85E-04	0.033	3.84E-06	11,495	0.0166	3.23E-06	1,067	271	6.48E-05	0.0034	0.0055	4.57E-05	884	50.4	0.0072	0.0017	0.66	0.0029	0	31.2
6	2.00E+05	2.33E+05	7.46	36,043	9.80	1,028	20,078	35.3	0.562	0.0012	884	3.90E-04	0.034	4.16E-06	11,552	0.0173	2.53E-06	937	283	5.10E-05	0.0035	0.0057	4.31E-05	759	50.7	0.0066	0.0017	0.69	0.0030	0	25.2
8	2.50E+05	2.83E+05	7.51	36,033	9.53	1,027	19,781	34.8	0.578	0.0012	871	3.29E-04	0.035	4.44E-06	11,589	0.0178	2.09E-06	853	292	4.20E-05	0.0036	0.0058	4.15E-05	677	50.9	0.0062	0.0016	0.71	0.0031	0	21.2
9	3.00E+05	3.33E+05	7.55	35,710	9.33	1,027	19,574	34.4	0.590	0.0011	861	2.86E-04	0.036	4.68E-06	11,615	0.0182	1.77E-06	794	297	3.58E-05	0.0037	0.0059	4.03E-05	620	51.1	0.0059	0.0016	0.72	0.0031	0	18.4
11	3.50E+05	3.83E+05	7.58	35,023	9.19	1,027	19,420	34.2	0.598	0.0011	854	2.54E-04	0.037	4.89E-06	11,634	0.0185	1.54E-06	750	302	3.11E-05	0.0038	0.0060	3.95E-05	579	51.2	0.0057	0.0016	0.73	0.0032	0	16.3
12	4.00E+05	4.33E+05	7.60	35,289	9.08	1,027	19,303	34.0	0.605	0.0010	849	2.29E-04	0.037	5.08E-06	11,648	0.0187	1.36E-06	717	305	2.76E-05	0.0038	0.0060	3.88E-05	546	51.3	0.0055	0.0015	0.74	0.0032	0	14.6
14	4.50E+05	4.83E+05	7.62	35,143	9.00	1,027	19,209	33.8	0.610	0.0010	845	2.10E-04	0.037	5.24E-06	11,660	0.0188	1.22E-06	690	308	2.48E-05	0.0038	0.0060	3.83E-05	521	51.3	0.0054	0.0015	0.75	0.0032	0	13.3
15	5.00E+05	5.33E+05	7.64	35,025	8.93	1,027	19,133	33.7	0.614	0.0010	841	1.94E-04	0.038	5.38E-06	11,669	0.0189	1.11E-06	668	310	2.25E-05	0.0039	0.0061	3.79E-05	500	51.4	0.0053	0.0015	0.75	0.0032	0	12.2
17	5.50E+05	5.83E+05	7.65	34,927	8.87	1,026	19,070	33.6	0.618	0.0010	838	1.81E-04	0.038	5.51E-06	11,677	0.0191	1.01E-06	651	311	2.06E-05	0.0039	0.0061	3.75E-05	483	51.4	0.0052	0.0015	0.76	0.0032	0	11.3
18	6.00E+05	6.33E+05	7.67	34,845	8.82	1,026	19,017	33.5	0.620	0.0010	836	1.70E-04	0.038	5.63E-06	11,684	0.0191	9.32E-07	636	313	1.90E-05	0.0039	0.0061	3.72E-05	468	51.5	0.0052	0.0015	0.76	0.0033	0	10.5
20	6.50E+05	6.83E+05	7.68	34,775	8.78	1,026	18,972	33.4	0.623	0.0009	834	1.61E-04	0.038	5.74E-06	11,689	0.0192	8.64E-07	623	314	1.76E-05	0.0039	0.0061	3.70E-05	456	51.5	0.0051	0.0015	0.76	0.0033	0	9.87
21	7.00E+05	7.33E+05	7.69	34,714	8.74	1,026	18,933	33.3	0.625	0.0009	832	1.53E-04	0.038	5.83E-06	11,694	0.0193	8.05E-07	612	315	1.64E-05	0.0039	0.0062	3.68E-05	445	51.5	0.0050	0.0015	0.76	0.0033	0	9.30
23	7.50E+05	7.83E+05	7.70	34,661	8.71	1,026	18,899	33.3	0.627	0.0009	831	1.46E-04	0.038	5.92E-06	11,698	0.0193	7.53E-07	602	316	1.54E-05	0.0039	0.0062	3.66E-05	436	51.5	0.0050	0.0015	0.77	0.0033	0	8.80
24	8.00E+05	8.33E+05	7.70	34,614	8.68	1,026	18,869	33.2	0.629	0.0009	829	1.40E-04	0.038	6.00E-06	11,702	0.0194	7.08E-07	593	317	1.45E-05	0.0039	0.0062	3.64E-05	428	51.6	0.0049	0.0015	0.77	0.0033	0	8.35
26	8.50E+05	8.83E+05	7.71	34,573	8.66	1,026	18,843	33.2	0.630	0.0009	828	1.34E-04	0.039	6.08E-06	11,705	0.0194	6.68E-07	586	318	1.37E-05	0.0040	0.0062	3.63E-05	420	51.6	0.0049	0.0015	0.77	0.0033	0	7.96
27	9.00E+05	9.33E+05	7.72	34,536	8.64	1,026	18,819	33.1	0.631	0.0009	827	1.29E-04	0.039	6.14E-06	11,708	0.0195	6.32E-07	579	318	1.30E-05	0.0040	0.0062	3.61E-05	414	51.6	0.0049	0.0015	0.77	0.0033	0	7.61
29	9.50E+05	9.83E+05	7.72	34,503	8.62	1,026	18,798	33.1	0.633	0.0009	826	1.25E-04	0.039	6.21E-06	11,711	0.0195	6.00E-07	573	319	1.23E-05	0.0040	0.0062	3.60E-05	408	51.6	0.0048	0.0015	0.77	0.0033	0	7.29
30	1.00E+06	1.03E+06	7.73	34,473	8.60	1,026	18,778	33.1	0.634	0.0009	825	1.21E-04	0.039	6.27E-06	11,713	0.0195	5.71E-07	568	319	1.18E-05	0.0040	0.0062	3.59E-05	403	51.6	0.0048	0.0014	0.77	0.0033	0	7.00
46	1.50E+06	1.53E+06	7.77	34,281	8.49	1,026	18,655	32.9	0.640	0.0009	819	9.54E-05	0.039	6.68E-06	11,728	0.0198	3.85E-07	532	323	8.04E-06	0.0040	0.0063	3.52E-05	369	51.7	0.0047	0.0014	0.78	0.0033	0	5.12
59	1.95E+06	1.98E+06	7.78	34,191	8.43	1,026	18,597	32.8	0.644	0.0008	817	8.35E-05	0.039	6.91E-06	11,736	0.0199	2.97E-07	516	325	6.30E-06	0.0040	0.0063	3.49E-05	353	51.8	0.0046	0.0014	0.79	0.0034	0	4.22
73	2.40E+06	2.43E+06	7.80	34,134	8.40	1,026	18,561	32.7	0.646	0.0008	815	7.59E-05	0.039	7.06E-06	11,740	0.0199	2.42E-07	506	326	5.20E-06	0.0041	0.0063	3.47E-05	343	51.8	0.0045	0.0014	0.79	0.0034	0	3.65
87	2.85E+06	2.88E+06	7.80	34,095	8.38	1,026	18,536	32.6	0.647	0.0008	814	7.07E-05	0.040	7.17E-06	11,743	0.0200	2.05E-07	499	326	4.44E-06	0.0041	0.0063	3.46E-05	337	51.8	0.0045	0.0014	0.79	0.0034	0	3.26
100	3.30E+06	3.33E+06	7.81	34,067	8.36	1,026	18,517	32.6	0.648	0.0008	813	6.70E-05	0.040	7.25E-06	11,746	0.0200	1.77E-07	493	327	3.89E-06	0.0041	0.0063	3.45E-05	332	51.8	0.0045	0.0014	0.79	0.0034	0	2.97
114	3.75E+06	3.78E+06	7.82	34,045	8.35	1,026	18,503	32.6	0.649	0.0008	813	6.41E-05	0.040	7.32E-06	11,747	0.0200	1.56E-07	489	327	3.47E-06	0.0041	0.0064	3.44E-05	328	51.8	0.0044	0.0014	0.79	0.0034	0	2.74
128	4.20E+06	4.23E+06	7.82	34,028	8.34	1,026	18,492	32.6	0.649	0.0008	812	6.18E-05	0.040	7.37E-06	11,749	0.0200	1.39E-07	486	327	3.14E-06	0.0041	0.0064	3.43E-05	325	51.8	0.0044	0.0014	0.79	0.0034	0	2.57
141	4.65E+06	4.68E+06	7.82	34,014	8.33	1,026	18,483	32.6	0.650	0.0008	812	6.00E-05	0.040	7.41E-06	11,750	0.0200	1.26E-07	484	328	2.87E-06	0.0041	0.0064	3.43E-05	322	51.8	0.0044	0.0014	0.79	0.0034	0	2.43
155	5.10E+06	5.13E+06	7.83	34,003	8.32	1,026	18,476	32.5	0.650	0.0008	811	5.85E-05	0.040	7.45E-06	11,751	0.0201	1.15E-07	482	328	2.65E-06	0.0041	0.0064	3.42E-05	320	51.8	0.0044	0.0014	0.80	0.0034	0	2.31
169	5.55E+06	5.58E+06	7.83	33,993	8.31	1,026	18,470	32.5	0.651	0.0008	811	5.72E-05	0.040	7.48E-06	11,751	0.0201	1.06E-07	480	328	2.46E-06	0.0041	0.0064	3.42E-05	319	51.9	0.0044	0.0014	0.80	0.0034	0	2.21
182	6.00E+06	6.03E+06	7.83	33,985	8.31	1,026	18,465	32.5	0.651	0.0008	811	5.61E-05	0.040	7.50E-06	11,752	0.0201	9.78E-08	478	328	2.30E-06	0.0041	0.0064	3.42E-05	317	51.9	0.0044	0.0014	0.80	0.0034	0	2.13
198	6.50E+06	6.53E+06	7.83	33,978	8.31	1,026	18,460	32.5	0.651	0.0008	811	5.51E-05	0.040	7.53E-06	11,753	0.0201	9.03E-08	477	328	2.15E-06	0.0041	0.0064	3.41E-05	316	51.9	0.0044	0.0014	0.80	0.0034	0	2.05
482	1.59E+07	1.59E+07	7.84	33,923	8.27	1,026	18,425	32.5	0.653	0.0008	809	4.78E-05	0.040	7.71E-06	11,757	0.0201	3.71E-08	467	329	1.09E-06	0.0041	0.0064	3.39E-05	306	51.9	0.0043	0.0014	0.80	0.0034	0	1.48
766	2.52E+07	2.52E+07	7.85	33,909	8.26	1,026	18,416	32.4	0.654	0.0008	809	4.59E-05	0.040	7.76E-06	11,758	0.0202	2.34E-08	464	330	8.17E-07	0.0041	0.0064	3.39E-05	304	51.9	0.0043	0.0014	0.80	0.0034	0	1.33
1050	3.46E+07	3.46E+07	7.85	33,902	8.26	1,026	18,411	32.4	0.654	0.0008	808	4.50E-05	0.040	7.79E-06	11,759	0.0202	1.71E-08	463	330	6.91E-07	0.0041	0.0064	3.39E-05	303	51.9	0.0043	0.0014	0.80	0.0034	0	1.26
1334	4.39E+07	4.39E+07	7.85	33,898	8.26	1,026	18,409	32.4	0.654	0.0008	808	4.45E-05	0.040	7.80E-06	11,759	0.0202	0	463	330	6.18E-07	0.0041	0.0064	3.38E-05	302	51.9	0.0043	0.0014	0.80	0.0034	0	1.22
1618	5.33E+07	5.33E+07	7.85	33,896	8.26	1,026	18,407	32.4	0.654	0.0008	808	4.42E-05	0.040	7.81E-06	11,759	0.0202	0	462	330	5.71E-07	0.0041	0.0064	3.38E-05	302	51.9	0.0043	0.0014	0.80	0.0034	0	1.19
1902	6.26E+07	6.26E+07	7.85	33,894	8.26	1,026	18,406	32.4	0.654	0.0008	808	4.40E-05	0.040	7.81E-06	11,759	0.0202	0	462	330	5.38E-07	0.0041	0.0064	3.38E-05	301	51.9	0.0043	0.0014	0.80	0.0034	0	1.18
2187	7.20E+07	7.20E+07	7.85	33,893	8.26	1,026	18,405	32.4	0.654	0.0008	808	4.38E-05	0.040	7.82E-06	11,759	0.0202	0	462	330	5.14E-07	0.0041	0.0064	3.38E-05	301	51.9	0.0043	0.0014	0.80	0.0034	0	1.16
2471	8.13E+07	8.13E+07	7.85	33,892	8.25	1,026	18,405	32.4	0.654	0.0008	808	4.37E-05	0.040	7.82E-06	11,759	0.0202	0	461	330	4.95E-07	0.0041	0.0064	3.38E-05	301	51.9	0.0043	0.0014	0.80	0.0034	0	1.15
2755	9.07E+07	9.07E+07	7.85	33,891	8.25	1,026	18,404	32.4	0.654	0.0008	808	4.36E-05	0.040	7.82E-06	11,760	0.0202	0	461	330	4.80E-07	0.0041	0.0064	3.38E-05	301	51.9	0.0043	0.0014	0.80	0.0034	0	1.14
3039	1.00E+08	1.00E+08	7.85	33,890	8.25	1,026	18,404	32.4	0.654	0.0008	808	4.35E-05	0.040	7.83E-06	11,760	0.0202	0	461	330	4.68E-07	0.0041	0.0064	3.38E-05	301	51.9	0.0043	0.0014	0.80	0.0034	0	1.14

SCENARIO 5A

Dilution Ratio	Volume - PoPA	Volume - Total	pH	Total Dissolved Solids	Temperature	Density	Cl(-1)	Salinity	Ti(+4)	Si(+4)	Se(+4)	Sb(+5)	S(+6)	Pb(+2)	P(+5)	Ni(+2)	Na(+1)	N(-3)	N(+5)	N(+3)	Mn(+2)
	L/hr	L/hr		mg/L	°C	kg/m3	mg/L	g/Kg	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
0	0	39,036	9.84	45,209	20.4	1,037	25,119	43.8	5.58E-05	3.78E-04	5.43E-04	0	1,140	1.74E-03	0.0002	0.0096	15,268	0	0	0	0
1	50,000	89,018	10.2	42,750	13.6	1,031	21,345	37.4	5.51E-05	1.98E-04	6.78E-04	0.006	954	7.84E-04	0.0053	0.0059	13,298	0.0114	0.1589	0.0428	0.0028
3	1.00E+05	1.39E+05	10.3	37,123	11.7	1,029	20,286	35.6	5.49E-05	1.66E-04	7.16E-04	0.007	901	5.17E-04	0.0066	0.0051	12,745	0.0145	0.2033	0.0548	0.0036
4	1.50E+05	1.89E+05	10.3	36,307	10.8	1,028	19,787	34.8	5.47E-05	1.54E-04	7.34E-04	0.008	876	3.91E-04	0.0076	0.0047	12,485	0.0160	0.2243	0.0605	0.0040
5	2.00E+05	2.39E+05	10.3	35,807	10.2	1,028	19,497	34.3	5.47E-05	1.47E-04	7.44E-04	0.008	862	3.18E-04	0.0084	0.0046	12,333	0.0169	0.2364	0.0637	0.0042
6	2.50E+05	2.89E+05	10.4	35,439	9.90	1,027	19,307	34.0	5.46E-05	1.42E-04	7.51E-04	0.009	853	2.71E-04	0.0090	0.0044	12,234	0.0175	0.2444	0.0659	0.0043
8	3.00E+05	3.39E+05	10.4	35,179	9.66	1,027	19,173	33.7	5.46E-05	1.39E-04	7.55E-04	0.009	846	2.37E-04	0.0094	0.0044	12,164	0.0179	0.2500	0.0674	0.0044
9	3.50E+05	3.89E+05	10.4	34,986	9.49	1,027	19,074	33.6	5.46E-05	1.37E-04	7.59E-04	0.009	841	2.12E-04	0.0098	0.0043	12,112	0.0182	0.2542	0.0685	0.0045
10	4.00E+05	4.39E+05	10.4	34,837	9.35	1,027	18,997	33.4	5.45E-05	1.36E-04	7.62E-04	0.009	837	1.93E-04	0.0101	0.0043	12,072	0.0184	0.2574	0.0694	0.0046
12	4.50E+05	4.89E+05	10.4	34,719	9.24	1,027	18,936	33.3	5.45E-05	1.34E-04	7.64E-04	0.009	834	1.77E-04	0.0104	0.0042	12,040	0.0186	0.2599	0.0701	0.0046
13	5.00E+05	5.39E+05	10.4	34,622	9.15	1,026	18,886	33.2	5.45E-05	1.33E-04	7.66E-04	0.009	832	1.65E-04	0.0106	0.0042	12,014	0.0187	0.2620	0.0706	0.0046
14	5.50E+05	5.89E+05	10.4	34,542	9.08	1,026	18,845	33.2	5.45E-05	1.33E-04	7.67E-04	0.009	830	1.55E-04	0.0108	0.0042	11,993	0.0189	0.2637	0.0711	0.0047
15	6.00E+05	6.39E+05	10.4	34,474	9.01	1,026	18,810	33.1	5.45E-05	1.32E-04	7.68E-04	0.009	828	1.46E-04	0.0110	0.0041	11,975	0.0190	0.2652	0.0715	0.0047
17	6.50E+05	6.89E+05	10.4	34,416	8.96	1,026	18,781	33.1	5.45E-05	1.31E-04	7.69E-04	0.009	827	1.38E-04	0.0112	0.0041	11,959	0.0190	0.2664	0.0718	0.0047
18	7.00E+05	7.39E+05	10.4	34,367	8.91	1,026	18,755	33.0	5.45E-05	1.31E-04	7.70E-04	0.009	825	1.32E-04	0.0113	0.0041	11,946	0.0191	0.2675	0.0721	0.0047
19	7.50E+05	7.89E+05	10.4	34,323	8.87	1,026	18,732	33.0	5.45E-05	1.30E-04	7.71E-04	0.010	824	1.26E-04	0.0114	0.0041	11,934	0.0192	0.2685	0.0724	0.0048
20	8.00E+05	8.39E+05	10.4	34,284	8.84	1,026	18,713	32.9	5.45E-05	1.30E-04	7.72E-04	0.010	823	1.21E-04	0.0116	0.0041	11,923	0.0193	0.2693	0.0726	0.0048
22	8.50E+05	8.89E+05	10.4	34,250	8.81	1,026	18,695	32.9	5.45E-05	1.29E-04	7.72E-04	0.010	822	1.17E-04	0.0117	0.0041	11,914	0.0193	0.2700	0.0728	0.0048
23	9.00E+05	9.39E+05	10.4	34,220	8.78	1,026	18,679	32.9	5.45E-05	1.29E-04	7.73E-04	0.010	822	1.13E-04	0.0117	0.0041	11,906	0.0194	0.2707	0.0730	0.0048
24	9.50E+05	9.89E+05	10.4	34,192	8.75	1,026	18,665	32.9	5.45E-05	1.29E-04	7.73E-04	0.010	821	1.09E-04	0.0118	0.0041	11,899	0.0194	0.2713	0.0731	0.0048
26	1.00E+06	1.04E+06	10.4	34,168	8.73	1,026	18,652	32.8	5.45E-05	1.29E-04	7.74E-04	0.010	820	1.06E-04	0.0119	0.0041	11,892	0.0194	0.2718	0.0733	0.0048
38	1.50E+06	1.54E+06	10.4	34,009	8.58	1,026	18,570	32.7	5.44E-05	1.27E-04	7.77E-04	0.010	816	8.55E-05	0.0124	0.0040	11,849	0.0197	0.2752	0.0742	0.0049
43	1.68E+06	1.72E+06	10.4	33,974	8.55	1,026	18,553	32.7	5.44E-05	1.27E-04	7.77E-04	0.010	815	8.10E-05	0.0125	0.0040	11,840	0.0197	0.2760	0.0744	0.0049
48	1.86E+06	1.90E+06	10.4	33,946	8.53	1,026	18,538	32.6	5.44E-05	1.26E-04	7.78E-04	0.010	815	7.74E-05	0.0126	0.0040	11,832	0.0198	0.2766	0.0746	0.0049
52	2.04E+06	2.08E+06	10.4	33,923	8.50	1,026	18,526	32.6	5.44E-05	1.26E-04	7.78E-04	0.010	814	7.44E-05	0.0127	0.0040	11,826	0.0198	0.2771	0.0747	0.0049
57	2.22E+06	2.26E+06	10.4	33,903	8.49	1,026	18,516	32.6	5.44E-05	1.26E-04	7.79E-04	0.010	814	7.18E-05	0.0128	0.0040	11,821	0.0198	0.2775	0.0748	0.0049
61	2.40E+06	2.44E+06	10.4	33,887	8.47	1,026	18,508	32.6	5.44E-05	1.26E-04	7.79E-04	0.010	813	6.97E-05	0.0129	0.0040	11,816	0.0199	0.2779	0.0749	0.0049
66	2.58E+06	2.62E+06	10.4	33,872	8.46	1,026	18,500	32.6	5.44E-05	1.26E-04	7.79E-04	0.010	813	6.78E-05	0.0129	0.0040	11,813	0.0199	0.2782	0.0750	0.0049
71	2.76E+06	2.80E+06	10.4	33,860	8.45	1,026	18,494	32.6	5.44E-05	1.26E-04	7.79E-04	0.010	812	6.62E-05	0.0130	0.0040	11,809	0.0199	0.2785	0.0751	0.0049
75	2.94E+06	2.98E+06	10.4	33,849	8.44	1,026	18,488	32.6	5.44E-05	1.25E-04	7.80E-04	0.010	812	6.48E-05	0.0130	0.0040	11,806	0.0199	0.2787	0.0751	0.0049
80	3.12E+06	3.16E+06	10.4	33,839	8.43	1,026	18,483	32.6	5.44E-05	1.25E-04	7.80E-04	0.010	812	6.35E-05	0.0130	0.0040	11,804	0.0199	0.2789	0.0752	0.0049
85	3.30E+06	3.34E+06	10.4	33,830	8.42	1,026	18,479	32.5	5.44E-05	1.25E-04	7.80E-04	0.010	812	6.24E-05	0.0131	0.0040	11,801	0.0200	0.2791	0.0752	0.0049
89	3.48E+06	3.52E+06	10.4	33,823	8.41	1,026	18,475	32.5	5.44E-05	1.25E-04	7.80E-04	0.010	811	6.14E-05	0.0131	0.0040	11,799	0.0200	0.2793	0.0753	0.0049
94	3.66E+06	3.70E+06	10.4	33,816	8.41	1,026	18,471	32.5	5.44E-05	1.25E-04	7.80E-04	0.010	811	6.05E-05	0.0131	0.0040	11,797	0.0200	0.2794	0.0753	0.0049
98	3.84E+06	3.88E+06	10.4	33,809	8.40	1,026	18,468	32.5	5.44E-05	1.64E-04	7.80E-04	0.010	811	5.97E-05	0.0145	0.0047	11,796	0.0200	0.2795	0.0754	0.0049
103	4.02E+06	4.06E+06	9.95	33,800	8.39	1,026	18,465	32.5	5.44E-05	0.002	7.80E-04	0.010	811	5.89E-05	0.0348	0.0231	11,794	0.0200	0.2797	0.0754	0.0050
108	4.20E+06	4.24E+06	9.41	33,796	8.39	1,026	18,462	32.5	8.54E-05	0.039	7.81E-04	0.010	811	5.82E-05	0.0381	0.0226	11,793	0.0200	0.2798	0.0754	0.0050
112	4.38E+06	4.42E+06	9.15	33,793	8.38	1,026	18,459	32.5	8.20E-05	0.207	7.81E-04	0.010	811	5.76E-05	0.0387	0.0216	11,791	0.0200	0.2799	0.0754	0.0050
117	4.56E+06	4.60E+06	9.01	33,791	8.38	1,026	18,457	32.5	7.88E-05	0.507	7.81E-04	0.010	811	5.70E-05	0.0393	0.0207	11,790	0.0200	0.2800	0.0755	0.0050
121	4.74E+06	4.78E+06	8.91	33,788	8.37	1,026	18,455	32.5	7.58E-05	0.791	7.81E-04	0.010	811	5.65E-05	0.0398	0.0199	11,789	0.0200	0.2801	0.0755	0.0050
126	4.92E+06	4.96E+06	8.80	33,787	8.37	1,026	18,453	32.5	7.30E-05	0.786	7.81E-04	0.010	810	5.60E-05	0.0398	0.0191	11,788	0.0200	0.2802	0.0755	0.0050
131	5.10E+06	5.14E+06	8.72	33,785	8.36	1,026	18,451	32.5	7.05E-05	0.781	7.81E-04	0.010	810	5.55E-05	0.0399	0.0184	11,787	0.0200	0.2802	0.0755	0.0050
135	5.28E+06	5.32E+06	8.65	33,784	8.36	1,026	18,449	32.5	6.81E-05	0.777	7.81E-04	0.010	810	5.51E-05	0.0399	0.0178	11,786	0.0200	0.2803	0.0756	0.0050
140	5.46E+06	5.50E+06	8.59	33,782	8.36	1,026	18,448	32.5	6.59E-05	0.773	7.81E-04	0.010	810	5.47E-05	0.0399	0.0172	11,785	0.0200	0.2804	0.0756	0.0050
144	5.64E+06	5.68E+06	8.55	33,781	8.35	1,026	18,446	32.5	6.38E-05	0.769	7.81E-04	0.010	810	5.43E-05	0.0399	0.0166	11,784	0.0201	0.2804	0.0756	0.0050
149	5.82E+06	5.86E+06	8.51	33,780	8.35	1,026	18,445	32.5	6.18E-05	0.766	7.81E-04	0.010	810	5.39E-05	0.0399	0.0161	11,784	0.0201	0.2805	0.0756	0.0050
154	6.00E+06	6.04E+06	8.47	33,778	8.35	1,026	18,444	32.5	6.00E-05	0.762	7.81E-04	0.010	810	5.36E-05	0.0399	0.0156	11,783	0.0201	0.2806	0.0756	0.0050
167	6.50E+06	6.54E+06	8.39	33,776	8.34	1,026	18,440	32.5	5.54E-05	0.754	7.81E-04	0.010	810	5.28E-05	0.0399	0.0143	11,781	0.0201	0.2807	0.0757	0.0050
326	1.27E+07	1.28E+07	8.07	33,758	8.30	1,026	18,421	32.4	2.84E-05	0.705	7.82E-04	0.010	809	4.79E-05	0.0399	0.0069	11,771	0.0201	0.2815	0.0759	0.0050
486	1.90E+07	1.90E+07	7.99	33,752	8.28	1,026	18,414	32.4	1.91E-05	0.689	7.82E-04	0.010	808	4.62E-05	0.0400	0.0043	11,767	0.0201	0.2818	0.0760	0.0050
646	2.52E+07	2.52E+07	7.95	33,749	8.27	1,026	18,410	32.4	1.43E-05	0.680	7.82E-04	0.010	808	4.53E-05	0.0400	0.0031	11,766	0.0202	0.2819	0.0760	0.0050
805	3.14E+07	3.15E+07	7.93	33,747	8.27	1,026	18,408	32.4	1.15E-05	0.675	7.82E-04	0.010	808	4.48E-05	0.0400	0.0023	11,764	0.0202	0.2820	0.0760	0.0050
965	3.77E+07	3.77E+07	7.92	33,746	8.27	1,026	18,407	32.4	9.61E-06	0.672	7.83E-04	0.010	808	4.44E-05	0.0400	0.0018	11,764	0.0202	0.2821	0.0760	0.0050
1125	4.39E+07	4.39E+07	7.91	33,745	8.26	1,026	18,406	32.4	8.24E-06	0.669	7.83E-04	0.010	808	4.42E-05	0.0400	0.0014	11,763	0.0202	0.2821	0.0760	0.0050
1284	5.01E+07	5.02E+07	7.90	33,744	8.26	1,026	18,405	32.4	7.22E-06	0.667	7.83E-04	0.010	808	4.40E-05	0.0400	0.0011	11,763	0.0202	0.2822	0.0761	0.0050
1444	5.64E+07	5.64E+07	7.90	33,744	8.26	1,026	18,405	32.4	6.42E-06	0.666	7.83E-04	0.010	808	4.39E-05	0.0400	0.0009	11,762	0.0202	0.2822	0.0761	0.0050
1604	6.26E+07	6.26E+07	7.89	33,743	8.26	1,026	18,404	32.4	5.78E-06	0.665	7.83E-04	0.010	808	4.38E-05	0.0400	0.0007	11,762	0.0202	0.2822	0.0761	0.0050
1763	6.88E+07	6.89E+07	7.89	33,743	8.26	1,026	18,404	32.4	5.26E-06	0.664	7.83E-04	0.010	808	4.37E-05	0.0400	0.0006	11,762	0.0202	0.2822	0.0761	0.0050
1923	7.51E+07	7.51E+07	7.89	33,743	8.26	1,026	18,404	32.4	4.82E-06	0.663	7.83E-04	0.010	808	4.36E-05	0.0400	0.0004	11,762	0.0202	0.2822	0.0761	0.0050
2083	8.13E+07	8.13E+07	7.88	33,894	8.26	1,026	18,403	32.4	4.45E-06	0.662	7.83E-04	0.010	808	4.35E-05	0.0400	0.0003	11,762	0.0202	0.2822	0.0761	0.0050
2242	8.75E+07	8.76E+07	7.88	33,742	8.26	1,026	18,403	32.4	4.14E-06	0.662	7.83E-04	0.010	808	4.35E-05	0.0400	0.0003	11,762	0.0202	0.2822	0.0761	0.0050
2402	9.38E+07	9.38E+07	7.88	33,893	8.26	1,026	18,403	32.4	3.86E-06	0.661	7.83E-04	0.010	808	4.34E-05	0.0400	0.0002	11,762	0.0202	0.2823	0.0761	0.0050
2562	1.00E+08	1.00E+08	7.88	33,893	8.26	1,026	18,403	32.4	3.62E-06	0.661	7.83E-04	0.010	808	4.34E-05	0.0400	0.0001	11,761	0.0202	0.2823	0.0761	0.0050

Dilution Ratio	Mg(+2)	Zn(+2)	K(+1)	Hg(+2)	Fe(+3)	Fe(+2)	F(-1)	Cu(+2)	Cr(+6)	Cr(+3)	Co(+2)	Cd(+2)	Ca(+2)	Br(-1)	Be(+2)	Ba(+2)	As(+5)	Al(+3)	NiTiO3
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
0	895	0.0010	0	4.51E-08	7.38E-10	0	0	7.81E-05	1.87E-04	5.10E-10	0.0722	5.41E-05	853	36.8	0	0	0.00	0.04	0.03
1	670	0.0040	186	2.17E-07	4.13E-10	0.0084	1.41	7.88E-05	1.53E-04	2.87E-10	0.0039	4.27E-05	484	45.3	0.0028	0.0028	0.0034	0.0465	0.0130
3	606	0.0049	238	2.65E-07	3.52E-10	0.0108	1.80	8.18E-05	1.43E-04	2.42E-10	0.0031	3.95E-05	381	47.7	0.0036	0.0036	0.0037	0.0480	0.0082
4	577	0.0053	262	2.87E-07	3.27E-10	0.0119	1.99	8.37E-05	1.39E-04	2.23E-10	0.0027	3.80E-05	332	48.8	0.0038	0.0040	0.0039	0.0488	0.0060
5	559	0.0055	276	3.00E-07	3.14E-10	0.0126	2.09	8.50E-05	1.36E-04	2.13E-10	0.0025	3.71E-05	304	49.4	0.0040	0.0042	0.0040	0.0494	0.0047
6	548	0.0057	286	3.09E-07	3.05E-10	0.0130	2.16	8.59E-05	1.35E-04	2.07E-10	0.0024	3.65E-05	286	49.9	0.0041	0.0043	0.0040	0.0497	0.0039
8	540	0.0058	292	3.15E-07	2.99E-10	0.0133	2.21	8.65E-05	1.33E-04	2.02E-10	0.0023	3.61E-05	273	50.2	0.0041	0.0044	0.0041	0.0500	0.0033
9	534	0.0059	297	3.20E-07	2.95E-10	0.0135	2.25	8.70E-05	1.33E-04	1.99E-10	0.0022	3.58E-05	263	50.4	0.0042	0.0045	0.0041	0.0502	0.0028
10	530	0.0059	301	3.23E-07	2.92E-10	0.0137	2.28	8.74E-05	1.32E-04	1.96E-10	0.0022	3.56E-05	256	50.6	0.0042	0.0046	0.0041	0.0503	0.0025
12	526	0.0060	304	3.26E-07	2.89E-10	0.0138	2.30	8.78E-05	1.31E-04	1.94E-10	0.0021	3.54E-05	250	50.7	0.0043	0.0046	0.0041	0.0505	0.0022
13	523	0.0060	306	3.28E-07	2.87E-10	0.0139	2.32	8.80E-05	1.31E-04	1.93E-10	0.0021	3.53E-05	245	50.8	0.0043	0.0046	0.0042	0.0506	0.0020
14	521	0.0060	308	3.30E-07	2.85E-10	0.0140	2.34	8.83E-05	1.30E-04	1.91E-10	0.0021	3.51E-05	241	50.9	0.0043	0.0047	0.0042	0.0507	0.0018
15	518	0.0061	310	3.31E-07	2.84E-10	0.0141	2.35	8.84E-05	1.30E-04	1.90E-10	0.0021	3.50E-05	238	51.0	0.0044	0.0047	0.0042	0.0507	0.0017
17	517	0.0061	311	3.33E-07	2.83E-10	0.0142	2.36	8.86E-05	1.30E-04	1.89E-10	0.0020	3.49E-05	235	51.0	0.0044	0.0047	0.0042	0.0508	0.0015
18	515	0.0061	313	3.34E-07	2.82E-10	0.0142	2.37	8.88E-05	1.30E-04	1.89E-10	0.0020	3.49E-05	232	51.1	0.0044	0.0047	0.0042	0.0509	0.0014
19	514	0.0061	314	3.35E-07	2.81E-10	0.0143	2.38	8.89E-05	1.29E-04	1.88E-10	0.0020	3.48E-05	230	51.2	0.0044	0.0048	0.0042	0.0509	0.0013
20	513	0.0061	315	3.36E-07	2.80E-10	0.0143	2.38	8.90E-05	1.29E-04	1.87E-10	0.0020	3.47E-05	228	51.2	0.0044	0.0048	0.0042	0.0510	0.0012
22	512	0.0062	316	3.37E-07	2.79E-10	0.0143	2.39	8.91E-05	1.29E-04	1.87E-10	0.0020	3.47E-05	226	51.2	0.0044	0.0048	0.0042	0.0510	0.0011
23	511	0.0062	316	3.37E-07	2.79E-10	0.0144	2.40	8.92E-05	1.29E-04	1.86E-10	0.0020	3.46E-05	225	51.3	0.0044	0.0048	0.0042	0.0510	0.0011
24	510	0.0062	317	3.38E-07	2.78E-10	0.0144	2.40	8.93E-05	1.29E-04	1.86E-10	0.0020	3.46E-05	223	51.3	0.0045	0.0048	0.0042	0.0511	0.0010
26	509	0.0062	318	3.39E-07	2.78E-10	0.0144	2.41	8.94E-05	1.29E-04	1.85E-10	0.0019	3.46E-05	222	51.3	0.0045	0.0048	0.0042	0.0511	0.0009
38	504	0.0063	322	3.42E-07	2.74E-10	0.0146	2.44	8.98E-05	1.28E-04	1.83E-10	0.0019	3.43E-05	214	51.5	0.0045	0.0049	0.0043	0.0513	0.0006
43	503	0.0063	323	3.43E-07	2.74E-10	0.0147	2.44	9.00E-05	1.28E-04	1.82E-10	0.0019	3.43E-05	213	51.6	0.0045	0.0049	0.0043	0.0513	0.0005
48	502	0.0063	323	3.44E-07	2.73E-10	0.0147	2.45	9.00E-05	1.28E-04	1.82E-10	0.0019	3.42E-05	211	51.6	0.0046	0.0049	0.0043	0.0514	0.0004
52	502	0.0063	324	3.44E-07	2.73E-10	0.0147	2.45	9.01E-05	1.28E-04	1.81E-10	0.0019	3.42E-05	210	51.6	0.0046	0.0049	0.0043	0.0514	0.0004
57	501	0.0063	324	3.45E-07	2.72E-10	0.0147	2.46	9.02E-05	1.28E-04	1.81E-10	0.0019	3.41E-05	209	51.6	0.0046	0.0049	0.0043	0.0514	0.0003
61	500	0.0063	325	3.45E-07	2.72E-10	0.0148	2.46	9.02E-05	1.27E-04	1.81E-10	0.0018	3.41E-05	208	51.7	0.0046	0.0049	0.0043	0.0514	0.0003
66	500	0.0063	325	3.45E-07	2.72E-10	0.0148	2.46	9.03E-05	1.27E-04	1.81E-10	0.0018	3.41E-05	208	51.7	0.0046	0.0049	0.0043	0.0515	0.0003
71	500	0.0063	325	3.46E-07	2.71E-10	0.0148	2.47	9.03E-05	1.27E-04	1.81E-10	0.0018	3.41E-05	207	51.7	0.0046	0.0049	0.0043	0.0515	0.0002
75	499	0.0063	326	3.46E-07	2.71E-10	0.0148	2.47	9.04E-05	1.27E-04	1.80E-10	0.0018	3.41E-05	206	51.7	0.0046	0.0049	0.0043	0.0515	0.0002
80	499	0.0063	326	3.46E-07	2.71E-10	0.0148	2.47	9.04E-05	1.27E-04	1.80E-10	0.0018	3.41E-05	206	51.7	0.0046	0.0049	0.0043	0.0515	0.0002
85	499	0.0063	326	3.46E-07	2.71E-10	0.0148	2.47	9.04E-05	1.27E-04	1.80E-10	0.0018	3.40E-05	205	51.7	0.0046	0.0049	0.0043	0.0515	0.0002
89	498	0.0063	326	3.47E-07	2.71E-10	0.0148	2.47	9.04E-05	1.27E-04	1.80E-10	0.0018	3.40E-05	205	51.7	0.0046	0.0049	0.0043	0.0515	0.0002
94	498	0.0063	327	3.47E-07	2.70E-10	0.0148	2.47	9.05E-05	1.27E-04	1.80E-10	0.0018	3.40E-05	205	51.7	0.0046	0.0049	0.0043	0.0515	0.0001
98	498	0.0063	327	3.47E-07	2.43E-10	0.0148	2.47	8.31E-05	1.27E-04	1.80E-10	0.0015	3.40E-05	204	51.7	0.0049	0.0049	0.0043	0.0455	0.0001
103	496	0.0063	327	3.47E-07	1.09E-10	0.0149	2.48	6.35E-05	1.27E-04	1.78E-10	0.0004	3.40E-05	205	51.8	0.0050	0.0050	0.0043	0.0162	0.0001
108	495	0.0064	327	3.47E-07	1.70E-10	0.0149	2.48	1.54E-04	1.27E-04	5.41E-10	0.0011	3.40E-05	207	51.8	0.0050	0.0050	0.0043	0.0047	0.0000
112	493	0.0064	327	3.47E-07	2.57E-10	0.0149	2.48	3.17E-04	1.27E-04	9.91E-10	0.0028	3.40E-05	210	51.8	0.0050	0.0050	0.0043	0.0026	0.0000
117	492	0.0064	327	3.47E-07	3.33E-10	0.0149	2.48	4.82E-04	1.27E-04	1.38E-09	0.0045	3.40E-05	213	51.8	0.0050	0.0050	0.0043	0.0019	0.0000
121	492	0.0064	327	3.48E-07	4.08E-10	0.0149	2.48	6.60E-04	1.27E-04	1.76E-09	0.0060	3.40E-05	215	51.8	0.0050	0.0050	0.0043	0.0015	0.0000
126	490	0.0064	327	3.48E-07	5.15E-10	0.0149	2.48	9.52E-04	1.27E-04	2.31E-09	0.0060	3.40E-05	218	51.8	0.0050	0.0050	0.0043	0.0012	0.0000
131	489	0.0064	328	3.48E-07	6.22E-10	0.0149	2.48	1.27E-03	1.27E-04	2.86E-09	0.0059	3.40E-05	221	51.8	0.0050	0.0050	0.0043	0.0010	0.0000
135	488	0.0064	328	3.48E-07	7.29E-10	0.0149	2.48	1.61E-03	1.27E-04	3.43E-09	0.0059	3.39E-05	224	51.8	0.0050	0.0050	0.0043	0.0008	0.0000
140	487	0.0064	328	3.48E-07	8.36E-10	0.0149	2.48	1.85E-03	1.27E-04	3.99E-09	0.0059	3.39E-05	226	51.8	0.0050	0.0050	0.0043	0.0007	0.0000
144	487	0.0064	328	3.48E-07	9.42E-10	0.0149	2.48	1.85E-03	1.27E-04	4.56E-09	0.0059	3.39E-05	228	51.8	0.0050	0.0050	0.0043	0.0007	0.0000
149	486	0.0064	328	3.48E-07	1.05E-09	0.0149	2.48	1.85E-03	1.27E-04	5.13E-09	0.0058	3.39E-05	231	51.8	0.0050	0.0050	0.0043	0.0006	0.0000
154	485	0.0064	328	3.48E-07	1.15E-09	0.0149	2.48	1.85E-03	1.27E-04	5.70E-09	0.0058	3.39E-05	233	51.8	0.0050	0.0050	0.0043	0.0006	0.0000
167	483	0.0064	328	3.48E-07	1.43E-09	0.0149	2.49	1.85E-03	1.27E-04	7.26E-09	0.0057	3.39E-05	238	51.8	0.0050	0.0050	0.0043	0.0005	0.0000
326	472	0.0064	329	3.49E-07	4.41E-09	0.0150	2.49	1.86E-03	1.27E-04	2.77E-08	0.0054	3.39E-05	268	51.9	0.0050	0.0050	0.0043	0.0001	0.0000
486	468	0.0064	329	3.49E-07	6.76E-09	0.0150	2.49	1.86E-03	1.27E-04	4.68E-08	0.0053	3.38E-05	279	51.9	0.0050	0.0050	0.0043	0.0001	0.0000
646	466	0.0064	329	3.50E-07	8.83E-09	0.0150	2.50	1.86E-03	1.27E-04	6.45E-08	0.0052	3.38E-05	284	51.9	0.0050	0.0050	0.0043	0.0001	0.0000
805	465	0.0064	330	3.50E-07	1.08E-08	0.0150	2.50	1.86E-03	1.27E-04	8.15E-08	0.0052	3.38E-05	287	51.9	0.0050	0.0050	0.0043	0.0001	0.0000
965	464	0.0064	330	3.50E-07	1.27E-08	0.0150	2.50	1.86E-03	1.27E-04	9.82E-08	0.0051	3.38E-05	289	51.9	0.0050	0.0050	0.0043	0.0001	0.0000
1125	463	0.0064	330	3.50E-07	1.47E-08	0.0150	2.50	1.86E-03	1.27E-04	1.15E-07	0.0051	3.38E-05	291	51.9	0.0050	0.0050	0.0043	0.0001	0.0000
1284	463	0.0064	330	3.50E-07	1.68E-08	0.0150	2.50	1.86E-03	1.27E-04	1.33E-07	0.0051	3.38E-05	292	51.9	0.0050	0.0050	0.0043	0.0001	0.0000
1444	463	0.0064	330	3.50E-07	1.90E-08	0.0150	2.50	1.86E-03	1.27E-04	1.52E-07	0.0051	3.38E-05	293	51.9	0.0050	0.0050	0.0043	0.0001	0.0000
1604	462	0.0064	330	3.50E-07	2.14E-08	0.0150	2.50	1.86E-03	1.27E-04	1.73E-07	0.0051	3.38E-05	293	51.9	0.0050	0.0050	0.0043	0.0001	0.0000
1763	462	0.0064	330	3.50E-07	2.42E-08	0.0150	2.50	1.86E-03	1.27E-04	1.97E-07	0.0051	3.38E-05	294	51.9	0.0050	0.0050	0.0043	0.0001	0.0000
1923	462	0.0064	330	3.50E-07	2.74E-08	0.0150	2.50	1.86E-03	1.27E-04	2.25E-07	0.0051	3.38E-05	294	51.9	0.0050	0.0050	0.0043	0.0001	0.0000
2083	462	0.0064	330	3.50E-07	3.14E-08	0.0150	2.50	1.86E-03	1.27E-04	2.58E-07	0.0051	3.38E-05	295	51.9	0.0050	0.0050	0.0043	0.0001	0.0000
2242	462	0.0064	330	3.50E-07	3.65E-08	0.0150	2.50	1.86E-03	1.27E-04	3.01E-07	0.0051	3.38E-05	295	51.9	0.0050	0.0050	0.0043	0.0001	0.0000
2402	462	0.0064	330	3.50E-07	4.35E-08	0.0150	2.50	1.86E-03	1.27E-04	3.60E-07	0.0051	3.38E-05	295	51.9	0.0050	0.0050	0.0043	0.0001	0.0000
2562	462	0.0064	330	3.50E-07	5.46E-08	0.0150	2.50	1.86E-03	1.27E-04	4.53E-07	0.0050	3.38E-05	296	51.9	0.0050	0.0050	0.0043	0.0001	0.0000

Dilution Ratio	NiFe2O4 (Trevorite)	NiCr2O4	Ni(OH)2 (Theophrastite)	NaAlCO3(OH)2 (Dawsonite)	Mg3Si2O5(OH)4 (Poor crystalline Antigorite)	Mg(OH)2 (Brucite)	CuO	Co3(PO4)2.8H2O	CaCO3 (Calcite)	Ca3(PO4)2	Be2(OH)2CO3	Al(OH)3 (Gibbsite)
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
0	0.77	0.02	4.00	0	85.9	8,197	0.0002	0.1654	263	0	0	0.37
1	0.3383	0.0115	1.75	0	39.4	3,540	0.0014	0.1604	260	0.033	0.000	0.33
3	0.2165	0.0091	1.12	0	26.4	2,236	0.0017	0.1063	259	0.075	0.000	0.31
4	0.1592	0.0080	0.82	0	20.2	1,622	0.0018	0.0806	258	0.093	0.001	0.31
5	0.1259	0.0073	0.65	0	16.7	1,265	0.0019	0.0657	257	0.102	0.001	0.30
6	0.1041	0.0069	0.53	0	14.4	1,031	0.0020	0.0560	257	0.108	0.002	0.30
8	0.0887	0.0066	0.45	0	12.7	867	0.0020	0.0491	257	0.112	0.002	0.30
9	0.0773	0.0063	0.39	0	11.5	745	0.0020	0.0440	257	0.115	0.002	0.29
10	0.0685	0.0062	0.35	0	10.6	650	0.0020	0.0400	256	0.116	0.002	0.29
12	0.0615	0.0060	0.31	0	9.80	575	0.0021	0.0369	256	0.118	0.002	0.29
13	0.0558	0.0059	0.28	0	9.19	514	0.0021	0.0343	256	0.119	0.002	0.29
14	0.0511	0.0058	0.26	0	8.69	463	0.0021	0.0322	256	0.120	0.002	0.29
15	0.0471	0.0057	0.24	0	8.26	420	0.0021	0.0304	256	0.121	0.002	0.29
17	0.0436	0.0057	0.22	0	7.89	384	0.0021	0.0289	256	0.121	0.002	0.29
18	0.0407	0.0056	0.20	0	7.58	352	0.0021	0.0276	256	0.122	0.002	0.29
19	0.0381	0.0056	0.19	0	7.30	325	0.0021	0.0264	256	0.122	0.002	0.29
20	0.0358	0.0055	0.18	0	7.06	300	0.0021	0.0254	256	0.122	0.002	0.29
22	0.0338	0.0055	0.17	0	6.84	279	0.0021	0.0245	256	0.123	0.002	0.29
23	0.0320	0.0054	0.16	0	6.65	259	0.0021	0.0237	256	0.123	0.002	0.29
24	0.0304	0.0054	0.15	0	6.48	242	0.0021	0.0229	256	0.123	0.002	0.29
26	0.0289	0.0054	0.14	0	6.32	226	0.0021	0.0223	256	0.123	0.002	0.29
38	0.0195	0.0052	0.09	0	5.32	126	0.0022	0.0181	255	0.125	0.002	0.29
43	0.0175	0.0051	0.08	0	5.10	104	0.0022	0.0172	255	0.125	0.002	0.29
48	0.0158	0.0051	0.07	0	4.92	85.9	0.0022	0.0164	255	0.125	0.002	0.29
52	0.0145	0.0051	0.07	0	4.77	71.2	0.0022	0.0158	255	0.125	0.002	0.29
57	0.0133	0.0051	0.06	0	4.65	58.9	0.0022	0.0153	255	0.125	0.002	0.29
61	0.0123	0.0050	0.06	0	4.55	48.3	0.0022	0.0148	255	0.125	0.002	0.29
66	0.0115	0.0050	0.05	0	4.46	39.3	0.0022	0.0145	255	0.125	0.002	0.29
71	0.0107	0.0050	0.05	0	4.38	31.4	0.0022	0.0141	255	0.125	0.002	0.29
75	0.0101	0.0050	0.04	0	4.31	24.4	0.0022	0.0138	255	0.126	0.002	0.29
80	0.0095	0.0050	0.04	0	4.25	18.2	0.0022	0.0136	255	0.126	0.002	0.29
85	0.0090	0.0050	0.04	0	4.19	12.8	0.0022	0.0134	255	0.126	0.002	0.29
89	0.0085	0.0050	0.04	0	4.14	7.82	0.0022	0.0131	255	0.126	0.002	0.29
94	0.0081	0.0050	0.03	0	4.10	3.36	0.0022	0.0130	255	0.126	0.002	0.29
98	0.0078	0.0049	0.03	0	4.06	0	0.0022	0.0138	255	0.118	0.000	0.30
103	0.0074	0.0049	6.64E-04	0	4.01	0	0.0022	0.0166	253	0.015	0.000	0.39
108	0.0071	0.0049	0	0	3.80	0	0.0021	0.0145	246	0	0	0.42
112	0.0068	0.0049	0	0	2.93	0	0.0019	0.0096	238	0	0	0.43
117	0.0065	0.0049	0	0	1.43	0	0.0017	0.0043	232	0	0	0.43
121	0.0063	0.0049	0	0	0	0	0.0015	0	226	0	0	0.43
126	0.0061	0.0049	0	0	0	0	0.0011	0	218	0	0	0.43
131	0.0059	0.0049	0	0	0	0	0.0007	0	210	0	0	0.43
135	0.0057	0.0049	0	0	0	0	0.0003	0	203	0	0	0.43
140	0.0055	0.0049	0	0	0	0	0	0	196	0	0	0.43
144	0.0053	0.0049	0	0	0	0	0	0	190	0	0	0.43
149	0.0051	0.0049	0	0	0	0	0	0	184	0	0	0.43
154	0.0050	0.0049	0	0	0	0	0	0	179	0	0	0.43
167	0.0046	0.0049	0	0.799	0	0	0	0	165	0	0	0
326	0.0024	0.0048	0	0.800	0	0	0	0	84.3	0	0	0
486	0.0016	0.0048	0	0.800	0	0	0	0	56.8	0	0	0
646	0.0012	0.0048	0	0.800	0	0	0	0	43.0	0	0	0
805	0.0010	0.0048	0	0.800	0	0	0	0	34.7	0	0	0
965	0.0008	0.0048	0	0.800	0	0	0	0	29.1	0	0	0
1125	0.0007	0.0048	0	0.800	0	0	0	0	25.1	0	0	0
1284	0.0006	0.0048	0	0.800	0	0	0	0	22.1	0	0	0
1444	0.0005	0.0048	0	0.800	0	0	0	0	19.8	0	0	0
1604	0.0005	0.0048	0	0.800	0	0	0	0	17.9	0	0	0
1763	0.0004	0.0048	0	0.800	0	0	0	0	16.4	0	0	0
1923	0.0004	0.0048	0	0.800	0	0	0	0	15.1	0	0	0
2083	0.0004	0.0048	0	0.800	0	0	0	0	14.0	0	0	0
2242	0.0003	0.0048	0	0.800	0	0	0	0	13.1	0	0	0
2402	0.0003	0.0048	0	0.800	0	0	0	0	12.3	0	0	0
2562	0.0003	0.0048	0	0.800	0	0	0	0	11.6	0	0	0

SCENARIO 5B

Dilution Ratio	Volume - PoPA	Volume - Total	pH	Total Dissolved Solids	Temperature	Density	Cl(-1)	Zn(+2)	Si(+4)	Se(+4)	Sb(+5)	S(+6)	Pb(+2)	P(+5)	Ni(+2)	Na(+1)	N(-3)	N(+5)	N(+3)	Mo(+6)	Mn(+2)	Mg(+2)	K(+1)	Hg(+2)	Fe(+2)	F(-1)	Cu(+2)	Cr(+6)	Cr(+3)	Co(+2)	Cd(+2)	Ca(+2)	Br(-1)	Be(+2)	Ba(+2)	As(+5)	Al(+3)	NiCr2O4	NaAlCO3(OH)2 (Dawsonite)	Mg3Si2O5(OH)4 (Poor-crystalline Antigorite)	Mg(OH)2 (Brucite)	CuO	CoCr2O4	Co3(PO4)2.8H2O	CaSO4.2H2O (Gypsum)	CaCO3 (Calcite)	Ca3(PO4)2	Be2(OH)2CO3	Al(OH)3 (Gibbsite)
	L/hr	L/hr		mg/L	°C	kg/m3	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
0	0	39,029	12.1	46,456	20.4	1,038	25,607	0.001	0.000	0.003	0.000	877	2.12E-03	0	8.08E-16	15,293	0	0	0	1.52E-05	0.0000	0.04	0	3.04E-04	0	0	2.60E-04	1.87E-04	1.94E-04	1.58E-12	8.45E-05	2,596	36.8	0	0	0.017	0.000	2.73E-03	0	0.00	7,789	0	1.75E-04	0	1,417	336	0	0	0
1	50,000	89,017	10.5	39,242	13.6	1,031	21,553	0.004	0.000	0.002	0.006	954	9.49E-04	0.0005	7.51E-05	13,306	0.0114	0.1589	0.0428	6.64E-06	0.0028	188	186	1.33E-04	0.0084	1.41	1.21E-04	1.53E-04	1.61E-09	2.19E-03	5.60E-05	1,390	45.3	0.0028	0.0028	0.0101	0.084	1.70E-03	0	1.81	3,577	0.0013	0.0025	0	0	293	0.110	0	0
3	1.00E+05	1.39E+05	10.4	37,206	11.7	1,029	20,419	0.005	0.000	0.002	0.007	901	6.23E-04	0.0010	1.12E-04	12,750	0.0145	0.2033	0.0548	4.25E-06	0.0036	298	238	8.52E-05	0.0108	1.80	1.04E-04	1.43E-04	1.26E-09	2.82E-03	4.80E-05	960	47.7	0.0036	0.0036	0.0080	0.068	1.35E-03	0	2.32	2,259	0.0016	0.0030	0	0	281	0.139	0	0.114
4	1.50E+05	1.89E+05	10.4	38,354	10.8	1,028	19,885	0.005	0.000	0.001	0.008	876	4.69E-04	0.0016	1.28E-04	12,488	0.0160	0.2243	0.0605	3.12E-06	0.0040	350	262	6.28E-05	0.0119	1.99	9.95E-05	1.39E-04	1.14E-09	3.12E-03	4.42E-05	758	48.8	0.0036	0.0040	0.0070	0.063	1.19E-03	0	2.56	1,639	0.0018	0.0033	0	0	275	0.151	0.0026	0.163
5	2.00E+05	2.39E+05	10.4	35,880	10.2	1,028	19,574	0.006	0.000	0.001	0.008	862	3.80E-04	0.0021	1.38E-04	12,336	0.0169	0.2364	0.0637	2.47E-06	0.0042	380	276	4.97E-05	0.0126	2.09	9.72E-05	1.36E-04	1.07E-09	3.29E-03	4.20E-05	641	49.4	0.0036	0.0042	0.0064	0.060	1.10E-03	0	2.70	1,278	0.0019	0.0035	0	0	271	0.157	0.0038	0.190
6	2.50E+05	2.89E+05	10.4	35,555	9.90	1,027	19,371	0.006	0.000	0.001	0.009	853	3.22E-04	0.0026	1.43E-04	12,236	0.0175	0.2444	0.0659	2.04E-06	0.0043	400	286	4.12E-05	0.0130	2.16	9.59E-05	1.35E-04	1.03E-09	3.41E-03	4.06E-05	564	49.9	0.0036	0.0043	0.0061	0.058	1.04E-03	0	2.79	1,043	0.0019	0.0036	0	0	269	0.160	0.0045	0.207
8	3.00E+05	3.39E+05	10.4	35,278	9.66	1,027	19,228	0.006	0.000	0.001	0.009	846	2.81E-04	0.0031	1.48E-04	12,166	0.0179	0.2500	0.0674	1.74E-06	0.0044	414	292	3.51E-05	0.0133	2.21	9.50E-05	1.33E-04	9.98E-10	3.49E-03	3.96E-05	510	50.2	0.0037	0.0044	0.0058	0.057	9.95E-04	0	2.86	876	0.0020	0.0036	0	0	267	0.162	0.0048	0.219
9	3.50E+05	3.89E+05	10.4	35,072	9.48	1,027	19,121	0.006	0.000	0.001	0.009	841	2.50E-04	0.0035	1.51E-04	12,114	0.0182	0.2542	0.0685	1.52E-06	0.0045	424	297	3.07E-05	0.0135	2.25	9.44E-05	1.33E-04	9.78E-10	3.55E-03	3.89E-05	469	50.4	0.0037	0.0045	0.0056	0.056	9.64E-04	0	2.91	753	0.0020	0.0037	0	0	266	0.163	0.0049	0.227
10	4.00E+05	4.39E+05	10.4	34,913	9.34	1,027	19,039	0.006	0.000	0.001	0.009	837	2.26E-04	0.0039	1.53E-04	12,074	0.0184	0.2574	0.0694	1.34E-06	0.0046	432	301	2.72E-05	0.0137	2.28	9.40E-05	1.32E-04	9.63E-10	3.59E-03	3.83E-05	438	50.6	0.0038	0.0046	0.0055	0.056	9.40E-04	0	2.94	658	0.0020	0.0037	0	0	265	0.163	0.0050	0.234
12	4.50E+05	4.89E+05	10.4	34,787	9.24	1,027	18,974	0.006	0.000	0.001	0.009	834	2.08E-04	0.0043	1.55E-04	12,042	0.0186	0.2599	0.0701	1.21E-06	0.0046	438	304	2.45E-05	0.0138	2.30	9.36E-05	1.31E-04	9.51E-10	3.63E-03	3.78E-05	414	50.7	0.0038	0.0046	0.0053	0.055	9.22E-04	0	2.97	582	0.0021	0.0038	0	0	264	0.163	0.0050	0.239
13	5.00E+05	5.39E+05	10.4	34,684	9.15	1,027	18,921	0.006	0.000	0.001	0.009	832	1.92E-04	0.0047	1.56E-04	12,016	0.0187	0.2620	0.0706	1.09E-06	0.0046	444	306	2.22E-05	0.0139	2.32	9.33E-05	1.31E-04	9.41E-10	3.66E-03	3.75E-05	394	50.8	0.0038	0.0046	0.0053	0.055	9.06E-04	0	2.99	520	0.0021	0.0038	0	0	263	0.162	0.0050	0.244
14	5.50E+05	5.89E+05	10.4	34,599	9.07	1,026	18,877	0.006	0.000	0.001	0.009	830	1.80E-04	0.0050	1.57E-04	11,994	0.0189	0.2637	0.0711	1.00E-06	0.0047	448	308	2.04E-05	0.0140	2.34	9.31E-05	1.30E-04	9.34E-10	3.68E-03	3.71E-05	377	50.9	0.0039	0.0047	0.0052	0.055	8.94E-04	0	3.01	469	0.0021	0.0038	7.97E-06	0	263	0.162	0.0050	0.247
15	6.00E+05	6.39E+05	10.4	34,527	9.01	1,026	18,839	0.006	0.000	0.001	0.009	828	1.69E-04	0.0053	1.50E-04	11,976	0.0190	0.2652	0.0715	9.23E-07	0.0047	451	310	1.88E-05	0.0141	2.35	9.29E-05	1.30E-04	9.51E-10	3.52E-03	3.69E-05	363	51.0	0.0039	0.0047	0.0051	0.054	9.14E-04	0	3.03	426	0.0021	0.0038	0.0006	0	262	0.161	0.0049	0.250
17	6.50E+05	6.89E+05	10.4	34,465	8.96	1,026	18,807	0.006	0.000	0.001	0.009	827	1.60E-04	0.0056	1.45E-04	11,960	0.0190	0.2664	0.0718	8.56E-07	0.0047	455	311	1.75E-05	0.0142	2.36	9.27E-05	1.30E-04	9.67E-10	3.38E-03	3.67E-05	351	51.1	0.0039	0.0047	0.0050	0.054	9.30E-04	0	3.05	389	0.0021	0.0038	0.0010	0	262	0.160	0.0048	0.253
18	7.00E+05	7.39E+05	10.4	34,412	8.91	1,026	18,780	0.006	0.000	0.001	0.009	825	1.52E-04	0.0059	1.40E-04	11,946	0.0191	0.2675	0.0721	7.98E-07	0.0047	457	313	1.63E-05	0.0142	2.37	9.26E-05	1.30E-04	9.81E-10	3.26E-03	3.65E-05	341	51.1	0.0040	0.0047	0.0050	0.054	9.44E-04	0	3.06	357	0.0021	0.0038	0.0014	0	261	0.159	0.0048	0.255
19	7.50E+05	7.89E+05	10.4	34,365	8.87	1,026	18,756	0.006	0.000	0.001	0.010	824	1.45E-04	0.0061	1.35E-04	11,935	0.0192	0.2685	0.0724	7.48E-07	0.0048	460	314	1.53E-05	0.0143	2.38	9.25E-05	1.29E-04	9.94E-10	3.16E-03	3.63E-05	331	51.2	0.0040	0.0048	0.0050	0.054	9.56E-04	0	3.07	329	0.0021	0.0038	0.0018	0	261	0.159	0.0047	0.257
20	8.00E+05	8.39E+05	10.4	34,324	8.84	1,026	18,735	0.006	0.000	0.001	0.010	823	1.39E-04	0.0064	1.32E-04	11,924	0.0193	0.2693	0.0726	7.03E-07	0.0048	462	315	1.44E-05	0.0143	2.38	9.24E-05	1.29E-04	1.01E-09	3.07E-03	3.61E-05	323	51.2	0.0040	0.0048	0.0049	0.054	9.67E-04	0	3.08	304	0.0021	0.0038	0.0021	0	261	0.158	0.0047	0.258
22	8.50E+05	8.89E+05	10.4	34,288	8.80	1,026	18,716	0.006	0.000	0.001	0.010	822	1.33E-04	0.0066	1.28E-04	11,915	0.0193	0.2700	0.0728	6.64E-07	0.0048	463	316	1.36E-05	0.0143	2.39	9.23E-05	1.29E-04	1.02E-09	3.00E-03	3.60E-05	316	51.2	0.0040	0.0048	0.0049	0.054	9.76E-04	0	3.09	282	0.0021	0.0038	0.0023	0	261	0.157	0.0046	0.260
23	9.00E+05	9.39E+05	10.4	34,255	8.78	1,026	18,699	0.006	0.000	0.001	0.010	822	1.29E-04	0.0068	1.25E-04	11,907	0.0194	0.2707	0.0730	6.28E-07	0.0048	465	316	1.29E-05	0.0144	2.40	9.22E-05	1.29E-04	1.03E-09	2.93E-03	3.59E-05	310	51.3	0.0041	0.0048	0.0048	0.053	9.85E-04	0	3.09	263	0.0021	0.0038	0.0026	0	260	0.156	0.0045	0.261
24	9.50E+05	9.89E+05	10.4	34,226	8.75	1,026	18,684	0.006	0.000	0.001	0.010	821	1.24E-04	0.0070	1.23E-04	11,899	0.0194	0.2713	0.0731	5.97E-07	0.0048	467	317	1.23E-05	0.0144	2.40	9.21E-05	1.29E-04	1.04E-09	2.87E-03	3.58E-05	304	51.3	0.0041	0.0048	0.0048	0.053	9.92E-04	0	3.10	245	0.0021	0.0037	0.0028	0	260	0.156	0.0045	0.262
26	1.00E+06	1.04E+06	10.4	34,200	8.73	1,026	18,670	0.006	0.000	0.001	0.010	820	1.20E-04	0.0072	1.20E-04	11,893	0.0194	0.2718	0.0733	5.68E-07	0.0048	468	318	1.17E-05	0.0144	2.41	9.21E-05	1.29E-04	1.04E-09	2.81E-03	3.57E-05	299	51.3	0.0041	0.0048	0.0048	0.053	9.99E-04	0	3.11	229	0.0021	0.0037	0.0030	0	260	0.155	0.0044	0.263
38	1.50E+06	1.54E+06	10.5	34,030	8.58	1,026	18,582	0.006	0.000	0.001	0.010	816	9.51E-05	0.0086	1.05E-04	11,850	0.0197	0.2752	0.0742	3.83E-07	0.0049	476	322	8.01E-06	0.0146	2.44	9.17E-05	1.28E-04	1.10E-09	2.46E-03	3.51E-05	266	51.5	0.0042	0.0049	0.0046	0.053	0.001	0	3.15	128	0.0022	0.0037	0.0042	0	258	0.149	0.0039	0.270
43	1.68E+06	1.72E+06	10.5	33,993	8.55	1,026	18,563	0.006	0.000	0.001	0.010	815	8.96E-05	0.0090	1.02E-04	11,840	0.0197	0.2760	0.0744	3.43E-07	0.0049	478	323	7.21E-06	0.0147	2.44	9.16E-05	1.28E-04	1.12E-09	2.39E-03	3.49E-05	259	51.6	0.0043	0.0049	0.0046	0.053	0.001	0	3.15	106	0.0022	0.0037	0.0044	0	258	0.148	0.0038	0.272
48	1.86E+06	1.90E+06	10.5	33,963	8.52	1,026	18,548	0.006	0.000	0.001	0.010	815	8.51E-05	0.0093	9.97E-05	11,833	0.0198	0.2766	0.0746	3.11E-07	0.0049	480	323	6.56E-06	0.0147	2.45	9.15E-05	1.28E-04	1.13E-09	2.33E-03	3.48E-05	253	51.6	0.0043	0.0049	0.0046	0.053	0.001	0	3.16	88	0.0022	0.0037	0.0046	0	258	0.147	0.0037	0.273
52	2.04E+06	2.08E+06	10.5	33,939	8.50	1,026	18,535	0.006	0.000	0.001	0.010	814	8.15E-05	0.0096	9.76E-05	11,826	0.0198	0.2771	0.0747	2.84E-07	0.0049	481	324	6.02E-06	0.0147	2.45	9.15E-05	1.28E-04	1.14E-09	2.28E-03	3.47E-05	248	51.6	0.0043	0.0049	0.0045	0.052	0.001	0	3.17	73	0.0022	0.0037	0.0048	0	258	0.145	0.0036	0.274
57	2.22E+06	2.26E+06	10.5	33,918	8.49	1,026	18,524	0.006	0.000	0.001	0.010	814	7.84E-05	0.0099	9.58E-05	11,821	0.0198	0.2775	0.0748	2.61E-07	0.0049	482	324	5.57E-06	0.0147	2.46	9.14E-05	1.28E-04	1.15E-09	2.24E-03	3.47E-05	244	51.6	0.0044	0.0049	0.0045	0.052	0.001	0	3.17	60	0.0022	0.0037	0.0050	0	257	0.144	0.0035	0.275
61	2.40E+06	2.44E+06	10.5	33,900	8.47	1,026	18,515	0.006	0.000	0.001	0.010	813	7.57E-05	0.0101	9.43E-05	11,817	0.0199	0.2779	0.0749	2.42E-07	0.0049	483	325	5.18E-06	0.0148	2.46	9.14E-05	1.27E-04	1.16E-09	2.20E-03	3.46E-05	241	51.7	0.0044	0.0049	0.0045	0.052	0.001	0	3.18	50	0.0022	0.0037	0.0051	0	257	0.144	0.0034	0.275
66	2.58E+06	2.62E+06	10.5	33,885	8.46	1,026	18,507	0.006	0.000	0.001	0.010	813	7.35E-05	0.0103	9.30E-05	11,813	0.0199	0.2782	0.0750	2.25E-07	0.0049	484	325	4.85E-06	0.0148	2.46	9.13E-05	1.27E-04	1.17E-09	2.17E-03	3.46E-05	238	51.7	0.0044	0.0049	0.0045	0.052	0.001	0	3.18	40	0.0022	0.0037	0.0052	0	257	0.143	0.0033	0.276
71	2.76E+06	2.80E+06	10.5	33,872	8.45	1,026	18,500	0.006	0.000	0.001	0.010	812	7.15E-05	0.0105	9.19E-05	11,809	0.0199	0.2785	0.0751	2.11E-07	0.0049	484	325	4.56E-06	0.0148	2.47	9.13E-05	1.27E-04	1.17E-09	2.15E-03	3.45E-05	235	51.7	0.0044	0.0049	0.0045	0.052	0.001	0	3.18	33	0.0022	0.0037	0.0053	0	257	0.142	0.0033	0.277
75	2.94E+06	2.98E+06	10.5	33,860	8.44	1,026	18,494	0.006	0.000	0.001	0.010	812	6.98E-05	0.0106	9.09E-05	11,806	0.0199	0.2787	0.0751	1.98E-07	0.0049	485	326	4.31E-06	0.0148	2.47	9.13E-05	1.27E-04	1.18E-09	2.12E-03	3.45E-05	233	51.7	0.0044	0.0049	0.0045	0.052	0.001	0	3.19	25	0.0022	0.0037	0.0053	0	257	0.141	0.0032	0.277
80	3.12E+06	3.16E+06	10.5	33,850	8.43	1,026	18,489	0.006	0.000	0.001	0.010	812	6.82E-05	0.0108	9.01E-05	11,804	0.0199	0.2789	0.0752	1.87E-07	0.0049	485	326	4.08E-06	0.0148	2.47	9.13E-05	1.27E-04	1.18E-09	2.10E-03	3.44E-05	231	51.7	0.0044	0.0049	0.0045	0.052	0.001	0	3.19	19	0.0022	0.0037	0.0054	0	257	0.141	0.0031	0.277
85	3.30E+06	3.34E+06	10.5	33,840	8.42	1,026	18,484	0.006	0.000	0.001	0.010	812	6.68E-05	0.0109	8.93E-05	11,801	0.0200	0.2791	0.0752	1.77E-07	0.0049	486	326	3.88E-06	0.0148	2.47	9.12E-05	1.27E-04	1.19E-09	2.08E-03	3.44E-05	229	51.7	0.0044	0.0049	0.0045	0.052	0.001	0	3.19	14	0.0022	0.0037	0.0055	0	257	0.140	0.0031	0.278
89	3.48E+06	3.52E+06	10.5	33,832	8.41	1,026	18,480	0.006	0.000	0.001	0.010	811	6.56E-05	0.0110	8.86E-05	11,799	0.0200	0.2793	0.0753	1.68E-07	0.0049	486	326	3.70E-06	0.0148	2.47	9.12E-05	1.27E-04	1.19E-09	2.07E-03	3.44E-05	228	51.7	0.0045	0.0049	0.0044	0.052	0.001	0	3.19	8.72361	0.0022	0.0037	0.0055	0	257	0.140	0.0031	0.278
94	3.66E+06	3.70E+06	10.5	33,825	8.41	1,026	18,476	0.006	0.000	0.001	0.010	811	6.45E-05	0.0111	8.80E-05	11,797	0.0200	0.2794	0.0753	1.59E-07	0.0049	487	327	3.54E-06	0.0148	2.47	9.12E-05	1.27E-04	1.20E-09	2.05E-03	3.43E-05	226	51.7	0.0045	0.0049	0.0044	0.052	0.001	0	3.19	4.22478	0.0022	0.0037	0.0056	0	256	0.139	0.0030	0.278
98	3.84E+06	3.88E+06	10.5	33,818	8.40	1,026	18,473	0.006	0.000	0.001	0.010	811	6.35E-05	0.0112	8.74E-05	11,796	0.0200	0.2795	0.0754	1.52E-07	0.0049	487	327	3.39E-06	0.0148	2.47	9.12E-05	1.27E-04	1.20E-09	2.04E-03	3.43E-05	225	51.7	0.0045	0.0049	0.0044	0.052	0.001	0	3.20	0.14352	0.0022	0.0037	0.0056	0	256	0.139	0.0030	0.279
103	4.02E+06	4.06E+06	10.1	33,809	8.39	1,026	18,469	0.006	0.001	0.001	0.010	811	6.26E-05	0.0235	5.56E-05	11,794	0.0200	0.2797	0.0754	1.45E-07	0.0050	486	327	3.25E-06	0.0149	2.48	6.20E-05	1.27E-04	2.89E-09	5.67E-04	3.43E-05	224	51.8	0.0050	0.0050	0.0044	0.022	0.001	0	3.19	0	0.0022	0.0036	0.0100	0	255	0.075	0	0.367
108	4.20E+06	4.24E+06	9.49	33,803	8.39	1,026	18,466	0.006	0.025	0.001	0.010	811	6.17E-05	0.0385	6.54E-05	11,793	0.0200	0.2798	0.0754	1.39E-07	0.0050	485	327	3.13E-06	0.0149	2.48	1.27E-04	1.27E-04	8.54E-09	8.97E-04	3.43E-05	225	51.8	0.0050	0.0050	0.0044	0.006	0.001	0	3.07	0	0.0022	0.0036	0.0090	0	250	0	0	0.413
112	4.38E+06	4.42E+06	9.17	33,800	8.38	1,026	18,464	0.006	0.182	0.001	0.010	811	6.09E-05	0.0391	9.75E-05	11,791	0.0200	0.2799	0.0754	1.33E-07	0.0050	484	327	3.02E-06	0.0149	2.48	2.89E-04	1.27E-04	1.40E-08	2.55E-03	3.42E-05	228	51.8	0.0050	0.0050	0.0044	0.003	0.001	0	2.30	0	0.0019	0.0037	0.0041	0	241	0	0	0.422
117	4.56E+06	4.60E+06	9.02	33,797	8.38	1,026	18,461	0.006	0.488	0.001	0.010	811	6.02E-05	0.0397	1.09E-04	11,790	0.0200	0.2800	0.0755	1.28E-07	0.0050	483	327	2.91E-06	0.0149	2.48	4.56E-04	1.27E-04	1.86E-08	3.98E-03	3.42E-05	229	51.8	0.0050	0.0050	0.0044	0.002	0.001	0	0.79	0	0.0017	0.0038	0	0	235	0	0	0.424
121	4.74E+06	4.78E+06	8.89	33,795	8.37	1,026	18,459	0.006	0.649	0.001	0.010	811	5.96E-05	0.0397	8.21E-05	11,789	0.0200	0.2801	0.0755	1.23E-07	0.0050	483	327	2.82E-06	0.0149	2.48	6.81E-04	1.27E-04	2.85E-08	4.00E-03	3.42E-05	231	51.8	0.0050	0.0050	0.0044	0.001	0.001	0	0	0	0.0015	0.0037	0	0	228	0	0	0.426
126	4.92E+06	4.96E+06	8.78	33,793	8.37	1,026	18,457	0.006	0.649	0.001	0.010	810	5.90E-05	0.0397	6.39E-05	11,788	0.0200	0.2802	0.0755	1.19E-07	0.0050	482	327	2.73E-06	0.0149	2.48	9.89E-04	1.27E-04	4.18E-08	4.02E-03	3.42E-05	234	51.8	0.0050	0.0050	0.0044	0.001	0.001	0	0	0	0.0011	0.0036	0	0	220	0	0	0.427
131	5.10E+06	5.14E+06	8.70	33,791	8.36	1,026	18,455	0.006	0.649	0.001	0.010	810	5.84E-05	0.0397	5.27E-05	11,787	0.0200	0.2802	0.0755	1.15E-07	0.0050	481	328	2.64E-06	0.0149	2.48	1.33E-03	1.27E-04	5.62E-08	4.04E-03	3.42E-05	236	51.8	0.0050	0.0050	0.0044	9.29E-04	0.001	0	0	0	0.0007	0.0036	0	0	212	0	0	0.428
135	5.28E+06	5.32E+06	8.63	33,789	8.36	1,026	18,453	0.006	0.650	0.001	0.010	810	5.79E-05	0.0397	4.52E-05	11,786	0.0200	0.2803	0.0756	1.11E-07	0.0050	480	328	2.57E-06	0.0149	2.48	1.69E-03	1.27E-04	7.13E-08	4.04E-03	3.42E-05	238	51.8	0.0050	0.0050	0.0044	7.98E-04	0.001	0	0	0	0.0002	0.0035	0	0	205	0	0	0.428
140	5.46E+06	5.50E+06	8.57	33,788	8.36	1,026	18,451	0.006	0.650	0.001	0.010	810	5.74E-05	0.0397	3.98E-05	11,785	0.0200	0.2804	0.0756	1.07E-07	0.0050	480	328	2.49E-06	0.0149	2.48	1.85E-03	1.27E-04	8.70E-08	4.05E-03	3.42E-05	240	51.8	0.0050	0.0050	0.0044	7.04E-04	0.001	0	0	0	0	3.52E-03	0	0	198	0	0	0.429
145	5.64E+06	5.68E+06	8.53	33,786	8.35	1,026	18,450	0.006	0.650	0.001	0.010	810	5.69E-05	0.0397	3.58E-05	11,784	0.0201	0.2804	0.0756	1.04E-07	0.0050	479	328	2.43E-06	0.0149	2.48	1.85E-03	1.27E-04	1.03E-07	4.06E-03	3.41E-05	242	51.8	0.0050	0.0050	0.0044	6.34E-04	0.001	0	0	0	0	3.50E-03	0	0	192	0	0	0.429
149	5.82E+06	5.86E+06	8.49	33,785	8.35	1,026	18,448	0.006	0.650	0.001	0.010	810	5.65E-05	0.0397	3.26E-05	11,784	0.0201	0.2805	0.0756	1.01E-07	0.0050	478	328	2.36E-06	0.0149	2.48	1.85E-03	1.27E-04	1.19E-07	4.06E-03	3.41E-05	244	51.8	0.0050	0.0050	0.0044	5.79E-04	0.001	0	0	0	0	3.49E-03	0	0	186	0	0	0.429
154	6.00E+06	6.04E+06	8.45	33,784	8.35	1,026	18,447	0.006	0.650	0.001	0.010	810	5.60E-05	0.0397	3.01E-05	11,783	0.0201	0.2806	0.0756	9.77E-08	0.0050	478	328	2.30E-06	0.0149	2.48	1.85E-03	1.27E-04	1.36E-07	4.06E-03	3.41E-05	246	51.8	0.0050	0.0050	0.0044	5.35E-04	0.001	0	0	0	0	3.48E-03	0	0	180	0	0	0.429
167	6.50E+06	6.54E+06	8.37	33,780	8.34	1,026	18,443	0.006	0.651	0.001	0.010	810	5.50E-05	0.0398	2.54E-05	11,781	0.0201	0.2807	0.0757	9.02E-08	0.0050	477	328	2.15E-06	0.0149	2.49	1.85E-03	1.27E-04	1.81E-07	4.07E-03	3.41E-05	250	51.8	0.0050	0.0050	0.0044	4.43E-04	0.001	0.7934	0	0	0	3.47E-03	0	0	166	0	0	0
326	1.27E+07	1.28E+07	8.06	33,761	8.30	1,026	18,422	0.006	0.652	0.001	0.010	809	4.90E-05	0.0399	1.24E-05	11,771	0.0201	0.2815	0.0759	4.62E-08	0.0050	468	329	1.27E-06	0.0150	2.49	1.86E-03	1.27E-04	6.74E-07	4.10E-03	3.40E-05	274	51.9	0.0050	0.0050	0.0043	1.20E-04	0.001	0.79745	0	0	0	3.42E-03	0	0	85	0	0	0
486	1.90E+07	1.90E+07	7.98	33,754	8.28	1,026	18,415	0.006	0.653	0.001	0.010	808	4.69E-05	0.0399	1.05E-05	11,767	0.0201	0.2818	0.0760	3.10E-08	0.0050	466	329	9.70E-07	0.0150	2.49	1.86E-03	1.27E-04	9.75E-07	4.11E-03	3.39E-05	283	51.9	0.0050	0.0050	0.0043	8.88E-05	0.001	0.79841	0	0	0	3.42E-03	0	0	57	0	0	0
646	2.52E+07	2.52E+07	7.95	33,750	8.27	1,026	18,411	0.006	0.653	0.001	0.010	808	4.59E-05	0.0399	9.69E-06	11,766	0.0202	0.2819	0.0760	2.34E-08	0.0050	464	329	8.17E-07	0.0150	2.50	1.86E-03	1.27E-04	1.17E-06	4.11E-03	3.39E-05	287	51.9	0.0050	0.0050	0.0043	7.76E-05	0.001	0.79888	0	0	0	3.42E-03	0	0	43	0	0	0
805	3.14E+07	3.15E+07	7.93	33,748	8.27	1,026	18,409	0.006	0.654	0.001	0.010	808	4.53E-05	0.0400	9.27E-06	11,764	0.0202	0.2820	0.0760	1.87E-08	0.0050	463	330	7.25E-07	0.0150	2.50	1.86E-03	1.27E-04	1.30E-06	4.11E-03	3.39E-05	289	51.9	0.0050	0.0050	0.0043	7.19E-05	0.001	0.79915	0	0	0	3.41E-03	0	0	35	0	0	0
965	3.77E+07	3.77E+07	7.92	33,747	8.27	1,026	18,408	0.006	0.654	0.001	0.010	808	4.48E-05	0.0400	9.00E-06	11,764	0.0202	0.2821	0.0760	0.00E+00	0.0050	463	330	6.63E-07	0.0150	2.50	1.86E-03	1.27E-04	1.39E-06	4.11E-03	3.39E-05	291	51.9	0.0050	0.0050	0.0043	6.84E-05	0.001	0.79933	0	0	0	3.41E-03	0	0	29	0	0	0
1125	4.39E+07	4.39E+07	7.91	33,746	8.26	1,026	18,406	0.006	0.654	0.001	0.010	808	4.45E-05	0.0400	8.82E-06	11,763	0.0202	0.2821	0.0760	0.00E+00	0.0050	462	330	6.18E-07	0.0150	2.50	1.86E-03	1.27E-04	1.46E-06	4.11E-03	3.38E-05	292	51.9	0.0050	0.0050	0.0043	6.61E-05	0.001	0.79946	0	0	0	3.41E-03	0	0	25	0	0	0
1285	5.01E+07	5.02E+07	7.90	33,745	8.26	1,026	18,406	0.006	0.654	0.001	0.010	808	4.43E-05	0.0400	8.69E-06	11,763	0.0202	0.2822	0.0761	0.00E+00	0.0050	462	330	5.85E-07	0.0150	2.50	1.86E-03	1.27E-04	1.51E-06	4.11E-03	3.38E-05	293	51.9	0.0050	0.0050	0.0043	6.44E-05	0.001	0.79956	0	0	0	3.41E-03	0	0	22	0	0	0
1444	5.64E+07	5.64E+07	7.89	33,744	8.26	1,026	18,405	0.006	0.654	0.001	0.010	808	4.41E-05	0.0400	8.59E-06	11,763	0.0202	0.2822	0.0761	0.00E+00	0.0050	462	330	5.59E-07	0.0150	2.50	1.86E-03	1.27E-04	1.56E-06	4.11E-03	3.38E-05	294	51.9	0.0050	0.0050	0.0043	6.32E-05	0.001	0.79963	0	0	0	3.41E-03	0	0	20	0	0	0
1604	6.26E+07	6.26E+07	7.89	33,744	8.26	1,026	18,405	0.006	0.654	0.001	0.010	808	4.40E-05	0.0400	8.51E-06	11,762	0.0202	0.2822	0.0761	0.00E+00	0.0050	462	330	5.38E-07	0.0150	2.50	1.86E-03	1.27E-04	1.59E-06	4.11E-03	3.38E-05	294	51.9	0.0050	0.0050	0.0043	6.22E-05	0.001	0.79969	0	0	0	3.41E-03	0	0	18	0	0	0
1764	6.88E+07	6.89E+07	7.89	33,744	8.26	1,026	18,404	0.006	0.654	0.001	0.010	808	4.39E-05	0.0400	8.44E-06	11,762	0.0202	0.2822	0.0761	0.00E+00	0.0050	462	330	5.21E-07	0.0150	2.50	1.86E-03	1.27E-04	1.62E-06	4.11E-03	3.38E-05	295	51.9	0.0050	0.0050	0.0043	6.14E-05	0.001	0.79974	0	0	0	3.41E-03	0	0	17	0	0	0
1923	7.51E+07	7.51E+07	7.88	33,743	8.26	1,026	18,404	0.006	0.654	0.001	0.010	808	4.38E-05	0.0400	8.39E-06	11,762	0.0202	0.2822	0.0761	0.00E+00	0.0050	461	330	5.07E-07	0.0150	2.50	1.86E-03	1.27E-04	1.65E-06	4.11E-03	3.38E-05	295	51.9	0.0050	0.0050	0.0043	6.08E-05	0.001	0.79978	0	0	0	3.41E-03	0	0	15	0	0	0
2083	8.13E+07	8.13E+07	7.88	33,743	8.26	1,026	18,404	0.006	0.654	0.001	0.010	808	4.37E-05	0.0400	8.35E-06	11,762	0.0202	0.2822	0.0761	0.00E+00	0.0050	461	330	4.95E-07	0.0150	2.50	1.86E-03	1.27E-04	1.67E-06	4.11E-03	3.38E-05	296	51.9	0.0050	0.0050	0.0043	6.03E-05	0.001	0.79982	0	0	0	3.41E-03	0	0	14	0	0	0
2243	8.75E+07	8.76E+07	7.88	33,743	8.26	1,026	18,403	0.006	0.654	0.001	0.010	808	4.36E-05	0.0400	8.31E-06	11,762	0.0202	0.2822	0.0761	0.00E+00	0.0050	461	330	4.85E-07	0.0150	2.50	1.86E-03	1.27E-04	1.69E-06	4.11E-03	3.38E-05	296	51.9	0.0050	0.0050	0.0043	5.98E-05	0.001	0.79985	0	0	0	3.41E-03	0	0	13	0	0	0
2402	9.38E+07	9.38E+07	7.88	33,742	8.26	1,026	18,403	0.006	0.654	0.001	0.010	808	4.36E-05	0.0400	8.28E-06	11,762	0.0202	0.2823	0.0761	0.00E+00	0.0050	461	330	4.76E-07	0.0150	2.50	1.86E-03	1.27E-04	1.71E-06	4.11E-03	3.38E-05	296	51.9	0.0050	0.0050	0.0043	5.94E-05	0.001	0.79987	0	0	0	3.41E-03	0	0	12	0	0	0
2562	1.00E+08	1.00E+08	7.88	33,893	8.26	1,026	18,403	0.006	0.654	0.001	0.010	808	4.35E-05	0.0400	8.25E-06	11,761	0.0202	0.2823	0.0761	0.00E+00	0.0050	461	330	4.68E-07	0.0150	2.50	1.86E-03	1.27E-04	1.72E-06	4.11E-03	3.38E-05	296	51.9	0.0050	0.0050	0.0043	5.91E-05	0.001	0.7999	0	0	0	3.41E-03	0	0	12	0	0	0

Attachment D: Reasonable Potential Analysis Spreadsheet Calculations - Temperature

Marine Temperature Reasonable Potential and Limit Calculation

Based on WAC 173-201A-200(1)(c)(i)--(ii) and Water Quality Program Guidance. All Data inputs must meet WQ guidelines. The Water Quality temperature guidance document may be found at: http://www.ecy.wa.gov/biblio/0610100.html

INPUT	May-Sep	Oct-Apr
1. Chronic Dilution Factor at Mixing Zone Boundary	195.0	195.0
2. Annual max 1DADMax Ambient Temperature (Background 90th percentile)	11.4 °C	10.0 °C
3. 1DADMax Effluent Temperature (95th percentile)	30.0 °C	30.0 °C
4. Aquatic Life Temperature WQ Criterion	16.0 °C	16.0 °C
OUTPUT		
5. Temperature at Chronic Mixing Zone Boundary:	11.50 °C	10.10 °C
6. Incremental Temperature Increase or decrease:	0.10 °C	0.10 °C
7. Incremental Temperature Increase 12/(T-2) if T≤ crit:	1.28 °C	1.50 °C
8. Maximum Allowable Temperature at Mixing Zone Boundary:	12.68 °C	11.50 °C
A. If ambient temp is warmer than WQ criterion		
9. Does temp fall within this warmer temp range?	NO	NO
10. Temp increase allowed at mixing zone boundary, if required:	---	---
B. If ambient temp is cooler than WQ criterion but within 12/(T_{amb}-2) and within 0.3 °C of the criterion		
11. Does temp fall within this incremental temp. range?	NO	NO
12. Temp increase allowed at mixing zone boundary, if required:	---	---
C. If ambient temp is cooler than (WQ criterion-0.3) but within 12/(T_{amb}-2) of the criterion		
13. Does temp fall within this Incremental temp. range?	NO	NO
14. Temp increase allowed at mixing zone boundary, if required:	---	---
D. If ambient temp is cooler than (WQ criterion - 12/(T_{amb}-2))		
15. Does temp fall within this Incremental temp. range?	YES	YES
16. Temp increase allowed at mixing zone boundary, if required:	NO LIMIT	NO LIMIT
RESULTS		
17. Do any of the above cells show a temp increase?	**NO**	**NO**
18. Temperature Limit if Required?	**NO LIMIT**	**NO LIMIT**

Notes:

Appendix B
Ecological Safety Methodology

Ecological Safety Methodology

1 Introduction

Note that this is a working document that will continue to be refined prior to and throughout operation of the project.

Project Macoma, LLC, a wholly owned subsidiary of Ebb Carbon, proposes to deploy a temporary small-scale pilot project of Ebb Carbon's marine carbon dioxide removal (mCDR) technology at Terminal 7 of the Port of Port Angeles (Port) in Port Angeles, Washington (pilot project or Project Macoma). Ebb Carbon's mCDR technology is designed to remove carbon dioxide (CO_2) safely and permanently from the atmosphere while reducing seawater acidity locally.

Ebb Carbon is developing an Ecological Safety Methodology (ESM)—a robust monitoring, modeling, and reporting tool designed to measure any positive impacts to water quality and marine life and ensure no adverse impacts to the environment from operation of its mCDR technology—with various experts. These experts include the scientific community (e.g., the Pacific Northwest National Laboratory-Sequim and the University of Washington), federal and state resource agencies. Project Macoma, LLC, and the Lower Elwha Klallam Tribe are also discussing the potential for partnership on this pilot project.

The ESM will describe intended data collection and analysis associated with this field trial of Ebb Carbon's mCDR technology. In pertinent part here, the ESM is also an adaptive management tool that will help ensure discharges of alkaline-enhanced seawater to Port Angeles Harbor do not result in adverse environmental effects by identifying circumstances when pilot project operations might need to be paused or modified for the protection of the marine environment. Project Macoma, LLC, will follow the ESM throughout the pilot project. The ESM will be refined over time as this emerging field and the science behind it further develops.

This document sets forth an initial framework for the ESM primarily from a regulatory compliance perspective, which includes initial considerations for establishing baseline conditions, describing initiation of project operations, identifying parameters that will be regularly monitored, and determining exceedance thresholds for modifying Project Macoma, LLC's discharge of higher alkaline seawater, if a need to do so is indicated. The initial version of the ESM will be released prior to commencement of pilot project operations, including obtaining any required permits or approvals needed to begin implementation. Ebb Carbon will continue to build upon this structure with input from its expert partners.

2 Background

2.1 Environmental Setting

This section describes the environmental conditions anticipated at the proposed location of the pilot project at Terminal 7 at the Port. This site is located adjacent to and within marine waters in the Port Angeles Harbor along the Strait of Juan de Fuca. The potential for impacts from the pilot project is related mainly to changes in water quality at and in the vicinity of the discharge location; therefore, the ESM focuses on aquatic resources.

2.1.1 Area of Interest

The area of interest for ESM implementation has been informed in part by mixing zone studies (Brown and Caldwell 2024). It extends from the point of discharge at the 25 proposed outfall ports spaced 2 feet apart along the 50-foot length of the barge, which would be moored near the Terminal 7 dock in Port Angeles Harbor. Preliminary mixing analyses indicate that surrounding pH would return to ambient within the nearfield mixing zone, approximately 21 feet from the discharge point at the barge. Water quality would return to ambient approximately 40 feet around the discharge, well within the allowable chronic mixing zone (approximately 207 feet). During operations, the mixing zone will be maintained within permitted limits. The standard Washington State Department of Ecology (Ecology)-required mixing zone distance is 207 feet from the point of discharge. Water quality monitoring and ecological monitoring would be conducted within both zones to ensure safe operations of the pilot study and to collect data to help inform further development and deployment of this technology. Water quality monitoring would occur to assess for potential acute and chronic mixing zone exceedances at proposed distances of 15 and 150 feet, respectively. The specific area for evaluation may be refined based on the mixing zone modeling and through further discussions with Ebb Carbon’s expert partners and Tribal and stakeholder engagement.

2.1.2 Aquatic Habitat

The project would be located in marine waters in Port Angeles Harbor. This area has the potential to include important aquatic habitat, such as areas designated under the Endangered Species Act (ESA) including Habitat Areas of Particular Concern (HAPCs), Essential Fish Habitat (EFH), or other important aquatic environmental features. These areas were preliminarily identified through desktop analysis (NOAA Fisheries 2023a, 2023b; NMFS 2023; WDFW 2023a, 2023b) but should be further verified through site surveys as noted in Section 4. Desktop analysis identifies the potential for the following habitats:

- Estuary HAPC
- Canopy kelp HAPC

- Groundfish EFH
- Salmon (pink, Chinook, and coho) EFH
- Coastal pelagic species EFH
- Forage fish (sand lance and smelt) spawning areas
- Critical habitat protected under the ESA

2.1.3 Aquatic Species

Several important aquatic species are likely to be present in the area of interest. These species are listed in Table 1 and were determined through a review of the following databases and input from the Lower Elwha Klallam Tribe and the Port:

- Protected Resources App (NOAA Fisheries 2023b)
- ESA Critical Habitat Mapper (NMFS 2023)
- Priority Habitats and Species on the Web (WDFW 2023a)
- iPaC – Information for Planning and Consultation (USFWS 2023)

It is assumed that species could be present if specific habitat characteristics are also present. Proposed baseline studies are described further in Section 4.1.1.

2.1.4 Site Contamination

The pilot project is located within an uplands area of Terminal 7 that is a part of Agreed Order DE 21560 and within a portion of Western Port Angeles Harbor that is under Agreed Order DE 9781, both issued under the Washington State Model Toxics Control Act. The site of the pilot project is also near sediments that are a part of the Rayonier Mill Cleanup Site.

Since the early 1900s, effluent discharged into the area from industrial facilities operating in Port Angeles Harbor. The distribution of hazardous substances corresponds with the locations of historical industrial activities and wastewater discharge sites identified within Port Angeles Harbor. Discharges resulted in harbor sediments contaminated by petrochemicals, polychlorinated biphenyls (PCBs), dioxins, and heavy metals (NOAA 2023).

The resulting contamination is in intertidal and subtidal sediments over the entirety of Port Angeles Harbor. Eleven sediment studies between 2002 and 2013 revealed hazardous substances at concentrations above state and federal standards, indicating potential injuries to benthic organisms, fish, shellfish, and birds (NOAA 2023). The pilot project is designed to be temporary and modular to allow future cleanup activities to occur, if and as required. The design of the intake and outfall system would be located near the surface of the water column and would not cause potentially contaminated sediments to be resuspended.

Table 1
Aquatic Species Assumed to be Present in the Area of Interest

Species	Population	Status	Critical Habitat	Presence/Timing	Habitat Preference in Project Area	Source
Mammals						
Gray whale (*Eschrichtius robustus*)	Eastern North Pacific DPS	SS	None designated	Year-round	Nearshore habitat for foraging, deeper offshore habitat for migration	WDFW 2022
Humpback whale (*Megaptera novaeangliae*)	Mexico DPS and Central America DPS	FE (CA DPS), FT (Mexico DPS), SE	Designated, not present in project area	Year-round; most frequent sightings in spring and fall	Migration and foraging in offshore waters; unlikely to be present in project area	NMFS 2023
Killer whale (*Orcinus orca*)	Southern Resident DPS	FE, SE	Designated, present in project area	Year-round; most frequent sightings in summer	Migration and foraging in nearshore and offshore waters; unlikely to be present in project area	NMFS 2023
Birds						
Marbled murrelet (*Brachyramphus marmoratus*)	USA (California, Oregon, Washington)	FT, SE	Designated, not present in project area	Year-round; breeding season May–September	Old-growth forest nesting sites, marine foraging areas within 1.2 to 3 miles offshore less than 100 feet deep; foraging habitat present in project area	USFWS 2023
Northern spotted owl (*Strix occidentalis*)	--	FT, SE	Designated, not present in project area	Not present	Older forest habitat; not present in project area	WDFW 2023a
Short-tailed albatross (*Phoebastria albatrus*)	--	FE, SC	None designated	Not present	Coastal shoreline and open ocean; not present in project area	USFWS 2023
Yellow-billed cuckoo (*Coccyzus americanus*)	Western DPS	FT, SE	Designated, not present in project area	Not present	Deciduous woodlands; not present in project area	USFWS 2023

Species	Population	Status	Critical Habitat	Presence/Timing	Habitat Preference in Project Area	Source
Fish						
Bocaccio (*Sebastes paucispinis*)	Puget Sound/Georgia Basin DPS	FE	Designated, not present in project area	Year-round offshore presence Larvae: January–July	Kelp, rocky subtidal habitat	NMFS 2023
Bull trout (*Salvelinus confluentus*)	Coastal Recovery Unit	FT, SC	Designated, present in project area (from mean lower low water to 10-meter depth)	Adult: fall (September–December) Juvenile: year-round, nearshore	Marine waters and shorelines, including estuaries, bays, inlets, shallow subtidal areas, and intertidal flats	USFWS 2023
Chinook salmon (*Oncorhynchus tshawytscha*)	Puget Sound ESU	FT, CI	Designated, present in project area (nearshore marine)	Adult: summer and fall (July–December) Juvenile: year-round, nearshore	Marine waters and shorelines, including estuaries, bays, inlets, shallow subtidal areas, and intertidal flats	NMFS 2023
Coho salmon (*O. kisutch*)	Olympic Peninsula ESU	CI	None designated	Adult: summer (July–August) Juvenile: year-round, nearshore	Marine waters and shorelines, including estuaries, bays, inlets, shallow subtidal areas, and intertidal flats	NMFS 2023
Chum salmon (*O. keta*)	Hood Canal Summer-Run ESU	FT	Designated, not present in project area	Adult: summer (June–August) Juvenile: year-round, nearshore	Marine waters and shorelines, including estuaries, bays, inlets, shallow subtidal areas, and intertidal flats	NMFS 2023
Dolly varden (*Salvelinus malma*)	Native char	FPT	None designated	Adult: fall (September–December) Juvenile: year-round, nearshore	Marine waters and shorelines, including estuaries, bays, inlets, shallow subtidal areas, and intertidal flats	USFWS 2023

Species	Population	Status	Critical Habitat	Presence/Timing	Habitat Preference in Project Area	Source
Eulachon (*Thaleichthys pacificus*)	Southern DPS	FT	Designated, not present in project area	Adult: spring (February–April) Juvenile: year-round, nearshore	Marine waters and shorelines, including estuaries, bays, inlets, shallow subtidal areas, and intertidal flats	NMFS 2023
Green sturgeon (*Acipenser medirostris*)	Southern DPS	FT	Designated, not present in project area	Summer and fall in estuaries and bays; winter off Vancouver Island	Marine waters and shorelines, including estuaries, bays, inlets, shallow subtidal areas, and intertidal flats	NMFS 2023
Pink salmon (*O. gorbuscha*)	Odd-year ESU	CI	None designated	Adult: summer (July–August) Juvenile: year-round, nearshore	Marine waters and shorelines, including estuaries, bays, inlets, shallow subtidal areas, and intertidal flats	NMFS 2023
Steelhead (*O. mykiss*)	Puget Sound DPS	FT	Designated, present in freshwater adjacent to project area	Adult: winter (December–April) Juvenile: year-round, nearshore	Marine waters and shorelines, including estuaries, bays, inlets, shallow subtidal areas, and intertidal flats	NMFS 2023
Yelloweye rockfish (*Sebastes ruberrimus*)	Puget Sound/Georgia Basin DPS	FT	Designated, not present in project area	Year-round offshore presence Larvae: April–December	Kelp, rocky subtidal habitat	NMFS 2023
Invertebrates						
Dungeness crab (*Cancer magister*)	--	CI	None designated	Breeding season: October–December Adult: year-round Larvae: December–March	Adult: coastal waters Larvae: current drift Megalopae: nearshore and estuarine Juvenile: oyster beds, gravel/rocky habitats	WDFW 2023
Pinto abalone (*Haliotis kamtschatkana*)	--	SE	None designated	Year-round	Rocky reefs and kelp forests in nearshore coastal habitats	Sowul et al. 2022

Species	Population	Status	Critical Habitat	Presence/Timing	Habitat Preference in Project Area	Source
Sunflower sea star (*Pycnopodia helianthoides*)	--	FPT	None designated	Year-round	Intertidal and subtidal coastal waters on various substrate types	88 Fed. Reg. 16212; March 16, 2023
Monarch butterfly (*Danaus plexippus*)	--	FC	None designated	Not present	Grasslands and prairies; not present in project area	USFWS 2023
Taylor's checkerspot (*Euphydryas editha taylori*)	--	FE, SE	Designated, not present in project area	Not present	Grasslands and prairies; not present in project area	USFWS 2023

Note:
--: no population assigned

2.2 Potential Effects of the Pilot Project

This section describes the anticipated impact mechanisms that could affect aquatic resources during operation of the pilot project. Environmental permitting for the pilot project is being conducted separately to ensure adverse effects are adequately addressed as part of obtaining the necessary approvals for construction and operation; however, operational information is presented here to provide context for the development and implementation of the ESM. Additional detail on potential impacts to species of concern and their habitat are more fully described in the Biological Assessment (Anchor QEA 2024a) and Critical Areas Report (Anchor QEA 2024b).

The purpose of the pilot project is to combat ocean acidification and ameliorate human-driven climate change by removing excess CO_2 from the atmosphere. Because the pilot project will potentially deacidify seawater locally, temporary changes in water quality are expected (Brown and Caldwell 2024). Preliminary analysis indicates these temporary changes would include increases in pH, temperature, and turbidity and decreases in dissolved oxygen levels. Significant or longer lasting increases in turbidity may indicate that the system is releasing CO_2, which is counter to the pilot project goal. The pilot project would not be operating effectively in this scenario, and operations would need to be ceased temporarily to address the issue. The long-term benefits from carbon storage are anticipated to outweigh any potential short-term adverse impacts from the pilot project. The potential benefits and operational impacts to aquatic resources will be monitored and evaluated as part of the ESM.

Table 2 presents potential impacts to species and life stages potentially present in the project area. Initial monitoring and adaptive management strategies are described in Section 4.

Table 2
Potential Pilot Operation Impacts to Species

Operation Impact	Description	Potentially Affected Species/Life Stages
Turbidity	Reduced light transmission through water column, decreasing visibility for organisms and reducing photosynthesis processes for aquatic vegetation	Juvenile fish species: clogging gills, increased predation, decreased foraging success, reduced habitat Benthic invertebrates (Dungeness crab, pinto abalone, sunflower sea star, shellfish): reduced habitat Mammal and bird species: reduced prey
pH	Increased pH associated with discharge from outfall, affecting aquatic species present	Fish: damage to gills, eyes, and skin; reduced habitat Benthic invertebrates (Dungeness crab, pinto abalone, sunflower sea star, shellfish): reduced diversity and biomass; increased susceptibility to disease; reduced habitat Mammal and bird species: reduced prey
Temperature	Increases in temperatures, affecting the distance and location of changes in water quality (e.g., pH, dissolved oxygen), and affecting aquatic species present	Fish: reduced presence due to area avoidance, increased metabolic needs Benthic invertebrates (Dungeness crab, pinto abalone, sunflower sea star, shellfish): reduced diversity and biomass, increased susceptibility to disease, reduced habitat Mammal and bird species: reduced prey
Dissolved oxygen	Decreases in dissolved oxygen, affecting aquatic species present	Fish: reduced growth, altered behavior, increased mortality, reduced reproduction Benthic invertebrates (Dungeness crab, pinto abalone, sunflower sea star, shellfish): reduced diversity and biomass prey, increased susceptibility to disease, reduced habitat Mammal and bird species: reduced

3 Tribal and Stakeholder Engagement

Ebb Carbon is committed to engaging its expert partners and other Indian Tribes, the Port, resource agency representatives and regulators, and scientists in the development and implementation of the ESM. Input from the community surrounding the pilot project will be solicited as well. It is understood that these entities may have important input on topics related to the pilot study, including the following:

- Identification of important habitat characteristics and species of concern
- Surveys and studies relevant to the execution of the pilot project
- Potential information about presence and absence of important aquatic resources
- Concerns over impact pathways
- Feedback on baseline data collection and monitoring
- Protocols for modifying higher-alkaline water discharge

The timeline for engagement will begin in early 2024 and will include the following three main touchpoints:

- Early 2024: presenting project/preliminary framework and receiving input, such as on aquatic resources of concern
- Mid-2024: sharing baseline data collection results, presenting refined monitoring and discharge protocols, and gathering additional input prior to beginning pilot-scale operations and data collection
- Mid-2025: presenting updates on implementation and discussing refinements

4 Baseline Data Collection

Baseline data will be collected to assess the ecological attributes of the project site prior to beginning operations. This information will be used to help inform development of the monitoring and discharge protocols. Data collection will focus on the following ecological attributes:

- Eelgrass
- Macroalgae
- Epibenthic and benthic sampling
- Forage fish spawning habitat
- Substrate characterization

These attributes were selected based on the potential presence of aquatic resources and the logistics of data collection and monitoring conditions anticipated at the site. These attributes are representative of key species of interest and would provide a solid basis for beginning field testing and evaluation but could be modified depending on site verification (since some attributes may not be present) and Tribal and stakeholder priorities.

Baseline studies will be conducted to confirm the presence or absence of important habitat features (i.e., eelgrass, macroalgae, macroinvertebrates, and fish habitat) and to establish baseline conditions prior to implementation of the pilot project. These studies will also identify a suitable reference site or sites to be sampled for comparison. Reference sites consist of locations with similar features in nearby locations that are not disturbed by human activity (e.g., harbor use or industrial activity along a shoreline) to provide a metric against which habitat conditions could be measured and emulated. Observations of fish will be documented, but it is not anticipated that fish data will be collected for the purposes of data analysis. The baseline studies could include transect/quadrant surveys to document aquatic vegetation, benthic organism presence, and habitat condition via snorkeling and video surveys.

5 Monitoring Protocol

The monitoring protocol will outline the specific attributes that will be monitored, how and at what frequency they will be monitored, and how the information will be documented and reported. Monitoring efforts of pilot project effects would include water quality sampling and biological monitoring, which would begin along with pilot project operations.

5.1 Water Quality Monitoring

Water quality monitoring would be accomplished by attaching sensors to existing piers to collect regular measurements of water temperature, salinity, dissolved oxygen, turbidity and suspended solids, chlorophyll, pH, and the partial pressure of CO_2. Data for water temperature, salinity, dissolved oxygen, turbidity, and pH would be collected continuously (recorded in increments up to 15 minutes). Less frequent (up to weekly) seawater samples would be collected and analyzed for total alkalinity and dissolved inorganic carbon.

Water quality parameters that exceed pre-set limits are to be determined in coordination with regulatory agencies and the Lower Elwha Klallam Tribe. Exceedances would alert the responsible party to determine and implement adaptive management actions (Table 3). During operations, the mixing zone will be maintained within permitted limits. The Ecology-required mixing zone distance is 207 feet from the point of discharge. Water quality monitoring would occur to assess for potential acute and chronic mixing zone exceedances at proposed distances of 15 and 150 feet, respectively.

5.2 Biological Monitoring

Biological monitoring would focus on assessing changes to aquatic habitat and species that may be present. The frequency and extent would be determined in coordination with Tribal and stakeholder input. Example methods could include recurring visual inspection by on-site staff for observable changes in habitat conditions, such as the development of algae or changes in aquatic vegetation that are visible from the surface at low tide. Additional surveys using submerged cameras could be used to look for changing vegetation boundaries and identify presence/absence of benthic invertebrate communities.

6 Discharge Protocol

This section describes the initial strategies that could be employed to safely adjust the pilot project's ongoing operations based on monitoring data. Table 3 describes the alkalinity releases planned for pre-operation and preliminary operations.

Table 3
Alkalinity Release Activities During Operational Phases

Operational Phase	Estimated Duration	Alkalinity Release	Description of Key Activities
Pre-operation	6 months	None	• Finalize system design. • Develop ocean models. • Obtain permits. • Collect baseline ocean chemistry and ecological data. • Test system safety, alarms and controls.
Preliminary operations	2 months	Yes – operations during normal business hours, monitored by Ebb team members.	• Verify system safety, alarms and controls. • Establish precipitate thresholds by collecting site-specific data that will more accurately correlate calcite concentrations to turbidity values. • Conduct field measurements after controlled alkalinity release and compare measurements to models. • WET testing to assess alkalinity discharge.

Note:
WET: whole effluent toxicity

Table 3 addresses potential issues that may arise during operation and suggests actions to reduce adverse impacts. It is expected that this protocol would be further developed through Tribal and stakeholder engagement. This would include the development of specific thresholds where corrective actions would be required, the timeline within which decisions would be made, and who would be responsible for making decisions and taking corrective actions.

Table 4
Adaptive Management Strategies During Operations

Potential Issue	Indicator	Adaptive Management Strategy
Water quality changes	Remote monitoring from moored sensors indicates unanticipated changes more than anticipated from baseline levels.	• Test and recalibrate moored sensors to ensure accurate readings. • Temporarily shut down operation to determine if all equipment is functioning properly. • Meet with partners to discuss changes to design prior to resuming operation.
	Recurring grab sample results document changes more than anticipated from baseline levels.	• Follow monitoring plan to include duplicate samples for collection and laboratory quality assurance/quality control. • Resample to ensure accurate results and identify problems. • Temporarily shut down operation to determine if all equipment is functioning properly. • Meet with partners to discuss changes to design prior to resuming operation.
Observations of aquatic vegetation changes	Weekly visual inspections document algal growth or changes in visible aquatic vegetation.	• Determine possible reason for observation and the role (if any) Project Macoma operation played in development of algal growth or changes in visible aquatic vegetation. • Conduct additional water quality sampling to measure changes in nutrient levels and other water quality triggers to unexpected changes in aquatic vegetation. • Temporarily shut down operation to determine if all equipment is functioning properly. • Meet with partners to discuss changes to design prior to resuming operation.
Observations of aquatic organism behavioral changes	Collect additional water quality grab samples and review moored sensor readings leading up to and during observation.	• Determine possible reason for observation and the role (if any) Project Macoma operation played in behavioral change. • Temporarily shut down operation if unexpected behavioral change occurs to determine if all equipment is functioning properly. • Meet with partners to discuss changes to design prior to resuming operation.
Observations of deceased aquatic organisms	Collect additional water quality grab samples and review moored sensor readings leading up to and during observation.	• Determine possible reason for observation and the role (if any) Project Macoma operation played in the die-off. • Temporarily shut down operation to determine if all equipment is functioning properly. • Meet with partners to discuss changes to design prior to resuming operation.

7 References

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Attachment 3
Environmentally Sensitive Areas Report

February 2024
Marine Carbon Dioxide Removal Pilot Project (Project Macoma)

Environmentally Sensitive Areas Report

Prepared for Ebb Carbon

February 2024
Marine Carbon Dioxide Removal Pilot Project (Project Macoma)

Environmentally Sensitive Areas Report

Prepared for
Ebb Carbon, LLC
950 Commercial Street
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Project Number: 233148-01.01

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ABBREVIATIONS

BA	Biological Assessment
BFE	base flood elevation
BMP	best management practices
City	City of Port Angeles
CMMP	Contaminated Materials Management Plan
CO_2	carbon dioxide
DPS	distinct population segment
Ecology	Washington State Department of Ecology
ESA	Endangered Species Act
ESAR	Environmentally Sensitive Areas Report
ESM	Ecological Safety Methodology
ESU	evolutionarily significant unit
FEMA	Federal Emergency Management Act
iPaC	Information for Planning and Consultation
mCDR	marine carbon dioxide removal
NAVD88	North American Vertical Datum of 1988
NMFS	National Marine Fisheries Service
NRCS	Natural Resources Conservation Service
NWI	National Wetlands Inventory
OHWM	ordinary high water mark
PAMC	Port Angeles Municipal Code
PCB	polychlorinated biphenyl
pCO_2	partial pressure of CO_2
PHS	Priority Habitats and Species
Port	Port of Port Angeles
SPCC	spill prevention, control, and countermeasure
TESC	temporary erosion and sediment control
USACE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture
USFWS	U.S. Fish and Wildlife Service
WAC	Washington Administrative Code
WDFW	Washington Department of Fish and Wildlife
WDNR	Washington State Department of Natural Resources

1 Introduction

Project Macoma, LLC, a wholly owned subsidiary of Ebb Carbon, is proposing a temporary pilot-scale marine carbon dioxide removal (mCDR) project (Project Macoma) sited within Terminal 7 of the Port of Port Angeles (Port) in Port Angeles, Washington (Figure 1). Ebb Carbon has developed an mCDR technology to safely and permanently remove carbon dioxide (CO_2) from the atmosphere while reducing seawater acidity locally. Ebb Carbon's mCDR technology removes acid from seawater, generating alkaline-enhanced seawater in the process. The alkaline-enhanced seawater is returned to the ocean, which enables the ocean to draw down and store additional CO_2 from the atmosphere.

The proposed pilot project, owned and operated by Project Macoma, LLC, would take in seawater via a barge moored at the Terminal 7 dock and would pipe the seawater over the existing Terminal 7 pier structures to a modular treatment facility on land and process and deacidify the seawater before returning it to Port Angeles Harbor via the barge-based outfall system (Figure 2). The purposes of the proposed pilot project are to operate Ebb Carbon's mCDR technology under real-world conditions, support scientific research through scientific and academic collaborations, and gather additional data to inform future deployments.

This Environmentally Sensitive Areas Report (ESAR) supports permitting and land use approvals for the proposed pilot project by providing information regarding the presence of environmentally sensitive areas within the Study Area and identifying potential impacts to existing environmentally sensitive areas and associated regulated buffers as defined in Port Angeles Municipal Code (PAMC) Chapter 15.20 – Environmentally Sensitive Areas Protection. The Study Area includes fish and wildlife habitats and critical aquifer recharge areas. The in-water portion of the Study Area is also located within a within a Zone AE floodplain. As described herein, no wetlands, streams, rivers, marine bluffs, or geologically hazardous areas are located within the Study Area. A site visit was conducted on December 1, 2023, to evaluate existing conditions and perform a reconnaissance-level review of the Study Area. This ESAR has been developed to meet the environmentally sensitive areas report content requirements per PAMC 15.20.060.

This ESAR supports Project Macoma, LLC's applications for Shoreline Substantial Development and Environmentally Sensitive Area permits. A comprehensive Project Description and Plan Set are included in Appendix A. Required permits and approvals include the following:

- U.S. Army Corps of Engineers (USACE) Letter of Permission or Nationwide Permit 7 for Outfall Structures and Associated Intake Structures
- National Marine Fisheries Service (NMFS) and U.S. Fish and Wildlife Service (USFWS) Endangered Species Act Section 7 Concurrence
- Washington State Department of Archaeology and Historic Preservation National Historic Preservation Act Section 106 Concurrence

- Washington State Department of Ecology (Ecology) National Pollutant Discharge Elimination System and State Waste Discharge Individual Permit
- Ecology Coastal Zone Management Act Consistency Determination
- Washington Department of Fish and Wildlife (WDFW) Hydraulic Project Approval
- City of Port Angeles (City) Shoreline Substantial Development Permit
- City Environmentally Sensitive Areas Ordinance Compliance
- City Waste Disposal Authorization
- City building, grading, and other local permits for construction activities requiring City review

1.1 Statement of Accuracy and Assumptions

The information provided in this ESAR has been prepared by professional ecologists using the best available science to evaluate environmentally sensitive areas and the potential impacts of the proposed pilot project. This ESAR has been prepared to meet the requirements outlined in PAMC 15.20.060 – Submittal Requirements and Support Information Required.

The proposed pilot project's upland and in-water areas are also located within City of Port Angeles Shoreline Master Program-designated High Intensity – Industrial and Aquatic shoreline environments, respectively. Compliance with the Shoreline Master Program is demonstrated in a separate application.

1.2 Review of Existing Information

Project staff gathered and reviewed the following existing information consistent with PAMC Chapter 15.20 to assess existing environmentally sensitive areas:

- Aerial photographs publicly available via Google Earth
- Clallam County Critical Areas, Clallam County Code 27.12 GIS Map (Clallam County 2024)
- Federal Emergency Management Act (FEMA) National Flood Hazard Layer (FEMA 2024)
- NMFS Endangered Species Act (ESA) Critical Habitat Mapper (v1.0) (NMFS 2024)
- U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) Web Soil Survey (USDA 2024)
- USFWS Wetlands Mapper for National Wetlands Inventory (NWI) Map Information (USFWS 2024a)
- USFWS Information for Planning and Consultation (iPaC) (USFWS 2024b)
- USFWS ESA Status Reviews and Listing Information (USFWS 2024c)
- WDFW Priority Habitats and Species (PHS) Maps (WDFW 2024a)
- WDFW SalmonScape Mapper (WDFW 2024b)
- Washington State Department of Natural Resources (WDNR) Coastal Atlas Map (WDNR 2024)

1.3 Qualified Professionals

The content in this ESAR has been prepared by qualified professionals in the areas of study required pursuant to PAMC 15.20.060. The following qualified professionals contributed to this report:

- Josh Jensen, Senior Managing Environmental Planner (16 years of experience)
- Brianna Blaud, Managing Fisheries Biologist (16 years of experience)
- Kendra Baird, Planner/Biologist (13 years of experience)

1.4 Site Development Alternatives

Several locations were considered for the proposed pilot project but were not carried forward because they did not meet the siting criteria for the pilot project. Siting requirements included a waterfront location; close proximity to the Pacific Northwest National Laboratory, where scientific studies to support this pilot project have been occurring for over a year; and proximity to a grid powered primarily by renewable energy to maintain the net carbon dioxide reduction goal for the program. The Port had available waterfront property that met these criteria and was carried forward as the preferred alternative. The Port has agreed to temporarily lease a portion of the current log yard to Project Macoma, LLC, for the pilot project.

1.5 Financial Guarantee

Project Macoma, LLC, is a licensed business that is fully funded through grant and private funding to operate this pilot project.

2 Study Area

The Study Area is an estimated 0.5-acre portion of Terminal 7 at the Port on Marine View Drive (no site address) in Port Angeles, Washington, plus an approximately 200-foot buffer (Figures 3 and 4). The parcel is zoned as "17.34 Industrial Heavy" on the City's Department of Community and Economic Development Zoning Map (City of Port Angeles 2024). The property is currently used as a log yard by the Port.

There are three existing structures at the site, as follows:

- The first structure is a two-room building. The larger room is an uninsulated space with walls made up of a combination of concrete, masonry, and wood framing. The wood-framed walls have metal siding and door openings. The roof is supported by wood framing.
- The second structure is a 16-inch-thick concrete retaining wall extending north from the building. The wall is about 16 feet high and 75 feet long.
- The third structure is a dock that extends from the property and connects to a wharf that was used to moor ships while loading logs. The dock includes relic wood chip conveyor infrastructure that was used for past wood chip transfer activities. The wood chip conveyor is currently not in operation and will not be operated by Project Macoma, LLC.

2.1 Soils

There are no available soil data for the Study Area in the NRCS Web Soil Survey because it is presumed to be primarily anthropogenic fill by previous users (USDA 2024). NRCS-mapped soils are shown in Figure 5.

A Geotechnical and Hydrogeologic Study was completed by Hart Crowser in 2003, which determined the subgrade soils to be highly variable. Near-surface subgrade soils contain a variable matrix of dredged sand, silt, and gravel (Appendix B).

2.2 Hydrology

The Study Area is located in Water Resource Inventory Area 18: Elwha/Dungeness (Ecology 2024). Hydrologic characteristics in the Study Area are influenced by regional groundwater, direct precipitation, surface water runoff, and the marine environment of Port Angeles Harbor, which is an embayment of the Strait of Juan de Fuca (Figures 6, 7, and 8). No wetlands, stream channels, areas of inundation, or seeps were identified in the Study Area during site visits. The Clallam County Critical Areas map (Clallam County 2024), WDFW PHS data (WDFW 2024a), and WDFW SalmonScape data (WDFW 2024b) do not identify any freshwater surface stream channels to Port Angeles Harbor within the Study Area. The closest freshwater bodies of water are Tumwater Creek, Valley Creek, and Peabody Creek, all located over 0.6 mile away and well outside of any 200-foot critical area buffers (Figure 8).

2.3 Topography

The site is situated on anthropogenic compacted fill that forms a relatively flat lowland (Figure 9). The USDA soil data do not identify any slopes upland in the Study Area (USDA 2024). The shoreline is composed of fill material with a large boulder riprap slope that extends from the upland to the substrate at an approximately 3:1 slope. The WDNR Coastal Atlas map classifies the geomorphology of the site as a "modified" slope stability, with no appreciable drift (WDNR 2024).

2.4 Plant Communities

The Study Area includes an industrial log yard that has been cleared and is primarily unvegetated. Plant species have grown through cracks in the pavement and riprap along the shoreline and mostly include weedy grass and shrub species, such as Himalayan blackberry (*Rubus armeniacus*), Scotch broom (*Cytisus scoparius*), and common dandelion (*Taraxacum officinale*), for example. The Port Angeles Harbor is mapped with fringe (patchy) kelp in the nearshore environment (WDNR 2024). During the site visit on December 1, 2023, bull kelp (*Nereocystis luetkeana*) was observed floating at the water surface in the nearshore area at the site.

No freshwater wetland features or streams with associated riparian habitat were observed within the Study Area. The *USFWS Wetlands Mapper for National Wetlands Inventory Map Information* (USFWS 2024a), WDFW PHS data (WDFW 2024a), and Clallam County Critical Areas map (Clallam County 2024) do not identify any freshwater wetland habitat within the Study Area. Anchor QEA ecologists did not identify any freshwater wetlands in the Study Area during the site visit, substantiating the online data. The marine environment of Port Angeles Harbor is mapped as Estuarine and Marine Deepwater (M1UBL; USFWS 2024a). Photographs of the Study Area taken during the site visit are presented in Appendix C.

3 Environmentally Sensitive Areas Review

This section describes environmentally sensitive areas within the Study Area, including wetlands, fish and wildlife habitat areas, geologically hazardous areas, frequently flooded areas, critical aquifer recharge areas, and unique features (e.g., ravines, marine bluffs, and beaches). Terrestrial habitats and plant communities are described in the following subsections. WDFW-documented species and priority habitats and ESA-listed species and critical habitats that occur or have the potential to occur within and in the vicinity of the Study Area are also identified.

3.1 Methods

To document and describe wetlands, fish and wildlife habitat areas, geologically hazardous areas, frequently flooded areas, critical aquifer recharge areas, and unique features within the Study Area, Anchor QEA reviewed existing information (Section 2) and performed an aerial photograph assessment. Additionally, Anchor QEA conducted a critical areas site visit on December 1, 2023. During the site visit, Anchor QEA documented general information regarding habitats and dominant plant species and communities. As described in the following subsections, no wetland or stream habitats were identified within the Study Area, so no wetland or stream ordinary high water mark (OHWM) delineations were performed. Photographs taken to document vegetation and habitat conditions are included in Appendix C.

3.2 Wetlands

Wetlands were assessed based on PAMC 15.24. No wetland conditions were observed within the Study Area during the December 1, 2023, site visit. Additionally, USFWS NWI data (USFWS 2024a) and the Clallam County Critical Area map (Clallam County 2024) do not identify freshwater wetland areas within the Study Area. The closest mapped wetlands are an 8.67-acre Freshwater Forested/Shrub Wetland located approximately 1 mile to the northwest and a 19.47-acre Estuarine and Marine Deepwater habitat located approximately 0.5 mile to the northwest (USFWS 2024b). These wetlands and associated buffers will not be affected by Project Macoma. Because there are no wetlands within the Study Area, and no impacts to wetlands or wetland buffers will result from the pilot project, no further evaluation is provided in this ESAR.

3.3 Fish and Wildlife Habitat Areas

Fish and wildlife habitat areas are typically identified by known locations of species (such as a nest or den) or by habitat areas or both and may occur on both public and private lands. No fish and wildlife habitat areas were observed within the Study Area during the site visit on December 1, 2023, apart from Port Angeles Harbor and the adjacent marine shoreline. The following subsections describe the fish and wildlife habitat areas at and adjacent to the Study Area in more detail.

3.3.1 Streams and Lakes

No streams, lakes, drainage channels, areas of inundation, seeps, ponds, or associated riparian habitat were identified within the Study Area during the site visit on December 1, 2023. Additionally, WDFW PHS data (WDFW 2024a), SalmonScape data (WDFW 2024b), and the Clallam County Critical Area map (Clallam County 2024) do not identify any stream channels within the Study Area. Because there are no streams, lakes, or ponds within the Study Area, and no impacts to streams, lakes, ponds, or associated buffers will result from Project Macoma, no further evaluation is provided in this ESAR.

3.3.2 Vegetation

The property is currently used as an industrial log yard and mostly lacks vegetation. Vegetation communities within the Study Area generally consist of grass and incidental herbaceous species, as described in Section 2.4. No trees, riparian vegetation communities, or buffers are located within or adjacent to the Study Area. Photographs of the Study Area are presented in Appendix C. Marine aquatic vegetation is discussed in Section 3.3.4.

3.3.3 Wildlife Habitat

Vegetation communities within the Study Area generally consists of grass and incidental herbaceous species, which do not provide quality habitat for native terrestrial wildlife species. Wildlife rely on vegetation for food, shelter, breeding habitat, and cover from predators. Wildlife diversity is generally related to the structure and composition of plant species within vegetative communities. In general, vegetation communities that contain few species or vegetative layers (herbaceous vegetation, shrubs, or trees) support a low diversity of wildlife, whereas vegetation communities that are more complex and contain a wide variety of plant species and vegetative layers can support a greater diversity of wildlife. Land use surrounding the Study Area is dominated by industrial log yard activities, which operate over a partially paved and compacted gravel surface, so undisturbed terrestrial habitat areas are also limited in these areas.

3.3.4 Marine Shoreline

The marine shoreline of Port Angeles Harbor is considered a fish and wildlife habitat area per PAMC Chapter 15.20. The marine shoreline within the Study Area is composed of fill material with a boulder riprap slope that is intended to protect the upland property from erosion. The Study Area is located within an uplands area of Terminal 7 that is a part of Agreed Order DE 21560 and within a portion of Western Port Angeles Harbor that is under Agreed Order DE 9781, both issued under the Washington State Model Toxics Control Act. The proposed location is also near sediments that are a part of the Rayonier Mill Cleanup Site. Eleven sediment studies between 2002 and 2013 revealed hazardous substances (petrochemicals, polychlorinated biphenyls [PCBs], dioxins, and heavy metals) at concentrations above state and federal standards, indicating potential injuries to benthic organisms, fish, shellfish, and birds (NOAA 2023). The contamination in the intertidal and subtidal sediments correlate with the historical use of Port Angeles Harbor for industrial activities and wastewater discharge sites. Project Macoma is designed to be temporary and modular to allow future cleanup activities to occur, if and as required. The design of the intake and outfall system would be located near the surface of the water column and would not cause potentially contaminated sediments to be resuspended.

Port Angeles Harbor is a marine waterbody connected to the Strait of Juan de Fuca. The waters of Port Angeles Harbor provide a productive habitat for a variety of fish, marine mammals, and other aquatic species. There is no documented forage fish spawning habitat in the nearshore of the Study Area. The boulder riprap shoreline does not provide appropriate sediment for forage fish spawning habitat. The nearest documented forage fish spawning habitat is Pacific sand lance (*Ammodytes hexapterus*) and surf smelt (*Hypomesus pretiosus*) spawning habitat located approximately 0.6 mile north of the project site, off Ediz Hook, the spit bordering Port Angeles Harbor (WDFW 2024c). The nearest documented Pacific herring spawning habitat is located in Dungeness Bay, approximately 12.8 miles east of the Project (WDFW 2024c).

Fringe (patchy) kelp is documented in the nearshore of the Study Area (WDNR 2024). The nearest documented eelgrass (*Zostera marina*) is located approximately 2.2 miles northeast of the Project, off the shore of Ediz Hook in Port Angeles Harbor (WDNR 2024). The existing conditions of the marine shoreline are shown in the photographs in Appendix C.

3.3.5 Priority Species and Habitats

The WDFW PHS data (WDFW 2024a) document the upland and shoreline habitat within the Study Area as a potential habitat for the Northern spotted owl (*Strix occidentalis*). No other terrestrial species or priority habitat occurrences are identified as potentially occurring within the Study Area.

No freshwater bodies are located within the Study Area. Salmonid species are documented utilizing the nearby Tumwater Creek, Valley Creek, and Peabody Creek, which connect to Port Angeles Harbor. These species include fall chum salmon (*Oncorhynchus keta*), resident coastal cutthroat trout (*O. clarkii clarkii*), summer and winter steelhead trout (*O. mykiss*), and coho salmon (*O. kisutch*) (WDFW 2024b). These creeks are located to the east of Project Macoma, outside of the Study Area. Additional analysis of federally listed species and critical habitats protected under the ESA, as identified by USFWS and NMFS, is discussed in Section 4.3.6.

WDFW PHS data (WDFW 2024a) also document the following species and habitats as occurring or potentially occurring within the marine environment of the greater area of Port Angeles Harbor, outside of the Study Area:

- Hardshell clam (*Mercenaria mercenaria*)
- Subtidal hardshell clam
- Pandalid shrimp
- Dungeness crab (*Cancer magister*)
- Surf smelt (*Hypomesus pretiosus*)
- Shorebird concentrations
- Harlequin duck (*Histrionicus histrionicus*)
- Eelgrass meadows
- Pacific sand lance

3.3.6 ESA-Listed Species and Critical Habitat Assessment

There are 19 ESA-listed or proposed species identified by the USFWS, NMFS, and WDFW as potentially occurring in the Study Area; however, as described in this section, many of these species do not occur or are very unlikely to occur in or near the Study Area based on the species' life history and habitat requirements. Table 1 provides the status of federally listed or proposed species and critical habitats protected under the ESA identified as potentially occurring within the Study Area as of the writing of this ESAR.

Table 1
Federally Listed Species That May Occur in the Study Area, with Their ESA and Critical Habitat Status

Species	Status	Agency with Jurisdiction	Critical Habitat
Killer whale (*Orcinus orca*)	Endangered (Southern Resident DPS)	NMFS	Designated
Humpback whale (*Megapterus novaeangliae*)	Threatened (Mexico DPS); endangered (Central America DPS)	NMFS	Designated but not in Study Area
Puget Sound Chinook salmon (*Oncorhynchus tshawytscha*)	Threatened (Puget Sound ESU)	NMFS	Designated
Puget Sound steelhead (*Oncorhynchus mykiss*)	Threatened (Puget Sound ESU)	NMFS	Designated
Hood Canal summer-run chum salmon (*Oncorhynchus keta*)	Threatened (Hood Canal ESU)	NMFS	Designated but not in Study Area
Bull trout (*Salvelinus confluentus*)	Threatened (Coastal-Puget Sound ESU)	USFWS	Designated

Species	Status	Agency with Jurisdiction	Critical Habitat
Bocaccio rockfish (*Sebastes paucispinus*)	Endangered (Georgia Basin DPS)	NMFS	Designated but not in Study Area
Yelloweye rockfish (*Sebastes ruberrimus*)	Threatened (Georgia Basin DPS)	NMFS	Designated but not in Study Area
Sunflower sea star (*Pycnopodia helianthoides*)	Proposed Threatened	NMFS	Not designated
Marbled murrelet (*Brachyramphus marmoratus*)	Threatened	USFWS	Designated but not in Study Area

3.4 Geologically Hazardous Areas

The Study Area is located in the Strait of Juan de Fuca region, along the coastline of Port Angeles Harbor. Large subduction earthquakes are possible in the coastal area, and several active and potentially active faults are present within the Strait of Juan de Fuca region (Hart Crowser 2003). Hart Crowser conducted a geotechnical and hydrogeologic study that included the Study Area and determined that liquefaction could develop in the upper two soil units under the 475-year earthquake but is unlikely to occur under the 190-year earthquake (Appendix B). Additionally, in the case of liquefication, lateral spreading may occur. However, liquefication should not significantly impact the site because it is relatively flat. The installation activities have been designed to have minimal ground disturbance, and Project Macoma is designed to be modular and fully removed as the conclusion of the pilot project. Because of these considerations, no impacts to geologically hazardous areas are anticipated. Therefore, geologically hazardous areas will not be discussed further in this ESAR.

3.5 Frequently Flooded Areas

The upland portion of the Study Area is not within the 100-year floodplain. The pier and barge would be located within a Zone AE floodplain, which is subject to inundation by a 1% annual chance flood event (FEMA 2023). This area's base flood elevation is 13 feet North American Vertical Datum of 1988 (NAVD88). The Study Area is not located within a regulatory floodway; thus, flood areas will not be discussed further in this ESAR.

3.6 Critical Aquifer Recharge Areas

The Clallam County Critical Areas map (Clallam County 2024) identifies the Study Area as located within a critical aquifer recharge area. Hart Crowser conducted a geotechnical and hydrogeologic study that included the site and noted that the groundwater levels are slightly higher than average water levels in the Port Angeles Harbor. Soil Unit 1 forms an upper aquifer above an average of 18 feet and consists of moderately permeable silty sand and gravel. Soil Units 2 and 3 form an upper sand/silt aquitard. Additionally, there was found to be a thin, deep aquifer layer beneath the silt/sand aquitard.

4 Critical Areas Impact Assessment

This section summarizes potential impacts on critical species, areas, and habitats that could arise from construction and operation of Project Macoma. Appendix A provides more detailed information about construction and operational activities.

4.1 Fish and Wildlife Habitat Areas Impact Assessment

Project activities will occur in the upland, overwater, and in-water areas of the Study Area. Project elements consist of installing modular shipping containers that house the mCDR equipment in the upland area, mooring the in-water barge and affixing the intake and outfall to it, and installing the piping that runs along the existing dock to connect the upland containers to the intake and outfall on the barge. The upland facility will be installed on fill material to level the site and minimize excavation. These activities will occur within 200 feet of the OHWM and in close proximity to fish and wildlife habitat areas.

4.1.1 Construction Impacts

Potential impacts from construction could occur from installation of the upland portions of the mCDR facility, barge, and piping. Construction activities have been designed to result in minimal ground disturbance. Grading activities will consist of adding a layer of gravel on top of the existing soil instead of the traditional method of rearranging the existing soils. These grading activities could result in soil erosion; however, the area of soil disturbance would be minor and would occur within an industrial area previously cleared to support ongoing log yard operations. No fill material would be placed into nearby surface waters. No vegetation is proposed for removal. As discussed further in the following subsections, best management practices (BMPs) would be implemented, including temporary erosion control measures, consistent with applicable permits and approvals to ensure there would not be indirect effects to the aquatic environment.

Dust emissions could also occur during upland construction during minor excavation or placement of fill material to bring the site to grade. The use of heavy equipment for construction activities also carries a risk of an accidental release of fuel, hydraulic fluids, or other toxic materials to the soil or water. However, these activities are consistent with the existing operational activities of the industrial log yard, and no change in use pattern is proposed for Project Macoma.

During construction, BMPs will be implemented to further avoid and minimize potential impacts to the environment from construction activities. Plans that will be prepared and implemented during construction include a Temporary Erosion and Sediment Control (TESC) plan; a stormwater site plan; a Contaminated Materials Management Plan (CMMP); and a Spill Prevention, Control, and Countermeasure (SPCC) plan. In addition to the plans, construction equipment will be maintained in good working order and dust control measured will be employed during construction. BMPs are discussed further in Section 5.1. Installation activities that would occur waterward of the OHWM include moorage of the temporary barge, outfitting the barge with pre-constructed intake and outfall components, and the installation of the piping across the existing overwater structure. These installation activities have been designed to be minimal and temporary.

Installation moorage of the barge and connecting the pre-constructed intake and outfall components to it would occur within Port Angeles Harbor. These actions would be temporary and would have negligible impact on critical species and fish and wildlife habitat areas, including water quality, relative to the surrounding commercial and industrial uses of the Harbor. Similarly, the installation of piping across the existing dock would be temporary and would result in negligible impacts to critical species and habitats.

The installation of Project Macoma has the potential to have short-term impacts on fish, marine invertebrates, marine mammals, amphibians, reptiles, small mammals, waterfowl, and other birds that may be present in the vicinity of the site. Initial upland construction activities would result in increased noise and overall disturbance associated with typical construction projects. Noise levels may be temporarily elevated but are expected to be similar to typical sounds levels at the working Port. Implementation of BMPs will help avoid and minimize potential construction impacts to nearby fish and wildlife habitat areas and sensitive species. Thus, no significant impacts on critical species or fish and wildlife habitat areas are anticipated to result from the installation of Project Macoma.

4.1.2 Operational Impacts

Potential impacts to fish and wildlife habitat areas and sensitive species from the operation of Project Macoma are expected to generally be commensurate with the operational activities of the existing log yard and the adjacent industrial properties. No change in use pattern for the property is proposed. Impacts to upland critical species and habitats are anticipated to be negligible, as discussed further in the following subsections.

Fish and wildlife habitat areas would be temporarily affected by an increase in the shading of the aquatic environment while the barge is moored for the operation of Project Macoma. The barge selected for Project Macoma will be relatively small (approximately 2,400 square feet) and will be situated in a deeper part of the nearshore area at a designated berth that currently includes a moored oil spill response vessel. This location does not include documented eelgrass beds, although bull kelp is likely to occur in the area. However, due to the small scale and relatively short-term duration of operations, no significant impacts to submerged aquatic vegetation is expected.

Project Macoma's operation includes the intake of seawater and discharge of alkaline-enhanced seawater into the waters of Port Angeles Harbor. The system will be designed to comply with current fish screening guidelines from the WDFW and the NMFS. The intake screen will be designed to prevent fish from entering the intake facilities.

The effects of the discharge of the higher alkaline seawater outside of a laboratory setting are not fully understood and would be studied during and after the short-term duration of the pilot project; however, the rates of discharge are not anticipated to produce adverse impacts. In addition, a framework to study the effects of Project Macoma is presented in the Ecological Safety Methodology (ESM) (Appendix B to the Biological Assessment [Appendix D]). The ESM is being further developed with project partners to include the protocol for how effluent discharges would proceed, be monitored, and be adapted if needed to ensure ecological safety. Currently, it is understood that the discharge would dilute to meet Washington State marine surface water standards (Washington Administrative Code [WAC] 173-201A-210) within 40 feet, with additional far-field water quality impacts extending up to 207 feet in any horizontal direction of the diffuser ports and including the entire vertical water column (Appendix A to the Biological Assessment [Appendix D]). Additional analysis based on existing mixing zone studies prepared for Project Macoma is also included in the Biological Assessment (Appendix D).

Overall, the operation of Project Macoma is expected to benefit the environment. The system is designed to deacidify local seawater and generate alkaline-enhanced seawater. When the alkaline-enhanced seawater is discharged into the ocean, this enables the ocean to draw down and store additional CO_2, resulting in the permanent removal of excess CO_2 from the atmosphere. Project Macoma has a rated capacity capability to remove 500 tons of CO_2 per year from the atmosphere. Findings from this small-scale pilot project would help support future commercial deployments at other locations throughout the world in order to help mitigate the effects of climate change.

Because of Project Macoma's restorative purpose, small scale, and temporary operations, and for the reasons described in this ESAR, it is not expected to have any significant or long-term impacts on nearby fish and wildlife species or habitat areas.

4.1.3 ESA Species and Critical Habitat Impact Assessment

The BA prepared for Project Macoma evaluates the potential effects on ESA-listed species and critical habitats identified as potentially occurring within the Study Area (Appendix D). The impacts on ESA-listed fish and wildlife species and associated habitat would be temporary and are expected to be low for the same reasons discussed in Sections 4.1.1 and 4.1.2. A summary of the ESA-listed species and critical habitat is presented in Table 1. Additional detail can be found in Appendix D.

4.2 Critical Aquifer Recharge Areas

Project Macoma is not anticipated to adversely impact groundwater or surface water. The site is currently used as an industrial log yard. The proposed use of Terminal 7 for the mCDR facility will not substantively change use patterns from existing conditions. Potential erosion and sedimentation and fuel and lubricant leaks from equipment during construction have the potential to adversely impact groundwater and surface water. However, the site has an existing stormwater management system that will be utilized. Additionally, Project Macoma, LLC, will develop, maintain, and implement a chemical management plan to control the spent material used throughout operation of the pilot project. Proposed avoidance, minimization, and mitigation measures to be implemented during construction and operation of Project Macoma are discussed in Section 5.

5 Avoidance, Minimization, and Mitigation Measures

The pilot project would require the intake and discharge of seawater in Port Angeles Harbor to remove additional CO_2 from the atmosphere and store it in the ocean as dissolved inorganic carbon. By nature, the pilot project is designed to improve conditions in the aquatic environment by safely and permanently removing acid from seawater locally.

An Ecological Safety Methodology (ESM) is the monitoring tool developed for the pilot project that would help to ensure that discharges to Port Angeles Harbor do not result in adverse environmental effects (Appendix B to the Biological Assessment [Appendix D]). The ESM would provide ecological safety by identifying the circumstances under which delivery of alkaline-enhanced seawater could be modified for the protection of the marine environment. The ESM would also study the pilot project's benefits to the marine environment.

The pilot project, as a field trial of Ebb Carbon's mCDR system, would include data collection and analysis by Project Macoma, LLC, and possibly others. During operations, the discharge of alkaline-enhanced seawater would be monitored for compliance with all regulatory requirements. Monitoring efforts of the pilot project's potential effects would begin once project deployment occurs. Water quality monitoring would be accomplished by attaching sensors to existing piers to collect regular measurements of water temperature, salinity, dissolved oxygen, turbidity and suspended solids, chlorophyll, pH, and the partial pressure of CO_2 (pCO_2). Monitoring and modeling would also take place to measure the benefits of this discharge, including the resultant CO_2 removal and sequestration. Monitoring would occur during and after operations.

Biological monitoring surveys areas would be identified during a baseline study, including areas with aquatic vegetation, rocky substrate, and shellfish beds, and would be used to identify when adaptive management strategies may be triggered and to track potential beneficial impacts. Additional data collection or monitoring opportunities may be implemented following discussions with reviewing federal and state agencies, the Lower Elwha Klallam Tribe, Pacific Northwest National Laboratory, and the University of Washington. Baseline monitoring surveys would occur prior to pilot project implementation.

The project would require short-term construction, including installation of a barge, intake and outfall structures, and piping system that would connect to the new temporary onshore facility. Avoidance and minimization measures include reducing the aquatic and upland footprint of the pilot project to the extent feasible to run it effectively and gather adequate scientific data to inform future deployments. Construction impacts would be minimized by reducing the amount of excavation to the extent practicable and installing temporary, modular equipment instead of permanent structures.

5.1 Best Management Practices

During construction and operation of the pilot project, BMPs would be implemented to further avoid and minimize potential impacts to the environment. BMPs include, but are not limited to, the following:

- Work would be performed according to the requirements and conditions of the project permits and approvals.
- Construction activities would be completed consistent with the TESC and stormwater site plans prepared for the pilot project. Erosion control measures may include installing a stabilized construction access; construction road stabilization; installing mulching, nets, and blankets; applying surface roughing, gradient terraces, interceptor dikes, and swales; dust control; material delivery storage and containment; outlet protection; and installing waffles, filter berms, or silt fencing.
- A CMMP would be prepared and implemented during construction to address potential issues if contaminated soils are encountered.
- The contractor would be required to develop and implement an SPCC plan to be used for the duration of the pilot project to safeguard against unintentional release of fuel, lubricants, or hydraulic fluid from construction equipment.
- Construction equipment used on the project would be maintained in good working order to minimize airborne emissions.
- Dust control measures, such as application of water, would be employed during construction, as necessary.
- No uncured concrete would be in contact with surface waters.
- The contractor would be required to properly maintain construction equipment and vehicles to prevent them from leaking fuel or lubricants; if there is evidence of leakage, the further use of such equipment would be suspended until the deficiency has been satisfactorily corrected.
- Excess or waste materials would not be disposed of or abandoned in Port Angeles Harbor or allowed to enter waters of the state.
- Project Macoma, LLC, would adopt and implement the Port's stormwater pollution prevention plan, which specifies measures to avoid and minimize impacts to surface, ground, and stormwater water and drainage pattern impacts.
- Project Macoma, LLC, would develop, maintain, and implement a chemical management plan that includes specific procedures for procurement, delivery, transfer, storage, inventory, use, spill prevention and cleanup, emergency response, and disposal. All employees and contractors would receive chemical management training within 1 month of hiring and annually thereafter.
- New light fixtures for overwater structures would be directed away from the water to the extent practicable to minimize impacts on aquatic species.

- The intake screen would be designed to screen fish from entering the intake facilities in compliance with current fish screening guidelines from WDFW and NMFS.
- All intake will go through multimedia filtration consisting of carbon filtration, sand filtration, and granular activated carbon filtration. All multimedia filters have to be backflushed daily, whereby trapped constituents like plankton will be returned to Port Angeles Harbor.
- A Monitoring and Inadvertent Discovery Plan for cultural resources would be prepared and implemented during project construction.

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Figures

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Miles

Figure 1
Site Vicinity
Environmentally Sensitive Areas Report
Ebb Carbon Marine Carbon Removal Project (Project Macoma)

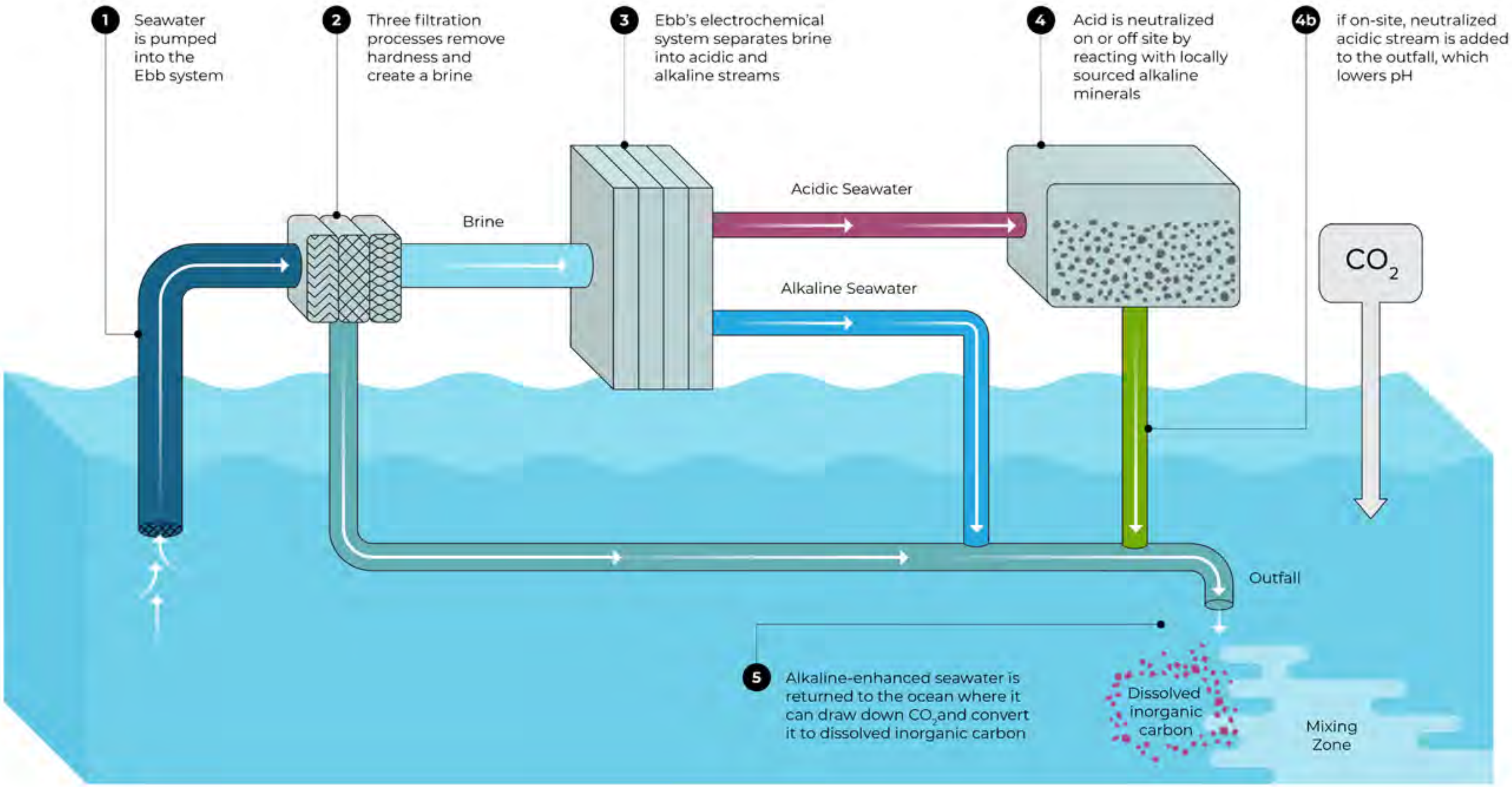

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Figure 2
Water Treatment Process Diagram
Environmentally Sensitive Areas Report
Marine Carbon Dioxide Removal Pilot Study (Project Macoma)

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Figure 3
Aerial Photograph of the Study Area

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Figure 4
Critical Areas Site Plan
Critical Areas Study and Habitat Assessment
Ebb Carbon Macoma Project

LEGEND:

Project Area

Soil Type

Clallam Gravelly Sandy Loam

Clallam-Hoypus Complex

Dystric Xerorthents

Neilton Very Gravelly Loamy Sand

0 800

Feet

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Figure 5
USDA NRCS Soils

Critical Areas Study and Habitat Assessment
Ebb Carbon Macoma Project

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Figure 6
Wetlands and Streams
Critical Areas Study and Habitat Assessment
Ebb Carbon Macoma Project

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Figure 7
FEMA Special Flood Hazard Areas
Environmentally Sensitive Areas Report
Ebb Carbon Marine Carbon Removal Project (Project Macoma)

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Figure 8
Nearby Streams

Environmentally Sensitive Areas Report
Ebb Carbon Marine Carbon Removal Project (Project Macoma)

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Figure 9
Topography
Environmentally Sensitive Areas Report
Ebb Carbon Marine Carbon Removal Project (Project Macoma)

Appendix A
Project Description and Plan Set

(Submitted with this report under separate cover)

Appendix B
2003 and 2014 Geotechnical Reports

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Port Angeles Graving Dock
Port Angeles, Washington

Prepared for
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January 28, 2003
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GEOTECHNICAL AND HYDROGEOLOGIC STUDY
PORT ANGELES GRAVING DOCK
PORT ANGELES, WASHINGTON

INTRODUCTION

This report presents the results of our geotechnical and hydrogeologic study to provide design, construction, and dewatering recommendations for the proposed graving dock project located in Port Angeles, Washington. This report supersedes our November 13, 2002, memorandum "Summary of Field Pumping Test and Dewatering Design" and the preliminary geotechnical engineering recommendations provided in a draft report dated November 18, 2002.

The first several pages of our report summarize the purpose and scope our work. The main body of the report presents our geotechnical design and construction dewatering recommendations. This is followed by appendices, which present current and previous explorations, laboratory test results, and the groundwater pumping tests data.

Our report includes the following:

- Project Understanding;
- Executive Summary;
- Purpose and Scope of Work;
- Site Geology;
- Subsurface Conditions;
- Seismic Conditions;
- Engineering Analysis and Recommendations; and
- Appendices that present:
  - Current geotechnical field exploration logs (Appendix A);
  - Laboratory test procedures and results (Appendix B);
  - Current and previous environmental borings (Appendix C); and
  - Data and analysis for the groundwater pumping test (Appendix D).

PROJECT UNDERSTANDING

The proposed Port Angeles Graving Dock site is located along the Port Angeles waterfront, just south of Ediz Spit. A Vicinity Map is provided on Figure 1. It is designed to serve as a graving dock for construction of the eastern half of the SR 104 Hood Canal Floating Bridge concrete pontoons. The graving dock will also be used in the future for construction of SR 520 floating bridge replacement pontoons.

We understand that the current preferred alternative of the proposed graving dock has a plan dimension of 460 by 905 feet. A 170-foot-wide deep channel will be constructed along the eastern part of the graving dock with a top of slab at elevation –15 feet. An upper slab at elevation 10 feet, where most of the pontoons will be constructed, will form the remainder of the graving dock. A wall will be constructed along the entire perimeter of the dock with the top of wall at elevation 28 feet. After constructing the pontoons, they will be floated out of the graving dock into the Port Angeles Harbor by flooding the graving dock with water up to elevation 27 feet. It is our understanding that the construction of the pontoons will last about 5 to 6 months, and the flooding operation to float the pontoons will only last a few days.

EXECUTIVE SUMMARY

The following summarizes the principal conclusions and recommendations contained within this report. Refer to subsequent sections of the report for further discussion of each point, as well as for other recommendations.

Explorations and Testing

Our field program included eight geotechnical borings, designated H-1-02 through H-8-02. Monitoring wells were installed in three of the eight geotechnical borings. A pumping test was performed in a large-diameter dewatering well (PW-02). An array of observation wells (OW-1 through OW-3) and monitoring wells were used to provide site-specific data for the drawdown response to pumping of groundwater. Exploration locations are shown on Figure 2.

Subsurface Conditions

There are five major soil units underlying the project site. From the ground surface downward, these units are:

- Soil Unit 1 – SAND/GRAVEL (upper aquifer);
- Soil Unit 2 – Silty SAND (upper aquitard);
- Soil Unit 3 – Sandy SILT (upper aquitard);
- Soil Unit 4 – Sand to Gravelly SAND (lower aquifer); and
- Soil Unit 5 – Glacially Overridden Soils (lower aquitard).

The depth to groundwater varies from 6.3 to 8.9 feet, which corresponds to elevation 4.8 to 5.7 feet. Figure 3 shows an elevation contour map of top of bearing layer (Soil Unit 5). Figures 4 through 8 illustrate a series of generalized subsurface cross sections.

Seismic Conditions

Two levels of earthquake have been considered in this study, including:

- An earthquake with a 10 percent probability of exceedance in a 50-year period (475-year return period) and a corresponding Peak Ground Acceleration (PGA) of 0.28g.

- An earthquake with a 10 percent probability of exceedance in a 20-year period (190-year return period), with a corresponding PGA of 0.14g.

Widespread liquefaction may occur in the silty Sandy and the sandy Silt soils (Soil Units 2 and 3) under the 475-year earthquake. Under the 190-year earthquake, only local and relatively isolated pockets of soils may liquefy.

Dewatering

Dewatering of the proposed layout and construction scenario for the graving dock can be accomplished to achieve the main objectives for safe construction in dry conditions. However, some of the on-site soils will not yield much water to gravity drainage and may benefit from more proactive dewatering systems (such as vacuum wellpoints or eductor systems) that are more appropriate than dewatering wells for reducing pore pressures in lower permeability soils. A conceptual dewatering schematic is illustrated on Figure 9.

The pumping test demonstrated the presence of a hydrologically significant lower sand horizon (Soil Unit 4) at depth, which, though relatively thin, appeared to exist across most of the site. The presence of this relatively permeable layer constitutes a potential source of uplift pressures beneath the base of the deep excavation. Depressurization of this layer as part of the dewatering approach may provide improved drainage of the poorly draining soils that exist above and below final grade in the deep channel section of the proposed excavation.

Retaining Structures

Feasible retaining wall alternatives include sheet piles, secant soldier pile walls, or a hybrid sheet pile/solider pile wall system. Ground freezing is likely not a long-term solution based on cost comparisons.

Deep Channel Wall

The walls surrounding the deep channel will be subjected to five different lateral loading cases.

(1) Construction Phase;
(2) Operational Phase;
(3) Super Flood Phase;
(4) Earthquake; and
(5) Post-Earthquake (Liquefaction).

Given the variation in soil conditions and the size of the deep channel, we have identified three segments designated as C-1 through C-3 (refer to Figure 10) along the perimeter of the channel, with each segment representing different soil conditions. Earth pressure parameters for wall segments C-1 through C-3 are presented in Tables 2 through 4, respectively. For illustrative purpose, the subsurface profile along segment C-1 and the corresponding earth pressure diagrams are presented on Figures 11 and 12. An important assumption associated with these earth pressure diagrams is that the lower aquifer will be permanently depressurized inside and beneath the deep channel, as discussed subsequently.

General assumptions and seismic-related loadings for each of the five loading cases should be used in conjunction with the soils parameters presented in Tables 2 through 4.

Upper Slab Wall

The super flood phase will likely govern the design of the upper slab wall. Two segments (U-1 and U-2) were identified as shown on Figure 10, each corresponding to different subsurface conditions. Table 5 and 6 presents earth pressure parameters for Segments U-1 and U-2, respectively. During the super flood case, the water pressure is assumed to start at elevation 27 feet and extends to the bottom of the sheet pile. This assumption implies that the slab will have joints or cracks such that the underlying soils are hydraulically connected to the water in the graving dock.

Seepage Cutoff

The deep channel walls should extend into the glacially overridden soils, which will provide adequate seepage cut off. For the upper slab walls, we recommend that the wall be embedded in Soil Unit 2 with the tip of the wall elevation at –17 feet.

Deadman and Tieback Recommendations

The sheet piles surrounding the deep channel will be supported with either deadman (concrete or sheet pile) or tieback anchors. The recommended static and seismic earth pressures for concreter deadman are shown on Figure 14. For the sheet pile deadman, the earth pressures parameters presented in Tables 2 through 4 should be used in the design.

Two criteria govern the deadman location. The first criterion is that the deadman should be located behind a line that extends from the point of zero moment on the sheet pile wall to the ground surface with an inclination that is equal to the soil friction angle measured from the horizontal. The second criterion is that the passive wedge acting on the deadman does not overlap with the active wedge acting on the sheet pile wall of the deep channel.

The main disadvantage of a tieback system is soil liquefaction. It is expected that tieback bond length would be located within the silty Sands (Soil Unit 2) and the sandy Silts (Soil Unit 3) where wide-spread liquefaction may occur under the 475-year earthquake, leading to a significant loss in tieback capacities. In this case, the tieback alternative may not be feasible, unless the bond length can be extended into the deeper no-liquefiable soils (Soil Unit 5).

Excavation Stability of Walls

Both the deep channel and the upper slab walls will have adequate factors of safety against global instability provided embedment recommendations presented above are implemented in the design.

Graving Dock Slabs

Deep Channel Slab

The super flood phase would likely be the critical case for slab settlements. Our analyses suggest the settlements would vary from about 1 inch toward the southern edge of the channel to 2 to 4 inches toward the northern edge of the channel. Settlements in the vicinity of the northern edge of the channel may cause downdrag on some piles supporting the gate.

Assuming the water pressure in Soil Unit 4 may equal the hydrostatic pressure outside the dock during the operational phase, our analyses suggest factors of safety of 0.55 and 0.9 against uplift along the southern and the northern edges of the channel, respectively. The vertical stress required to achieve a factor of safety of 1.25 against uplift varies linearly from 1,000 psf along the southern edge to 500 psf along the northern edge of the deep channel. A pressure relief system alone or combined with a structural system can be used to reduce uplift impacts. The structural system may consist of piles, micropiles, or tiedowns embedded into the glacially overridden soils to resist uplift forces. Regardless of the use a structural system, a pressure relief system will be required to avoid reduction of passive earth pressures acting on the sheet pile wall.

Upper Slab

Settlement would vary across the upper slab from about 1 inch toward the southeast corner to 6 inches toward the northwest corner. We understand that these settlements are tolerable, and therefore, preloading is not required. These settlements would occur due to the compression of the soils located mainly below the tip (elevation −17 feet) of the sheet pile for the upper slab. Therefore, downdrag forces are not anticipated on the sheet piles for the upper slab. For the deep channel sheet piles, settlement-induced downdrag would be insignificant given the much higher axial capacity of the sheet piles.

The estimated settlement due to liquefaction would range from 6 to 10 inches under the 475-year earthquake. Under the 190-year earthquake, local zones of liquefiable zones may induce 2 or 3 inches of settlement.

Pile Foundation for Gate Structure

The preliminary design calls for 24-inch-diameter open-end structural steel pipe piles with a 3/4-inch pile wall thickness. We understand that vertical piles will be used to resist both the axial and lateral loads.

Axial Load Capacity

In addition to the uplift forces from the superstructure, the piles should be designed to resist uplift forces due to the water pressure within Soil Unit 4. The additional uplift stress will be about 1,000 and 1,300 psf on the base of the pile cap at elevation −22 and −25 feet, respectively.

The recommended <u>ultimate skin friction</u> values (in compression and tension) are as follows:

- Between elevation −25 and −43 feet, use 200 psf for tension, ignore resistance for compression to account for settlement-induced downdrag on piles due to static and/or liquefaction;

- Between elevation −43 and −53 feet, use 2,000 psf; and

- Below elevation −53 feet, use 3,000 psf.

Use ultimate end bearing (in compression) of 200 kips (assuming inside-fit cutting shoe and no plug)

Use FS = 2.0 for both tension and compression with pile capacity verified by pile driving analyzer (PDA) and CAPWAP analysis on at least 2 to 5 percent of the production piles. Group effects for axial loads will not be significant provided that piles are spaced at least 2½D.

Laterally Load Capacity

The p-y curve soil parameters for single pile under static and post-earthquake cases are provided in Table 7. Group reduction factors for lateral analysis should be incorporated into the analysis, in accordance to the procedure outlined in the *WSDOT Bridge Design Manual*, as revised July 2000.

Walls Attached to the Gate Foundation

Two concrete walls along the east and west sides of the gate will be attached to its foundation. The top of the wall long the east will be at elevations 14 feet with a total height of about 30 feet. Along the west side, the top of the wall will at elevation 21 feet with a total height of about 37 feet. The recommended earth pressures are presented in Table 9.

PURPOSE AND SCOPE OF WORK

The purpose of our work is to provide the Washington State Department of Transportation (WSDOT) and their design consultants with geotechnical engineering and hydrogeologic recommendations related to the design and construction of the proposed graving dock.

Scope of Work

Our scope of work for this project included:

- Evaluate the groundwater regime and estimate the amount of water that can be expected in the graving dock excavation;

- Install a test well and observation wells and perform a groundwater pumping test;

- Develop conceptual construction methods that would allow for bottom slab construction in the dry or wet construction with seals;

- Present recommendations for a dewatering system for construction and operation of the graving dock;

- Assess seepage rates including water quantity and quality that can be expected in excavations if a dewatering system is used and not used, during both construction and operation;

- Assess treatment that may be required for discharge from excavations, well points, graving dock valves, and pumping systems, during both construction and operation;

- Drill seven geotechnical borings and collect representative soil sample for laboratory index testing;

- Present recommendations for feasible wall types for the graving dock walls;

- Develop earth pressures and water pressures for wall design;

- Present tieback or deadmen recommendations, if needed;

- Develop recommendations for wall stability and constructability;

- Define seismic design parameters and seismic design recommendations;

- Present foundation recommendations for the graving dock floor;

- Develop recommendations for seepage forces and uplift forces acting on the walls and floor;

- Evaluate excavation stability based on wet construction and dry construction, bottom heave, and side wall stability;

- Evaluate deep foundation alternatives, such as piles, shafts, and micro piles to carry uplift loads and compressive loads applied to the graving dock;

- Develop special provisions and plan sheets to support geotechnical recommendations;

- Review the contract documents and seal all geotechnical plans; and

- Prepare interim memoranda and final geotechnical/hydrogeologic report.

The scope of work also includes environmental drilling, sampling, and testing. Results of environmental investigation are presented in a report under separate cover dated October 25, 2002. Additional test results on soil samples obtained from the latest round of geotechnical explorations are presented in the environmental report addendum dated December 6, 2002.

SUBSURFACE EXPLORATIONS AND TESTING

Our field program consisted of eight geotechnical borings (designated H-1-02 through H-8-02), three observation wells (designated OW-1 through OW-3), and a large diameter test well (designated PW-02). Boring H-8-02 was drilled as a result of a survey error and was terminated at a relatively shallow depth. The locations of the explorations are shown on Figure 2. The geotechnical borings were drilled to depths ranging from 44 to 90 feet using hollow-stem augers. Monitoring wells were installed in three (H-5-02 through H7-02) of the geotechnical borings. Observation wells OW-1 and OW-3 were drilled to a depth of 20 feet. Observation well OW-2 was drilled to a depth of 35 feet. The logs of the geotechnical borings, the test well, and the observation wells are presented in Appendix A.

The laboratory testing consisted of water content determination, grain size analyses, hydrometer tests, and Atterberg limits. The results of the water content determinations and the Atterberg limits are presented on the boring logs. The test procedures and results of the Atterberg limits and the grain size analyses are presented in Appendix B.

As part of our scope of work, Hart Crowser previously performed an environmental investigation for the project site. Five environmental borings were drilled for the environmental investigation (refer to Figure 2). Groundwater monitoring wells were also installed in these borings. Physical laboratory testing was performed on samples obtained in one of the current environmental boring (HC-NW-02), and consisted of water content determination and grain size analyses. Additionally, Hart Crowser drilled 10 environmental borings for a previous study in 1988. Locations of the 1988 borings, which are located in the vicinity of the subject dock, are shown on Figure 2. The current and previous environmental borings are presented in Appendix C.

Given the depth of proposed construction below the water table, the program also included an investigation into the feasibility of dewatering the site, and determination of the recommended methods for achieving dewatering objectives. A pumping test was performed in a large-diameter dewatering well installed at the site, and an array of observation wells was used to provide site-specific data for the drawdown response to pumping of groundwater. Results and analysis of the pumping test data and observed drawdown responses are presented in Appendix D. This information is used to develop a proposed dewatering concept for the project and to evaluate the performance of potential alternative methods. The current graving dock layout and construction concept have been taken into account in developing the current dewatering system design.

SITE GEOLOGY

Based on our understanding of the site from current and previous explorations, the site is situated on filled ground that forms a relatively flat lowland area adjacent to Port Angeles Harbor. The property was used for most of the 20th century as a sawmill and lumber processing yard. A 150- to 200-foot-high bluff, located just south of the property, forms the boundary of the uplands to the south. The site area was part of the intertidal zone prior to being filled.

In general, the site stratigraphy from the current ground surface downward includes recent fills consisting of dredged silts, sands, and gravel as well as a localized area of wood chips. The dredged fills overlie natural beach deposits consisting of interbedded silts, sands, and gravel, which in turn overlie glacially overridden and consolidated sediments at depth. Materials encountered in our explorations were near-surface fill material including wood debris over intertidal and beach deposits of sand and gravel with interbeds of cleaner sand as well as silt layers. These intertidal and beach deposits generally contain shell fragments but are difficult to distinguish from the overlying dredged fill, which also contains shell fragments in places.

The bluff and the soils underlying the original beach deposits consist of an interlayered and very dense sequence of glacially derived sediments ranging from relatively permeable sands and gravels to hard silts of very low permeability.

Much of the fill was placed over the original beach deposits prior to the 1920s. The fill is reported to be dredge material, and at the site, consists of sandy gravel and gravelly sand. Based upon the explorations at the site, the upper portions of the fill (generally above 5 feet in depth) consist of a loose to medium dense mixture of sand with silt and gravel, and containing varying amounts of bark and wood debris, coarse gravel, and angular riprap used as ballast on the dirt log haul roads.

SUBSURFACE CONDITIONS

Soil Conditions

Based on current and previous explorations, there are five major subsurface units underlying the subject site. A contour map of top of bearing elevations and a series of generalized subsurface profiles are illustrated on Figures 3 though 8. The following sections describe each of the major five soil units as encountered in current and previous borings.

Soil Unit 1 - SAND/GRAVEL (Upper Aquifer)

This unit underlies a thin surficial fill, and extends to depths varying from 6 to 25 feet, with an average depth of about 18 feet (elevation –5 feet). For simplicity, the overlying fill layer and this unit are presented as one soil unit on the generalized cross sections. The relative density of most of the soils in this unit varies from medium dense to dense, occasionally very dense. The inferred high relative density, based on blow counts in the borings, may be attributed to the presence of gravel and may not be representative of actual soil density.

Soil Unit 2 - Silty SAND (Upper Aquitard)

This unit was encountered underlying Soil Unit 1 and consists of loose to medium dense, occasionally dense, silty Sand. Within the footprint of the graving dock, the thickness of this unit ranges from 10 to 35 feet. Based on results of laboratory grain size analyses, the fines content in this unit ranges from 24 to 40 percent. The unit is entirely submerged under the groundwater table.

Soil Unit 3 - Sandy SILT (Upper Aquitard)

This unit was only encountered in borings drilled along the northern side of the graving dock (refer to Cross Section A-A'). In current and previous environmental borings, this unit was not differentiated from the overlying silty Sand. The boundaries between Soil Units 2 and 3 at the locations of the environmental borings, however, were interpreted based on the distinct difference in SPT blow counts between the two soil units. The unit consists of very soft to soft, sandy Silt, with thickness varying from 20 to 30 feet.

Based on two combined grain size (grain size and hydrometer) tests, the sand content is 25 to 28 percent; the silt content is 60 to 65 percent; and the clay content is about 10 to 12 percent. However, this soil unit appears to be of very low plasticity or non-plastic.

In boring H-1-02, the blow counts of this layer were mostly zero (refer to Cross Section A-A'). Although we believe these low blow counts were not caused by heave or negative water head in the bore hole, it may warrant additional cone penetration testing for verification of this anomalous ground condition.

Soil Unit 4 - SAND to Gravelly SAND (Lower Aquifer)

This unit appears to be thin, generally about 2 to 5 feet in thickness. This soil unit was NOT noted in many of the earlier borings, particularly in the environmental borings. This can be attributed in part to its limited thickness. The results of the groundwater pumping test indicate that this unit is relatively permeable, suggesting that it may be relatively clean of fines, in spite of the "silty" description in some of the boring logs.

Soil Unit 5 - Glacial Overridden Soils (Lower Aquitard)

This unit mainly consists of hard, sandy Silt with interbedded layers of very dense, silty Sand. Occasionally, this unit contains layers of very dense, gravelly Sand. This unit is a suitable bearing layer for the sheet pile around the deep channel and for the deep foundations supporting the graving dock gate. Figure 3 presents a contour map showing the elevation of the top of the bearing layer. As shown on the map, the elevation of top of this unit dips toward the north, with about 25 feet difference in elevation across the site. Throughout this report this unit is referred to as the "bearing layer " or "lower aquifer," depending on the context of our recommendations.

Groundwater Conditions and Tidal Fluctuations

Soils below the water table are saturated and under hydrostatic conditions controlled primarily by the average tide level and supplemented by surface recharge due to the infiltration of rainfall on land. These conditions lead to groundwater levels that are slightly higher than average water levels in Port Angeles Harbor.

Upper Aquifer

Soil Unit 1 forms an upper aquifer above an average depth of 18 feet (elevation –5 feet) consisting of moderately permeable silty sand and gravel. This water-bearing zone contains the water table that is slightly above mean sea level in the adjacent Port Angeles Harbor. The predominant groundwater flows are expected to occur in this upper aquifer, which may have a direct source of recharge at or near the shoreline.

Prior to the start of the pumping test (see Appendix D) on October 30, 2002, the water table in the upper aquifer was measured in monitoring wells at elevation 5.65 ±0.2 feet. The water table at the test location appears to be unaffected by tidal fluctuations in Port Angeles Harbor. Based on "static" water level data observed in the various wells, the water table in the upper aquifer is essentially flat, with a very slightly sloping surface toward the harbor giving an estimated hydraulic gradient of 1 in 250 (0.004 ft/ft; H:V).

Measurements of tidal fluctuation in the upper aquifer (unaffected by pumping) were made in monitoring well HC-NW-02 during the pumping test (October 29-30, 2002). Although this well is the closest to the sea wall, it showed little if any discernible tidal influence. It should be noted that the effect of tidal fluctuations dissipates rapidly with increasing distance inland from the shoreline, especially in unconfined aquifers, where the larger storativity (drainable porosity) provides a greater damping effect than in a confined aquifer (see below). Also, construction of the adjacent seawall may limit the hydraulic connection between the shallow groundwater in the upper aquifer and the water in Port Angeles Harbor.

In either event, the dewatering design includes the assumption that the hydraulic connection is fully effective at the shoreline. This constitutes a factor of safety for the recharge effect provided by the presence of water in Port Angeles Harbor, proximally adjacent to the proposed excavation. The assumed presence of this recharge source does not produce large amounts of recharge flow that would preclude dewatering efforts, but it ensures that conservative conditions are considered in the design of the dewatering system.

Upper Sand/Silt Aquitard

The fine sand and silt horizons of Soil Units 2 and 3, below an average depth of 18 feet (elevation –5 feet), forms a lower permeability aquitard in which groundwater flow is relatively limited. Laboratory grain size and hydrometer tests (see Appendix B) show this aquitard to contain a substantial proportion of silt, such that its hydraulic conductivity is likely lower than was indicated from earlier soil descriptions. The hydraulic conductivity of fine sand and silt layer estimated on the basis of grain size analysis (Appendix C) is 1×10^{-5} cm/sec, but depositional layering could introduce anisotropy in the vertical plane, such that the vertical permeability may be somewhat lower.

Despite the relatively low hydraulic conductivity, saturated conditions and hydrostatic pore pressures within these loose/soft silty sandy soils represent a potential issue for the stability and workability of the deep channel excavation subgrade at elevation −20 feet, and will need to be adequately dewatered to provide stable working conditions in the excavations of the deep channel and gate structure. Gravity drainage of the silt/sand aquitard will be slow; it is likely to take between 2 to 4 weeks to obtain sufficient drainage of these soils that will increase their strength to permit excavation in the dry. Reduction of pore pressures within these soil units is also required outside of the deep channel excavation to reduce lateral loads on the sheet pile wall proposed for ground support and final construction of the channel.

The installation of dewatering systems in advance of excavation work, coupled with the time constraints that limit the speed of excavation, usually provide sufficient time for drainage to occur before potentially saturated soils are encountered at depth.

Lower Sand Aquifer

The water level data and pumping test response from monitoring well H-5-02 revealed the presence of a thin deep aquifer layer beneath the silt/sand aquitard. The data also demonstrate the lateral continuity between this aquifer and the body of water in Port Angeles Harbor, although its presence was not recognized in some of the previous site explorations.

The proposed sheet pile wall forming lateral support for the deep channel section for the project is expected to fully penetrate this aquifer and provide a cutoff from lateral sources of recharge. However, if the lateral connection persists through construction, excess water pressure (i.e., a pressure head of +6 feet) in this layer at depth below the base of the channel excavation (subgrade elevation −20 feet) may cause potential problems of uplift and heave. For prudent design analysis, it must be assumed that the pressure head at depth is not dissipated and that it acts on the base of a relatively impermeable plug of soil between the subgrade and the top of the aquifer. If the hydrostatic pressure on the base of the soil plug exceeds the total weight of the soil plug, an uplift condition may exist. Therefore, it will be necessary to depressurize the lower aquifer to reduce excess water pressures and increase the factor of safety against uplift and heave.

Lower Aquitard

No water level data were collected from Soil Unit 5, which forms a deep aquitard composed of hard silt that appears to be glacially compacted. From a hydrogeologic perspective, this layer is considered to form a low-permeability boundary beneath the entire site. Sheet piles driven into this layer should form an effective hydraulic cutoff for lateral flow in all overlying soil units. However, some allowance should be made for possible pile separation or deviation that could create "windows" for groundwater leakage through the sheet piles.

SEISMIC CONDITIONS

Site Seismicity

The graving dock site is located along the northern coastline (along Strait of Juan de Fuca) of the Olympic Peninsula of Washington State. Major earthquakes in the region are generally associated with shallow-subduction plate tectonic activity off the west coast. Research within the last few decades indicates that earthquakes with magnitudes of up to 9.0 are capable of occurring in the coastal areas. No shallow subduction earthquakes have been recorded within the region in the recent historical period. The most recent large (at least magnitude 8 or more) event appears to have occurred in 1700, based on ethnographic data.

In addition to the large subduction earthquakes, several active and potentially active faults are present within the Strait of Juan de Fuca region (Mosher and Johnson 2000). Seismic events on these faults are generally attributed to the intraplate seismicity within the Juan de Fuca plate. They are similar in nature to the historical Puget Lowland earthquakes, including the April 13, 1949, Olympia earthquake (Richter magnitude 7.0); the April 29, 1965, Seattle earthquake (Richter magnitude 6.5); and the February 28, 2001, Nisqually earthquake (Richter magnitude 6.8).

The seismic hazards from both of these sources are included in the probabilistic USGS seismic hazard mapping project that forms the basis of the seismic acceleration map in the WSDOT Bridge Design Manual.

Seismic Design Considerations

For seismic design, an acceleration coefficient of 0.28 g is interpolated from the current acceleration map in the WSDOT Bridge Design Manual. The recommended acceleration coefficient is based on expected ground motion at the project site that has a 10 percent probability of exceedance in a 50-year period (475-year return period).

Design response spectra presented in AASHTO (1996 and 1998) are considered appropriate for seismic design of the structures on this project. A Type III soil profile response spectrum is recommended for seismic design. An associated Site Coefficient of 1.5 is recommended.

We understand there may be interest in designing the graving dock for a life expectancy shorter than that used for highway bridges. For comparative purposes, we developed the seismic acceleration at the site that would be consistent with a 20-year life span for the graving dock. Applying a 10 percent probability of exceedance in 20-year period (190-year return period), the acceleration coefficient was determined to be 0.14 g, or about one half that of the 10 percent probability of exceedance in a 50-year period value that is used for bridges with life expectancies on the order of 75 to 100 years. The lower acceleration value would result in lower Monobe-Okobe seismic earth pressures and less potential for liquefaction, which may govern the design of the graving dock walls.

Liquefaction Potential

Liquefaction of saturated sands occurs when the sands are subject to cyclic loading. The cyclic loading causes the water pressure to increase in the sand, reducing the intergranular stresses. As the intergranular stresses are reduced, the shearing resistance of the sand decreases. If pore pressures develop to the point where the effective stresses acting between the grains become zero, the soil will behave like a viscous fluid. Under this condition soil flow is possible. The effect of liquefaction can range from reduced shear strength to viscous fluid behavior.

The liquefaction potential of saturated sands is evaluated mainly on soil gradation, relative density, and the depth of the deposit. The potential for liquefaction is highest for saturated loose, fine- to medium-grained sands and silty sands above a depth of about 40 feet. The potential for liquefaction at the Port Angeles Graving Dock site was assessed using the procedure originally developed by Seed and Idriss (1982) and later updated by Youd and Idriss (2001).

Based on the available subsurface information, we conclude that liquefaction could develop in the upper two soil units under an earthquake with a 475-year return period. In Soil Unit 1, liquefaction would likely be local and relatively isolated. For the silty Sand in Soil Unit 2, a more wide-spread liquefaction may occur, particularly in the vicinity of borings H-5-02 and H-6-02, leading to significant loss of soil strength and ground settlement.

For the sandy Silt (Soil Unit 3), assessing the potential for liquefaction is quite complex. Based on our visual and laboratory classification, this soil has very low plasticity or is non-plastic. Assuming this would behave like sands, the Seed and Idriss procedure indicates that wide-spread liquefaction is likely to occur under the 475-year earthquake but unlikely to occur under the 190-year earthquake.

Lateral Spreading

In the case of liquefaction, lateral spreading may occur on sites adjacent to bodies of water (similar to the subject site) or on gently sloping sites. Using the equation presented in Youd et al. (2002), our engineering analyses indicate that negligible (less than 0.2 inch) lateral deformations may occur under the 475-year earthquake due to the vicinity of the site to the water. This magnitude of deformation should not significantly impact the proposed graving dock. The subject site is relatively flat and, therefore, lateral spreading is not anticipated due to the effect of sloping.

ENGINEERING ANALYSES AND RECOMMENDATIONS

This section describes the engineering analyses conducted to support the design recommendations for construction dewatering and for the geotechnical aspects of retaining structures, graving dock slabs, and pile foundations.

Dewatering Considerations

Construction dewatering and the control of groundwater levels or pore water pressures to ensure safe construction and operation of the proposed graving dock facility present a number of significant challenges due to the ground conditions and high water table described above. A number of dewatering methods have been considered in the context of the project to achieve the desired degree of dewatering. The relative merits and drawbacks of each method are described below. A recommended approach to dewatering for each stage of excavation, construction, and operation is then described.

Recommendations are based mainly on the results of a single pumping test, which helped to reveal the complexity of the hydrogeologic conditions of the site, and take into consideration drilling conditions in the loose fine-grained soils that could limit the efficiency of installed dewatering systems. Given the potential difficulties that could be encountered, these recommendations should be considered as a starting point rather than a definitive design, with steps taken to measure the effectiveness of each part of the recommended system as it is installed and operated. Modifications can then be implemented as necessary based on drawdown responses observed in piezometers that measure water pressures at key locations and depths both inside and outside the deep channel section of the graving dock.

Dewatering Methods

Since groundwater exclusion will be achieved at the graving dock mainly by using sheet pile walls, this description concentrates on suitable methods for consideration at the Port Angeles site that will work together with the sheet pile walls.

Dewatering Wells. The first choice for dewatering this type of facility is typically the installation of dewatering wells drilled to between 1½ and 2 times the depth of the proposed excavation (i.e., at least 60 feet deep). Dewatering wells with individual submersible pumps are best suited to ground conditions exhibiting moderate to high permeability, such as Soil Unit 1. Provided that wells are designed to be efficient and are adequately screened and developed, multiple wells typically spaced 50 to 150 feet apart can effectively pump groundwater from permeable soils to create reasonably large cones of depression that coalesce together, lowering the water level over relatively broad areas. However, to be effective in this application, relatively permeable deposits need to be present above and below foundation grade.

The limited depth of Soil Unit 1 and the presence of less permeable materials (Soil Units 2 and 3) above the deeper foundation grade of elevation -20 feet at the Port Angeles site limits the use of this approach. Dewatering wells would be effective in lowering water levels within the upper aquifer to a depth of no more than 15 to 18 feet (i.e., to lower the water table by approximately 10 feet). The effectiveness of the wells will be adversely impacted by the interface between Soil Units 1 and 2 that have lower permeability. The contrast in soil permeability prevents the drawdown cone from dropping below this interface, even if the wells are significantly deeper. Greater lowering of the groundwater levels within the silt/sand aquitard by using dewatering wells will thus be prevented, and a dewatering system consisting only of conventional dewatering wells will not be effective.

Vacuum Wellpoints. Wellpoints are small-diameter wells that are drilled or jetted to depths of between 25 and 30 feet but on a much closer spacing than dewatering wells (typically between 5 and 10 feet). Wellpoints are connected to a common suction manifold to which a vacuum is applied using a vacuum-assisted centrifugal wellpoint pumpset. Performance of the system is limited by the constraint of maximum suction lift in the manifold, which is around 25 feet. Water in the wellpoints cannot be lowered beyond this depth. However, additional stages of wellpoint installations with headers and wellpoints installed at lower elevations within the excavation can achieve greater depths of dewatering.

Wellpoints are suited to draining fine sands and silts such as Soil Units 2 and 3, where the application of a vacuum to the soil mass can assist the dewatering action, improving the strength of loose or soft materials by lowering pore water pressures and increasing effective stresses. This approach is expected to be workable inside the deep channel excavation; however, the depth limitation imposed by limited suction lift would restrict the performance of wellpoints installed outside the sheet piles. Wellpoints installed with headers at the ground surface (elevation 13 feet) could dewater soils down to an elevation no lower than -12 feet.

Eductor Systems. Eductor systems overcome the depth constraint that limits the application of vacuum wellpoint systems, and allow the dewatering of lower-permeability soils that do not yield water readily via gravity drainage to wells or wellpoints. Eductor systems feature modified wellpoints that include a jet-pump orifice at the tip of each wellpoint, and require a second manifold system that provides pressurize water to each wellpoint. The venturi action of the jet-pump nozzle provides significant suction and pumping action at the tip, which draws water into the eductor wellpoint.

At the Port Angeles site, eductor systems offer the most effective solution for dewatering the fine sand and silt of Soil Units 2 and 3. To achieve dewatering of these units to the depths required, eductors will need to be installed at least 50 to 60 feet deep outside the sheet pile walls of the deep channel section.

Sump Pumping. Sumps are essentially shallow wells that are excavated typically a few feet below the water table to extract excess water locally to aid excavation work. They usually perform best for shallow excavations below the water table in moderate to high permeability soils, but can induce significant loss of fines if used with coarse filter materials in fine-grained or silty sediments.

The use of sumps or shallow wells in parts of the Port Angeles site may be appropriate for lowering groundwater levels in the shallow upper gravelly sand aquifer due to the limited depth of this formation. Sumps may be needed to remove groundwater that is "perched" at the interface between Soil Units 1 and 2. Sumps may also be effective in controlling locally wet areas, such as sand or gravel pockets; however, they will not be effective for dewatering the fine sand and silt of Soil Units 2 and 3.

Dewatering System Design Recommendations

This section provides a description of the dewatering issues and recommended approaches considered to facilitate excavation and construction of the graving dock, or to improve safety conditions for specific stages of the work. As part of the dewatering approach, piezometers should be installed at key locations to provide direct indication of the drawdowns being achieved, and to allow the effectiveness of system components to be assessed as dewatering progresses.

The primary dewatering objective for the revised layout is to lower the water table beneath the deep channel section of the future graving dock to permit excavation and base-slab construction in dry conditions. Under the revised structural design concepts prepared by KPFF, this objective will be achieved in concert with the installation of sheet pile walls around the perimeter of the deeper excavation. External dewatering of the soils outside these sheet piles is required to reduce hydrostatic pressure on the sheet pile wall.

Dewatering Outside of the Deep Sheet Pile Walls

Design of the sheet pile wall requires a reduction in groundwater levels outside the excavation to reduce lateral hydrostatic loads, until sufficient horizontal reaction can be obtained from the casting of the lower graving dock floor slab and transfer struts. This dewatering objective requires lowering of groundwater levels in all soils around the outside of the sheet pile structure that will form the deeper walls of the channel section in the eastern portion of the graving dock.

The ground conditions at the Port Angeles site present a significant challenge to successful dewatering because the relatively permeable Soil Unit 1 overlies the saturated but much less permeable soils of Soil Units 2 and 3, both of which must be dewatered. Dewatering outside of the deep sheet pile walls cannot be achieved to a sufficient depth using vacuum wellpoints. Wellpoints will be limited to around 10 feet of drawdown (below the static water table) due to the change in soil conditions that occurs at a depth of around 18 feet. The resulting partial reduction of hydrostatic loads on the outside of the sheet pile walls would not be sufficient in that additional bracing for the sheet pile walls would be required during the excavation phase.

The recommended approach for lowering external water levels within the finer soils of Soil Units 2 and 3 is a system of eductor wells. Eductor wells should initially be installed on 10-foot centers, set between the dead-man tiebacks and installed from the ground surface after the tieback trench has been backfilled. Eductor wells should be drilled to depths of between 50 and 60 feet (i.e., to elevations between –37 and –47 feet), screened from a depth of 50 to 20 feet, and connected to injection and vacuum headers laid on the ground surface.

Eductors may need to be installed within pre-drilled holes (at least 8-inch-diameter) and completed with 4-inch-diameter PVC casings and screens so that sufficient filter material can be placed around the casing to provide a vertical conduit for water from the upper aquifer to percolate down to the wellscreen. Drillholes may need to have temporary casing installed during construction to keep the borehole annulus free from fines and prevent clogging of the filter material by the loose fine sands and slits. Water inflows from the aquitard are likely to be insufficient to ensure effective development of the filter material.

The eductor system is anticipated to extract a total flow of up to 20 gpm from the silt/sand aquitard and should be effective in lowering external water levels below the required elevation of –20 feet, provided that the system is not "swamped" by lateral recharge and inflow to the area of dewatering via the more permeable materials of Soil Unit 1. Lateral flow in the upper aquifer is expected to be around 100 gpm for full drawdown and this should be assumed as the design flow for the eductor system, although it will be reduced by the presence of the deadman sheet pile wall. However, it may not be possible to capture all shallow groundwater flow in the upper aquifer using the deeper eductor wells alone. A few feet of saturation may potentially remain above the silty fine sand layer due to the remnant groundwater mounds that will exist between each eductor well.

Depending on the amount of remnant groundwater remaining in the upper aquifer, additional measures in the form of shallow (25-foot-deep) dewatering wells or vacuum wellpoints may also be required in the assumed worst case to adequately dewater Soil Unit 1. The need for additional wells or wellpoints should be determined by measuring water levels in piezometers installed to the base of Soil Unit 1, and spaced at approximately 100-foot centers along the outside of the deep sheet pile walls. Additional dewatering efforts, if required, could be contracted on a force-account basis.

Dewatering of the Deep Channel Excavation

To facilitate construction of the floor slab and transfer struts forming the lower section of the graving dock, dewatering is required to produce dry working conditions at a base grade elevation of –20 feet. Transfer struts will be cast at this elevation, with the top of the slab at elevation –15.5 feet. Groundwater levels need to be lowered ideally 2 feet below the deepest part of the excavation, i.e., to elevation –22 feet, to ensure dry conditions and avoid surface softening.

Penetration of the sheet pile wall through the sand/silt aquitard and the underlying thin aquifer (Soil Unit 4) will provide a hydraulic cutoff to potential groundwater inflow via both the upper and lower aquifers. Groundwater in the soil mass contained by the sheet piles should be effectively isolated in this manner. Given the potential for achieving a full hydraulic cut-off with the deep sheet pile walls, the need for dewatering of the soils contained between the sheet piles must be considered. Although the soils will be isolated from lateral sources of recharge, they will still be fully saturated with entrained pore water.

Excavation contractors may be tempted to rely on sump pumping to deal with the remnant pore water that is contained within the soils inside the sheet pile walls, once the cut-off has become effective. While this approach may realize savings on the substantial cost of internal dewatering, the potential disadvantages should not be overlooked. Loose, silty, fine sands and soft to very soft silts of Soils Units 2 and 3 that are fully saturated will degrade rapidly when disturbed. Excavation without the benefit of proactive dewatering could result in the base of the excavation becoming potentially unworkable, and having insufficient integrity to support the construction of transfer struts or the placement of structural fill/draining layer material. However, sumps may be effective for removing entrained water from the more permeable upper aquifer in Soil Unit 1.

The potential construction risks can be eliminated with the inclusion of a properly designed proactive dewatering system. Without such a system, the added construction costs in terms of delays, difficulty in materials handling, and constraints on the mobility of equipment in the excavation can rapidly add up and substantially exceed the investment in up-front dewatering costs.

Given the target elevation of –22 feet for dewatering in the deeper section of the graving dock, our recommendation is to install a system of eductor wells inside the sheet pile wall to remove entrained water and firm up the soft silts and loose sands of Soil Unit 3. Eductor wells have the advantage over other alternatives in that one system should be capable of producing the required dewatering.

To minimize interference with excavation and construction activities, the system on the inside the western wall could be installed first, immediately following the installation of the sheet pile wall separating the upper and lower sections of the graving dock. This could allow eductor headers to be laid on the excavated ground surface (or upper slab) at around elevation 10 feet, thus avoiding the need to suspend the system from the sheet piles.

Since the sheet piles form a cutoff to lateral flow, eductor wells located inside the deeper section of sheet pile wall should operate more effectively than outside the excavation, especially once the water contained within the sheet piles in the overlying aquifer of Soil Unit 1 has been completely removed. If excavation and construction schedules allow, it may be more cost-effective to operate this single system along the western side of the deep channel for 2 to 3 weeks and monitor its effectiveness in a series of piezometers installed in the central and eastern parts of the deep channel area.

An extended period of operation (at least 2 to 4 weeks) may be required before the internal eductor systems are able to fully lower water levels across the full area of the deep channel section. The system will need to remove at least 2.5 million gallons of entrained water, plus any leakage through the sheet piles and upward flow from below. To achieve full drawdown within a month, the system will need to operate continuously at a rate of at least 60 gpm. Piezometers should be installed to allow system performance and effectiveness to be monitored, and to permit system modifications in a timely manner, if required.

Other Alternative Dewatering Methods. As an alternative to the eductor systems, dewatering inside sheet pile walls forming the deep channel section of the graving dock excavations could be accomplished using other methods in a series of stages or options:

- With shallow wells or sumps to drain water by gravity from the upper more permeable aquifer soils, followed by wellpoints installed from above the lowered water table:

  - Shallow wells or sumps could be drilled or excavated from the water table (elevation 7 feet) to the base of the upper aquifer (elevation –5 feet). The effectiveness of this system would be limited by the interface with loose, silty, fine sand/sandy silt below approximate elevation –5 feet that is not expected to drain effectively.

  - Wellpoints could be jetted from within the partial excavation to a depth of 25 feet (i.e., to elevation –18 to –27 feet), set back inside the sheet piles by approximately 2 feet, and connected to vacuum headers hung from brackets welded to the sheet piles (see Figure 9).

  This is expected to be the least costly method for dewatering the excavation but it carries the risk that the wellpoint headers may not be installed low enough for dewatering of the subgrade soils to be fully effective down to the desired depth.

- Alternatively, with two stages of wellpoints:

    - The first stage of wellpoints installed to maximum depth (30 feet) once the excavation reaches the water table at a depth of around 6 feet below ground level (elevation 7 feet).

    - As the excavation proceeds to the top of the loose, silty, fine sand/sandy silt aquitard, a second tier of wellpoints will be required to be installed between the first tier, and jetted to a depth of 25 feet (i.e., to elevation –30 feet).

  This option has a high likelihood for success, but is likely to be significantly more expensive than a single ring of conventional wellpoints installed from the deepest practical elevation, and will likely exceed the cost of a single eductor system. Two wellpoint rings will also impose the greatest interference to excavation and construction work in the deep channel section and are, therefore, not recommended.

To be fully effective, internal wellpoints need to be installed as low as possible inside the sheet pile walls; however, this work will be constrained by saturated conditions below the original water table (elevation 7 feet). Sump pumping is likely to help in removing water only from the upper aquifer materials within the excavation, as the lateral source of recharge will have been cut off by the sheet pile walls. The internal wellpoints will need to be installed as low as possible if it is to effectively reduce pore pressures in the subgrade soils beneath the transfer struts, which will also benefit from the cut-off effect of the sheet pile walls.

Deep Aquifer Depressurization

The deep sheet piles are expected to extend down to and through the medium dense to dense sand layer of Soil Unit 4 that forms a thin aquifer beneath the fine sand/silt layer, and penetrate into the hard underlying silt of Soil Unit 5 by 5 to 10 feet However, the complete effectiveness of a hydraulic cut-off at this depth cannot be guaranteed, since pile separation or the presence of a few windows at depth could provide the small amount of lateral inflow needed to maintain high potentiometric pressure levels within the lower aquifer (Soil Unit 4). The dewatering design therefore must consider the need for depressurization of the groundwater in this deep layer to maintain the stability of the overlying soils in the critical excavated condition.

Pressure relief of groundwater in the lower aquifer layer will be required to ensure that the plug of soils contained beneath the base of the final excavation within the sheet piles is not subject to heave due to high groundwater head at depth. This could be achieved with a group of deep wells installed inside the excavation to penetrate at least 3 feet into the underlying deep silt aquitard (Soil Unit 5), generally below elevation –47 feet. Wells could be installed:

1. Either from the ground surface (60+ feet deep) prior to the start of excavation. However, the wells would be exposed and vulnerable to damage throughout the period of excavation; or

2. From a lower elevation inside the partially completed excavation, depending on the performance and effectiveness of the deep cut-off and the other methods of internal dewatering, as determined by ongoing piezometer measurements.

Wells would be relatively widely spaced, between 100 and 200 feet apart. A layout of eight deep wells strategically located within the excavation is proposed. Based on the results of the pumping test, we expect that well yields could vary between 5 and 50 gpm, with the effectiveness of the system dependent on the individual well yields that are obtained. Actual well yields will depend on the thickness and permeability of the lower aquifer at each well location, and the effectiveness of the hydraulic cut-off achieved by the sheet piles. Well construction and development will also be a key factor given the difficult drilling conditions at the site and the risk for gravel pack materials to become clogged with fine sand and silt from the aquitard layer. Temporary drillhole casing to the full depth may be required to ensure that the filter material does not become clogged.

To ascertain the performance of deep well depressurization as work proceeds, water pressures within the lower aquifer layer should be monitored using piezometers located centrally within the excavation. If the initial system of eight wells does not appear to be lowering water levels as expected (taking into consideration actual well yields achieved), then additional wells may be required.

Although the deep depressurization system will be drawing water from an aquifer that is directly connected to Port Angeles Harbor, flowrates will be limited by the permeability of the soil, such that sufficient loss in head (hydraulic gradient within the soil mass) can be sustained between Port Angeles Harbor and the depressurization system due to the hydraulic resistance of the aquifer. Flow rates should be further limited by the cut-off provided by the sheet piles, subject to their degree of effectiveness. Fluctuations due to tide levels will be small (less than 1 foot) and will be translated into corresponding periodic minor changes in flow rate from the deep wells.

Dewatering for the Gate and Pump/Fish Exit Structure

Construction of the gate and pump/fish exit structure are expected to take place within a temporary cofferdam constructed as a northward extension of the deeper channel section of the graving dock. We understand this portion of the dewatering work may be contractor-designed. Depending on the timing of this work and the related channel dredging to provide access to the gate area, the general recommendations on dewatering of the deeper channel section likely apply to this area as well.

The cofferdam for this area is expected to provide a hydraulic cut-off at depth, but the subgrade soils contained within the cofferdam will still require dewatering. Seepage flow paths will be correspondingly shorter, which will give rise to higher flowrates and greater pumping needed to achieve the same drawdowns as in the deep channel section.

Long-Term Control of Groundwater Pressures

Post-construction and long-term performance of the graving dock has also been considered in terms of the need for control of pore pressures in the foundation soils beneath both the upper and lower sections of the floor slab during conditions that include super flood, dry, and transitional phases of graving dock operation. The potential effects of these conditions on wall and slab integrity are considered, and alternative recommendations are provided relating to structures that are resistant to uplift forces and for the relief of excess hydrostatic pressures.

To prevent heave and uplift of the lower floor slab in the graving dock, we recommend the installation of below-slab drainage layer with a network of perforated underslab drainage pipes that will allow subgrade pore pressures to dissipate. The drainage layer should comprise at least 12 inches of clean coarse sand and gravel (free of fines), laid on the subgrade below the floor slab, and spanning between or above the transfer struts. Perforated drainage pipes (4-inch-diameter) should be laid within the drainage layer between each transfer strut. The current design calls for a peripheral drainage trench cast into the lower slab, where the underslab drainage pipes would discharge.

The volume of pore water inflow to the underslab drainage system during dry dock conditions is expected to be relatively low, assuming a reasonably effective sheet pile cut-off, and should be manageable as a small but continuous baseflow of no more than 5 to 10 gpm. This is likely to be a lot less than the flow rates for stormwater generated from rainfall on the lower slab, and should not be an issue in sizing the pumps. The current design calls for four sumps equipped with submersible pumps.

Eductor wells installed for the internal dewatering of the deep channel section could be incorporated into the permanent pressure-relief scheme, rather than being decommissioned or removed. The current floor slab design includes a perimeter drainage channel cast into the floor of the graving dock (see Figure 9). The trench section of the slab could be cast around the installed wellpoints while leaving them in place. Wellpoint riser pipes could then be cut off at (or slightly above) the drain invert level, allowing them to "bleed" water into the drainage channel, thus helping to dissipate excess pore pressures in the subsoils directly below the drain.

Passively flowing wellpoints would not be as effective in lowering underslab pore pressures as ones operated with active vacuum pumping, hence the need for underslab drainage. When the graving dock is flooded, the relief holes and cut-down wellpoints could allow water pressures to equalize on either side of the floor slab, thus reducing potential heave and uplift or settlement problems. Alternatively, the drainage pipes and wells/wellpoints could be sealed with one-way or flap valves to prevent sediment from entering the subsurface drainage facilities.

Similar drainage facilities are not required beneath the upper slab for dry operations but the super flood condition will potentially recharge the shallow soils above the water table, and potentially create excess pressures beneath the upper slab during pump-down of the dock. This assumes that the upper slab will not be waterproof, with cracks and construction joints allowing flood water to seep through and enter underlying (unsaturated) soils.

The most significant outflow component during super flooding is likely to be the water volume required to saturate the soils beneath the upper slab that are above the water table. Assuming a vadose zone thickness of 4 feet and a fillable porosity of 15 percent, this represents a pore volume of over 200,000 cubic feet. If the filling process above the upper slab takes 56 hours, the average seepage flow required to saturate the soil in the vadose zone below the slab is over 450 gpm. Leakage through the upper slab at this rate would depend on the existence of sufficient pathways through cracks and construction joints.

Transient effects of pore filling and drainage related to the cycle of dock flooding and emptying are likely to exceed the overall rates of seepage through the subsoils and beneath the upper sheet pile wall. Steady-state values estimated for this rate of seepage are between 50 and 100 gpm, using both a simple flownet analysis and assuming large-scale radial flow. However, this simplified analysis ignores any leakage through the sheet piles.

Dewatering System Monitoring

Construction monitoring of dewatering system performance and effectiveness is a key component to assuring a successful project. Monitoring should include:

- Documentation of the installation: well depths, screen locations, pump settings;
- Operating hours and flowrates for pumps;
- Water levels in piezometers and monitoring wells; and
- Periodic sampling of discharge flows for water quality parameters.

Ideally, system monitoring should be incorporated into the design and implementation approach, given the difficult ground conditions. Potential uncertainties in soil properties and system performance may require more or less dewatering effort than is envisioned in this design recommendation.

Water Treatment and Disposal

Water flows from the dewatering system are expected to be relatively clean despite the presence of localized contamination hot spots in the surface soils. Flows from the system may be initially turbid, especially during the development of individual wells and during system restarts, but should otherwise produce clear, sediment-free water. Salinity levels do not appear to be elevated, based on water quality monitoring during the pumping test (Table 1), but wells closer to the shoreline are more likely to produce brackish or saline water.

Discharges from the dewatering system should be initially passed through one or more Baker tanks that will allow suspended sediment to settle out, and enable the detection of surface films, which could indicate petroleum contamination. Baker tanks can be fitted with cartridge filters on their discharge lines to deal with specific contaminants. Alternatively, dewatering discharges could be routed to the stormwater system, and subjected to treatment train that includes oil separation, retention ponds, and an infiltration bioswale.

Disposal may be permissible to Port Angeles Harbor but this is likely to require approval from the Washington State Department of Ecology and/or Department of Fish and Wildlife. It would be preferable to discharge to the Port's stormwater system, in which case the quality of the water should meet any applicable discharge requirements.

Alternatively, disposal to any local sewer system may be considered but this option may incur discharge fees based an assumed waste treatment parameters, even if the water is clean. Sewer districts also commonly impose discharge volume limitations, especially during the winter months when the sewer system capacity is reserved to handle peak flows.

Water should be sampled for potential contaminants, per the requirements of the agency overseeing the disposal of water. Sampling should occur soon after system start-up, and should be conducted with expedited lab turnaround to ensure that pumping contaminated waters is kept to a minimum.

Side Effects of Dewatering

This section considers potential side effects of dewatering, including induced settlements, pumping of contaminated groundwater, and the potential drawdown effect on existing water supply wells in the vicinity of the project site.

Structural Settlements

Reduction of water levels associated with construction dewatering increases the effective stress in soils below the water table. Generally these stress levels occur within the range of stress history already experienced by the soil. However, if the new levels of effective stress achieved through dewatering exceed the stress history for the soil at a given depth, additional settlements could occur. Settlement occurring beneath the foundations of sensitive buildings or other structures could cause structural damage. We understand that there are no major structures within the immediate vicinity of the site.

For the graving dock, depending on construction schedule, external dewatering to relieve hydrostatic loads on the sheet pile wall for the deep channel could occur after all or some of the upper slab is cast. This could potentially subject the upper slab to some differential settlements (2 to 3 inches), decreasing in magnitude away from the lower dock. We understand that these settlements are tolerable.

Contaminated Soils and Groundwater

We received preliminary environmental test results for soil samples from the recent geotechnical borings. Based on our discussions with WSDOT and our review of the boring logs and field notes, we selected soil samples for analyses primarily in the upper 5 to 10 feet and one per boring. However, two of the borings exhibited potential environmental impacts (odor and staining) so we analyzed two samples in those borings (H-3-02 and H-4-02). In addition, five environmental borings were previously advanced for WSDOT, and soil samples were collected and chemically analyzed. Groundwater monitoring wells were also installed in these five borings and groundwater samples were collected and analyzed as part of the environmental investigation.

The chemical results indicated low concentrations (73 and 54 mg/kg) of TPH in the diesel-range in H-3-02 between 3 and 9 feet below grade. Only one of the soil samples in H-4-02 had detectable concentrations of TPH. This was the shallow soil sample at 2.5 to 4.0 feet and the concentration was 640 mg/kg TPH in the heavy oil-range. The other H-4-02 sample at 12.5 to 14.0 feet had no detectable concentrations of TPH. We did not have a soil sample between these two samples because there was no soil recovery due to silt and wood jammed into the sampling shoe.

Only one soil sample from the five borings advanced as part of the environmental investigation, was found to have a detectable concentration of 30 mg/kg TPH in the diesel range, between 5.0 and 6.5 feet (HC-SE-02). The soil samples above and below this depth contained non-detectable concentrations of TPH. None of the groundwater samples analyzed contained any detectable concentrations at TPH, semivolatiles, or PAHs.

There were no detectable concentrations of semivolatiles, including PAHs, in any of the soil samples analyzed. Based on this information and our field observations, there does not appear to be any wide-spread contamination in the soils in the areas sampled by the geotechnical borings or the previous five environmental borings.

Given that contaminated soils are relatively rare at the site, and are generally present only at or around the water table, we do not expect that any of the dewatering activities described above would result in significant mobilization of subsurface contaminants. It is considered highly unlikely that such contaminants, if present, would be detectable in the water being pumped from the proposed dewatering system.

Impacts to Adjacent Wells

A record review was completed to address the potential for drawdown in the upper aquifer caused by external dewatering of the sheet pile wall to impact water levels or production rates in any existing water supply wells in the vicinity. The review included a query of the Washington State Department of Health and Department of Ecology public records. Documents indicate the closest water supply or irrigation well to be greater than one mile away from the site. Moreover, the closest well is located on the bluff to the south, significantly above the elevation of the site. Dewatering of the graving dock excavation will not affect any of the water supply or irrigation wells located by this record review.

Retaining Structures

The construction of the graving dock will require a relatively watertight permanent wall along the entire perimeter of the graving dock, and the western side of the deep channel. The depth of excavation in the deep channel area is expected to be about 28 to 30 feet. Along the outside perimeter of the upper slab, the perimeter wall will mainly support water pressure during the super flood period. The following sections present discussions about wall type alternatives and design recommendations on the lateral earth pressures.

Types of Permanent Retaining Walls

The purpose of the retaining walls is to provide hydraulic cut off in addition to support lateral loads. Sheet piles and continuous secant soldier piles represent two feasible alternatives to support the deep channel excavation and the upper slab walls. A hybrid wall consisting of soldier piles to resist lateral forces and sheet piles to cut off seepage is technically feasible but may not be economical. Additionally, given the permanent use of these walls, ground freezing is likely not feasible in our opinion.

The sheet pile wall alternative is likely more favorable because it provides a continuous section for the above and below grade walls. However, it may have some limitations regarding its flexural capacity and the ability to penetrate dense to very dense gravelly soils. Hard driving through dense granular soils could potentially be a source of leakage due to sheeting ripping out of the interlocks.

A secant soldier pile wall could be constructed below grade to provide hydraulic cut off and lateral support for the deep channel. A separate retaining structure would be required for the above-grade wall. The above-grade wall may include a cast-in-place concrete wall or a Mechanically Stabilized Earth (MSE) wall. Some special detailing will likely be required to provide a watertight connection between the above- and below-grade walls.

The preliminary design by KPFF, the structural engineer of the project, calls for sheet pile walls. The recommended earth pressures presented below are applicable to both types of walls provided they are supported by deadman or with a single level of tiebacks.

Deep Channel Walls

The walls surrounding the deep channel will be subjected to five different lateral loading cases.

- **Construction Phase (No Slab and Transfer Beam Support).** Groundwater outside the deep channel will be lowered to the bottom of excavation elevation (elevation −22 feet).

- **Operational Phase.** Groundwater outside the dock will be at about elevation 7 feet. The floor slab and transfer struts will provide lateral support.

- **Super Flood Phase (Water at Elevation 27 Feet).** During this phase, the direction of loading will be reversed. In other words, the soils outside the dock will support the wall by mobilizing passive pressures rather than active pressures. For this case, the wall will behave as a cantilevered wall. The deadman/tieback, the floor slab and transfer struts will not provide support to the wall.

- **Earthquake.** Two levels of earthquakes, 475-year and 190-year events, have been considered in our engineering analyses as described previously. Because of the relatively short period of the super flood phase (a few days every 5 to 6 months), we have assumed that earthquake loading is only relevant to the operational phase.

- **Post-Earthquake (Liquefaction).** Based on our analyses, wide-spread liquefaction may only occur under the 475-year earthquake. Again this case is only relevant to the operational phase. It is important to note that we have assumed that liquefaction would occur after peak shaking (i.e., earthquake loading and liquefaction would not be combined).

Design Wall Sections and Corresponding Earth Pressures

Given the variations in soil conditions and the size of the deep channel, we have provided multiple design wall sections along the perimeter to achieve a cost-effective design. Along the perimeter of the channel, we have identified three segments designated as C-1 through C-3 (refer to Figure 10). Earth pressure parameters for each segment are presented in Tables 2 through 4.

- **Segment C-1.** Widespread liquefaction may occur within Soil Unit 2 along this segment under the 475-year earthquake. Therefore, the post-earthquake scenario should be considered in the design. The sandy Silt (Soil Unit 3) was not encountered in borings H-6-02 drilled in the vicinity of this segment. Soil parameters for this segment are presented in Table 2. For illustrative purpose, the subsurface profile along this segment and the corresponding earth pressure diagrams are presented on Figures 11 and 12.

An important assumption associated with these earth pressure diagrams is that the lower aquifer will be permanently depressurized as discusses subsequently. As illustrated on these figures, the earth pressures directions near the wall toe are applicable for the **free earth support** method, which will be discussed subsequently. For the **fixed earth support** method, assuming adequate embedment, the active and passive pressures near the tip of the pile would be on the opposite sides of what were shown on these figures.

- **Segment C-2.** This segment may represent the assumed worst-case scenario for all the loading cases because of the presence of the medium stiff sandy silt (Soil Unit 3) and the depth to the top of the bearing layer. Soil parameters for this segment are presented in Table 3.

- **Segment C-3.** This segment is characterized by the relatively dense Soil Unit 2 (i.e., no global liquefaction) and by the relatively shallow load bearing layer (refer to Figure 3). Additionally, the sandy Silts (Soil Unit 3) were not encountered in borings drilled in the vicinity of this segment. Soils parameters for this segment are presented in Table 4.

Earth Pressures Assumptions

The following general assumptions and seismic-related loadings should be used in conjunction with the soils parameters presented in Tables 2 through 4.

1—Construction Phase

- Groundwater table inside the excavation is at least 2 feet below the bottom of excavation;
- Neglect top 2 feet of passive pressure; and
- Effect of seepage pressure beneath the wall can be ignored assuming embedment in hard SILT (Lower Aquitard).

2—Operational Phase

- Groundwater table outside the dock is at elevation 7 feet;
- Groundwater table inside the dock is at the bottom of underslab drain; and

- Passive pressure mobilized in the construction phase will remain effective on the wall. In other words, placing the concrete floor slab and the transfer struts would not reduce the passive pressures mobilized during construction.

3—Super Flood Phase

- Assume the water pressure starts at elevation 27 feet and extends to the bottom of the sheet pile. This assumption implies that the slab will have joints or cracks such that the underlying soils are hydraulically connected to the water in the channel.

4—Earthquake Loading

- 475-year Earthquake
  - **Active Pressures.** Add distributed pressure approximately 5.5Z psf, where Z is the depth to the bottom of the excavation.
  - Ignore hydrodynamic effect within the Sand and Gravel unit (minor effect).
  - **Passive Pressures.** Use K_P (ultimate) to estimate passive resistance. K_P (ultimate)= K_P (design) x 1.5 (FS) x 0.9 (reduction due to earthquake based on M-O method).

- 190-year Earthquake
  - **Active Pressures.** Add distributed pressure =2.5Z psf, where Z is the depth to the bottom of the excavation.
  - **Passive Pressures.** Use K_P (design). The reason for that is that the earthquake loading would reduce K_P by about 5 percent based on M-O method. On the other hand, K_P will increase as the wall moves outward. So, earthquake loading would have opposite effects on K_P, which can be practically equal. For simplicity use K_P (design).

5—Post-Earthquake (Liquefaction) - Segments C-1 and C-2 Only

- Liquefaction due to 475-year Earthquake

  No change in water and active earth pressures except for the silty Sand and the sandy Silt (Soil Units 2 and 3).

  - **Active Pressures.** Active earth pressure at the top and bottom of the liquefiable layer should be calculated using the following equation:

$$p_a = \sigma'_v - 2 * S_r$$

Where:
p_a = effective active earth pressure;
σ'_v = effective vertical stress; and
S_r = residual shear strength (refer to Tables 2 and 3). Note that the effective active earth pressure should not be less than the static active earth pressure.

- **Passive Pressures.** Use K_P (ultimate) rather than K_P (design) for soils except for liquefiable soils (Soil Units 2 and 3).

$$K_p(\text{ultimate}) = 1.5 * K_p(\text{design})$$

For liquefiable soils , use the following equation to calculate passive pressure at the top and bottom of the liquefiable layer:

$$p_P = \sigma'_v + 2 * S_r$$

Where:
p_P = effective passive earth pressure;
σ'_v = effective vertical stress; and
S_r = residual shear strength (refer to Tables 2 and 3). Note that the effective passive earth pressure should not be higher than the static passive earth pressure.

- 190-year Earthquake. No global liquefaction.

6—Surcharge Loading

Refer to Figure 11 for distributed surcharge loading. For other cases, refer to Figure 13.

7—Fill Behind the Wall

The upper 6 to 7 feet below grade will be excavated to install the deadman anchors spaced 10 feet on center. On-site, granular soils can be reused for backfill. Feasible compaction effort depends on the moisture conditions of these soils, weather conditions, and the project schedule. In Tables 2 and 4, we presented parameters of on-site granular soils compacted to 90 or 95 percent of the maximum dry density as determined by the modified Proctor maximum ASTM D 1557 test procedure. The project specifications should be consistent with the soil parameters used in the design. Note that soils within the passive zone of the deadman should compacted to 95 percent of the maximum dry density as discussed subsequently.

Methods of Sheet Pile Wall Design

There are two conventional methods for designing sheet pile walls: (1) free earth support and (2) fixed earth support. Geotechnical considerations for each method are discussed below.

Free Earth Support. This design method assumes that the pile tip is free to rotate (i.e., point of zero moment is at the bottom of the wall). The point of zero moment is critical in determining the location of the deadman as discussed subsequently. The assumption of free rotation implies that that passive pressures will only be mobilized on one side of the wall as shown on the Figures 11 and 12. This assumption can be realistic for a certain wall penetration, below which wall fixity starts to develop gradually till it reaches full fixity at a certain penetration. A Rowe's moment reduction can be applied for sheet pile walls designed using the free earth support provided the walls are NOT embedded in very loose to loose granular soils. We understand that this method will require less penetration into the load bearing layer than the fixed earth support for this project.

Fixed Earth Support. This design method assumes the pile tip is not free to rotate (i.e., fixed). In this case, the wall is deformed in such a way that the point of zero moment is somewhere, depending on the soil stiffness, between the bottom of excavation and the tip of the sheet pile. In this case, the passive pressures will be mobilized on both sides of the wall. The Rowe's moment reduction is NOT applicable for this design method. Two approaches are normally used to analyze sheet pile using this method: (1) equivalent beam method and (2) deflection method. The deflection approach is typically performed using computer software.

Appropriate Design Method. From a geotechnical perspective, both methods are applicable to the site, each with its advantages and disadvantages. The main advantage of the free earth method is the shallower penetration, which will reduce the sheet pile driving through the glacial soils (Soil Unit 5). The main advantage of the fixed earth support method is that the glacial soils (Soil Unit 5) will provide adequate fixity for the sheet piles walls without relatively deep penetration.

However, it is our understanding that the governing factors are the location of the anchor (dependent on the point of zero moment), the maximum bending moment, and the anchor force. According to KPFF, the use of the fixed earth support, as compared to the free earth support method, results in: (1) the point of zero moment is higher, (2) the maximum bending moment is lower, and (3) the anchor force is lower. Therefore, it is our understanding that the fixed earth support method has been used in the design of the sheet piles for the deep channel.

Minimum Embedment into Glacial Soils. The passive coefficients presented in Tables 2 through 4 include a factor of safety of 1.5. According to Teng (1962), which is the reference used by AASHTO (1996) on this subject, an additional factor of safety is NOT required for the wall embedment. However, for wall segments C-1 and C-2 where liquefiable soils overlie the glacial soils, we recommend that the sheet piles be embedded at least 5 feet into the glacial soils. For wall segment C-3, we recommend that the sheet pile be embedded at least 3 feet into glacial soils to provide adequate seepage cutoff.

Sheet Pile Drivability

We performed a wave equation analysis to assess the drivability of the proposed sheet pile section based on KPFF's preliminary sheet pile design. We assumed a Delmag D-46 impact hammer and a 80-foot-long AZ48 section (50 ksi) with about 15 feet of embedment (friction distribution in the lower 20 percent of shaft) into the glacial soils.

For a 15-foot embedment, the ultimate axial capacity of the AZ48-section would be about 300 kips. The analyses suggests a range of blow counts between 20 to 50 blows per foot (bpf) and maximum compressive stresses of 33 to 41 ksi, for a predicted axial capacity of 300 to 600 kips. The higher load was examined to account for uncertainties in estimating the load capacity. Based on our discussion with local pile contractors, we feel that a reasonable maximum sheet pile penetration depth into the glacial soils would be about 10 feet, but probably no greater than 15 feet.

Note that using a box section will require more energy because of the increase of the surface area and the potential developing of a plug. Therefore, a 10-foot penetration of a box section into the glacial soils may not be feasible.

Effect of Super Flood on Pore Water Pressure

This issue is only relevant to the western wall of the deep channel (top of the wall at elevation 10 feet). During the super flood phase, the pore water pressure within the soil mass behind the wall may increase to correspond to the water level at elevation 27 feet. Following the super flood phase, the soil mass may retain excess pore water pressures for some time, which would increase the lateral pressures on the wall.

This may occur in Soil Unit 2 and/or Soil Unit 3, which have relatively low permeability. However, the build-up of pore water pressure would be mainly due to the consolidation process of these layers rather than due to hydraulic connection between the water above and below the slab. Because the loading period is short (a few days), the excess pore water pressure would dissipate relatively fast (within a few days) following the end of the super flood phase.. Therefore, we do not recommend any special measures to reduce this excess pore water pressures.

Upper Slab Walls

The upper slab walls will extend up to elevation 28 feet. The water inside the graving dock will be at elevation 27 feet. It is our understanding that the current design calls for a 30-foot-wide berm behind the upper slab walls to laterally support the perimeter wall during the super flood phase. The top of the berm as shown on the preliminary drawings provided by KPFF will be at elevation 21 feet (i.e., about 8 feet above the existing grade).

For the upper slab walls, we have not considered earthquake and post-earthquake loadings because of the low probability that the design earthquake would occur during the super flood level. During the operational phase, the wall will only support the proposed berm. However, the super flood phase will likely govern the design of the sheet pile wall.

The perimeter wall surrounding the upper slab can be divided into two wall segments (U-1 and U-2) to reflect varying soil conditions. The limits of the two segments are shown on Figure 10. Earth pressure parameters for segments U-1 and U-2 are presented in Tables 5 and 6, respectively. Note that for wall segments supported by the proposed earth berm, the passive earth pressure coefficients for relatively deep layers were reduced to account for the limited width of the earth berm (about 30 feet).

On-site granular soils can be used to construct the berm. Feasible compaction effort depends on the moistures conditions of these soils, weather conditions, and the project schedule. In Tables 5 and 6, we presented parameters for on-site granular soils compacted to 90 or 95 percent of the maximum dry density as determined by the WSDOT Test Method No. 606 (for soils with at least 30 percent gravel) or by AASHTO T99 (for soils with less than 30 percent gravel). The project specifications should be consistent with the soil parameters used in the design.

Embedment Factor of Safety. The passive coefficients presented in Tables 5 and 6 include a factor of safety of at least 1.5. According to Teng (1962), which is the reference used by AASHTO (1996) on this subject, an additional factor of safety is not required for the wall embedment.

Water Pressure during the Super Flood Case

Active Side (Inside the Dock). Assume the water pressure starts at elevation 27 feet and extends to the bottom of the sheet pile. We assume that the slab will have joints or cracks that allow hydraulic connection between the top and bottom of the slab.

Passive Side. Assume groundwater table is at elevation 7 feet.

Seepage Cutoff

Deep Channel Walls. It is anticipated that the walls would extend into the glacially overridden soils, which are predominantly silts. These soils are relatively impervious and would provide adequate seepage cut off.

Upper Slab Walls. We recommend that the wall be embedded in Soil Unit 2 (Sand/Silt aquitard) with the tip of the wall being at elevation –17 feet (i.e., the depth of penetration is about 27 feet below top of slab). Based on results of the pumping test, this permeability of this layer is estimated to be about 1×10^{-5} cm/sec, which is adequate to cut off seepage during the super flood phase.

Additionally, the 27-foot-deep penetration (from elevation 10 to –17 feet) will provide an adequate factor of safety (greater than 2.0) against heave in soils located outside the dock based on NAVFAC DM–7.01.

Deadman and Tieback Design Recommendations

The sheet piles surrounding the deep channel will be supported with either deadman (concrete or sheet pile) or tiebacks. The current design calls for a continuous sheet pile deadman with anchors spaced at 10-foot on center. Along the western wall, the deadman will be entirely below the groundwater table. Elsewhere, the deadman will be partially below the groundwater table. As an alternative to deadman, tiebacks might be used.

Deadman - Earth Pressures

The recommended static and seismic earth pressures for concrete deadman are shown on Figure 14. For the sheet pile deadman, the earth pressures parameters presented in Tables 2 through 4 should be used in the design.

In our earth pressure recommendations, we assume that the excavation for the deadman anchors within the passive wedge will be backfilled with granular soils compacted to 95 percent of the maximum dry density as determined by the WSDOT Test Method No. 606 (for soils with at least 30 percent gravel) or by AASHTO T99 (for soils with less than 30 percent gravel). The passive wedge is determined by a line inclined at $(45° - \phi'/2)$ from the horizontal and extending from the bottom of concrete deadman or from the point where passive pressure reverses its direction (sheet pile deadman) to the ground surface.

Deadman - Location

Two criteria govern the deadman location. The first criterion is that the deadman should be located behind a line that extends from the point of zero moment on the sheet pile wall to the ground surface with an inclination that varies from one soil unit to another. Through each soil unit, the line inclination is equal to the soil friction angle of this layer measured from the horizontal. By placing the deadman behind this line, no additional horizontal loads will be acting on the sheet pile perimeter wall under static conditions.

The second criterion is that the passive wedge acting on the deadman does not overlap with the active wedge acting on the sheet pile wall of the deep channel. The passive wedge is estimated by a line inclined at $(45° - \phi'/2)$ from the horizontal, and the active wedge is estimated by a line inclined at $(45° + \phi'/2)$ from the horizontal. The top of deadman should be at least 2 feet below grade.

Tiebacks

Tiebacks would be required in the case that the deadman embedded to a practical depth does not provide adequate lateral support. The main disadvantage of a tieback system is soil liquefaction. Given the practical tieback inclination and the anticipated no load zone limits, it is expected that tieback bond length would be located within the silty Sands (Soil Unit 2) and the sandy Silts (Soil Unit 3). As mentioned previously, wide-spread liquefaction may occur within Soil Units 2 and 3 under the 475-year earthquake, leading to a significant loss in tieback capacities. In this case, the tieback alternative may not be feasible, unless the bond length can be extended into the deeper non-liquefiable soils (Soil Unit 5).

In the case of the designing the graving dock based on the 190-year earthquake, the tieback alternative would be feasible because no wide-spread liquefaction is anticipated. Within Soil Units 2 and/or 3, the bond length of the anchor should be determined using an allowable unit friction of 0.5 ksf and a maximum pullout capacity of 2.0 kips/ft, assuming gravity-grouted tiebacks. Secondary or pressure grouting can be used to increase the allowable unit friction. Along the southern edge of the channel, higher bond capacity can be achieved if anchors are installed in the glacial soils.

Excavation Stability

Deep Channel Walls. For the deep channel excavation, it is expected that the sheet piles would be embedded several feet into the glacial overridden soils. Therefore, global instability is not anticipated.

Upper Slab Walls. We performed global stability analyses for segment U-1 (refer to Figure 10), which represents the assumed worst-case scenario. As discussed above, the super flood phase is the only case considered in the analyses. Soils parameters presented in Table 7 were used in the analyses except for the berm, which was not considered in the analysis (conservative assumption). The stability analysis results suggest that the wall would have an adequate factor of safety (greater than 2.0).

Graving Dock Slabs

Deep Channel Slab

Settlement and Bearing Pressure

Total and differential settlements would likely govern the slab design. Due to the excavation for the deep channel, the reduction in effective stress reduction on the soils underlying the slab is about 2,000 psf. During the operational phase, the weight of the heaviest pontoon will cause about 600 psf of vertical stress. During the super flood phase the weight of the water (42 feet of water head) would increase the effective stresses on the soils underlying the slab by about 2,680 psf. In this case, we have assumed that Soil Units 2 and 3 are NOT hydraulically connected to water above the slab. Therefore, the super flood will be the critical case. For the 2,680 psf increase in vertical stress, about 2,000 psf will be re-compression (i.e., stress within the range of stress history already experienced by the soil) and the reminder 700 psf will exceed the preconsolidation stress.

Because of the variation of the depth to the top of bearing and the presence of the sandy Silt soils, settlement would vary across the site. Our engineering analyses suggest the settlement would vary from about 1 inch toward the southern edge of the channel to 2 to 4 inches toward the northern edge of the channel. Settlement in the vicinity of the northern edge of the channel may cause downdrag on some piles supporting the gate.

Modulus of Subgrade. The slab will be mostly supported on saturated, loose to medium dense, silty Sand (Soil Unit 2). Therefore, we recommend a subgrade modulus of 50 pci.

Slab Uplift

As described in the dewatering section, a complete hydraulic cut off cannot be guaranteed. Therefore, the water pressure in Soil Unit 4 may reflect the water pressure outside the dock during the operational phase. Our analyses suggest that the factor of safety against uplift can be as low as 0.5 along the southern edge of the channel. The factor of safety increases to about 0.9 near the northern edge of the deep channel where the deep aquifer is relatively deep. The vertical stress required to achieve a factor of safety of about 1.25 against uplift varies linearly from 1,000 psf along the southern edge to about 500 psf along the northern edge of the deep channel.

A pressure relief system as described in the dewatering section is required to reduce the risk of slab uplift. Combined with a relief system, the slab can be supported against uplift using piles, micropiles, or tiedowns, embedded into the glacially overridden soils. Because of their stiffness, piles or micropiles will also carry the compression loads (about 2,680 psf during the super flood phase) acting on the slab. Tiedowns should be designed for only uplift forces.

It should be noted that a pressure relief system is required regardless of the use of piles, micropiles, or tiedowns, for the purpose of not reducing the passive pressures acting on the sheet piles.

Pile Recommendations

Design recommendations for driven pipe piles, are provided as follows:

- **Ultimate Skin Friction in Compression and Tension.** 2,000 psf below top of bearing unit shown on Figure 3.

- **Ultimate End Bearing in Compression.** 400 ksf (assumes inside-fit cutting shoe and no plug).

- **ASD Minimum Factor Safety.** Use FS = 2.0 for both tension and compression provided that pile capacity should be verified by pile driving analyzer (PDA) and CAPWAP analysis.

Micropiles and Tiedowns

Our preliminary recommendations for gravity-grouted micropiles and tiedowns are as follows:

- **Ultimate Skin Friction in Compression (only micropiles) and Tension.** 2,000 psf below top of bearing unit shown on Figure 3.

- **Ultimate End Bearing in Compression.** End bearing is typically ignored in micropiles.

Secondary or pressure grouting can be used to increase the allowable unit friction. Further discussions regarding tiedowns and micropiles installation, factor of safety, testing, and location could be provided to the design team, if required.

Upper Slab Walls

The top of the slab will be at elevation 10 feet, which is about 3 feet below existing grade. During the super flood phase, the slab will support 17 feet of water, about 1,100 psf, with a net (water stress minus the removed 3 feet of soils) increase of effective pressure of about 725 psf. Because the pontoons will float during the super flood phase, their weights will not be acting on the slab. Based on our engineering analyses, settlement would vary across the upper slab from about 1 inch toward the southeast corner to 6 inches toward the northwest corner.

The major source of settlement in the vicinity of the northwest corner is the compression of the silty soils encountered in boring H-1-02. As discussed previously in the ***Subsurface Conditions*** section, the subsurface conditions encountered in boring H-1-02 could be further verified by cone penetration testing. It should be noted that dewatering for the deep channel would not significantly impact the groundwater level in the vicinity of the northwest corner.

Settlement in the vicinity of the deep channel would result in down drag forces on the sheet pile wall. These forces, however, would be insignificant given the much higher axial capacity of the sheet piles.

Modulus of Subgrade. The slab will be mostly supported on saturated, medium dense to dense Sand/Gravel (Soil Unit 1). Therefore, we recommend a subgrade modulus of 125 pci.

Preloading

Preloading would be an option for reducing settlement. However, we understand that the estimated settlement presented above is considered tolerable. Therefore, preloading is not required.

Slab Settlements Due to Liquefaction

Typically, liquefaction-induced settlement varies from 2 to 5 percent of the thickness of the liquefiable layer (Ishihara and Yoshimine 1992). Based on soil conditions in borings H-5-02 and H-6-02, the estimated settlement due to liquefaction would range from 6 to 10 inches under the 475-year earthquake. Under the 190-year earthquake, local liquefiable zones may induce 2 or 3 inches of settlement.

Pile Foundation for Gate Structure

Foundation Type Alternatives

Open-end, structural steel pipe piles represent the most feasible alternative for supporting the gate structure of the new graving dock when considering the axial and lateral load demands on the piles, and the need to achieve adequate penetration below very dense soils to attain the required pile capacity. Other pile types such as precast concrete or closed end steel pipes were considered but were ruled out because these piles will likely be difficult to be installed to a sufficient depth in the glacial deposits. Shafts are also considered feasible, but are likely more expensive than the driven pile. Shallow foundations are not feasible due to both settlement and bearing capacity concerns.

Discussions with the structural engineer, KPFF, and the results of our preliminary analysis suggest that 24-inch-diameter open-end structural steel pipe piles likely will be used for the project. We understand that vertical piles will be used to resist both the axial and lateral loads.

To achieve the required compressive, uplift, and lateral capacities, the piles should be driven open-ended with and inside-fit cutting shoe. We understand the piles will be structural steel and not filled with reinforced concrete, similar to ferry dock wingwall piles. For drivability, we recommend using a pile section no thinner than ¾-inch unless Hart Crowser performs a wave equation drivability analysis.

Axial Capacity

In general, we understand that the piles will be spaced at least 3-pile diameters on center. The top of the piles is anticipated to be at about elevation -25 feet, or about 40 feet below the existing ground surface. Each pile may be required to resist up to 100 tons in axial tension, and 150 to 200 tons in axial compression.

We recommend that the ultimate compression and tension capacities of 24-inch-diameter pipe piles be computed using the following parameters:

- Ultimate skin friction (in compression and tension):
  - Between elevation –25 and –43 feet, use 200 psf for tension only, ignore resistance for compression to account for settlement-induced downdrag on piles due to static and/or liquefaction
  - Between elevation -43 and -53 feet, use 2,000 psf
  - Below elevation -53 feet, use 3,000 psf

- Ultimate end bearing (in compression):
  - 200 kips (assumes inside-fit cutting shoe and no plug)

- **ASD Minimum Factor Safety.** Use FS = 2.0 for both tension and compression with pile capacity verified by pile driving analyzer (PDA) and CAPWAP analysis on at least 2 to 5 percent of the production piles.

- **LRFD Strength Limit State Resistance Factor.** Use 0.75 for both tension and compression with pile capacity verified by pile driving analyzer (PDA) and CAPWAP analysis on at least 2 to 5 percent of the production piles. Resistance factors for service and extreme limit states, a resistance factor of 1.0 should be used.

- Group effects for axial loads will not be significant providing that piles are spaced at least 2½D.

Laterally Loaded Pile Analyses

The behavior of structural steel pipe piles subjected to lateral loads was evaluated using the computer software LPILE. As noted previously, the sandy Silt (Soil Unit 3) may experience global liquefaction under the 475-earthquake. The p-y curve parameters for single pile under static and post-earthquake cases are shown in Table 7. For the earthquake case, the soil parameters for the static case can be used with corresponding additional seismic loads.

Group reduction factors for lateral analysis were also incorporated into our analysis, in accordance to the procedure outlined in the *WSDOT Bridge Design Manual*, as revised July 2000. The factors account for pile interaction effects due to proximity and are a function of pile spacing based on pile diameter, D. Assuming a pile spacing of 6-foot on center, or 3 times the pile diameter, a reduction factor of 0.5 for the subgrade reaction modulus was selected (see Table 8). Also, the soil friction angle for each unit was reduced according to the procedure outlined in the bridge manual.

The results of our analysis for the static condition indicate approximately 0.5 inch of lateral pile top deflection when a 50 kip lateral load is applied to the pile top. For the post-earthquake (liquefaction) case, the analyses indicate approximately 0.8 inch of deflection. It should be noted that piles longer than 40 feet likely would be required to meet the axial load demand.

Minimum Tip Elevations

Because the piles must resist axial compression, uplift, and lateral loads, a minimum tip elevation should be specified in the contract as the lowest elevation needed to limit lateral deflection under lateral loading. A minimum tip elevation for uplift requirements based on the ultimate capacities presented above may be deeper than that needed to limit lateral deflection. If so, the deeper minimum tip elevation should be specified, with the provision that the elevation could be modified on the basis of PDA and CAPWAP data during construction. Hart Crowser should be contacted after pile design is finalized to assess the potential for overdriving to reach the minimum tip elevation.

Walls Attached to the Gate Foundation

Based on the design information provided by KPFF, two concrete walls along the east and west sides of the gate will be attached to its foundation. The top of the wall along the east will be at elevations 14 feet with a total height of about 30 feet. Along the west side, the top of the wall will at elevation 21 feet with a total height of about 37 feet. Temporary cofferdams will be used to construct these walls.

These walls will be subjected to lateral hydrostatic and soils pressures. On-site granular soils can be used to backfill behind the walls. Static and seismic earth pressures will depends on the level of compaction of these soils, and on whether the top of the wall is free to rotate (yielding wall) or not (non-yielding). Table 9 presents our recommended earth pressures assuming:

- Two levels of compaction, 90 and 95 percent of the maximum dry density as determined by WSDOT Test Method No. 606 (for soils with at least 30 percent gravel) or by AASHTO T99 (for soils with less than 30 percent gravel);
- Two levels of earthquakes as described previously; and
- Yielding and non-yielding wall.

It should be noted that the seismic pressures for non-yielding walls presented in Table 9 are less than what AASHTO recommends as a *first approximation*. It has been observed after major earthquakes that seismic pressures are typically overestimated, particularly for rigid walls. Accordingly, in our opinion, the seismic earth pressure values presented in Table 9 are quite reasonable given the significance of the graving dock as compared to other structures such as bridges.

For surcharge loads, cases illustrated on Figure 11 and 13 are only applicable for yielding walls. For non-yielding walls, the surcharge lateral pressures are greater by a factor of **1.4**.

RECOMMENDED ADDITIONAL GEOTECHNICAL EXPLORATIONS

The variable subsurface conditions and revised layout of the graving dock may warrant additional explorations in the following areas to further characterize the subsurface conditions at specific locations within the site.

- **Graving Dock Gate.** Boring H-4-02 in the vicinity of the gate was terminated at a depth of 78 feet, which corresponds to elevation –63 feet. Based on our recommended ultimate pile skin friction, the piles would have to be driven below the bottom of boring H-4-02, to achieve the required tension capacity. Although we do not anticipate ground conditions to change beyond the current boring depth, a deeper boring may be necessary to avoid potential contractor claims.

- **Northwest Corner of Upper Slab.** As mentioned previously, the zero blow counts of the sandy Silt encountered in boring H-1-02 appear to be anomalous compared to other borings at the site. The presence of such low blow count would affect the depth of the sheet pile and settlement.

Depending on the impact of subsurface uncertainties on the design of the graving dock, additional borings may or may not be warranted. For example, if the upper slab can sustain significant settlement as much as 6 inches throughout the super flood periods and the depth of sheet pile is governed by seepage, then no additional boring would be necessary in the vicinity of boring H-01-02.

CONSTRUCTION CONSIDERATIONS

- Temporary shoring and/or slopes will be required during construction of the pile caps. The design and construction of temporary shoring/slopes should be the responsibility of the contractor, but the need for the shoring should be indicated in the plans. Groundwater will be encountered in the excavations and seals will be required. Sumps and dewatering should be designed in consideration of the dewatering section of this report.

- Test piles should be driven in accordance with Section 6-05.3(10) of the Standard Specs. A minimum of one test pile should be driven at each end of the gate pile cap. Test piles should be monitored using PDA and analyzed using CAPWAP prior to commencing production pile driving.

Other construction considerations will discussed in the final report following advances in current the feasibility studies.

LIMITATIONS OF OUR WORK

We completed this work in general accordance with our Task Assignment Y-7672, No. 4 issued by WSDOT. Our draft report is for the exclusive use of WSDOT and their design consultants for specific application to the subject site. We completed this study in accordance with generally accepted geotechnical practices for the nature and conditions of the work completed in the same similar localities at the time the work was performed. We make no other warranty, express or implied.

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Table 1
Discharge Water Quality from PW-02 during Pumping Test

Date	Time	Temperature in degrees C	EC[a] in mS/cm[b]	% Salinity	pH	Turbidity in NTU[c]	Dissolved Oxygen in mg/L
10/31/2002	10:00	11.80	3.68	0.18	8.49	20	5.69
	10:43	13.00	2.58	0.13	8.16	138	4.34
	11:43	12.90	2.69	0.14	7.85	14	4.46
	13:20	13.00	2.82	0.13	8.19	<10	3.50
	15:30	13.00	2.92	0.15	8.03	<10	3.21
	17:00	12.60	2.95	0.14	8.02	<10	3.85
	18:00	12.40	2.95	0.14	7.98	<10	4.27
11/1/2002	1:00	11.40	2.99	0.14	7.76	<10	3.40
	5:00	12.10	3.02	0.14	7.68	<10	2.33
	7:30	12.50	3.00	0.15	7.75	<10	2.85
	9:45	12.80	3.00	0.16	7.66	<10	2.75

Notes:
a- EC = Electrical Conductivity
b- mS/cm = milliSiemens per Centimeter
c- NTU = Nephelometric Turbidity Unit

Table 2 - Soil Parameters - Deep Channel
Wall Segment C-1

Soil Unit	Layer	Depth to Top of Layer[a] in Feet	Total Unit Weight in pcf	Friction Angle in Degrees	K_a	K_p (design)	Residual Shear Strength in psf (liquefiable soils- 475-year event)[b]
-	Compacted Granular Fill	0 (at ground surface)	130 (123)[c]	37 (34)[c]	0.23 (0.26)[c]	4.5 (3.9)[c]	No Liquefaction
1	Existing Sand/Gravel	6	125	35	0.25	4.0	No Liquefaction
2	Loose to Medium Dense Silty Sand	22	120	32	0.28	3.5	**570**
5	Dense Sand and Hard Sandy Silt	50	135	38	0.22	5.0	No Liquefaction

Notes:
Refer to the text for earthquake loading and assumptions.
For earth pressure diagrams (operational and earthquake cases and post-earthquake), refer to Figures 10 and 11
a- Assuming top of slab is at elevation 10.0 feet
b- Soils at this location would not experience global liquefaction under an earthquake with 10% in 20 years (190-year event)
c- The first value corresponds to 95 percent compaction and the second value (in parenthesis) corresponds to 90 percent compaction.

Table 3 - Soil Parameters - Deep Channel
Wall Segment C-2

Soil Unit	Layer	Depth to Top of Layer in Feet	Total Unit Weight in pcf	Friction Angle in Degrees	Ka	Kp (design)	Residual Shear Strength in psf (liquefiable soils- 475-year event)[a]
-	Compacted Granular Fill	0 (at ground surface)	130 (123)[b]	37 (34)[b]	0.23 (0.26)[b]	4.5 (3.9)[b]	No Liquefaction
1	Existing Sand/Gravel	6	125	35	0.25	4.0	No Liquefaction
2	Loose to Dense Silty Sand	22	125	35	0.25	4.0	No Liquefaction
3	Very Soft to Medium Stiff Sandy Silt	35	115	28	0.33	2.6	**500**
5	Hard Sandy Silt	55	135	38	0.22	5.0	No Liquefaction

Note:
Refer to the text for earthquake loading and assumptions.
a- Soils at this location would not experience global liquefaction under an earthquake with 10% in 20 years (190-year event)
b- The first value corresponds to 95 percent compaction and the second value (in parenthesis) corresponds to 90 percent compaction

Table 4 - Soil Parameters - Deep Channel
Wall Segment C-3

Soil Unit	Layer	Depth to Top of Layer in Feet	Total Unit Weight in pcf	Friction Angle in Degrees	K_a	K_p (design)
-	Compacted Granular Fill	0 (at ground surface)	130 (123)[a]	37 (34)[a]	0.23 (0.26)[a]	4.5 (3.9)[a]
1	Existing Sand/Gravel	6	130	37	0.23	4.5
2	Loose to Medium Dense Silty Sand	20	125	35	0.25	4.0
5	Dense Sand and Hard Sandy Silt	50	135	38	0.22	5.0

Note:
Refer to the text for earthquake loading and assumptions
a- The first value corresponds to 95 percent compaction and the second value (in parenthesis) corresponds to 90 percent compaction

Table 5 - Soil Parameters - Upper Slab
Wall Segment U-1

Soil Unit	Layer	Depth to Top of Layer in Feet	Total Unit Weight in pcf	Friction Angle in Degrees	K_a	K_p (design)
-	Berm (outside the dock)	8 feet high above ground surface	130 (123)[a]	37 (34)[a]	0.23 (0.26)[a]	4.5 (3.9)[a]
1	Existing Sand/Gravel	0.0 (ground surface)	120	32	0.28	3.5
2	Loose to Medium Dense Silty Sand	20	120	32	0.28	3.5 (2.6)[b]
3	Very Soft Sandy Silt	32	110	26	0.36	2.2 (1.6)[b]
4	Medium Dense Sand	60	120	32	0.28	3.5 (2.6)[b]
5	Dense Sand and Hard Sandy Silt	68	135	38	0.22	5.0 (3.8)[b]

Notes:
Refer to the text for earthquake loading and assumptions.
a- The first value corresponds to 95 percent compaction and the second value (in parenthesis) corresponds to 90 percent compaction
b- The K_p in parenthesis is reduced to account for the limited width of the earth berm and should be used where the earth berm is accounted for

Table 6 - Soil Parameters - Upper Slab
Wall Segment U-2

Soil Unit	Layer	Depth to Top of Layer in Feet	Total Unit Weight in pcf	Friction Angle in Degrees	K_a	K_p (design)
-	Berm (outside the dock)	8 feet high above ground surface	130 (123)[a]	37 (34)[a]	0.23 (0.26)[a]	4.5 (3.9)[a]
1	Existing Sand/Gravel	0.0 (ground surface)	125	35	0.25	4.0
2	Medium Dense Sand	20	120	32	0.28	3.5 (2.6)[b]
5	Dense Sand and Hard Sandy Silt	52	135	38	0.22	5.0 (3.8)[b]

Notes:
Refer to the text for earthquake loading and assumptions
a- The first value corresponds to 95 percent compaction and the second value (in parenthesis) corresponds to 90 percent compaction
b- The K_p in parenthesis is reduced to account for the limited width of the earth berm and should be used where the earth berm is accounted for

Table 7 - P-y Curve Parameters Used in LPILE Analysis

Top of pile: -25 feet

				STATIC ANALYSIS				
Soil Layer	Bottom of Layer Elevation in Feet	Soil Type	Soil Type (KSOIL)	Effective Unit Weight of Soil in pci	Cohesion in psi	Axial Strain ε_{50}	Friction Angle in Degrees[a]	Modulus of Subgrade Reaction in pci[b]
1	-43	SAND	4	0.03	0 (500)[d]	N/A	28	25 (5)[c]
2	-65	SAND	4	0.04	0	N/A	38	125

Notes

a- The friction angle presented in this table should be reduced to account for group effect as outlined in the 2000 WSDOT Bridge Design Manual

b- The modulus of subgrade reaction presented in this table should be reduced to account for group effect. The group effect reduction factors are presented in Table 8

c- The value in parenthesis (5) should be used for post-earthquake case

d- The post-liquefaction residual strength of soil layer 2 is 500 psf. Due to the low overburden stress, shear strength calculated using friction angle is less than the residual strength. Therefore, the friction angle of 28 degrees is recommended for the LPILE analysis of the liquefaction case.

Table 8 - Group Reduction Factors for Lateral Analysis

Pile Spacing[a]	Group Reduction Factor
6D	0.9
5D	0.8
4D	0.65
3D	**0.5**
2D	0.4

Note:
a- As a function of pile diameter, D.

Table 9 - Earth Pressures for Walls Attached to the Gate Foundation

Compaction Level (Modified Proctor)	Wall Case	Static in pcf[a]	Seismic Pressure in psf[b] (in terms of H[c])	
			190-Year earthquake	475-Year earthquake
90 Percent	Yielding	32 (16)[d]	2.5	5.4
	Non-Yielding	54 (27)[d]	5.4	13
95 Percent	Yielding	30 (15)[d]	2.4	5.2
	Non-Yielding	52 (26)[d]	5.2	12

Notes:

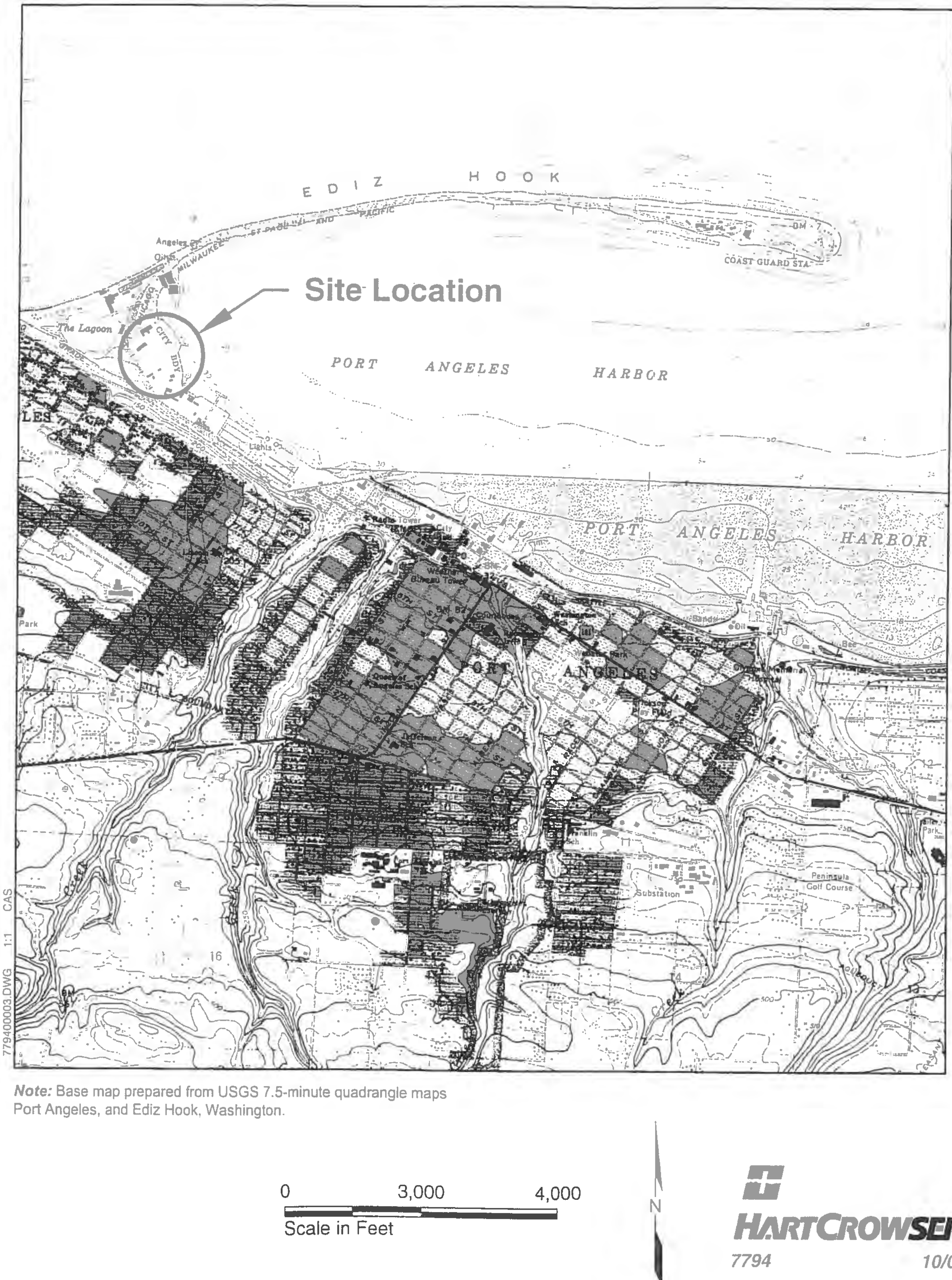
a- Static Equivalent Density

b- Seismic Uniform Earth Pressure

c- H = Wall Height in Feet

d- The first value corresponds to soils above groundwater and the second value (in parenthesis) corresponds to soils below groundwater

Vicinity Map



Note: Base map prepared from USGS 7.5-minute quadrangle maps Port Angeles, and Ediz Hook, Washington.

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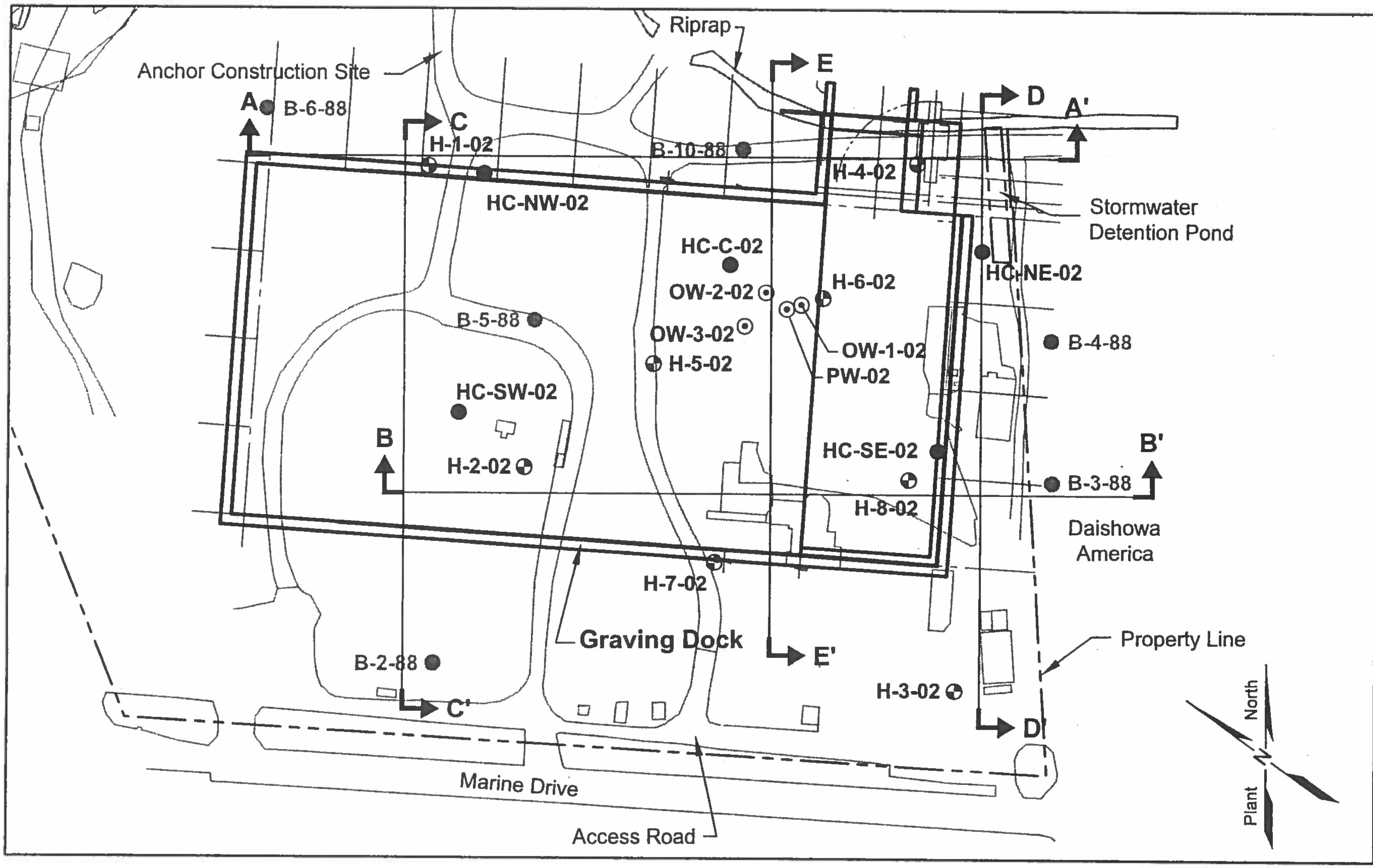
Figure 1

Site and Exploration Plan



Exploration Location and Number

H-1-02 ⊕ Geotechnical Boring (Current Study)

OW-2-02 ⊙ Wells (Current Study)

HC-SW-02 ● Environmental Boring (Current Study)

B-2-88 ● Environmental Boring (1988 Study)

B — B' Cross Section Location and Designation

0 200 400
Scale in Feet

Notes:
1) Current exploration locations were surveyed by WSDOT except geotechnical boring H-8-02 (refer to Appendix A for explanation).
2) Base map including the location of the graving dock was provided by KPFF dated 12-10-02.

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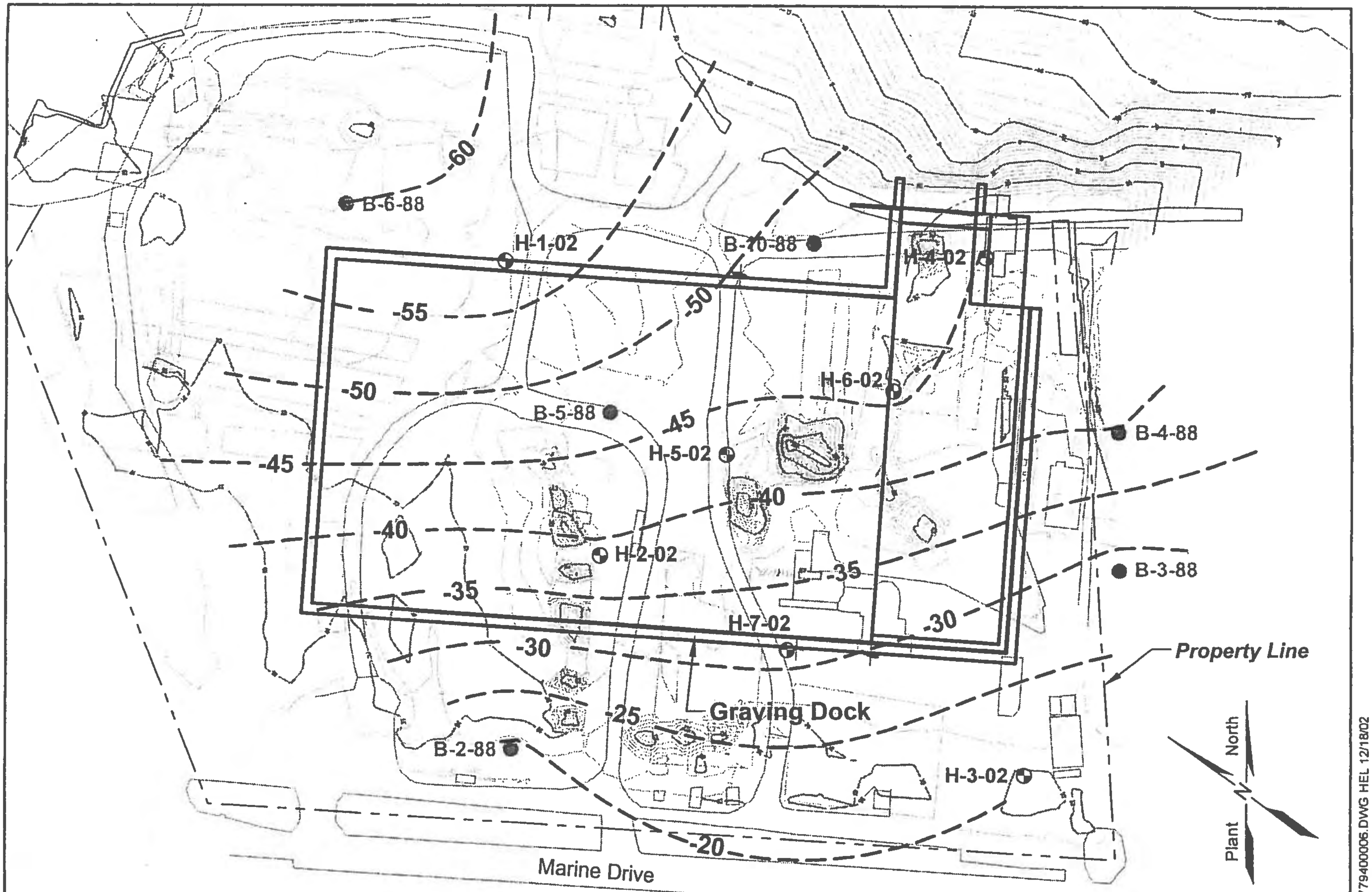
Figure 2

Top of Bearing Layer Elevation Contour Map



Note: Elevation contours are based on borings shown on this figure.

H-3-02 ⊕ Exploration Location and Number (Current Study)

B-2-88 ● Exploration Location and Number (1988 Study)

-40 Elevation Contour in Feet of Top of Bearing Layer

0 200 400
Scale in Feet

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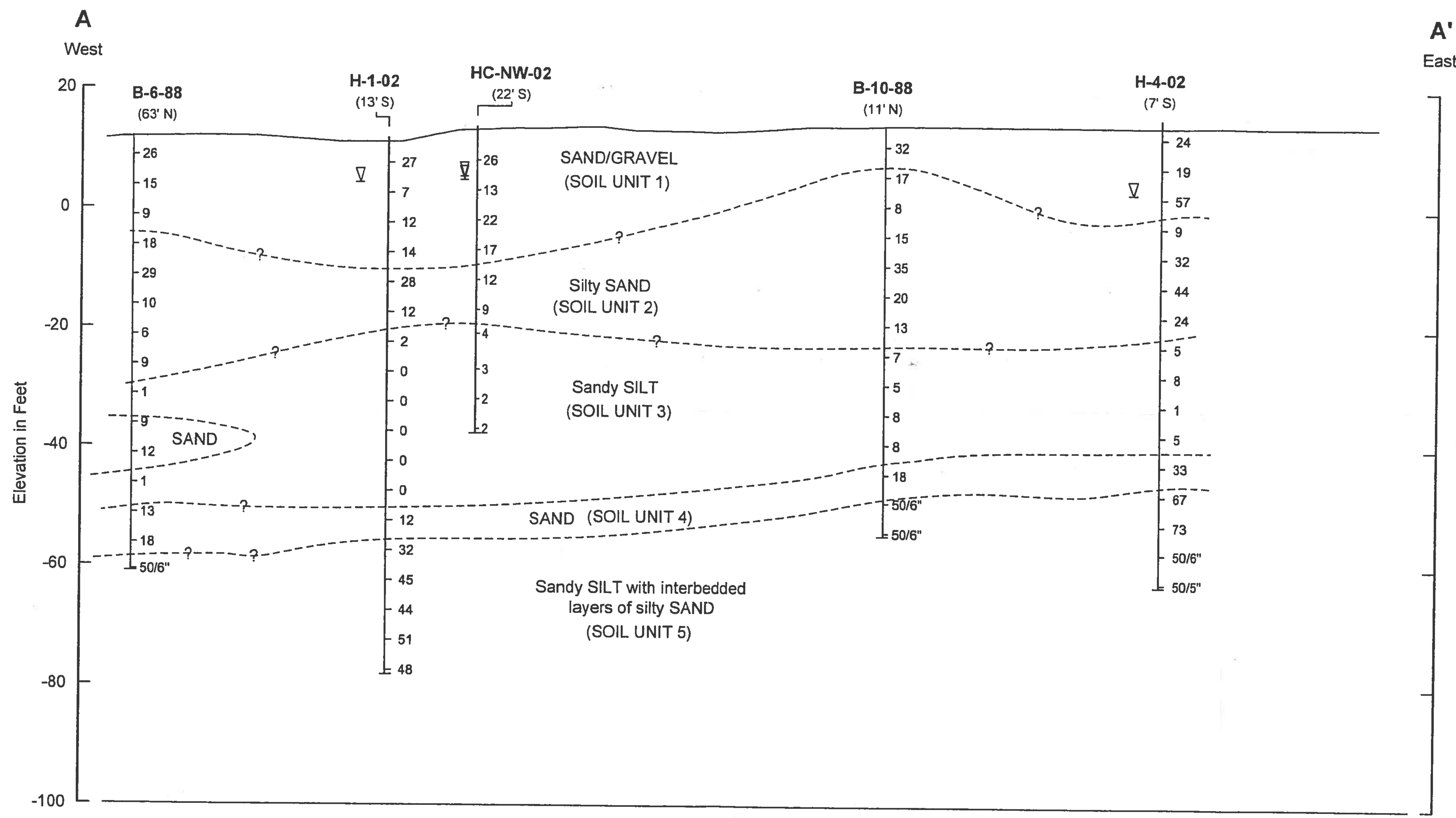
Figure 3

Cross Section A-A'



Note:
Contacts between soil units are based upon interpolation between borings and represent our interpretation of subsurface conditions based on currently available data.

Legend:

HC-1-02 (13' S) Exploration Number (Offset Distance and Direction)

Exploration Location

∇ Water Level

9 Standard Penetration Resistance in Blows per Foot

Horizontal Scale in Feet: 0 100 200

Vertical Scale in Feet: 0 20 40

Vertical Exaggeration x 5

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Figure 4

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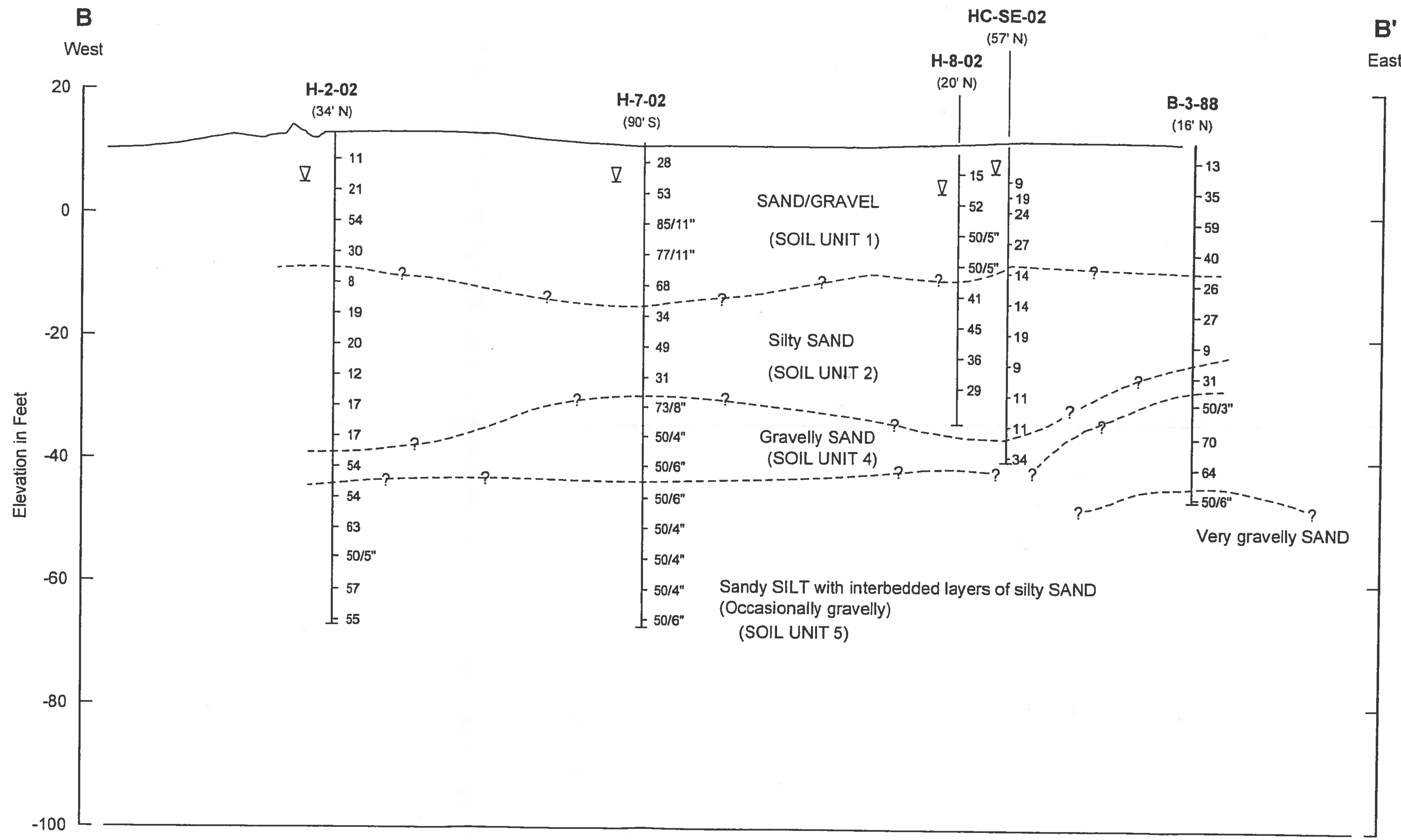
Cross Section B-B'



Legend:

HC-2-02 (34' N) Exploration Number (Offset Distance and Direction)

Exploration Location

Water Level

9 Standard Penetration Resistance in Blows per Foot

Note:
Contacts between soil units are based upon interpolation between borings and represent our interpretation of subsurface conditions based on currently available data.

Horizontal Scale in Feet
0 100 200

0 20 40
Vertical Scale in Feet
Vertical Exaggeration x 5

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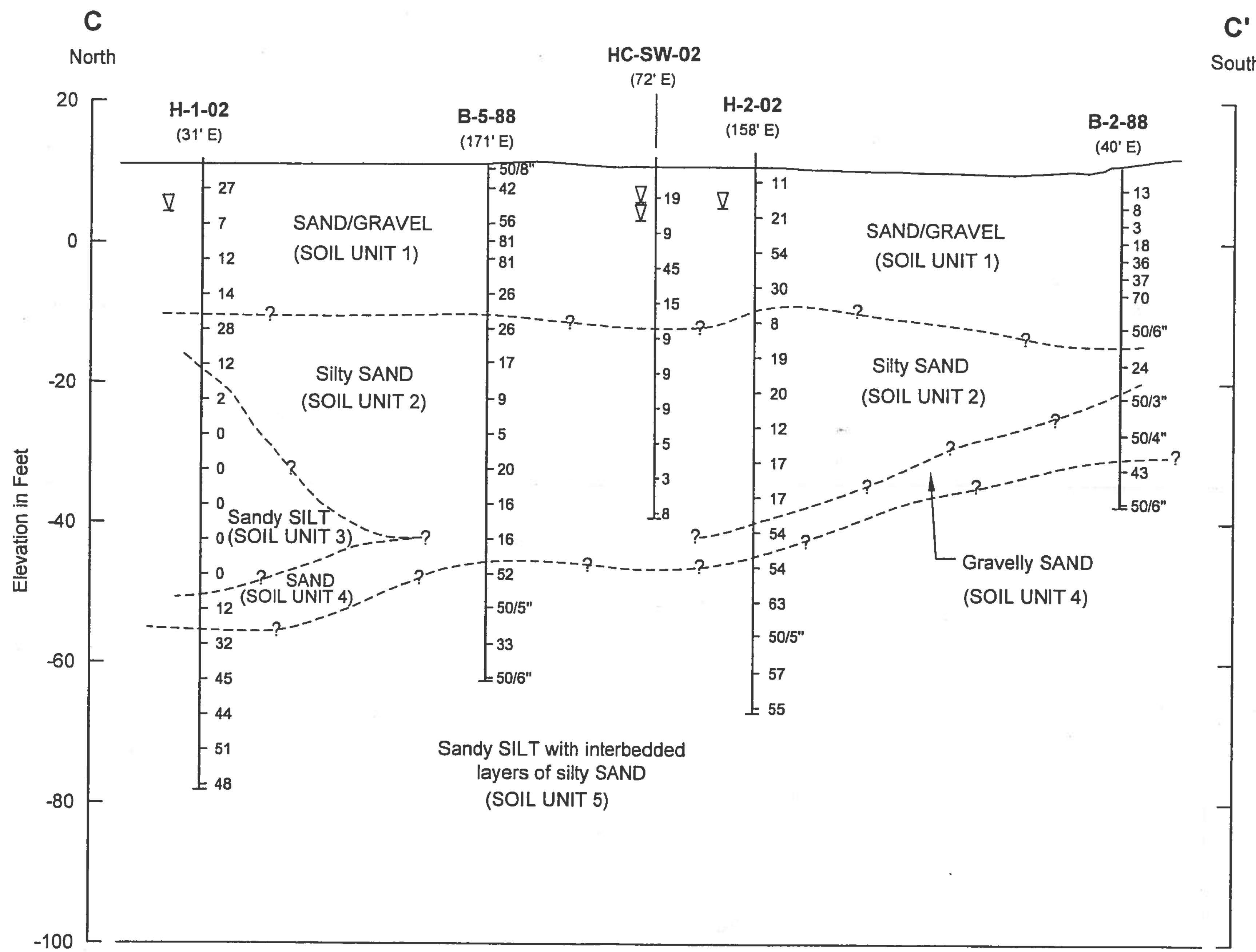
Cross Section C-C'



Legend:

HC-1-02 (31' E) Exploration Number (Offset Distance and Direction)

Exploration Location

Water Level

Standard Penetration Resistance in Blows per Foot

Horizontal Scale in Feet: 0, 100, 200

Vertical Scale in Feet: 0, 20, 40

Vertical Exaggeration x 5

Note:
Contacts between soil units are based upon interpolation between borings and represent our interpretation of subsurface conditions based on currently available data.

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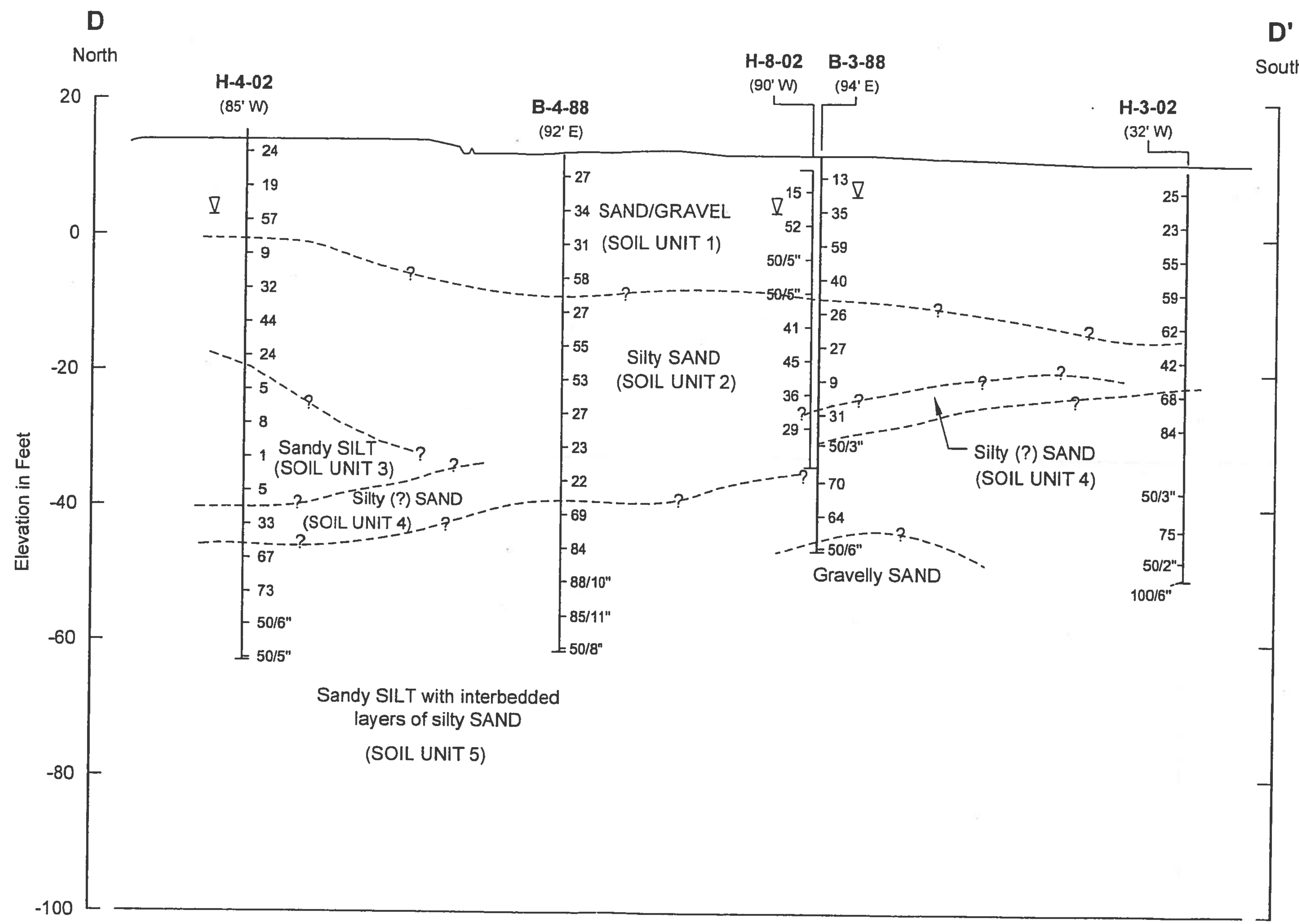
Figure 6

Cross Section D-D'



Legend:

HC-4-02 (85' W)	Exploration Number (Offset Distance and Direction)
	Exploration Location
∇	Water Level
9	Standard Penetration Resistance in Blows per Foot

Note:
Contacts between soil units are based upon interpolation between borings and represent our interpretation of subsurface conditions based on currently available data.

Horizontal Scale in Feet
0 100 200

0 20 40
Vertical Scale in Feet
Vertical Exaggeration x 5

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Figure 7

Cross Section E-E'

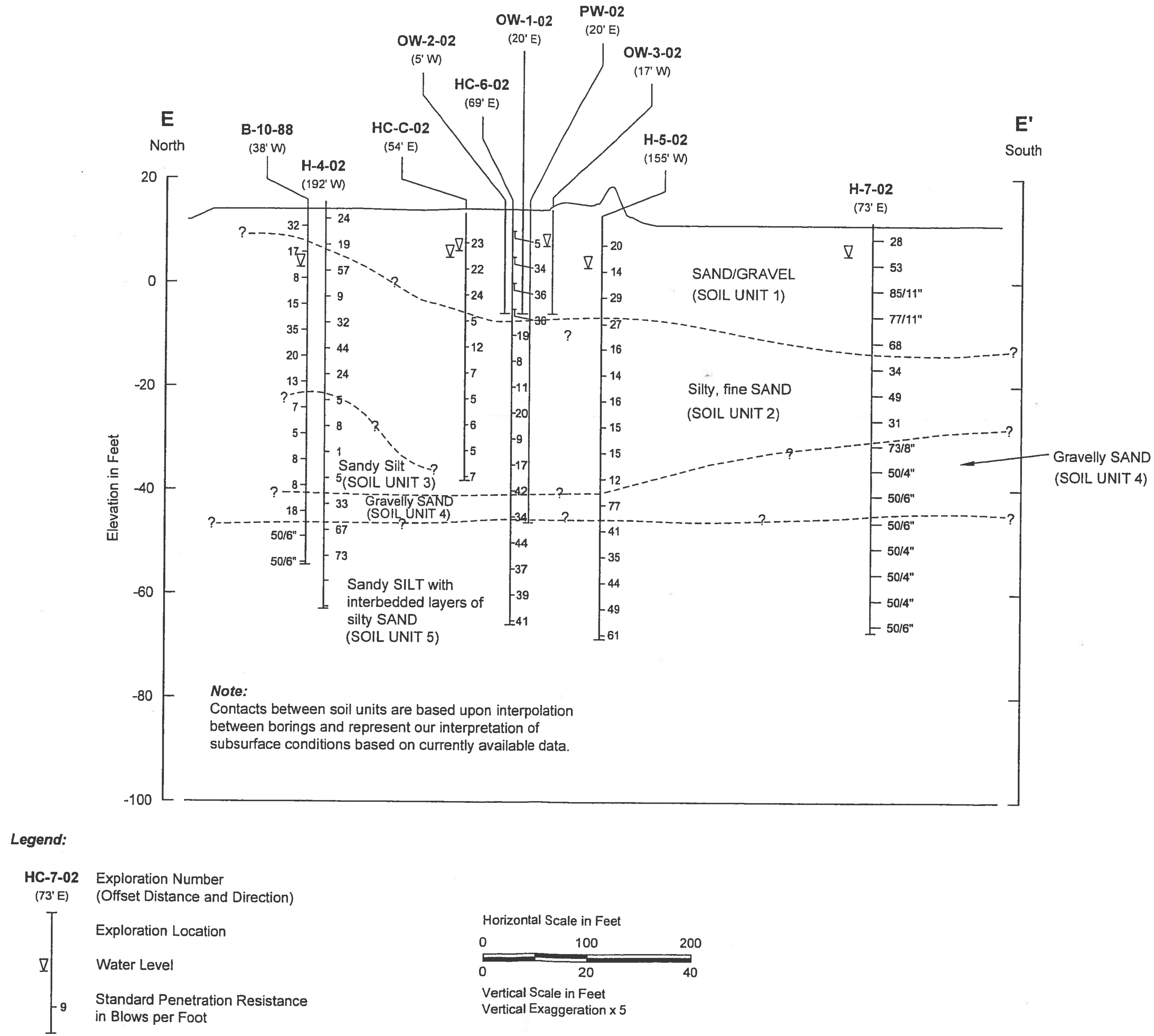

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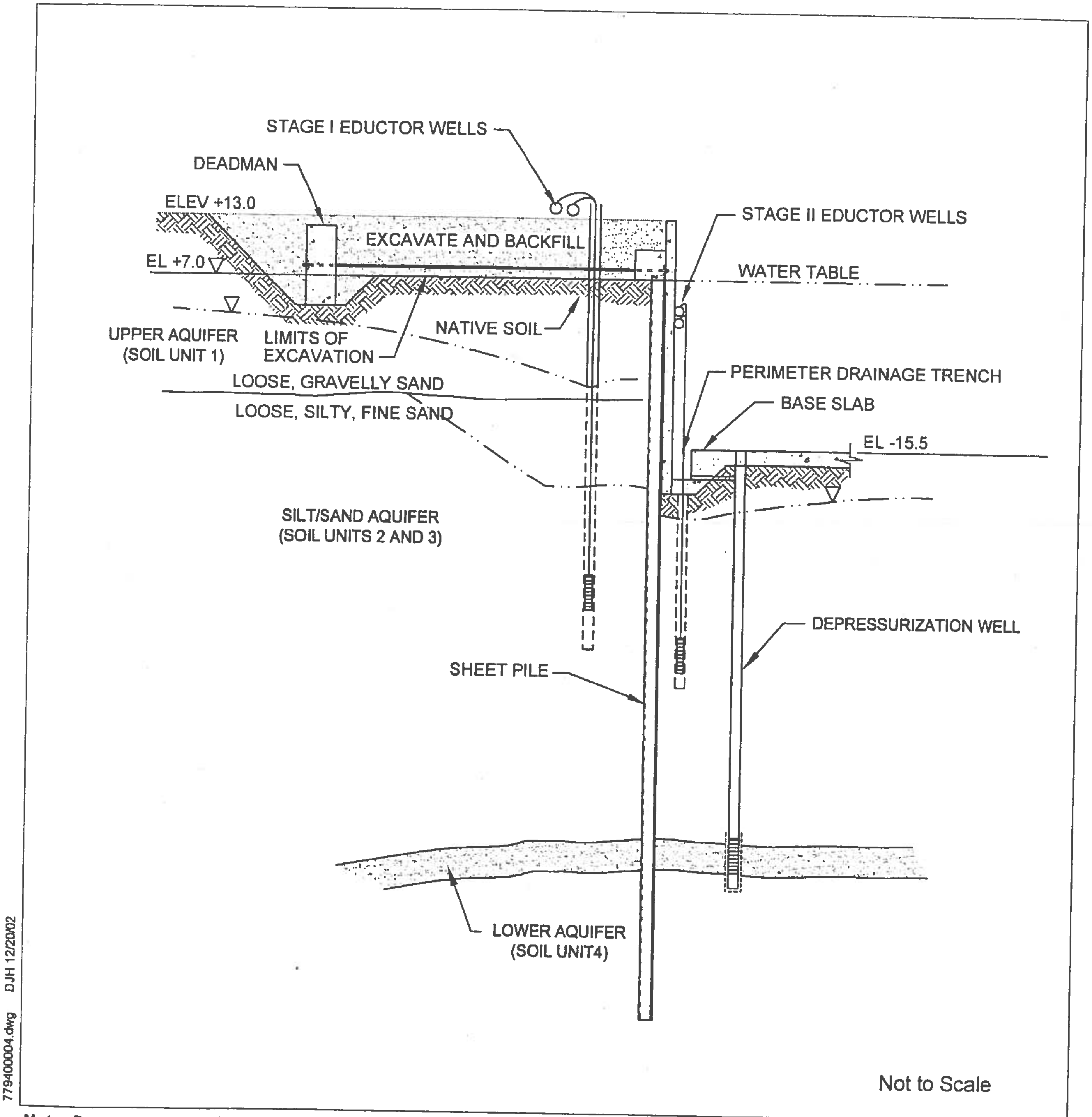
Figure 8

Conceptual Dewatering Schematic



Note: Base map prepared from drawing provided by KPFF Consulting Engineers, named "Pagd-exihibit-3.dwg", dated October 22, 2002.

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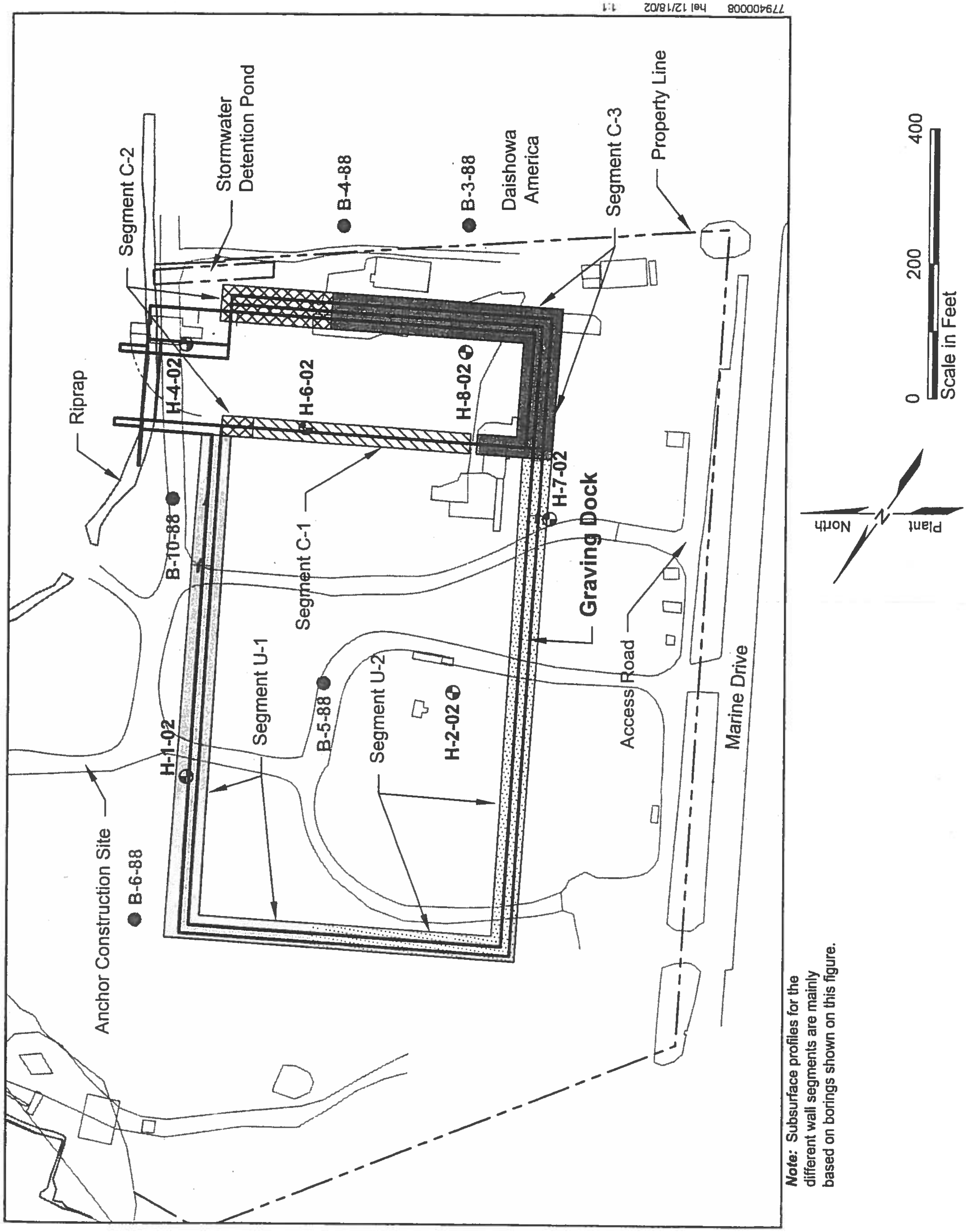
Figure 9

Wall Segments Corresponding to Different Earth Pressures



Note: Subsurface profiles for the different wall segments are mainly based on borings shown on this figure.

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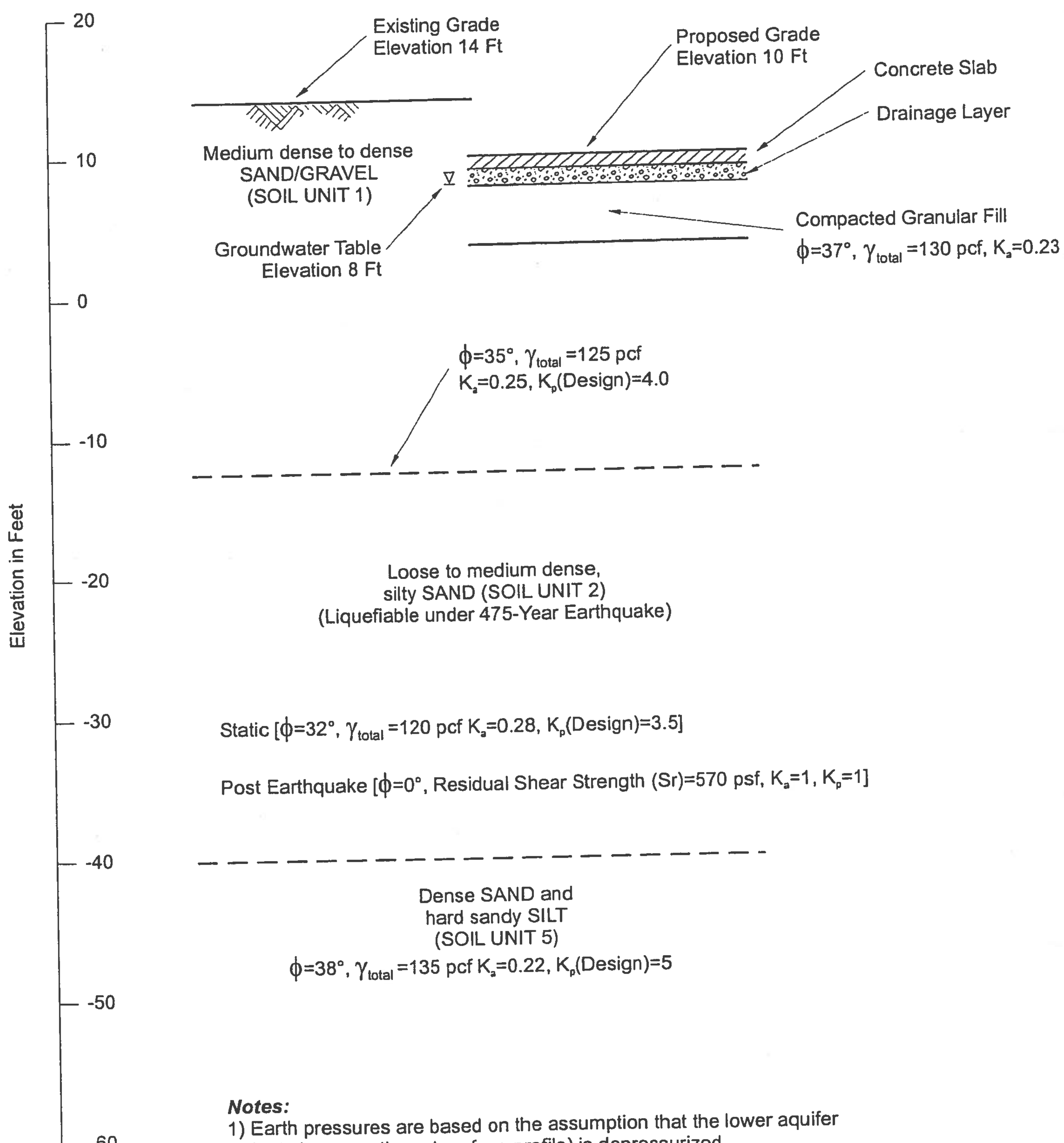
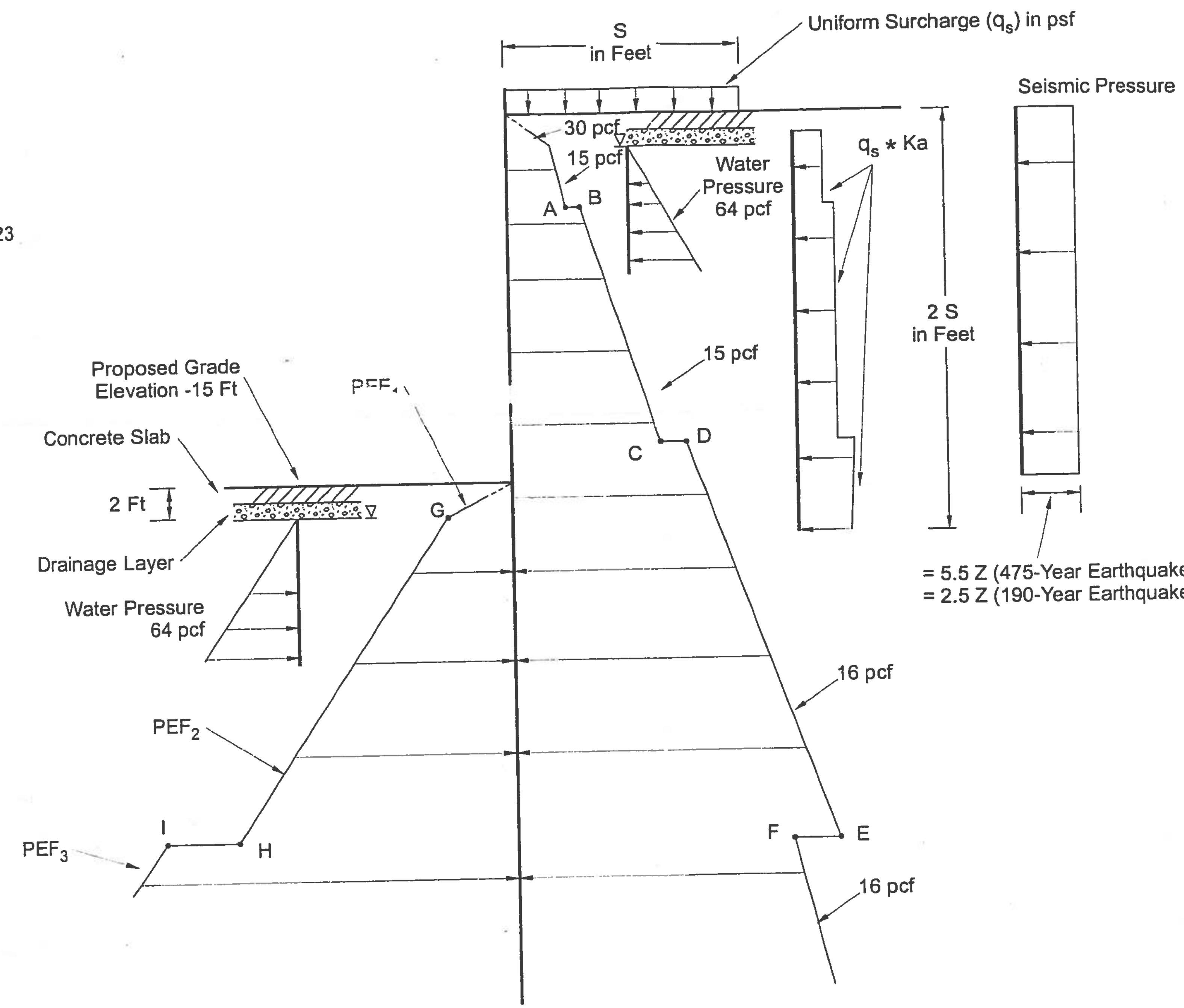
Figure 10

Subsurface Profile and Earth Pressure (Operational and Earthquake)
Segment C-1

Subsurface Profile



Earth Pressures - Operational and Earthquake Cases



Passive Equivalent Fluid Density
(PEF) in pcf

	Static	190-Year Earthquake	475-Year Earthquake
PEF_1	580	580	790
PEF_2	196	196	265
PEF_3	355	355	530

Earth Pressure (EP):
at "B"=EP at "A" * 0.25/0.23
at "D"=EP at "C" * 0.28/0.25
at "F"=EP at "E" * 0.22/0.28
at "I"=EP at "H" * 5/3.5

Notes:
1) Earth pressures are based on the assumption that the lower aquifer (not shown on the subsurface profile) is depressurized.
2) Location of segment C-1 is shown on Figure 10.
3) Subsurface profile is based on boring H-6-02.
4) For post-earthquake (liquefaction) case, refer to Figure 12.
5) For other surcharge loading cases, refer to Figure 13.

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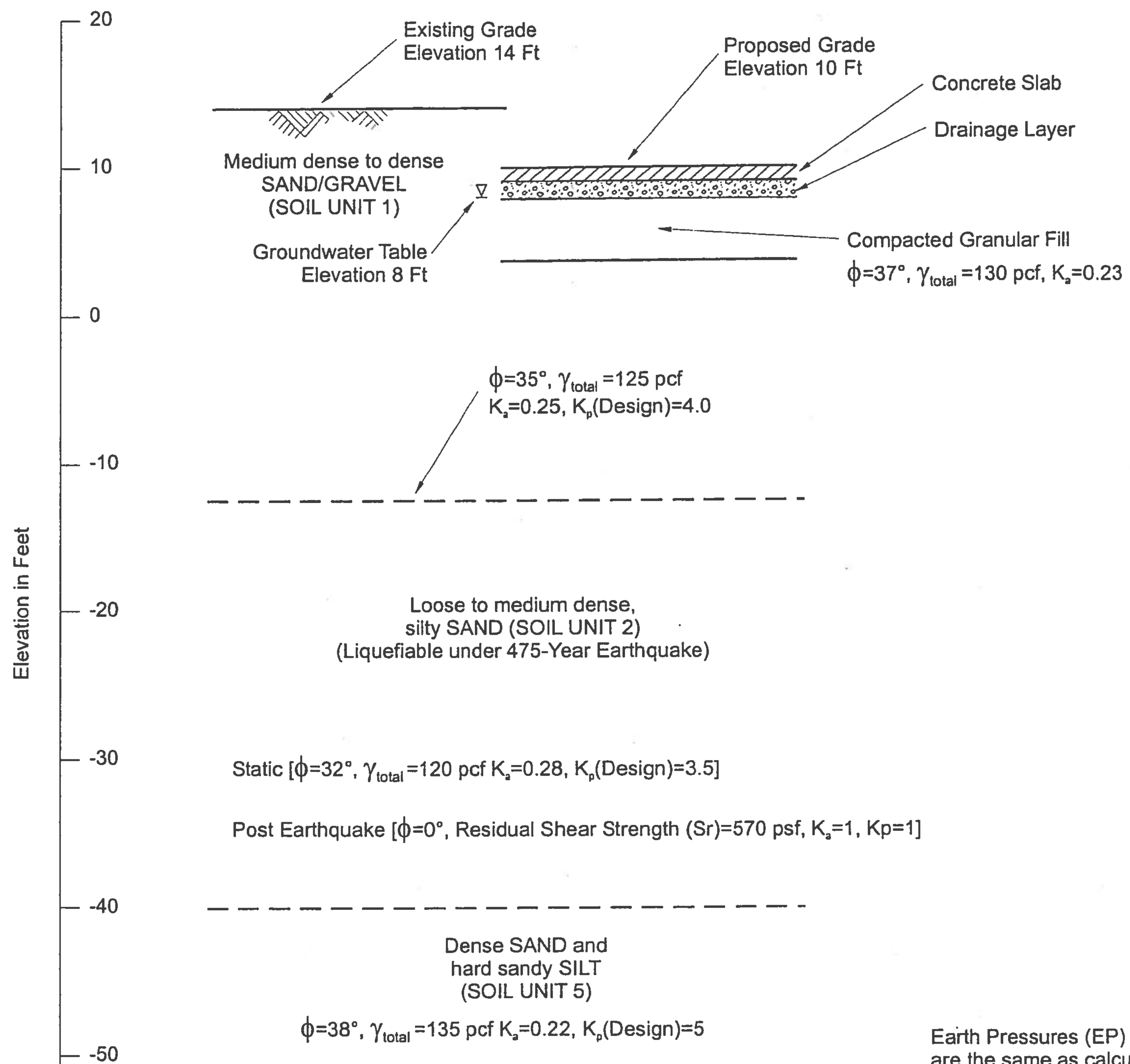
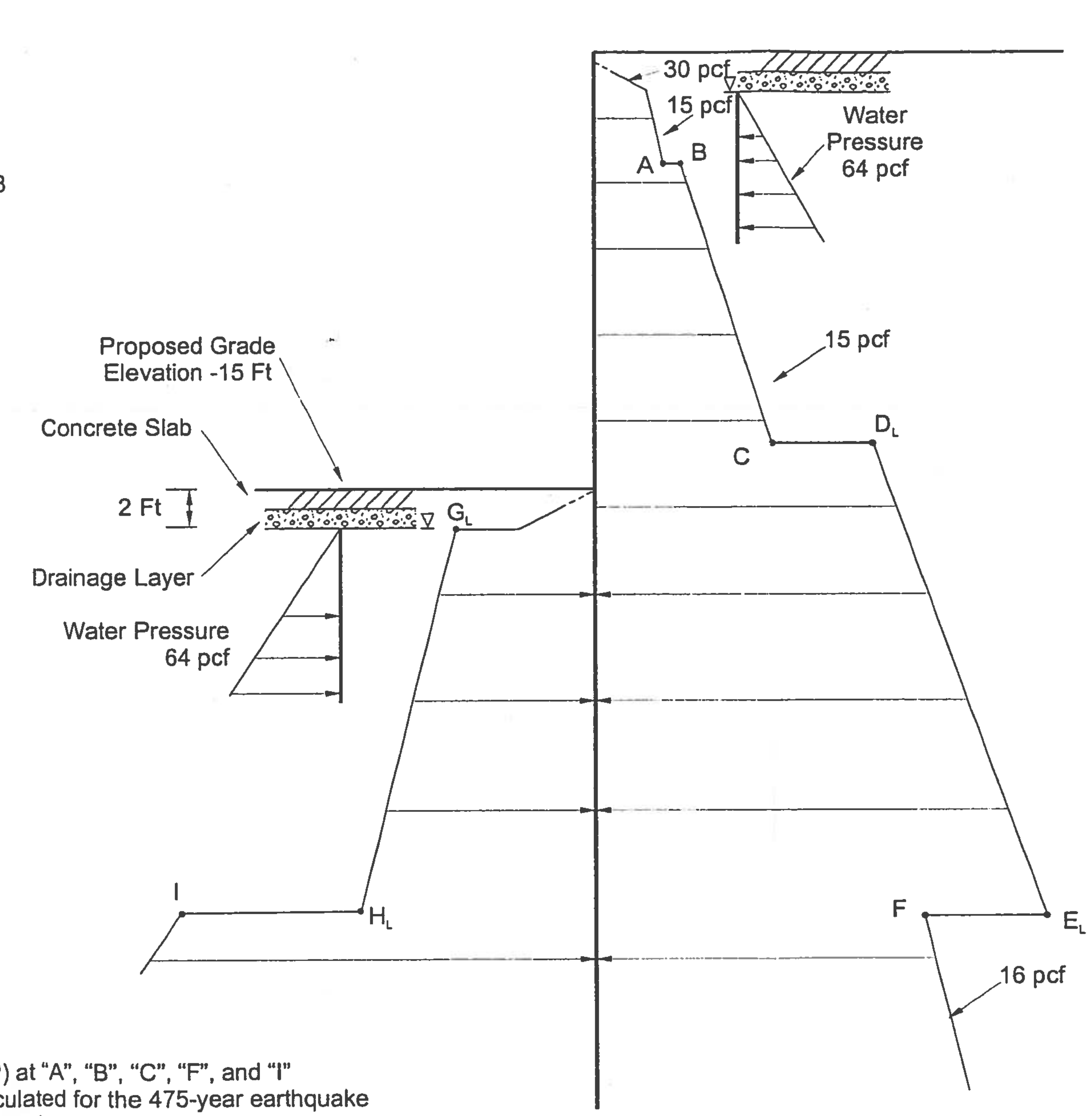
Figure 11

Subsurface Profile and Earth Pressure (Post-Earthquake)
Segment C-1

Subsurface Profile



E... Pressures - Post-Earthquake (Liquefaction)



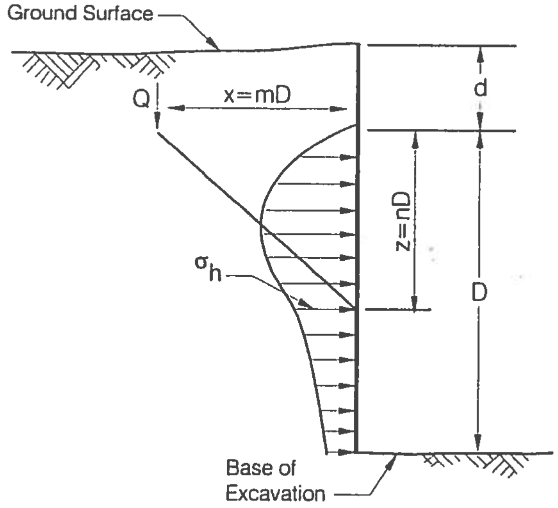
Earth Pressures (EP) at "A", "B", "C", "F", and "I" are the same as calculated for the 475-year earthquake event (refer to Figure 11).

Earth Pressure (EP):
at "D_L"= Effective Vertical Stress at "D_L"-2 * Sr (where Sr=Residual Shear Strength = 570 psf) $\geq$ EP at "D" on Figure 9
at "E_L"= Effective Vertical Stress at "E_L"-2 * Sr $\geq$ EP at "E" on Figure 9
at "G_L"= Effective Vertical Stress at "G_L"+2 * Sr $\leq$ EP at "G" on Figure 9
at "H_L"= Effective Vertical Stress at "H_L"+2 * Sr $\leq$ EP at "H_L" on Figure 9

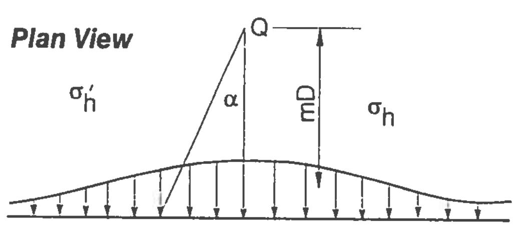
Note:
1) Apply surcharge loads as appropriate.
2) Earth pressures are based on the assumption that the lower aquifer (not shown on the subsurface profile) is depressurized.

Surcharge Pressures
Determination of Lateral Pressure Acting on Permanent Walls Due to:

A. Small Isolated Footing Cross Section View



Plan View



$\sigma'_h = \sigma_h \cos^2(1.1\alpha)$

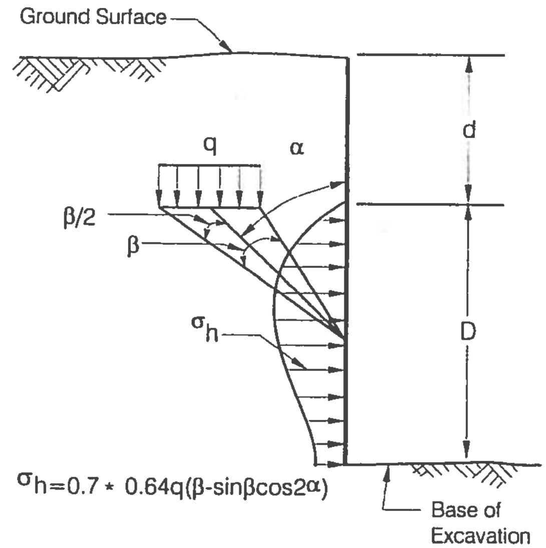
(For m > 0.4)

$\sigma_h = 0.7 * \frac{1.77Q}{D^2} \frac{m^2n^2}{(m^2+n^2)^3}$

(For m ≤ 0.4)

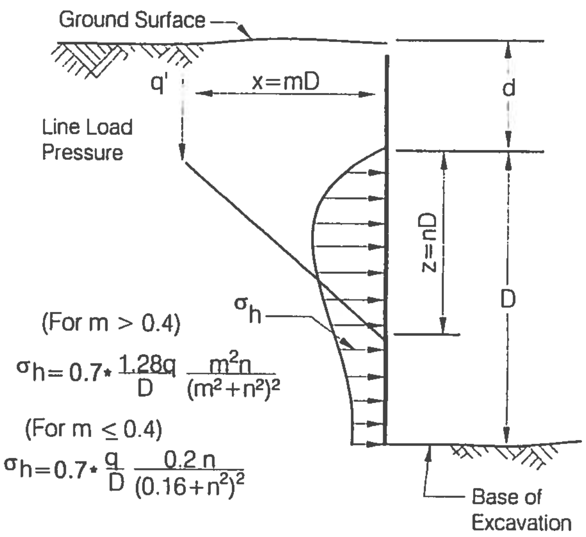
$\sigma_h = 0.7 * \frac{0.28Q}{D^2} \frac{n^2}{(0.16+n^2)}$

B. Large Isolated Footing Cross Section View



$\sigma_h = 0.7 * 0.64q(\beta - \sin\beta \cos 2\alpha)$

C. Continuous Wall Footing Parallel to Excavation Cross Section View



(For m > 0.4)

$\sigma_h = 0.7 * \frac{1.28q}{D} \frac{m^2n}{(m^2+n^2)^2}$

(For m ≤ 0.4)

$\sigma_h = 0.7 * \frac{q}{D} \frac{0.2n}{(0.16+n^2)^2}$

Definition and Units

Q	Footing Load in Pounds
D	Excavation Depth below Footing in Feet
d	Depth to Base of Footing in Feet
σ_h	Lateral Soil Pressure in PSF
q	Unit Loading Pressure in PSF
α, β	Radians

Notes: 1. Lateral pressures due to adjacent structures should be added to lateral pressures on Figures 11 and 12.
2. Wall footings acting other than parallel to the excavation can be treated as series of discrete point loads, using approach A.

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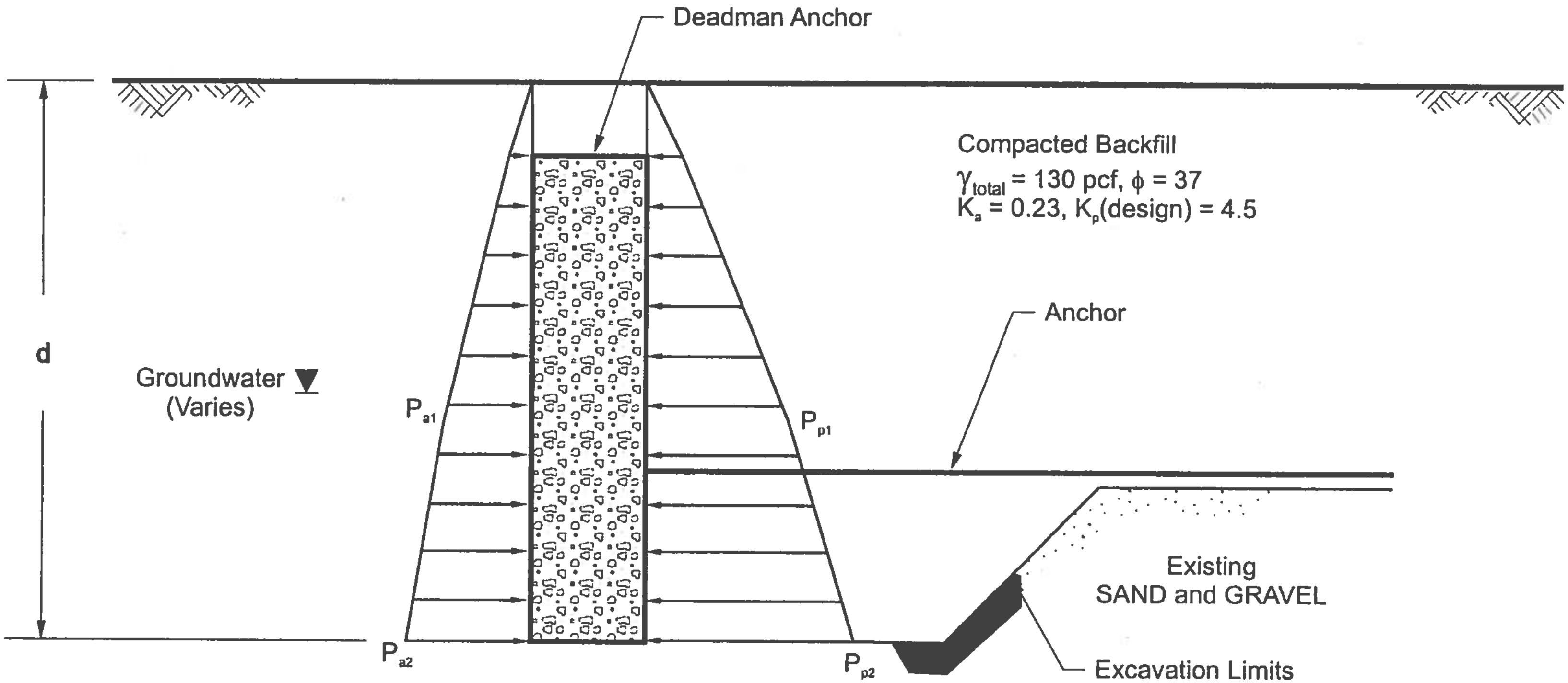
Figure 13

Deadman Earth Pressures



Note:
Anchor location should be at the location of the resultant earth pressures acting on the vertical face of the deadman.

Seismic Pressures:

475-Year Earthquake: Add active distributed pressure = 5.3d (psf) where d is the depth to the bottom of the deadman for passive resistance, use K_p(ultimate)

190-Year Earthquake: Add active distributed pressure = 2.5d (psf) for passive resistance, use K_p(design)

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Figure 14

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Final Geotechnical Report
Phase 2 Combined Sewer Overflow Project
City of Port Angeles, Washington

April 7, 2014

SHANNON & WILSON, INC.

GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

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Submitted To:
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21-1-20617-004

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APPENDICES

FINAL GEOTECHNICAL REPORT
PHASE 2 COMBINED SEWER OVERFLOW PROJECT
CITY OF PORT ANGELES, WASHINGTON

1.0 INTRODUCTION

This geotechnical report presents the results of our geotechnical engineering studies for the Phase 2 Combined Sewer Outflow (CSO) Project located in Port Angeles, Washington. The proposed project is located between Marine Drive and Lincoln Street in downtown Port Angeles, Washington, as shown in Figure 1.

The information and recommendations presented in this report are intended to provide the Brown and Caldwell design team with the information required to assist with advancing the design to 100 percent. Included in this report are a site and project description, a discussion of the completed geotechnical explorations and laboratory testing, the interpreted subsurface soil and groundwater conditions, and geotechnical engineering recommendations.

The work detailed in this report was conducted in general accordance with the scope of work as outlined in our subcontract with Brown and Caldwell.

2.0 SITE AND PROJECT DESCRIPTION

The Phase 2 CSO Project is part of a concerted effort by the City of Port Angeles to reduce CSO discharge events. The proposed project consists of replacing Pump Station No. 4 (PS 4), completing the remaining section of force main from Phase 1 along Front Street, and constructing a new gravity diversion sewer along Lincoln Street and Front Street. The proposed force main and gravity diversion sewer alignments and location of the new PS 4 are shown in Figure 1.

The new PS 4 will be located in a triangular-shaped property across from the existing PS 4, near the intersection of Front Street and Marine Drive. The new PS 4 will consist of a below grade structure containing the motor room and wet well (buried pump station) and at grade facilities including an odor control building, generator building, and a screen wall. The below grade structure will by approximately 75 feet long by 45 feet wide and 35 feet deep. The odor control building will be about 21 feet long by 18 feet wide and supported by a slab-on-grade. The generator building, also supported by a slab-on-grade, will be about 30 feet long by 10 feet wide. The screen wall will be 8 feet high and about 85 feet long.

The proposed force main completion will include the installation of about 900 lineal feet of 30-inch-diameter pipe. The force main will be constructed along the north side of Front Street between Oak Street and the new PS 4. We understand that the force main will be constructed using conventional open-cut construction methods with a depth to pipe invert of about 5 feet below the existing ground surface (bgs).

The new gravity diversion sewer will include the installation of about 2,470 feet of 30-inch-diameter sewer pipe along Lincoln and Front Streets, 64 feet of 30-inch-diameter sewer pipe from the existing sanitary sewer to the new diversion sewer, about 30 feet of 42-inch-diameter pipe at the new PS 4, and 10 new manholes. The new gravity diversion sewer will be constructed using conventional open-cut construction methods with a depth to pipe invert of about 8 to 14 feet bgs. The exception is near the new PS 4, where the depth to pipe invert is about 17 to 19 feet bgs.

3.0 GEOTECHNICAL INVESTIGATIONS

To evaluate the subsurface and groundwater conditions, geotechnical investigations were conducted at the pump station site and along the proposed gravity sewer and force main alignment. The geotechnical investigations included a review of existing geotechnical data and a phased field exploration program.

3.1 Existing Geotechnical Data

The City of Port Angeles provided copies of geotechnical reports for nearby projects, including:

- Geotechnical Engineering Evaluation Report, Proposed Multi-Use Development, Northwest Corner of Oak Street and Front Avenue, Port Angeles, Washington (ALKAI Consultants, LLC, 2006)
- The CSO Project – Phase I, The First Street Stormwater Interceptor Subsurface and Geotechnical Assessment, Draft Report of Findings (NTI Engineering and Land Surveying, Inc., 2010)
- The CSO Project – Phase I, Oak Street Geotechnical Evaluation, Preliminary Report of Findings (NTI Engineering and Land Surveying, 2012)

Boring logs performed by CH2M Hill in 1967 for the City of Port Angeles were also provided. Boring data pertinent to the project is presented in Appendix C. The elevation and corresponding datum, where available, are indicated on the logs. The approximate locations of the previous borings used to develop the generalized subsurface profile are shown in the Site and Exploration Plan, Figure 1.

3.2 Current Explorations

A total of three geotechnical borings were drilled to characterize the subsurface conditions at the proposed pump station and along the project alignment. Four cone penetration tests (CPTs) were also performed to provide additional subsurface information. The designation, type, drilling or test method, depth, and date for each of the field explorations are summarized below in Table 1. The approximate locations of the borings and the CPTs are shown in Figure 1.

TABLE 1
SUMMARY OF EXPLORATIONS

Designation	Type of Exploration	Depth (feet)	Date Completed
B-1	Mud Rotary Boring	40.5	8/17/2006
B-3	HSA Boring	25.5	8/26/2009
B-4	HSA Boring	21.3	8/18/2009
CPT-1	CPT	19	8/18/2009
CPT-2	CPT	16	8/19/2009
CPT-3	CPT	16.5	8/19/2009
CPT-4	CPT	53	8/19/2009

Notes:
CPT = cone penetration test
HSA = hollow-stem auger

3.2.1 Geotechnical Borings

The three borings completed in May 2013 (borings B-1, B-3, and B-4) were drilled by Holt Services of Edgewood, Washington, using a truck-mounted drill rig. All drilling was conducted under subcontract to Shannon & Wilson, Inc. (Shannon & Wilson). A representative from Shannon & Wilson was present during the field exploration periods to observe the drilling and sampling operations, retrieve representative soil samples for subsequent laboratory testing, and to prepare descriptive field logs. The samples were placed in jars and returned to our laboratory for testing.

The borings were drilled using hollow-stem auger (HSA) drilling or mud rotary techniques, as noted in Table 1. HSA drilling consisted of using continuous-flight augers to advance the boring and to remove soil from the borehole. Samples were obtained by removing the center bit and lowering a sampler through the auger. Mud rotary borings are advanced by circulating drilling mud from a mud tank at the ground surface, down the drill rods, out through the drill bit, up the annulus between the drill rods and borehole, and back into the mud tank. The circulation of drilling mud removes the cuttings generated during the drilling process and carries them to the surface where they are allowed to settle out in the mud tank. The drilling mud also helps keep the hole from caving or collapsing during drilling and sampling. Samples are obtained by removing the drill rods and drill bit from the borehole, removing the drill bit from the ends of the rods, attaching the sampler to the drill rods, and lowering the sampler to the bottom of the mud-filled open hole.

The boring logs for this project are presented in Figures A-2 through A-4 (Appendix A). A boring log is a written record of the subsurface conditions encountered in the boring. It graphically shows the geologic units (layers) encountered in the boring and the Unified Soil Classification System (USCS) symbol of each geologic layer. It also includes the natural water content (where tested), penetration resistance, and various depths within the boring log where tests were performed. Other information shown in the boring logs includes ground surface elevation, types and depths of sampling, descriptions of obstructions and debris encountered in the borings, and observed drilling problems and soil behavior related to caving, raveling, and heave. A soil classification and log key for the boring logs is presented in Figure A-1 (Appendix A).

After completion of the drilling and sampling, an observation well was installed in boring B-1 to measure groundwater levels at the pump station site. A driller licensed in Washington installed the well. The installation details for the observation well and the highest groundwater level measurement are included in the boring log in Appendix A.

An archeologist from the City of Port Angeles was on site during the drilling of all borings to screen the samples and cuttings for artifacts. Screening of samples and cuttings for potential contamination was conducted on site by a Shannon & Wilson representative.

For all borings, the cuttings were transferred into drums and disposed of offsite by the drilling subcontractor.

3.2.2 Cone Penetration Tests (CPTs)

CPTs along the proposed Front Street gravity sewer alignment and at the pump station site were performed to supplement the borings. The locations of the CPTs are shown in Figure 1. The CPTs were performed by In-Situ Engineering, Inc., under subcontract to Shannon & Wilson, in general accordance with procedures outlined in ASTM International (ASTM) Designation: D3441-94, Test Method for Deep, Quasi-static, Cone and Friction-Cone Penetration Tests of Soil. A Shannon & Wilson representative coordinated and was on-site during the CPTs. The electric piezocone test provides a continuous subsurface profile of soil conditions at a particular location. Soil samples are not obtained in this test method. In this test, steel rods with a cone tip on the end are pushed hydraulically into the soil at a relatively constant rate of approximately 2 centimeters per second (cm/sec) (0.8 inch/second). The pore pressure filter element, located behind the cone tip, is a high-air-entry polypropylene disk that was discarded and replaced after every test hole. This filter element transmits pore pressures to the pressure transducer located within the cone tip. Readings are recorded every 5 cm (2 inches). The CPT instrument is capable of recording tip resistance, sleeve friction, pore pressure, and inclination as it penetrates into the ground.

Logs of the CPT probes are presented in Figures A-5 through A-9 (Appendix A). Interpreted soil description, corrected cone tip resistance, friction ratio, pore pressure, shear wave velocity (where applicable), as well as the estimated soil properties of internal friction angle, undrained shear strength, and equivalent uncorrected N value, are plotted versus depth on the logs. While advancing probe CPT-1 (at the pump station site), downhole seismic shear wave measurements were obtained approximately every 5 feet to a depth of 35 feet. Shear waves were generated at the ground surface by striking a steel beam with a hammer. Transducers located in the cone-tipped apparatus recorded the arrival and traces of the generated shear waves at each test depth. These data were subsequently used to calculate the shear wave velocity of the soil at each 5-foot interval. Shear wave velocities for CPT-1 are presented in Figure A-6.

3.2.3 Soil Sampling

Soil samples from the geotechnical borings were obtained in conjunction with the Standard Penetration Test (SPT) at the depths shown in the boring logs. SPTs were performed in general accordance with ASTM Designation: D1586, Standard Method for Penetration Testing and Split-Barrel Sampling of Soils (ASTM, 2009). SPTs were generally performed every 2.5 feet to a depth of 20 feet and then every 5 feet to the bottom of the borehole. The SPT consists of driving a 2-inch outside-diameter, split-spoon sampler a distance of 18 inches into the bottom of the borehole with a 140-pound hammer falling 30 inches. The number of blows required for the last 12 inches of penetration is termed the Standard Penetration Resistance (N-value). These values are plotted at the midpoint of the sample depths on the boring logs. Generally, whenever 50 or more blows were required to cause 6 inches or less of penetration, the test was terminated, and the number of blows and the corresponding penetration were recorded. The N-value is an empirical parameter that provides a means for evaluating the relative density, or compactness, of granular soils and the consistency, or stiffness, of cohesive soils.

3.2.4 Test Pits

As part of the Infiltration Feasibility Study documented in our December 12, 2013, report (included as Appendix D), two test pits were excavated to depths between 4 and 4.5 feet below the ground surface at the new PS 4 site. The test pits were excavated by City of Port Angeles personnel. Our observations of the test pits and the test pit logs are included in Appendix D.

4.0 LABORATORY TESTING

Laboratory tests were performed on selected soil samples retrieved from the geotechnical borings. The laboratory testing program included a variety of tests to classify the soils and to provide data for engineering studies. Classification and index laboratory tests included visual classification and tests to determine natural water content, grain size distribution, and Atterberg Limits. The results from the laboratory tests are included in Appendix B.

4.1 Visual Classification

Soil samples recovered from the borings were visually reclassified in our laboratory using a system based on ASTM Designation: D2487, Standard Test Method for Classification of Soil for Engineering Purposes, and ASTM Designation: D2488, Standard Recommended Practice for Description of Soils (Visual-Manual Procedure). This visual classification method allows for convenient and consistent comparison of soils from widespread geographic areas. Using this method, the soils are classified using the USCS. The individual sample classifications have been incorporated into the boring logs presented in Appendix A.

4.2 Water Content Determinations

Water content was determined on selected samples in general accordance with ASTM Designation: D2216, Test Method for Determination of Water (Moisture) Content of Soil and Rock. The water content is shown graphically in each boring log (Appendix A).

4.3 Grain Size Analyses

The grain size distribution of selected samples was determined in general accordance with ASTM Designation: D422, Standard Test Method for Particle-Size Analysis of Soils and ASTM Designation: D1140, Amount of Material in Soils Finer than the No. 200 Sieve (75 micrometers). Results of these analyses are presented as gradation curves in Figures B-1 through B-4. In addition, the fines content of samples tested are presented in the boring logs in Appendix A. Each gradation sheet provides the USCS group symbol, the sample description, and water content. The USCS for samples with fewer than 50 percent fines was classified in general accordance with ASTM Designation: D2488, Standard Recommended Practice for Description of Soils (Visual-Manual Procedure). Grain size distributions are used to assist in classifying soils and to provide correlation with soil properties, including permeability, capillarity, susceptibility to liquefaction, and sensitivity to moisture.

4.4 Atterberg Limits

Atterberg Limits were determined on selected samples of fine-grained soil obtained in the geotechnical borings in general accordance with ASTM Designation: D4318, Standard Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils. The Atterberg limits include Liquid Limit (LL), Plastic Limit (PL), and Plasticity Index (PI=LL-PL). They are generally used to assist in classification of soils, to indicate soil consistency (when compared with natural water content), and to provide correlation to soil properties, including compressibility and strength. The results of the Atterberg limits determination are shown graphically in the plasticity chart presented in Figure B-5 and in the boring logs included in Appendix A.

5.0 SUBSURFACE CONDITIONS

The geology and subsurface conditions along the project alignment were inferred from visual classification and laboratory testing of soil samples obtained from the current geotechnical borings; from observation well readings; from data gathered from existing projects in the vicinity; and from geologic maps of the area (Schasse and others, 2004). The following sections include a description of the general geology, geologic units, and the subsurface soil and groundwater conditions encountered in the project area.

5.1 General Geology

The project site, located near downtown Port Angeles, lies at the base of the northern foothills of the Olympic Mountains. Tectonically, the Olympic Mountains are in a subduction zone. In general, the Olympic Mountains are composed of a core of marine sedimentary rocks surrounded by a belt of oceanic basaltic rock (Crescent Formation) and an overlying sequence of Tertiary marine sedimentary rocks.

Through multiple sequences of glaciation and interglacial stages during the Pleistocene period, glacial and non-glacial sediments were deposited on the Tertiary sedimentary rocks. Between 28,000 and 15,000 years ago, during the last glacial stage, the glaciers from British Columbia advanced into the Puget Lowland, where they split into the smaller Juan de Fuca ice sheet that reached the end of the Strait of Juan de Fuca and the main ice sheet that extended south near Olympia. Drift sediments observed just south of the project area consist of normally consolidated coarse-grained recessional outwash deposits over glacially consolidated glacial till.

To mitigate tidal flooding, the waterfront and downtown areas of Port Angeles were built up with man-made fill by up to approximately 25 feet beginning in 1914 (Wegmann and others, 2012). Development prior to 1914 occurred primarily on the beach above the high water elevation, and above the tidally influenced shore on elevated structures and docks founded on timber piles. Between Oak Street and Lincoln Street, Front Street was elevated on timber piles and planking. The area west of Oak Street, as far south as First Street, was below the high water elevation prior to 1914, according to historic photographs and shoreline reconstruction by Wegmann and others (2012). In the summer of 1914, a large-scale regrading project was undertaken to fill low-lying areas and raise the city streets above tidal flooding. The timber piles supporting the planked city streets were cut at approximately beach elevation, and cross-tied timber or concrete retaining walls were erected along the curb lines at the edges of the city streets. Glacial soils from the bluffs south of the downtown area were excavated with high-pressure jets of water and sluiced as a slurry into the areas to be filled along First and Front Streets and Railroad Avenue. This hydraulic fill was generally about one building story in height (about 12 feet) and locally exceeded 16 feet (Wegmann and others, 2012). The area west of Oak Street was filled sometime after 1953, likely with nonengineered dredged sediments.

5.2 Geologic Units

Based on our review of geologic maps and geotechnical investigations, the project area is predominately underlain by recent fill over estuarine and beach deposits. Underlying the beach deposits are glacially deposited, recessional outwash and glacial till soils. The soil units encountered in our geotechnical investigations along the proposed alignment, from youngest to oldest, are as follows:

- **Fill (Hf)** – Materials placed by humans, both engineered and nonengineered. Typically, very loose to dense, comprised of various materials including soil, construction debris, cobbles, boulders, and wood chips and debris. The fill thicknesses identified in the borings ranged from 12 to over 20 feet.
- **Estuarine Deposits (He)** – Depression fillings or tidal flat deposits of organic materials. Typically, very loose and soft, organic silt and clay; includes peat.
- **Beach Deposits (Hb)** – Deposits along present and former shorelines of the Strait of Juan de Fuca. Typically, loose to medium dense sands and gravels; includes organics, wood, and shells.
- **Recessional Outwash (Qvro)** – Glaciofluvial sediments deposited as glacial ice retreated. Typically, medium dense to very dense, slightly silty to silty, sand and gravel and sandy silt with scattered cobbles and boulders. May include recessional glaciolacustrine sediments consisting of dense to very dense and medium stiff to hard, fine sand, silt, and clay.
- **Glacial Till (Qvt) –** Deposits laid down in advance or along the base of the glacial ice. Typically, dense to very dense silts, sands and gravels with cobbles and boulders; can include glacial till and advance outwash deposits.

5.3 Subsurface Conditions

Our understanding of the subsurface soil conditions at the pump station site and along the force main and sewer alignments are based on our review of geologic maps, existing data, recent geotechnical investigations, and on our general understanding of the geologic history and stratigraphy of the region. Our interpretation of the subsurface soil and groundwater conditions along the project alignment is shown on the Generalized Subsurface Profile in Figure 2.

In general, the project site is underlain by a variety of normally consolidated deposits including very loose to medium dense or soft to stiff fill (Hf), estuarine deposits (He), and beach deposits (Hb). Underlying these recent deposits are medium dense to very dense recessional outwash (Qvro) deposits and dense to very dense glacial till (Qvt) deposits. Bedrock was not encountered in any of the explorations. The interpreted subsurface conditions at the pump station and along the proposed pipelines are presented below.

5.3.1 Pipelines

The subsurface conditions along the proposed pipeline alignments can be divided into three sections including: from the PS 4 site along Front Street to Oak Street, along Front Street from Oak Street to Lincoln Street, and along Lincoln Street to the project termination.

5.3.1.1 Front Street from Pump Station No. 4 (PS 4) to Oak Street

The subsurface soil and groundwater conditions along the Front Street sewer and force main alignment from PS 4 to Oak Street were inferred from borings B-1, TH-6 (CH2M Hill, 1967), and B-3 (NTI Engineering and Land Surveying, 2012) and from CPT-2 and CPT-3. The subsurface soil and groundwater conditions along this section of the alignment are shown in Figure 2 (Sheets 1 and 2).

From the proposed PS 4 site along Front Street to Oak Street, soil conditions consist of about 10 to 12 feet of fill (Hf), over an approximately 3- to 5-foot-thick layer of estuarine deposits (He), underlain by beach deposits (Hb) with recessional outwash (Qvro) at depth. The fill (Hf) consists of loose to medium dense, silty, sandy gravel to silty, gravelly sand. The upper 3 to 5 feet of this fill (Hf) appear to be the densest, and may consist of more recent, engineered fill associated with the construction of the subbase of Front Street. The estuarine deposits (He) consist of very soft to soft, silty clay and clayey silt and are saturated. This deposit is likely associated with the tideflats at this location, prior to fill being placed. The beach deposits (Hb) below the estuarine deposits (He) generally consist of loose to medium dense, slightly gravelly to gravelly, silty sand to silty, sandy gravel. Based on the currently proposed alignment, the invert of the gravity sewer will range from approximately 11 to 14 feet bgs and would be founded in loose fill (Hf) or very soft estuarine deposits (He).

Groundwater information obtained from the observation well installed in B-1 indicates a groundwater depth of about 12 feet bgs (elevation 6 feet) with a tidal influence of about 1 foot. Observations made in CPT-2 and CPT-3 indicate groundwater depths of approximately 10 to 11 feet bgs (elevation 5 to 6 feet).

5.3.1.2 Front Street from Oak Street to Lincoln Street

The subsurface soil and groundwater conditions along this section of sewer pipeline alignment were inferred from borings B-3 and B-4, and CPT-4. The subsurface soil and groundwater conditions along this section of the alignment are shown in Figure 2 (Sheets 2, 3, and 4).

Based on these explorations, the soils along this alignment consist of 15 to 17 feet of fill (Hf) over beach deposits (Hb). The beach deposits (Hb) are underlain by recessional outwash (Qvro). The estuarine deposits (He) observed in explorations west of Oak Street were not observed east of Oak Street. The fill (Hf) is random and was hydraulically placed as described above. The fill (Hf) generally consists of very loose to medium dense, slightly gravelly to gravelly, slightly silty to silty, sand and sandy silt. Because of its method of construction, the fill (Hf) may contain cobbles, boulders, and rubble. The timber or concrete retaining walls and the tie rods across the street are likely still buried within the fill. The timber piles that previously supported the elevated Front Street were likely cut off near the elevation of the beach deposits (Hb) and probably still remain intact below that elevation. The beach deposits (Hb) consist of medium dense, slightly silty, gravelly sand to slightly silty, sandy gravel. The recessional outwash (Qvro) consists of dense to very dense, silty, sandy gravel. Based on the current alignment, the invert of the gravity sewer along this section will range from approximately 9 to 11 feet bgs and will primarily be founded near the contact between the loose fill (Hf) and medium dense beach deposits (Hb).

Groundwater information, obtained from observations made during the drilling of borings B-3 and B-4 and in CPT-4, indicates a groundwater depth of about 8 to 12 feet bgs (elevation 10 to 12 feet).

5.3.1.3 Lincoln Street

The subsurface soil and groundwater conditions along this section were inferred from CPT-4 and boring TH-10 (CH2M Hill, 1967). The subsurface soil and groundwater conditions along this section of the alignment are shown in Figure 2 (Sheets 4 and 5).

Based on these explorations, the soils along this section vary from north to south as Lincoln Street climbs uphill. At the north end of this section, near the intersection of Lincoln and Front Streets, the soils consist of 5 to 6 feet of fill (Hf) overlying 5 to 6 feet of beach deposits (Hb), underlain by recessional outwash (Qvro). As the alignment transitions south and uphill, the beach deposits (Hb) appear to pinch out as the recessional outwash (Qvro) becomes shallower. At boring TH-10, located mid-block between Front Street and First Street, the beach deposits (Hb) are absent, and about 5 feet of fill (Hf) overlies recessional outwash (Qvro). South of TH-10, the fill (Hf) may be thinner, with recessional outwash (Qvro) shallower than 5 feet from the ground surface. The fill (Hf) consists of very loose to medium dense, slightly silty to silty, slightly gravelly to gravelly sand. Because of its method of construction, the fill may contain cobbles, boulders, and rubble. The method of fill construction along Lincoln Street is unknown; buried retaining walls near the curblines and associated tie-rods may or may not be present. The beach deposits (Hb) consist of medium dense, slightly silty, gravelly sand and sandy gravel. The underlying recessional outwash (Qvro) consists of dense to very dense, silty, sandy gravel. Based on the current alignment, the invert of the gravity sewer along this section will range from approximately 8 to 13 feet bgs and will primarily be founded in medium dense beach deposits near Front Street, and in very dense recessional outwash (Qvro) farther south on Lincoln Street.

Groundwater was not encountered in explorations along this portion of the alignment. Based on nearby explorations, groundwater is likely deeper than 12 feet bgs at the intersection of Front and Lincoln Streets, becoming deeper still to the south.

5.3.2 Pump Station No. 4 (PS 4)

The subsurface soil and groundwater conditions at this structure were inferred from current explorations B-1 and CPT-1. The subsurface soil and groundwater conditions at this structure are shown in Figure 2 (Sheet 1 of 5).

Based on these explorations, the soils at this structure consist of 10 to 13 feet of fill (Hf) over an approximately 3- to 5-foot-thick layer of estuarine deposits (He), underlain by 15 to 20 feet of beach deposits (Hb) with recessional outwash (Qvro) at about 32 feet bgs. Glacial till (Qvt) underlies the recessional outwash (Qvro) at a depth of about 45 to 48 feet bgs. The fill (Hf) consists of loose to dense, silty, sandy gravel and silty, gravelly sand with scattered organics. The upper 5 to 7 feet of this fill appear to be the densest, and may consist of more recent, engineered fill associated with previous construction at the site. The estuarine deposits (He) consist of very soft to soft, silty clay and clayey silt and are saturated. This deposit is likely associated with the tideflats at this location prior to it being filled. Beach deposits (Hb) below the estuarine layer generally consist of loose to medium dense, slightly gravelly to gravelly, silty sand to silty, sandy gravel. The recessional outwash (Qvro) consists of very dense, gravelly, slightly silty to silty sand to sandy gravel and is underlain by glacial till (Qvt) composed of very dense, sandy silt. Based on initial design drawings, the base of the structure will be about 35 feet bgs and will be founded in very dense recessional outwash (Qvro) deposits.

Groundwater information obtained from the observation well in boring B-1 indicates a groundwater depth of about 10 feet bgs (elevation +6 feet) with a tidal influence of about 1 foot.

5.4 Soil Properties

For design purposes, soil engineering properties are presented in Table 2 for the geologic units encountered during our geotechnical investigations. The values in this table are based on relationships with laboratory test results and our experience with these soil units on similar projects.

TABLE 2
SOIL ENGINEERING PROPERTIES

Geologic Unit	Total Unit Weight (pcf)	Drained Shear Strength		Hydraulic Conductivity K (cm/sec)
		c' (tsf)	ϕ' (degrees)	
Fill (Hf)	125	0	34	10^{-2} to 10^{-4}
Estuarine Deposits (He)	115	0	28	10^{-5} to 10^{-6}
Beach Deposits (Hb)	125	0	36	10^{-2} to 10^{-3}
Recessional Outwash (Qvro)	130	0	38	10^{-3} to 10^{-4}
Glacial Till (Qvt)	135	0	40	10^{-3} to 10^{-5}

Notes:
cm/sec = centimeters per second
pcf = pounds per cubic foot
tsf = tons per square foot

6.0 ENGINEERING STUDIES AND RECOMMENDATIONS

6.1 General

Based on the subsurface conditions encountered in the current, and described in the existing, explorations and our understanding of the project, engineering studies were performed to develop conclusions and recommendations regarding the following: (a) seismic design considerations, (b) groundwater control, (c) excavation and temporary shoring, (d) loads on permanent structures and buried pipes, (e) foundation support, (f) uplift resistance, (g) backfill placement and compaction, and (h) wet weather considerations. A discussion of our studies, analyses, conclusions, and recommendations is presented in the following sections.

6.2 Seismic Design Considerations

The potential seismic hazards within the project area include seismic-induced liquefaction of the recent fill, beach, and estuarine deposits and surcharge loading of buried structures. Liquefaction could result in settlement of the pipelines and reduction of micropile capacity for the at-grade structures at the PS 4 site. The surcharge loading could result in cracking of buried structural walls. An evaluation of liquefaction potential of the site and the seismic design criteria is presented in the following sections.

6.2.1 Liquefaction Analyses

Liquefaction of loose, saturated, cohesionless soils due to seismic loading has been studied over the past 35 years, resulting in methods based on both laboratory and field procedures to evaluate liquefaction potential. The most widely used methods are empirical and based on correlations between SPT N-value, peak ground acceleration (PGA), and earthquake magnitude.

We used the following methods to evaluate liquefaction potential at this site:

- Youd and others (2001)
- Seed and others (2003)
- Idriss and Boulanger (2006)
- Seed and De Alba (1986) and Seed and Idriss (1971
- Suzuki and others (1997)
- Robertson and Wride (1997)

An important factor in evaluating liquefaction potential is the fines content (percent of soil by weight smaller than 0.075 millimeter or a No. 200 sieve) of the soil deposit. We performed grain size analyses and fines content tests to measure the fines content of the subsurface soils at the site. Where we did not perform laboratory tests, we visually estimated the fines content.

We performed our liquefactions analyses for an earthquake of magnitude 6.6 and a design PGA of 0.71g. We obtained the magnitude and PGA from regional probabilistic 2008 U.S. Geological Survey (USGS) National Seismic Hazard Maps (Petersen and others, 2008). These seismic parameters are representative of a 2,475-year return period ground motion.

Results of our analyses indicate that liquefaction may occur in the granular recent deposits above the dense to very dense recessional outwash (Qvro) deposits. In general, the depth of these liquefiable deposits ranges from the groundwater table to approximately 32 feet at the pump station. Along the proposed pipelines, liquefaction-induced settlements are estimated to range from 1 to 3 inches. For all remaining structures, liquefaction-induced settlement is not anticipated to occur, provided that foundation recommendations provided later in this report are implemented.

6.2.2 Seismic Design Criteria

We understand that the seismic design of the facilities will be in accordance with the International Building Code (IBC) (International Code Council, 2012). Computation of forces used for seismic design for this code is based on seismological input and site soil response factors.

The seismological inputs are short-period spectral acceleration, S_S, and spectral acceleration at the 1-second period, S_1, which were determined using the probabilistic 2008 USGS National Seismic Hazard Maps (Petersen and others, 2008). For IBC 2012, S_S and S_1 are for a maximum considered earthquake, which correspond to ground motions with a 2 percent probability of exceedance in 50 years, or about a 2,475-year return period.

The site soil response factors are based on the determination of the Site Class. Based on the subsurface explorations at the site, it is our opinion that the site in the vicinity of most of the structures can be characterized as Site Class D. The IBC 2012 response spectra and seismic parameters for seismic design of structures are presented in Figure 3. The evaluation of liquefaction and soil strength loss for the PGA consistent with Maximum Considered Earthquake Geometric mean (MCE_G), see IBC 2012 Section 1803.511. The PGA for the MCE_G is 0.71g.

6.3 Groundwater Control

As discussed above, the current and existing geotechnical exploration data indicates that groundwater levels vary from about 8 to 12 feet bgs along most of the pipeline alignment and at PS 4. Consequently, the PS 4 excavation and portions of the pipeline alignment will be constructed beneath the groundwater level and some form of groundwater control will be necessary to complete the work.

Groundwater control for excavations or trenches typically consists of sumps and pumps, well points, or deep dewatering wells. Sumps and pumps would be appropriate for controlling groundwater where it is not more than about 2 to 3 feet above the bottom of the trench or excavation. In our opinion, sumps and pumps are not sufficient or practical if the groundwater surface is 3 feet or more above the bottom of the trench or excavation. In these cases, closely spaced well points or dewatering wells are generally required. Construction dewatering should be the Contractor's responsibility and should be conducted in conjunction with the shoring design. The temporary dewatering system should be reviewed by the design team prior to its implementation.

For the majority of the new gravity sewer alignments, the proposed excavation depths are 8 to 12 feet bgs, with the exception of near PS 4, where the excavation will be about 17 to 19 feet deep. The force main pipeline trenches will be about 5 feet deep. The observed groundwater levels are 8 to 12 feet bgs along Front Street, becoming deeper south along Lincoln Street. Consequently, groundwater is anticipated to be no more than 1 to 2 feet above the bottom of the proposed gravity sewer excavation. The exception is the portion near PS 4, where the excavation will be about 17 to 19 feet deep, and the groundwater table will be about 8 feet above the bottom of the trench. For the force main and gravity sewer with excavations no more than 3 feet below the groundwater level, sumps and pumps could be used to lower and maintain the groundwater level. For the deeper section of the gravity sewer near PS 4, closely spaced well points will likely have to be used to lower and maintain the groundwater levels.

For the buried structure at PS 4, the measured groundwater level is about 10 feet bgs (with a tidal fluctuation of about 1 foot) or about 25 feet above the anticipated bottom of the excavation. Lowering of the groundwater 25 feet or more would likely result in consolidation-induced settlement of facilities in the area. Consequently, we anticipate the use of watertight shoring for the construction of the pump station, as discussed later in this report. To provide adequate groundwater cutoff and limit groundwater inflow from the base of the excavation, shoring walls should extend deep enough below the base of the excavation to penetrate a minimum of 5 feet into the underlying, lower permeability, glacial till (Qvt) (about 51 feet bgs or elevation -33 feet). Once the watertight shoring is installed, the soils within the watertight shoring could be dewatered with wells or sumps and pumps prior to excavation. We anticipate some leakage through the shoring, but this can likely be handled with sumps and pumps. Closely spaced well points, 5 to 10 feet apart, could also be used in lowering and maintaining groundwater levels below the base of the excavation. Well points should be installed in the dense to very dense recessional outwash (Qvro) and glacial till (Qvt) deposits below the bottom of the excavation to lower the groundwater. To maintain a firm working surface and to adequately prepare the subgrade soils, we recommend that the groundwater level be lowered and maintained at least 2 feet below the bottom of the excavation.

6.4 Excavation and Temporary Shoring

The construction of the buried pump station and installation of the gravity sewer and force main pipelines will require excavation depths ranging from 5 to 35 feet bgs. We anticipate that temporary shoring will be required for the buried pump station and gravity sewer pipeline. We also anticipate that temporary shoring will be required for portions of force main located within City right-of-way. The temporary shoring is required to limit disturbance to existing improvements such as streets, curbs, sidewalks, utilities, and structures. Open-cut excavations with temporary excavation slopes could be considered for the portion of the force main on the pump station site and in the upper portion of select excavations. The design of temporary shoring systems and excavation slopes and the method of construction should be the responsibility of the Contractor.

6.4.1 Excavation

We anticipate that all excavations could be made using conventional excavating equipment such as rubber-tired backhoes or tracked hydraulic excavators. For the pipelines, trench widths should be wide enough to allow for safe worker access and for satisfactory placement and compaction of backfill materials. The trench widths should also conform to pipe manufacturer's recommendations.

Temporary excavation slopes above the groundwater level may be possible in the upper 10 feet of excavations where sufficient space is available to construct the slopes without impacting existing improvements such as streets, curbs, sidewalks, utilities, and structures. We anticipate that temporary excavation slopes will be limited to relatively shallow excavations on the pump station site. Consistent with conventional practice, temporary excavation slopes should be made the responsibility of the Contractor since the Contractor is able to observe full-time the nature and conditions of the subsurface materials encountered, including groundwater, and has the responsibility for methods, sequence, and schedule of construction. All temporary excavation slopes should be accomplished in accordance with local, state, and federal safety regulations. For planning purposes only, we recommend temporary excavation slopes be no steeper than 2 Horizontal to 1 Vertical.

The excavations will encounter fill (Hf), estuarine (He) deposits, beach (Hb) deposits, and recessional outwash (Qvro) soils. These soils in the subgrade are potentially moisture-sensitive and therefore potentially easily disturbed and softened by construction equipment and operations. Consequently, we recommend that the last 2 feet of excavation be made using an excavating bucket equipped with a smooth, flat, steel plate over the digging teeth to reduce construction disturbance of the subgrade soil and, therefore, reduce post-construction settlements. Where encountered, the soft to soft estuarine (He) deposits should be overexcavated and backfilled as described in Section 6.6.3 of this report. For the buried pump station, a gravel working mat or mud slab should be placed immediately after final excavation to protect the subgrade from becoming disturbed.

As discussed above, a large-scale regrading project was undertaken in 1914 to fill low-lying areas and raise the city streets above tidal flooding. Along the section of Front Street to the east of Oak Street, timber piles supporting the planked city street were cut at approximately the beach elevation and cross-tied timber or concrete retaining walls were erected and filled to raise the street. The steel tie rods and piles between the retaining walls are likely still present and may be encountered during trench excavations along Front Street. Although the tie rods are likely to be corroded, there may be some difficulty during excavation, which will require cutting and removal. Timber piles may also be encountered near the bottom of the pipeline trench. When above the groundwater level, the timber piles will likely be decomposed and can be removed by an excavator. However, below the groundwater level, the timber piles may be intact and will require cutting and removal.

6.4.2 Temporary Shoring

As discussed previously, temporary shoring systems will be required for the excavation and installation of the buried pump station, gravity sewer, and force main. For temporary shored excavations, construction practice in the region generally includes trench boxes, slide rail shoring systems, interlocking steel sheet piles, soldier piles and horizontal lagging, secant pile, and cutter soil-mix walls. Regardless of the method selected, the shoring system should provide adequate protection for workers and should prevent damage to adjacent utilities, streets, and other facilities.

Design of temporary shoring systems and the means and methods of construction should be the responsibility of the Contractor, based on recommendations provided in the contract documents. In addition, it is normally the Contractor's responsibility to monitor the stability of shored excavations and take corrective measures if any deficiencies or potentially dangerous conditions are observed or encountered. The Contractor is also typically responsible for all damages related to instability and ground movements.

The buried pump station excavation will be about 35 feet deep with measured groundwater at about 10 feet bgs (elevation 8 feet). As discussed above under groundwater control, excavation dewatering would likely result in unacceptable dewatering discharge rates and potential settlements in the vicinity of the excavation and, therefore, some form of watertight shoring is recommended. The shoring system could likely consist of sheet pile, secant pile, or cutter-soil mix walls. Regardless of the watertight shoring type selected, at a minimum, the shoring walls should extend deep enough below the base of the excavation to penetrate a minimum of 5 feet into the underlying, lower permeability, glacial till (Qvt), located about

51 feet bgs or elevation -33 feet. Penetration into the glacial till (Qvt) should provide a groundwater cutoff. Once the shoring is installed, well points or deep dewatering wells can be installed within the excavation and the groundwater should be lowered to at least 2 feet below the bottom of the excavation.

Secant and cutter-soil mix walls are expensive to install; consequently, we expect the Contractor will likely select sheet pile walls. In our experience, pre-drilling for sheet pile installation will be required in the dense to very dense recessional outwash (Qvro) and glacial till (Qvt). In addition, pre-drilling and driving sheet piles lessens the potential adverse impacts of sheet pile installation compared to using vibratory methods. However, driving sheet piles, even with pre-drilling the underlying dense to very dense recessional outwash (Qvro) and very dense glacial till (Qvt), could result in settlement of adjacent utilities, streets, and other facilities within about 5 to 10 feet of the sheet piles. In our opinion, the installation of sheet piles using vibratory methods should not be allowed. Relative to pre-drilling and impact driving, using vibratory methods would likely result in more damage to adjacent utilities, streets, and other facilities related to vibrations and potential vibration-induced consolidation of the looser soils near the excavations.

Most of the gravity sewer pipeline excavations will be about 8 to 12 feet deep, with the exception of the portion near PS 4, where the excavation will be about 17 to 19 feet deep. Groundwater is expected at 8 to 12 feet bgs (elevation +6 to +10 feet) along Front Street and is expected to be below the gravity sewer pipeline along Lincoln Street. We anticipate that the shoring for these trench excavations will consist of trench boxes and temporary construction dewatering, where necessary, that lowers the groundwater to about 2 feet below the base of the trenches.

The force main pipeline trenches will be about 5 feet deep with groundwater expected 10 feet bgs (elevation 8 feet). We anticipate that the shoring for these trench excavations will consist of trench boxes.

6.4.3 Temporary Shoring Design

In general, all temporary shoring should be designed for lateral earth and surcharge pressures. Where watertight shoring is used, it should also be designed for groundwater pressures. The total design pressure acting on the temporary shoring is the sum of these pressures. The recommended lateral earth and groundwater pressures for the buried pump station temporary shoring design are shown in Figure 4. Due to the possibility of higher-than-measured groundwater levels, we recommend assuming that the groundwater table could be as high as the ground surface (0 foot bgs) for design of the PS 4 shoring walls. The lateral earth pressures provided assume multiple-braced walls. Recommended lateral surcharge pressures are provided in Figure 6. The recommended lateral earth and surcharge pressures should be included into the contract plans.

Figure 4 also includes the lateral resistance from passive pressures for the embedded portion of the shoring. For groundwater control purposes, the shoring for the buried pump station should extend to at least elevation -33 feet. The shoring design should also consider providing adequate kickout resistance without causing undesirable lateral movement and disturbance to adjacent soils.

6.5 Loads on Permanent Structures and Buried Pipes

6.5.1 Permanent Structures

Unyielding permanent buried structures, such as the buried pump station, should be designed for lateral earth, groundwater, seismic, and surcharge pressures. The total design pressure acting on the structures is the sum of these pressures. The design should also be checked for the liquefied condition earth pressure. The recommended lateral earth, groundwater, seismic pressures, and liquefied condition earth pressure for the permanent buried structure design are shown in Figure 5. Due to the possibility of higher-than-measured groundwater levels, we recommend assuming that the groundwater table could be as high as the ground surface (0 foot bgs) for design of the PS 4 retaining walls. Recommended lateral surcharge pressures are provided in Figure 6.

6.5.2 Manholes

We understand that concrete manholes will be installed along the new gravity sewer alignment. An unyielding, precast manhole above the groundwater level should be designed to resist an at-rest lateral earth pressure using an equivalent fluid density of 55 pounds per cubic foot (pcf). Unyielding precast manholes below the groundwater level should be designed to resist an at-rest lateral earth pressure using an equivalent fluid density of 90 pcf. In our experience, unyielding, precast manholes that extend both above and below the groundwater level are typically designed using an equivalent fluid density of 90 pcf. The recommended at-rest lateral earth pressures are based on the assumption that a well-compacted structural fill, meeting the gradational requirements specified in 9-03.14(1), Gravel Borrow of the Washington

State Department of Transportation (WSDOT) Standard Specifications, will be placed around the manholes.

6.5.3 Buried Pipes

General recommendations regarding backfill and surcharge loading on buried pipes are presented in Figure 7. We anticipate that trenching would be used to install the proposed sewer pipe; therefore, Case (a) for a conduit in a trench would likely apply. We recommend that the effect of backfill loads, as shown in Figure 7 from Case (a) and the H-20 live load shown in Case (b), be added (where appropriate) to obtain the total load on the pipe under vehicular traffic. We recommend using a unit weight for the structural backfill of 130 pcf.

6.6 Foundation Support

6.6.1 Buried Pump Station

The base of the buried pump station will be about 35 feet deep; therefore, the structure would be founded in very dense recessional outwash (Qvro) deposits. These soils are considered to be suitable for foundation support. Our liquefaction analyses indicate that the buried pump station will be founded below the potentially liquefiable soils and, therefore, liquefaction of the foundation soils is not anticipated. For design purposes, we recommend a net allowable bearing capacity of 6,000 pounds per square foot (psf) be used for the buried pump station. The estimated settlement of the buried pump station is about ½ inch with a differential settlement across the structure of less than ¼ inch. Settlement is expected to occur as loads are applied during construction. Friction along the base of the buried pump station can be estimated using a coefficient of friction of 0.45 between the concrete and very dense recessional outwash (Qvro) deposits. The allowable lateral passive resistance for the embedded portion of the structure, which includes a factor of safety (FS) of 1.5, can be estimated using an equivalent fluid density of 150 and 300 pcf below and above groundwater, respectively.

For potential use in the design of the buried pump station, we developed a preliminary estimate of the unit modulus of vertical subgrade reaction (K_{v1}) of 200 pounds per cubic inch (pci) for the structure's foundation soils. We developed the estimates based on published correlations (Das, 1999) and experience with other projects for the soil types encountered at the site.

These K_{v1} values are for loading applied over a 1-foot-square area. It should be adjusted for the actual size and geometry of the loaded area prior to use in the analyses, depending on the design method used. Guidance on how to adjust the K_1 value for different foundation areas was published by Terzaghi (1955). The published relationship for the vertical subgrade reaction modulus (K_v) for a foundation of a given size, bearing on sand and gravel soils, is as follows:

$$K_v = K_{v1}\left(\frac{B+1}{2B}\right)^2$$

Where: B = width of footing in feet
K_{v1} = vertical subgrade reaction modulus for a 1-foot-square plate
K_v = vertical subgrade reaction modulus in pci

6.6.2 Odor Control Building, Generator Building, and Screen Wall

The odor control building, generator building, and screen wall are founded on loose to medium dense fill (Hf) soils. While these soils are generally considered to be suitable for buildings, liquefaction of the saturated portion of these soils and the underlying beach deposits (Hb) is anticipated as a result of the design seismic event. Therefore, we recommend that these improvements be founded on micropile supported foundations. We recommend 8-inch-diameter micropiles. The bonded length or transfer zone of each micropile should be pressure grouted and post grouted at least once and should begin below a depth of 35 feet bgs (elevation -17 feet). In the upper portion of the micropile (above elevation -17 feet), the steel casing or pipe used during installation should be left in-place to help reduce potential down-drag forces and to provide lateral stiffness. For the static case, the allowable transfer (capacity) of each micropile is 6 kips per foot of pile below elevation -17 feet and 10 kips per foot of pile below elevation -30 feet. For the seismic case, the allowable transfer (capacity) of the micropile can be increased to 10 kips per foot of pile below elevation -17 feet and 16 kips per foot of pile below elevation -30 feet. Since the soils above elevation -17 feet are potentially liquefiable and will settle during a seismic event, a downdrag load of 25 kips should be applied to each micropile. The vertical capacity used in the design of the micropiles should be the lower of the two cases (static or seismic). It should be noted that these capacities presented assume a minimum pile spacing of at least three diameters (center-to-center) or 30 inches, whichever is greater. For a tighter spacing, a reduction in capacity is required to account for group effects.

The allowable lateral resistance from passive pressures for the embedded portions of the structures can be estimated using an equivalent fluid density of 300 pcf, which includes a FS of 1.5.

6.6.3 Gravity Sewer, Manholes, and Force Main

The new gravity sewer and manholes are founded on loose to medium dense fill (Hf) and beach deposits (Hb), very soft to soft estuarine deposits (He), and dense to very dense recessional outwash (Qvro). The new force main will be founded on loose to medium dense fill (Hf). The fill (Hf), beach deposits (Hb), and recessional outwash (Qvro) are generally considered to be suitable foundation soils for pipelines and manholes. The very soft to soft estuarine deposits (He) are not considered to be good foundation soils and, consequently, we recommend, where encountered, that they be overexcavated and replaced with geosynthetic-wrapped backfill. After overexcavating the estuarine deposits (He), the geosynthetic filter fabric (Mirafi 500X or equivalent) should be placed across the bottom of the overexcavated trench and up the sidewalls of the shoring. The filter fabric should then be backfilled up to the design trench base elevation using clean quarry spalls. After the filter fabric is wrapped and overlapped over the backfill, the trench would be ready for bedding and pipe or manhole placement.

Settlement due to construction disturbance of subgrade soils and placement of the pipeline, manholes, and backfill is expected to be about ½ to 1 inch. For manholes founded on the fill (Hf), beach deposits (Hb), or geosynthetic-wrapped backfill, we recommend a net allowable bearing capacity of 2,000 psf. For manholes founded on the recessional outwash (Qvro), we recommend a net allowable bearing capacity of 5,000 psf. Friction along the base of the structures can be estimated using a coefficient of friction of 0.45 between the concrete and subgrade soils.

6.7 Uplift Resistance

Watertight, permanent buried improvements including the buried pump station, gravity sewer, and manholes will be subjected to hydrostatic uplift pressures. To account for potential groundwater levels changes during the lifetime of these improvements, we recommend a groundwater level of 0 foot bgs (the ground surface) be used to design for uplift resistance of these permanent buried improvements.

For the buried pump station and manholes, recommended values for use in calculating uplift resistance are presented in Figure 8. This figure is presented in a general form so that it can be used with and without an extended base. Recommend values for use in calculating uplift resistance for buried pipes are presented in Figure 9.

6.8 Ground Movement and Settlement

Ground movements and settlement could result from vibration-induced consolidation of the soils during sheet pile installation at the pump station and lateral deformation of temporary shoring systems during excavation. The ground settlement estimates presented below should be reviewed relative to the proximity and condition of adjacent utilities, pavements, and facilities. If the settlements appear to be excessive and could pose a risk of unacceptable damage to adjacent facilities, the Contractor should be required to alter their construction means and methods to limit ground movements. In all cases, a monitoring program should be established to evaluate performance during construction.

Shoring elements installed using vibratory or impact hammers could cause vibration-induced consolidation of the soils beneath nearby pavements, utilities, and structures. Settlement due to vibration-induced densification of the underlying soils could extend approximately as far as the piling is long or about 50 feet from the shoring. Although dependent on the acceleration of the vibrations, assuming medium accelerations, the magnitude of settlement could range from about 3 inches to 0.5 inch for pavements, utilities, and structures located about 10 to 50 feet away, respectively.

In addition to vibration-induced consolidation, lateral deformations of the temporary shoring systems during excavation will likely result in settlement behind the support systems. The magnitude of lateral deformation and the resulting settlement is a function of the soil and groundwater conditions, the stiffness of the temporary shoring system, and the means and methods selected by the Contractor. Based on work performed by Clough and O'Rourke (1990), the maximum anticipated settlement resulting from ground movements could range between about 0.15 and 0.5 percent of the height of the excavation, depending on the type of support. The typical model for the settlement trough behind shoring supporting granular materials is linear from the point of maximum settlement located immediately behind the shoring to less than ⅛ inch of settlement at a horizontal distance equal to one to 1.5 times the height of the excavation. For the pump station shoring, settlements caused by shoring deformations are estimated to be about 0.5 to 2 inches immediately behind the shoring and decreasing linearly to ⅛ inch at about 50 feet away from the shoring walls. For the deeper section of gravity sewer near the pump station, settlements caused by shoring deformations are estimated to be about 0.3- to 1-inch immediately behind the shoring and decreasing linearly to ⅛ inch at about 30 feet away from the shoring walls. For the gravity sewer shoring systems along Front Street and Lincoln Street, settlements caused by shoring deformations are estimated to be about 0.2- to 0.7-inch immediately behind the shoring and decreasing linearly to ⅛ inch at about 18 feet away from the shoring walls.

6.9 Backfill Placement and Compaction

We recommend that imported fill be used for the following reasons:

- The relatively high fines content of the existing fill and native soils.
- The difficulty in segregating, transporting, and storing the excavated soils.

6.9.1 Pipe Bedding

We recommend that the pipe bedding consist of imported granular bedding material meeting the gradational requirements specified in 9-03.12(3), Gravel Backfill for Pipe Zone Bedding of the WSDOT and American Public Works Association (APWA) Standard Specifications (2012). The bedding should extend a minimum of 6 inches below the bottom of the pipe and up to 12 inches above the top of the pipe.

6.9.2 Subsequent Trench Backfill

We recommend that the subsequent trench backfill, above the pipe bedding materials, meet the gradational requirements specified in 9-03.14(1), Gravel Borrow of the WSDOT Standard Specifications (WSDOT and APWA, 2012).

6.9.3 Structural Backfill

Structural backfill beneath and around permanent structures and manholes should meet the gradational requirements specified in 9-03.14(1), Gravel Borrow of the WSDOT Standard Specifications (2012).

6.9.4 Placement and Compaction

All fill should be placed in layers and systematically compacted to a dense, unyielding condition. In general, the thickness of soil layers before compaction should not exceed 8 inches for heavy, self-propelled, compaction equipment and 4 inches for hand-operated, mechanical compactors. Pipe bedding should be carefully worked under the pipe by means of slicing with a shovel, vibration, tamping, or other approved method. Heavy mechanical compaction equipment should not be allowed over the pipe until the pipe bedding is at least 12 inches above the top of pipe.

The pipe bedding and subsequent backfill should be placed in uniform lifts and compacted to a dense and unyielding condition and to 90 percent of its Modified Proctor maximum dry density (ASTM Designation: D1557, Method C or D), except beneath paved areas where 95 percent compaction is recommended. All structural fill should be compacted to 95 percent of its Modified Proctor maximum dry density.

6.10 Wet Weather Considerations

In the project area, wet weather generally begins about mid-October and continues through May. While the Contractor should be responsible for selecting the equipment and methods necessary to complete the work in accordance with the specifications, in our experience, the following procedures are required if wet weather earthwork is unavoidable:

- The ground surface in the construction area should be sloped to promote the rapid runoff of precipitation away from work areas and to prevent ponding of water.
- Covering work areas or slopes with plastic, sloping, ditching, using sumps, dewatering, and other measures should be employed as necessary to permit proper completion of the work.
- Earthwork should be accomplished in small sections to minimize exposure to wet conditions. Excavation, or the removal of unsuitable soil, should be followed immediately by the placement of concrete or compaction of a suitable thickness (generally 12 inches or more) of clean structural fill. The size and type of construction equipment and its mode of mobility (wheels or track) should be selected to prevent soil disturbance. It may be necessary to excavate soils with a backhoe, Gradall, or equivalent, located so that the equipment does not traffic over the excavated area; thus, subgrade disturbance caused by equipment traffic will be reduced.
- Uncompacted soil should not be left exposed to moisture. Where vibration-settlement-sensitive facilities are not located within 10 feet, a smooth-drum vibratory roller, or equivalent, should roll the surface to seal out as much water as possible.
- In-place soils or fill soils that are, or become, wet and unstable and/or are too wet to suitably compact should be removed and replaced with clean granular soil (see above).
- Excavation and placement of structural fill material should be observed on a full-time basis by an engineer or engineer's representative experienced in earthwork, to determine that all work is being accomplished in accordance with the intent of the specifications.

6.11 Geotechnical Instrumentation Recommendations

Geotechnical instrumentation should be installed to monitor the response of the ground and adjacent structures, utilities, and pavement to the construction of the new pump station, gravity sewer, and force main. Data collected from the monitoring program would be used to assess:

- The validity of any claims.
- Effectiveness of remedial measures.
- Performance of the shoring.
- Performance of the dewatering system.

The construction of the project will require a relatively deep-shored excavation for the pump station with sheet pile installation, dewatering, and shallow trench excavations for the gravity sewer and force main. Each of these construction activities could result in vibrations, groundwater drawdown, lateral deformations, and vertical settlements, which may affect adjacent structures, utilities, and pavements. Each of these and other related elements should be monitored prior to construction and during construction, as required. For final design, we assume the following geotechnical instrumentation systems may be employed:

- Utility settlement points on existing water mains and sewers that are within 100 feet of the pump station excavation and within 15 feet of the trench excavations for the gravity sewer along Front and Lincoln Streets. Utility settlement points consist of a 1-inch-diameter fiberglass rod attached to the top of the utility. The rod is installed within a 3-inch-diameter sleeve pipe and is protected by a surface monument and lid.
- Structure settlement points on any structures within 100 feet of the pump station excavation and within 15 feet of the trench excavations for the gravity sewer along Front and Lincoln Streets. Structure settlement points typically consist of stainless steel bolts or survey targets installed into or bonded onto the structures.
- Piezometers for monitoring groundwater levels at the pump station site to assess drawdown that could be indicative of settlement. We anticipate that piezometers would be located at the south, east, and northwest sides of the pump station property to monitor groundwater drawdown.
- Vibration monitors for measuring vibration levels at adjacent structures and utilities. We anticipate vibration monitors will be installed and monitored at the three structures nearest to the pump station during sheet pile installation and at the nearest structure to any pavement breaking along Front and Lincoln Streets.

7.0 LIMITATIONS

This report was prepared for the exclusive use of the Brown and Caldwell design team, and in no way guarantees that any agency or its staff will reach the same conclusions as Shannon & Wilson.

The conclusions and recommendations presented in this report are based on site conditions as they presently exist and assume that the explorations are representative of the subsurface conditions throughout the site; i.e., the subsurface conditions are not significantly different from those encountered in the explorations, or observed in our site reconnaissance. If, during construction, subsurface conditions different from those encountered in the explorations are observed or appear to be present, we should be advised at once so that we can review those conditions and reconsider our recommendations where necessary. If there is a substantial lapse of time between submission of our report and the start of work at the site, we recommend that this report be reviewed to determine the applicability of the conclusions and recommendations, considering the changed conditions and/or elapsed time.

Within the limitations of scope, schedule, and budget, the conclusions presented in this report were prepared in accordance with generally accepted professional geologic/geotechnical engineering principles and practices in this area at the time this report was prepared. We make no other warranty, either expressed or implied.

This report was prepared for the use of the Owner, Engineer, and Architect in the design of the facilities. With respect to construction, it should be made available for information on factual data only and not as a warranty of subsurface conditions, such as those interpreted from the logs and discussion of subsurface conditions included in this report.

Unanticipated conditions are commonly encountered and cannot be fully determined merely by taking soil samples or making explorations. Such unexpected conditions frequently require that additional expenditures be made to achieve a properly constructed project. Some contingency fund is recommended to accommodate such potential extra costs.

Please note that the scope of our services did not include environmental assessments or evaluations for the presence or absence of wetlands or hazardous or toxic substances in the soil, surface water, groundwater, or air on, below, or around this site. We are able to provide these services and would be pleased to discuss these with you as the need arises.

Shannon & Wilson has prepared a document, "Important Information About Your Geotechnical/Environmental Report," to assist you and others in understanding the use and limitations of our report. This document is included in this report as Appendix E.

SHANNON & WILSON, INC.

Michael S. Kucker, P.E.
Vice President

MDH:MSK/mdh

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LEGEND

- Boring - Alkai Consultants 2006
- Test Hole - CH2M Hill 1967
- Boring - Northwestern Territories 2010-11
- Boring - Shannon & Wilson 2013
- CPT - Shannon & Wilson 2013
- Test Pit - Shannon & Wilson 2013

0 150 300
Feet

Phase 2 Combined Sewer Overflow Project
Port Angeles, WA

SITE AND EXPLORATION PLAN

April 2014 21-1-20617-004

SHANNON & WILSON, INC.
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FIG. 1

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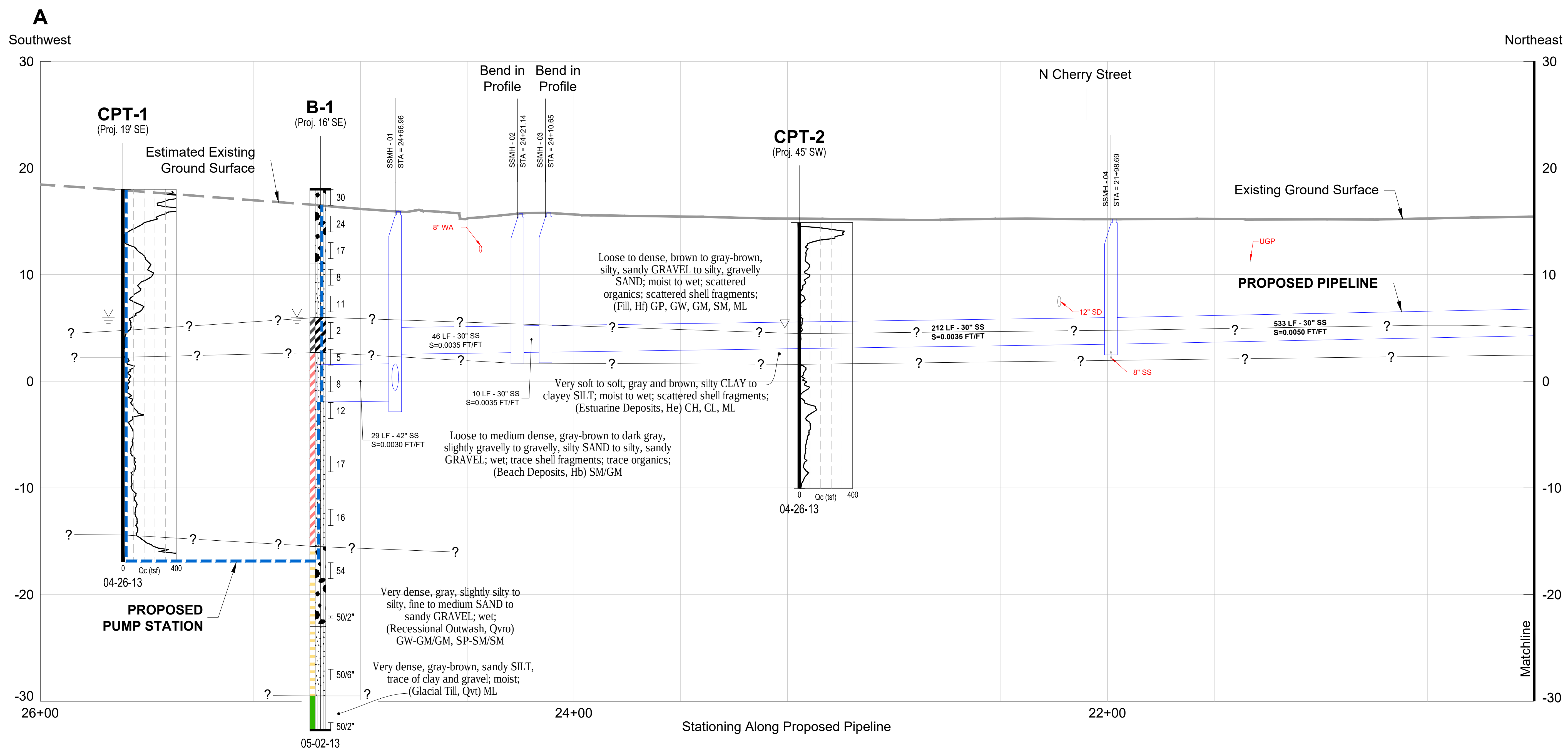

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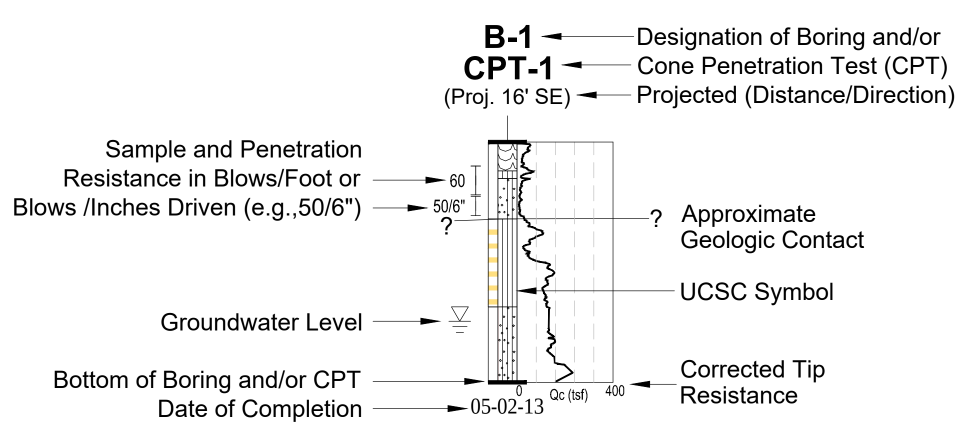

0 10 20

Vertical Scale in Feet

0 40 80

Horizontal Scale in Feet

Vertical Exaggeration = 2X

NOTES

1. Ground surface and pipeline features are adapted from client file, *"144083-C-014-XSITE.DWG"*, received 7-2-2013.
2. This subsurface profile is generalized from materials observed in soil borings. Variations may exist between profile and actual conditions.

Phase 2 Combined Sewer Overflow Project
Port Angeles, Washington

GENERALIZED SUBSURFACE PROFILE A-A'

April 2014 21-1-20617-004

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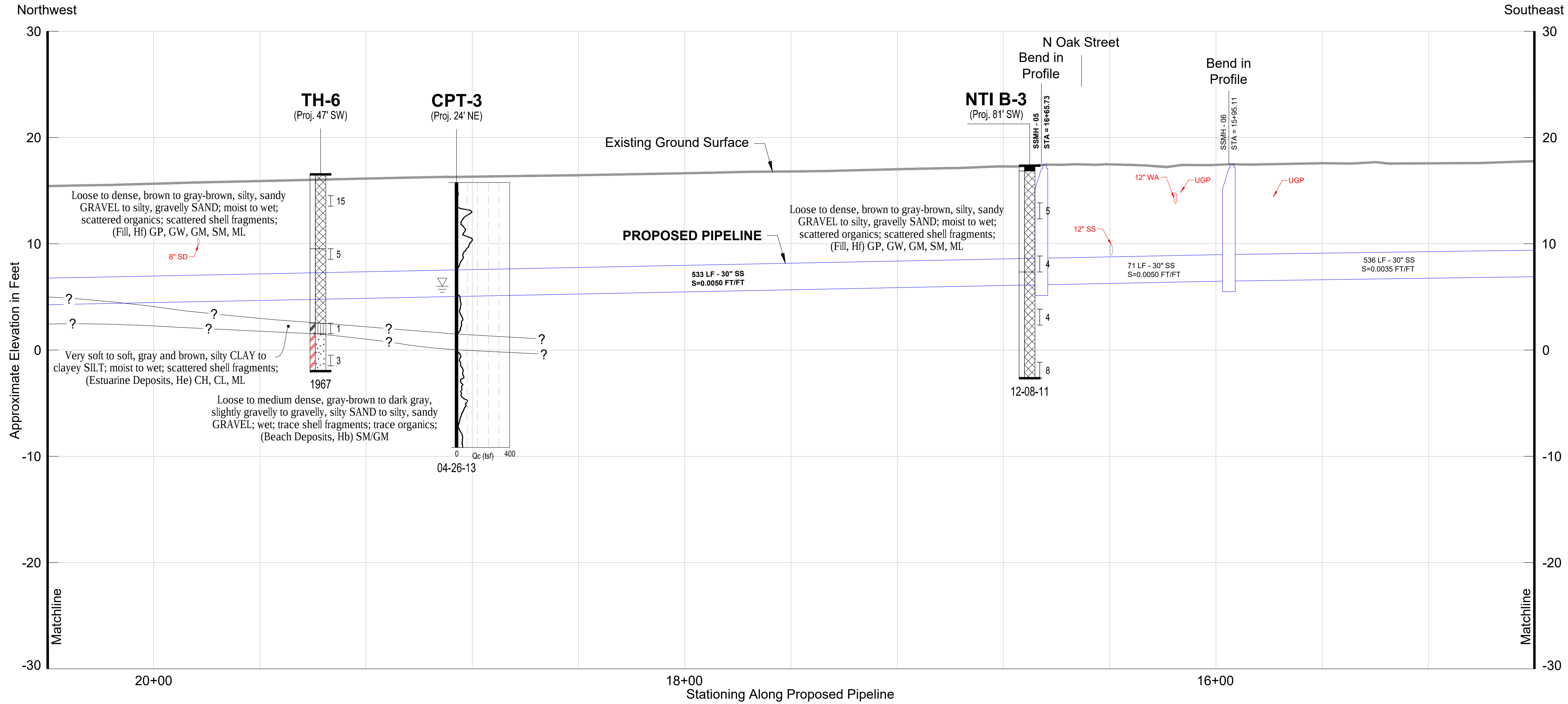
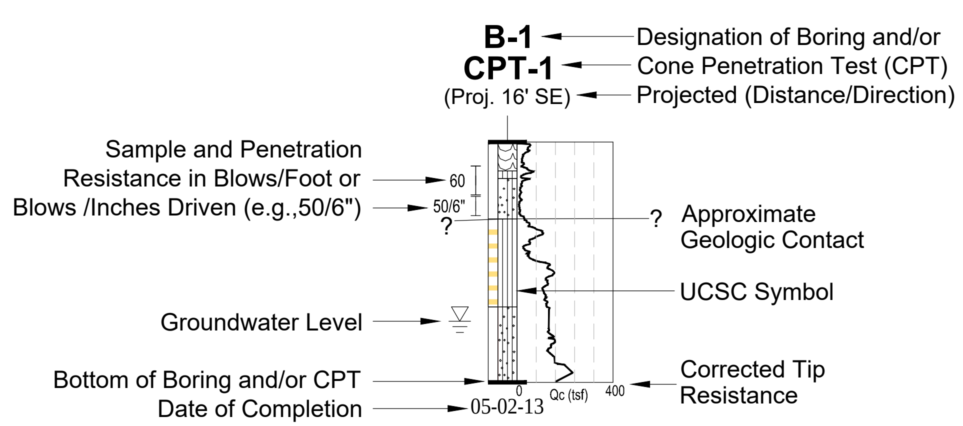
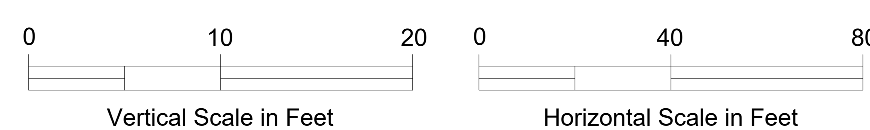
FIG. 2
Sheet 1 of 5

Filename: J:\211\20617-004\21-1-20617-004 Fig 2.dwg Date: 04-07-2014 Login: SAC



LEGEND





Vertical Exaggeration = 2X

NOTES

1. Ground surface and pipeline features are adapted from client file, *"144083-C-014-XSITE.DWG"*, received 7-2-2013.

2. This subsurface profile is generalized from materials observed in soil borings. Variations may exist between profile and actual conditions.

Phase 2 Combined Sewer Overflow Project
Port Angeles, Washington

GENERALIZED SUBSURFACE PROFILE A-A'

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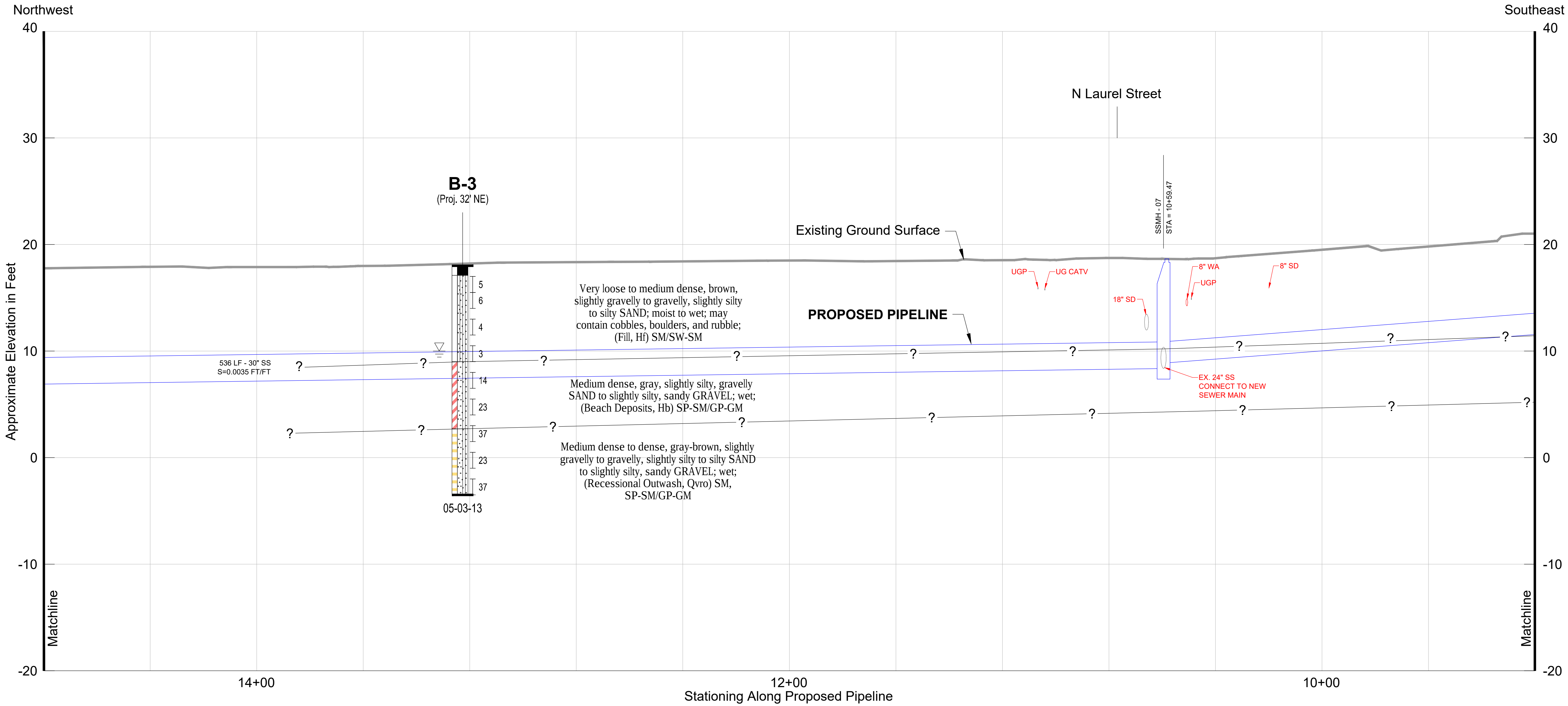
FIG. 2
Sheet 2 of 5



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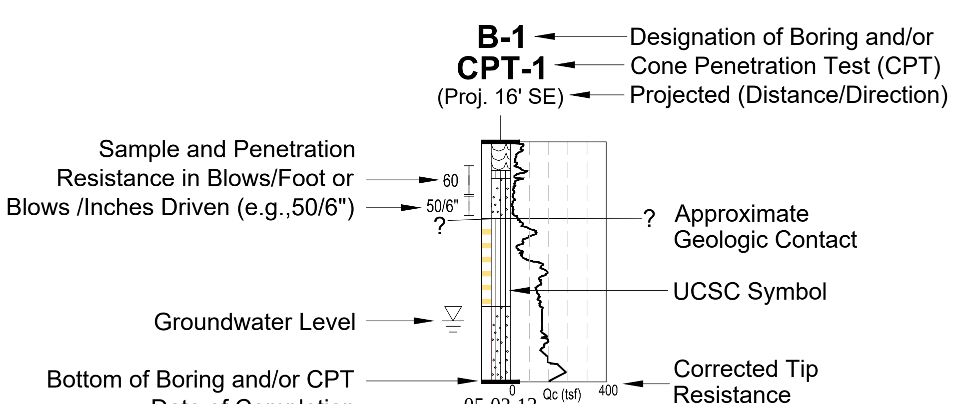

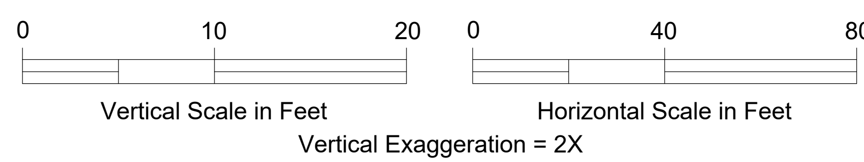

NOTES

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2. This subsurface profile is generalized from materials observed in soil borings. Variations may exist between profile and actual conditions.

Phase 2 Combined Sewer Overflow Project
Port Angeles, Washington

GENERALIZED SUBSURFACE PROFILE A-A'

April 2014 21-1-20617-004

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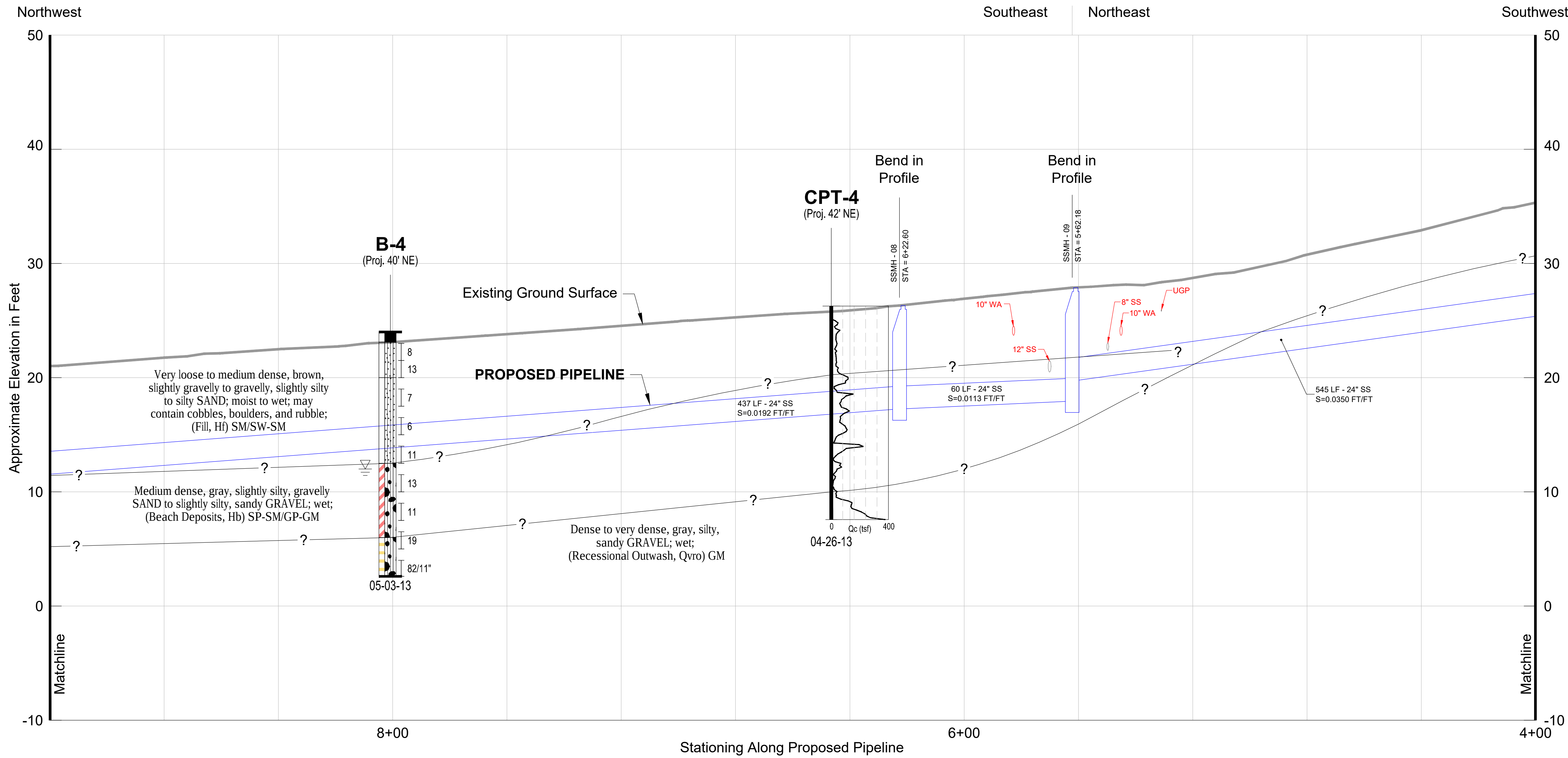
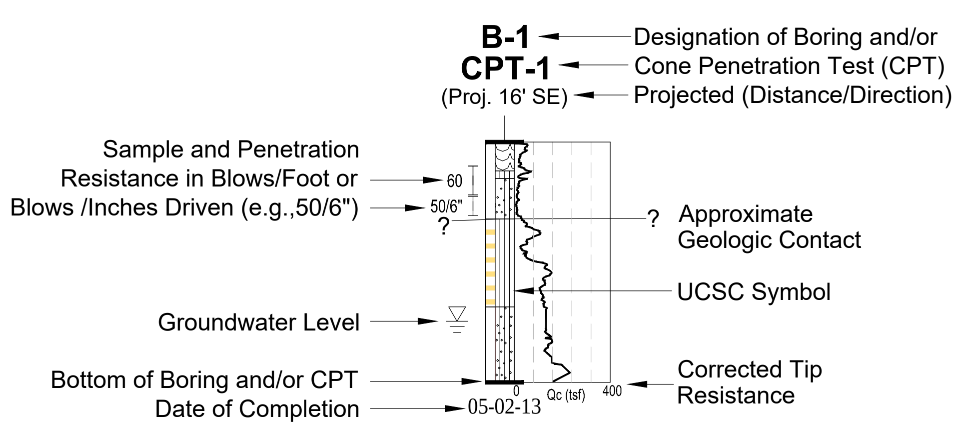
FIG. 2
Sheet 3 of 5



LEGEND



0 10 20

Vertical Scale in Feet

0 40 80

Horizontal Scale in Feet

Vertical Exaggeration = 2X

NOTES

1. Ground surface and pipeline features are adapted from client file, *"144083-C-014-XSITE.DWG"*, received 7-2-2013.

2. This subsurface profile is generalized from materials observed in soil borings. Variations may exist between profile and actual conditions.

Phase 2 Combined Sewer Overflow Project
Port Angeles, Washington

GENERALIZED SUBSURFACE PROFILE A-A'

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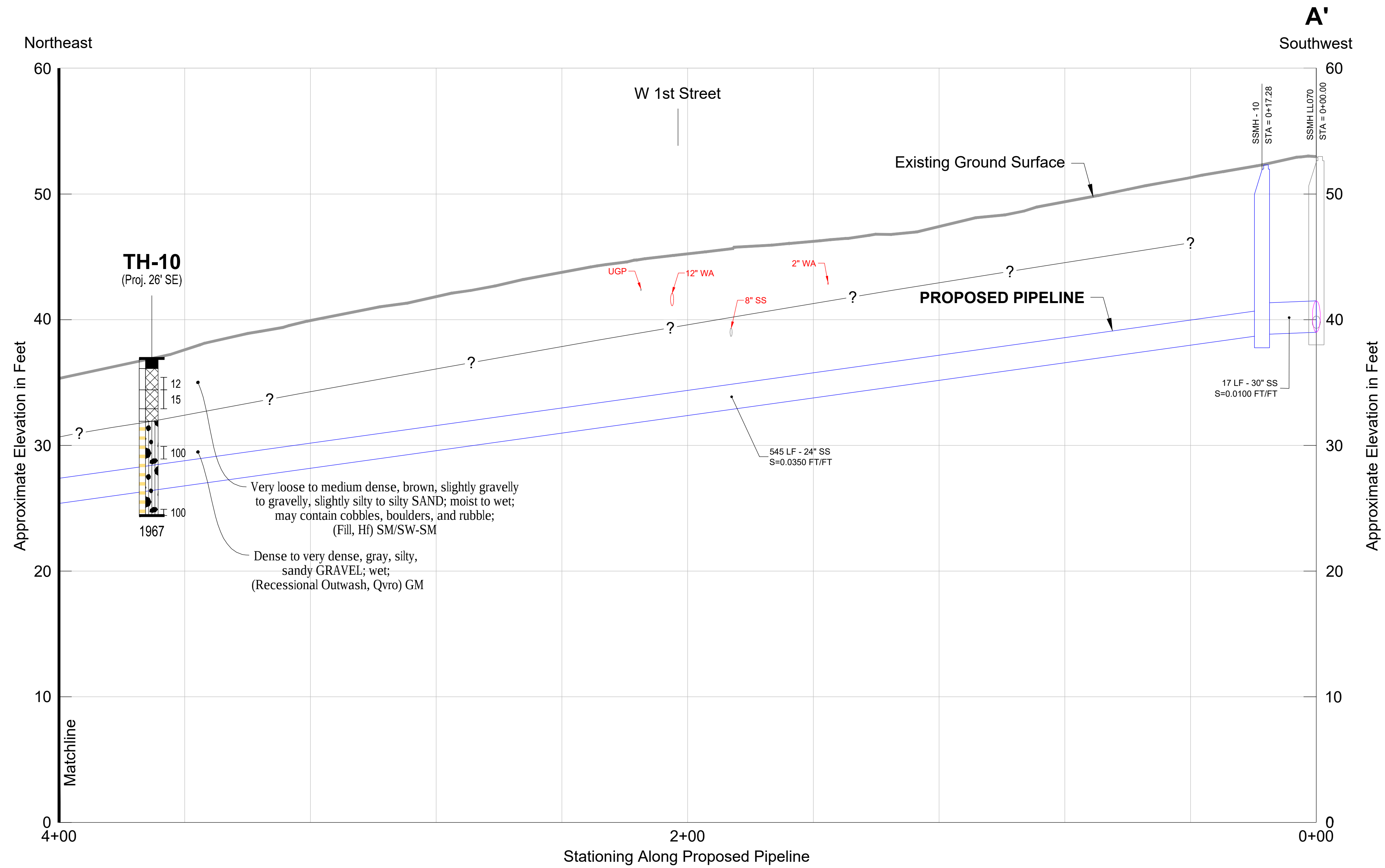
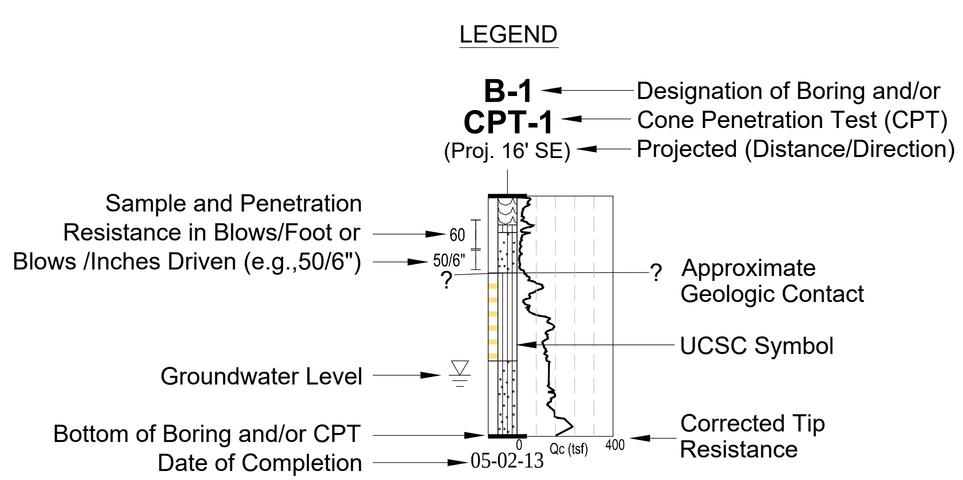
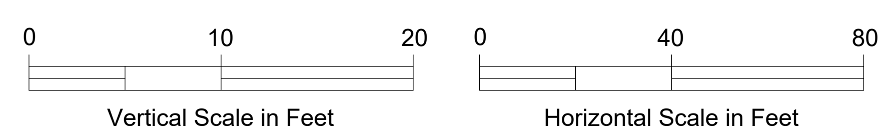
FIG. 2
Sheet 4 of 5

Filename: J:\211\20617-004\21-1-20617-004 Fig 2.dwg Date: 04-07-2014 Login: SAC







Vertical Exaggeration = 2X

NOTES

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2. This subsurface profile is generalized from materials observed in soil borings. Variations may exist between profile and actual conditions.

Phase 2 Combined Sewer Overflow Project
Port Angeles, Washington

GENERALIZED SUBSURFACE PROFILE A-A'

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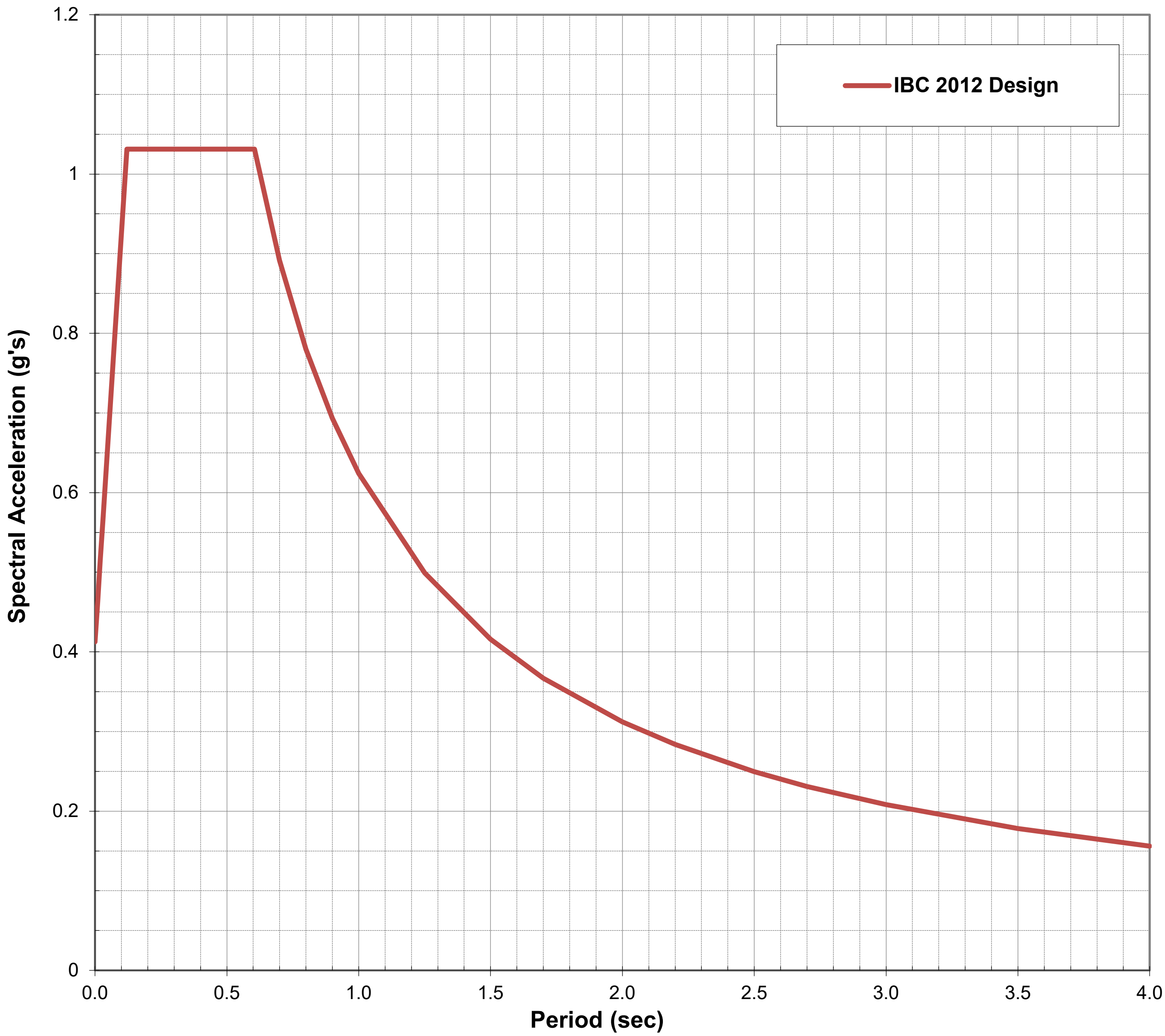
FIG. 2
Sheet 5 of 5

Filename: J:\211\20617-004\21-1-20617-004 Fig 2.dwg Date: 04-07-2014 Login: SAC



Response Spectrum Parameters (IBC)[1]

S_S = 1.55 g	F_a = 1.00
S_1 = 0.62 g	F_v = 1.50
S_{MS} = 1.55 g	T_0 = 0.12 sec.
S_{M1} = 0.94 g	T_S = 0.61 sec.
S_{DS} = 1.03 g	PGA = 0.41 g
S_{D1} = 0.62 g	

NOTE

1. The IBC response spectrum is calculated following procedures from 2012 IBC
2. Mapped Spectral Response Acceleration (SRA) and Design SRA values are in units of gravity (g).
3. The Mapped SRA values are based on regional probabilistic ground motion studies conducted by the U.S. Geological Survey and Frankel and others (2008).

City of Port Angeles
Front Street CSO Phase 2
Port Angeles, Washington

HORIZONTAL RESPONSE SPECTRUM
SITE CLASS D

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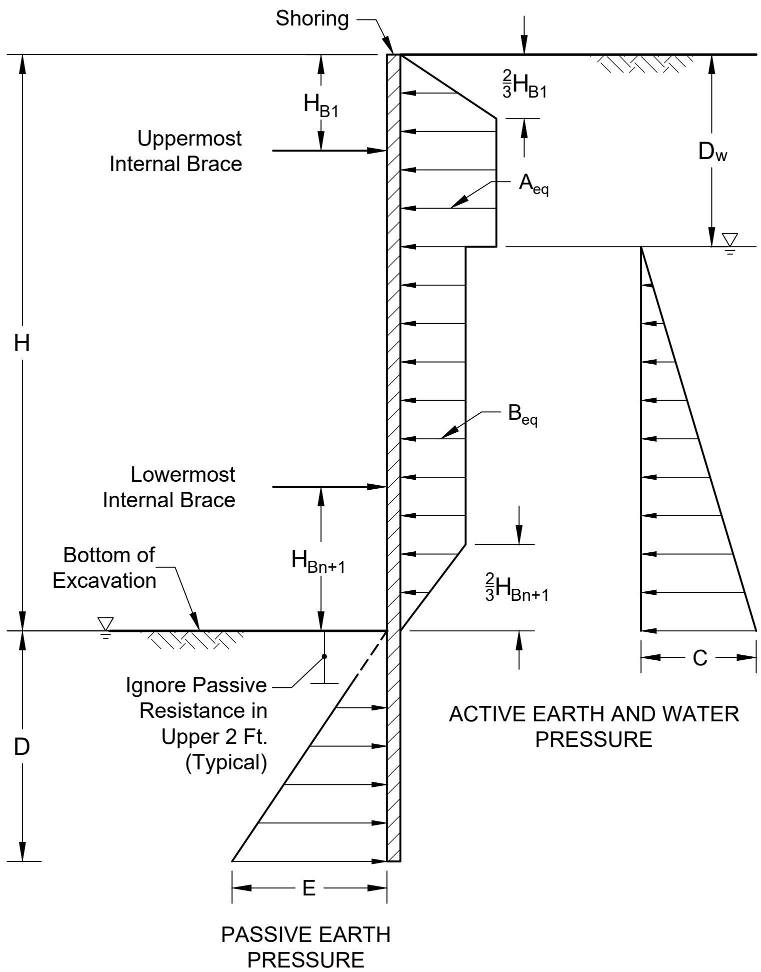
FIG. 3



RECOMMENDED EARTH AND WATER PRESSURES

A	B	C	E
35 H	17 H	γ_w (H-D_w)	230 D

LEGEND

A, B, C... Earth and Water Pressure; See Table

H Total Excavation Height, feet

H_{B1} Depth to Uppermost Brace Level, feet

H_{Bn+1} Distance from Bottom of Excavation to Lowermost Brace Level, feet

H_{eq} $\left[\frac{H}{1.5H - \frac{1}{2}H_{B1} - \frac{1}{2}H_{Bn+1}}\right]$

A_{eq} $A \bullet H_{eq}$

B_{eq} $B \bullet H_{eq}$

D_w Depth to Water, 0 feet

D Total Embedment Depth, feet

γ_w Unit Weight of Water, 62.4 pounds per cubic foot

NOTES

1. All earth pressures are in units of pounds per square foot.
2. Diagrams are not to scale.
3. The recommended pressure diagrams are based on a continuous, multiple-braced shoring system.
4. The total lateral pressure is the sum of the active earth, water, and lateral surcharge pressures (see Figure 6).
5. Passive earth pressures include F.S. = 1.5.
6. No drainage is assumed behind the shoring and groundwater is assumed to be lowered and maintained at the bottom of excavation during construction.
7. Shoring embedment (D) should consider kickout resistance. Embedment should be determined by satisfying horizontal static equilibrium about the bottom of the shoring. Minimum recommended embedment is elevation -33 feet to assist with groundwater control.

Phase 2 Combined Sewer Overflow Project
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TEMPORARY LATERAL PRESSURES
MULTIPLE BRACE SHORING

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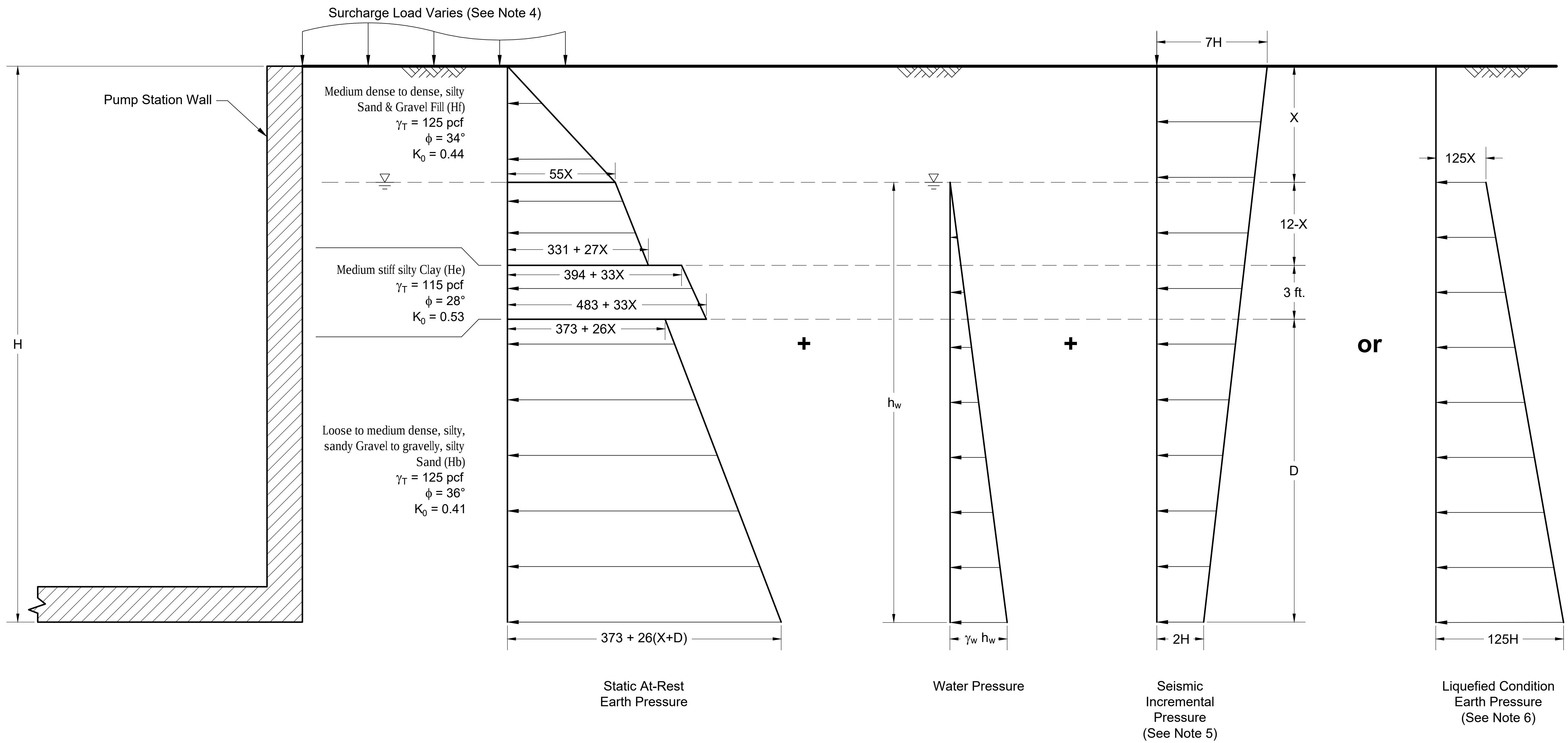
FIG. 4



Not to Scale

NOTES

1. The lateral earth pressure units are in pounds per square foot (psf).
2. The lateral earth pressures provided assume at-rest earth pressure conditions (the wall moves less than 0.001 x H).
3. Water and earth pressures are to be combined; the values shown above assume a horizontal backslope.
4. Surcharge pressures should be added as required. See Figure 6 for additional details.
5. Permanent wall design should consider seismic loading. Under seismic loading condition, a seismic incremental pressure, as shown, should be added to the static earth pressures. The seismic incremental pressure is based on a peak ground acceleration of 0.314g
6. Permanent wall design should consider loading from potentially liquefied soils. For the liquefied soil loading condition, apply the Liquefied Condition Earth Pressure only. Do not add Water Pressure or Seismic Incremental Pressure.

LEGEND

X = Design Depth of Groundwater Below Ground Surface (ft.) Use X = 0 Ft.

γ_w = Unit Weight of Water (pcf)

h_w = Height of Water (ft.)

▽ = Groundwater Level

H = Height of Wall/Excavation (ft.)

γ_T = Total Unit Weight of Soil Above Groundwater Level (pcf)

K_0 = Coefficient of Lateral Earth Pressure At-Rest (unitless)

ϕ = Soil Effective Stress Friction Angle (deg.)

Phase 2 Combined Sewer Overflow Project
Port Angeles, Washington

RECOMMENDED LATERAL EARTH PRESSURES FOR PERMANENT PUMP STATION WALL

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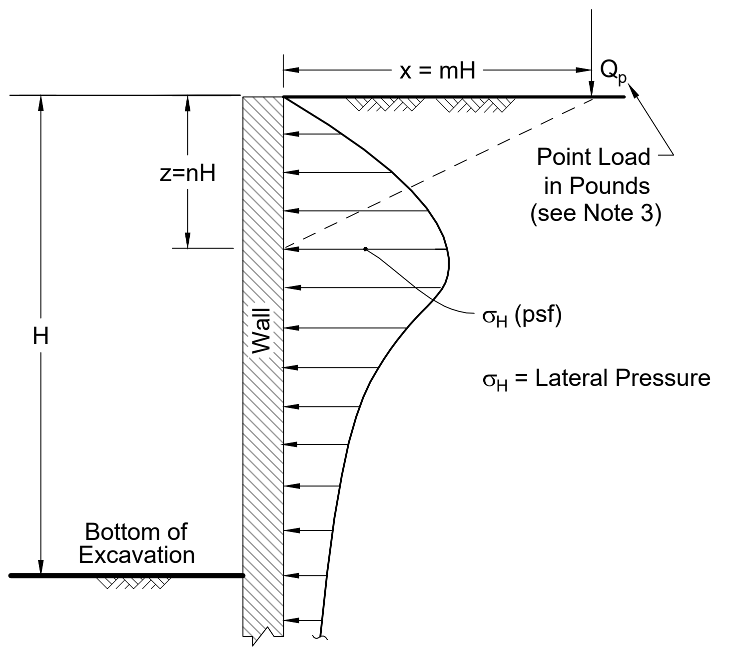
FIG. 5

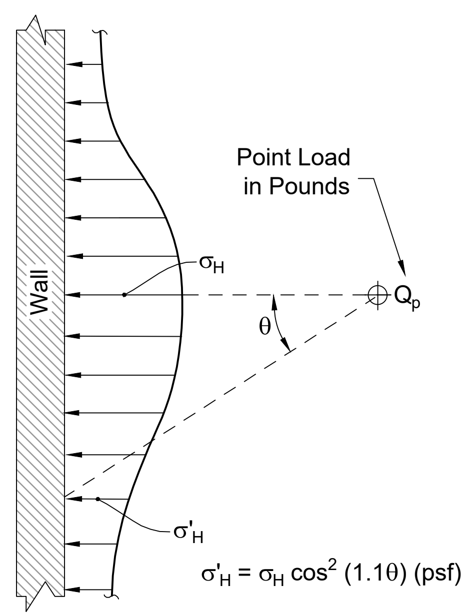
File: J:\211\20617-004\21-1-20617-004 Fig 5.dwg Date: 04-07-2014 Author: SAC



ELEVATION VIEW

For m ≤ 0.4: $\sigma_H = 0.28 \dfrac{Q_p}{H^2} \dfrac{n^2}{(0.16 + n^2)^3}$ (psf) (see Note 3)

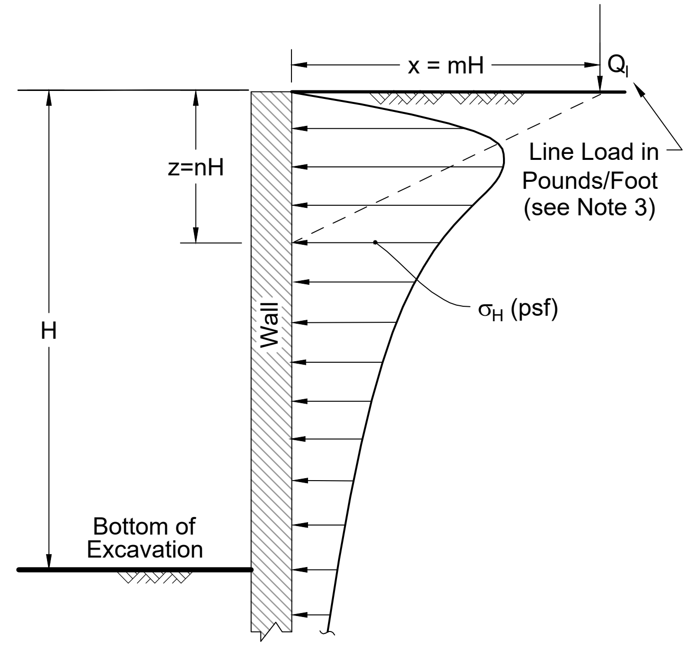
For m > 0.4: $\sigma_H = 1.77 \dfrac{Q_p}{H^2} \dfrac{m^2 n^2}{(m^2 + n^2)^3}$ (psf)



PLAN VIEW

A) LATERAL PRESSURE DUE TO POINT LOAD i.e. SMALL ISOLATED FOOTING OR WHEEL LOAD

(NAVFAC DM 7.2, 1986)



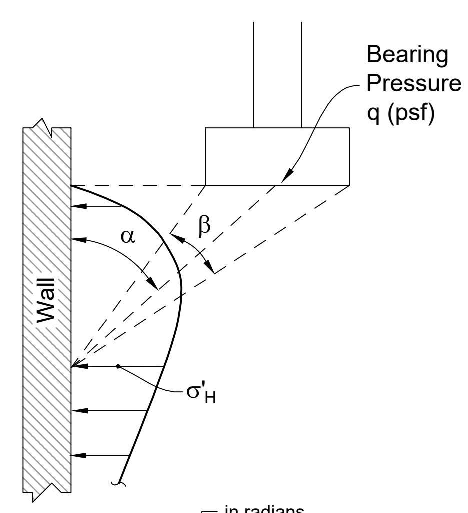
ELEVATION VIEW

For m ≤ 0.4: $\sigma_H = 0.20 \dfrac{Q_l}{H} \dfrac{n}{(0.16 + n^2)^2}$ (psf) (see Note 3)

For m > 0.4: $\sigma_H = 1.28 \dfrac{Q_l}{H} \dfrac{m^2 n}{(m^2 + n^2)^2}$ (psf)

B) LATERAL PRESSURE DUE TO LINE LOAD i.e. NARROW CONTINUOUS FOOTING PARALLEL TO WALL

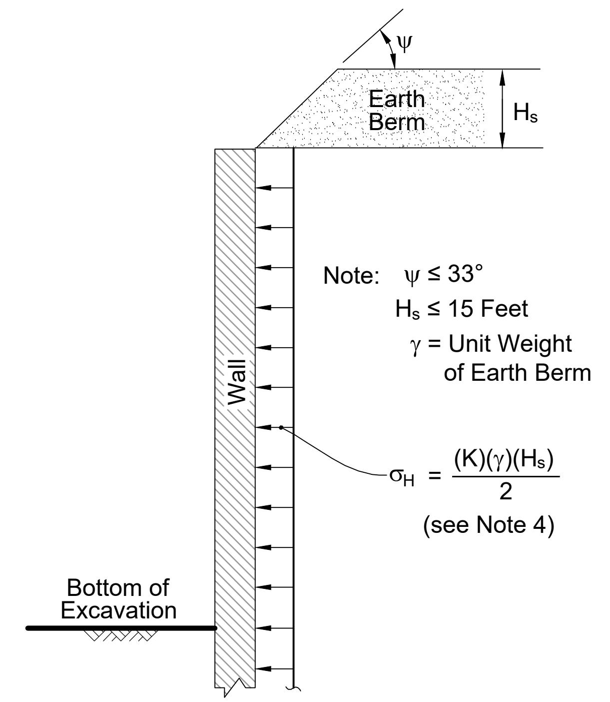
(NAVFAC DM 7.02, 1986)



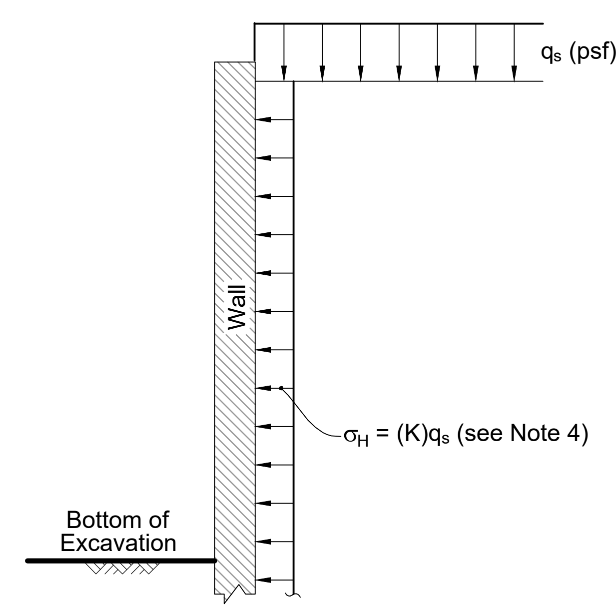
$\sigma_H = \dfrac{2q}{\pi}(\beta - \sin\beta \cos 2\alpha)$ (psf) (β in radians)

C) LATERAL PRESSURE DUE TO STRIP LOAD

(derived from Fang, *Foundation Engineering Handbook*, 1991)



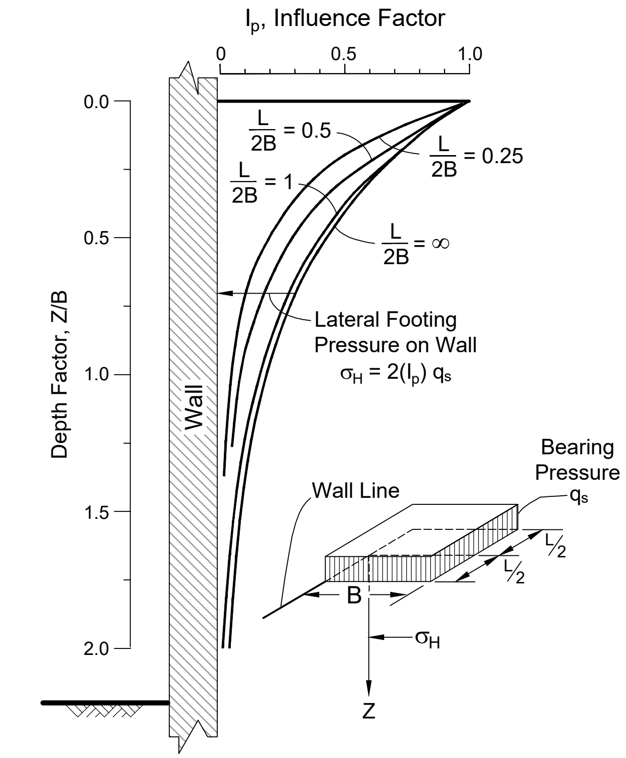
EARTH BERM



UNIFORM SURCHARGE

D) LATERAL PRESSURE DUE TO EARTH BERM OR UNIFORM SURCHARGE

(derived from Poulos and Davis, *Elastic Solutions for Soil and Rock Mechanics*, 1974; and Terzaghi and Peck, *Soil Mechanics in Engineering Practice*, 1967)



E) LATERAL PRESSURE DUE TO ADJACENT FOOTING
(see Notes 5 and 6)

(derived from NAVFAC DM 7.02, 1986; and Sandhu, *Earth Pressure on Walls Due to Surcharge*, 1974)

NOTES

1. Figures are not drawn to scale.
2. Applicable surcharge pressures should be added to appropriate permanent wall lateral earth and water pressure.
3. If point or line loads are close to the back of the wall such that m ≤ 0.4, it may be more appropriate to model the actual load distribution (i.e., Detail E) or use more rigorous analysis methods.
4. For pump station walls, use k = 0.44 (assumes at-rest condition).
5. The stress is estimated on the back of the wall at the center of the length, L, of loading.
6. The estimated stress is based on a Poisson's ratio of 0.5.

Phase 2 Combined Sewer Overflow Project
Port Angeles, Washington

RECOMMENDED SURCHARGE LOADING FOR TEMPORARY AND PERMANENT WALLS

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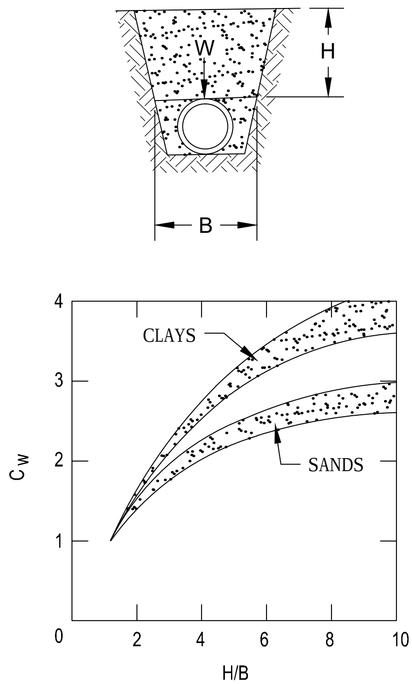
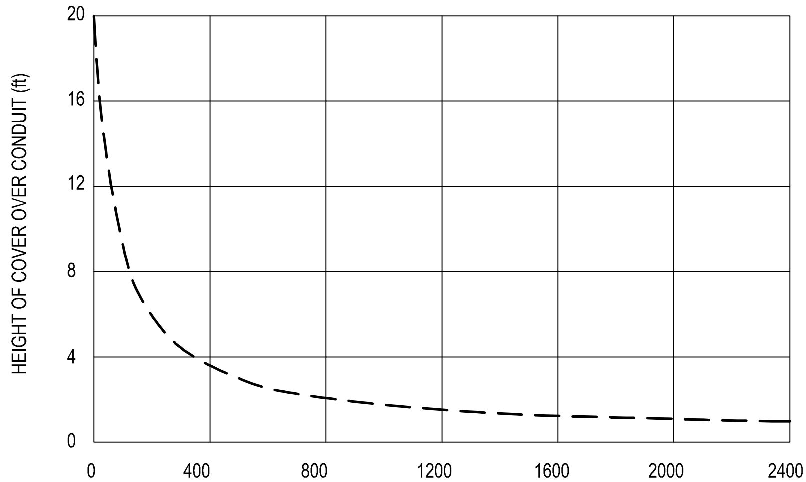
FIG. 6

File: J:\211\20617-004\21-1-20617-004 Fig 6.dwg Date: 04-07-2014 Author: SAC



(a) C_W FOR CONDUIT IN A TRENCH



(b) VERTICAL PRESSURE DUE TO H-20 LIVE LOAD ON CONDUIT (PSF)

NOTES

1. W = Total Dead Load per Unit Length.

2. For trench backfill, Figure 7(a): $W = C_W(\gamma)(B)^2$

   where: γ = Soil Unit Weight.

   B = Trench Width at Top of Pipe Level.

3. Live loads of Figure 7(b) include effect of impact.

4. This figure was reproduced from figures presented in the NAVFAC DM7.

Phase 2 Combined Sewer Overflow Project
Port Angeles, Washington

LOADS ON BURIED UTILITIES

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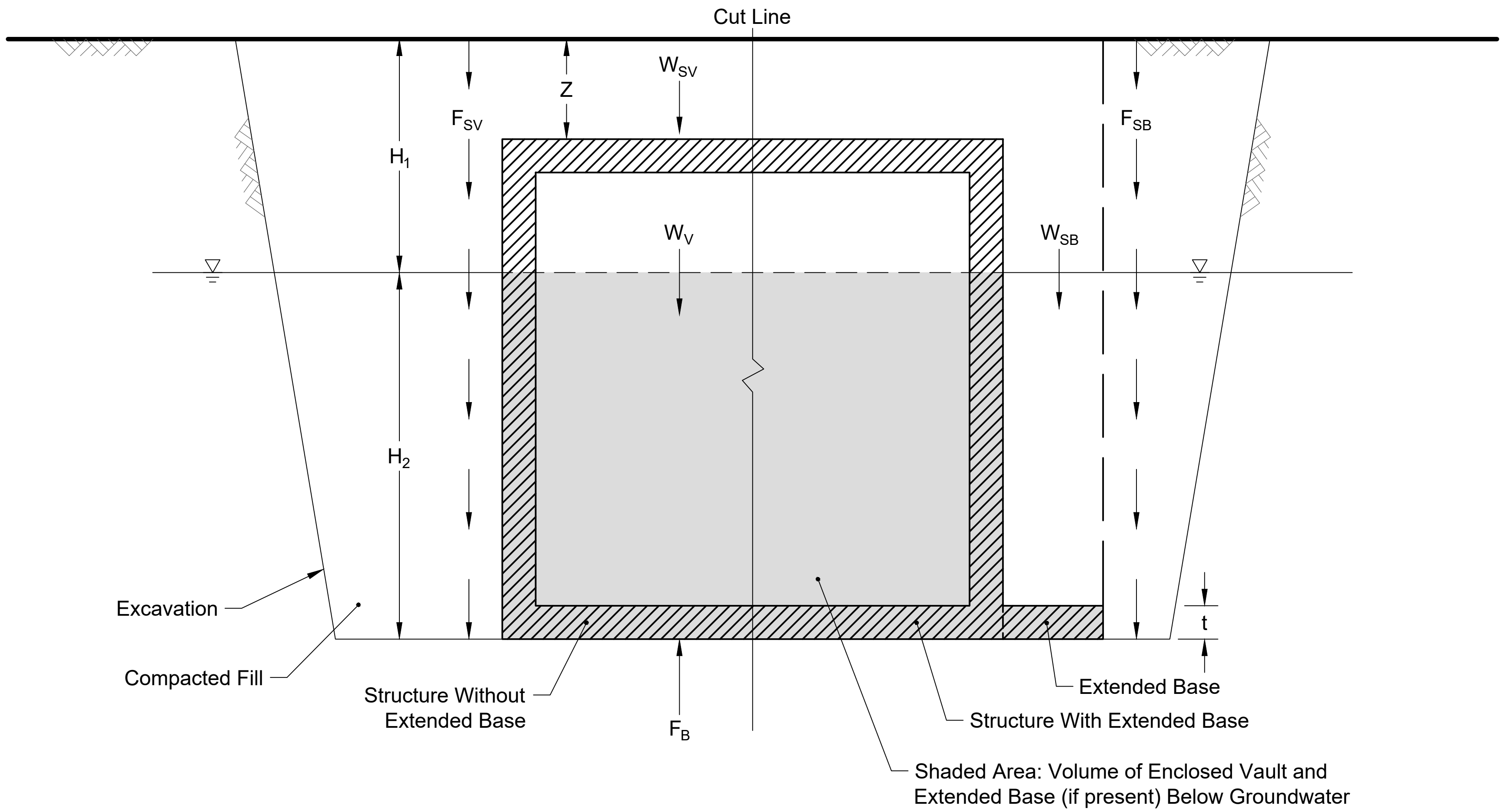
FIG. 7

Filename: J:\211\20617-004\21-1-20617-004 Fig 7.dwg Date: 04-07-2014 Login: Sandy Cottrell



Not to Scale

NOTATION

γ_T = Total Unit Weight of Soil Above Groundwater Level, γ_T = 125 pcf

γ_B = Buoyant Unit Weight of Soil Below Groundwater Level, γ_B = 62.6 pcf

γ_W = Unit Weight of Water, γ_W = 62.4 pcf (Fresh Water)

ϕ = Soil Effective Stress Friction Angle, ϕ = 30°

δ = Soil - Structure Interface Friction Angle, $\delta = \frac{2}{3}\phi$ (Precast Concrete)

K = K_o for Unshored Excavations, K = K_a otherwise

- K_o = At-Rest Earth Pressure Coefficient, $K_o = 1 - \sin\phi$
- K_a = Active Earth Pressure Coefficient, $K_a = \frac{1-\sin\phi}{1+\sin\phi}$

A_{Top} = Area of Top of Vault, Ft^2

A_{EB} = Area of Extended Base, Ft^2

P = Perimeter Distance Around Base of Vault and Extended Base (if present), Ft. May Not Be Same Shape as Shown

t = Thickness of Extended Base, Ft.

V = Volume of Enclosed Vault and Extended Base (if present) Below Groundwater, Ft^3. May Not Be Same Shape as Shown

Z = Depth to Top of Vault

H_1 = Depth to Groundwater - Use H_1 = 0 Ft.

H_2 = Depth from Groundwater to Base of Vault

$\underline{\nabla}$ = Groundwater Level

EQUATIONS

$$\text{Factor of Safety without Extended Base} = \frac{W_V + W_{SV} + F_{SV}\,(P)}{F_B}$$

$$\text{Factor of Safety with Extended Base} = \frac{W_V + W_{SV} + W_{SB} + F_{SB}\,(P)}{F_B}$$

W_V = Weight of Vault and Extended Base (if present), lb

W_{SV} = Weight of Soil Above Vault (if present), lb

Buried Vault with Groundwater Below Top of Vault: $W_{SV} = \gamma_T\, Z\, A_{Top}$ (lb)

Buried Vault with Groundwater Above Top of Vault: $W_{SV} = [\gamma_T H_1 + \gamma_B (Z - H_1)]\, A_{Top}$ (lb)

W_{SB} = Weight of Soil Above Extended Base (if present), lb

$= [\gamma_T H_1 + \gamma_B (H_2 - t)]\, A_{EB}$

F_{SV} = Shearing Resistance of Soil to Vault Wall, lb/Ft

$= (\frac{1}{2})(\tan\delta)(K)(2\,\gamma_T H_1 H_2 + \gamma_T H_1^2 + \gamma_B H_2^2)$

F_{SB} = Shearing Resistance of Soil, lb/Ft

$= (\frac{1}{2})(\tan\phi)(K)(2\,\gamma_T H_1 H_2 + \gamma_T H_1^2 + \gamma_B H_2^2)$

F_B = Buoyant Force, lb

$= V\,\gamma_W$

NOTES

1. Uplift could result in high moments in bottom slab.
2. If temporary or permanent shoring is left in place adjacent to vault, F_{SV} and F_{SB} should be ignored.

Phase 2 Combined Sewer Overflow Project
Port Angeles, Washington

PUMP STATION NO. 4
UPLIFT RESISTANCE

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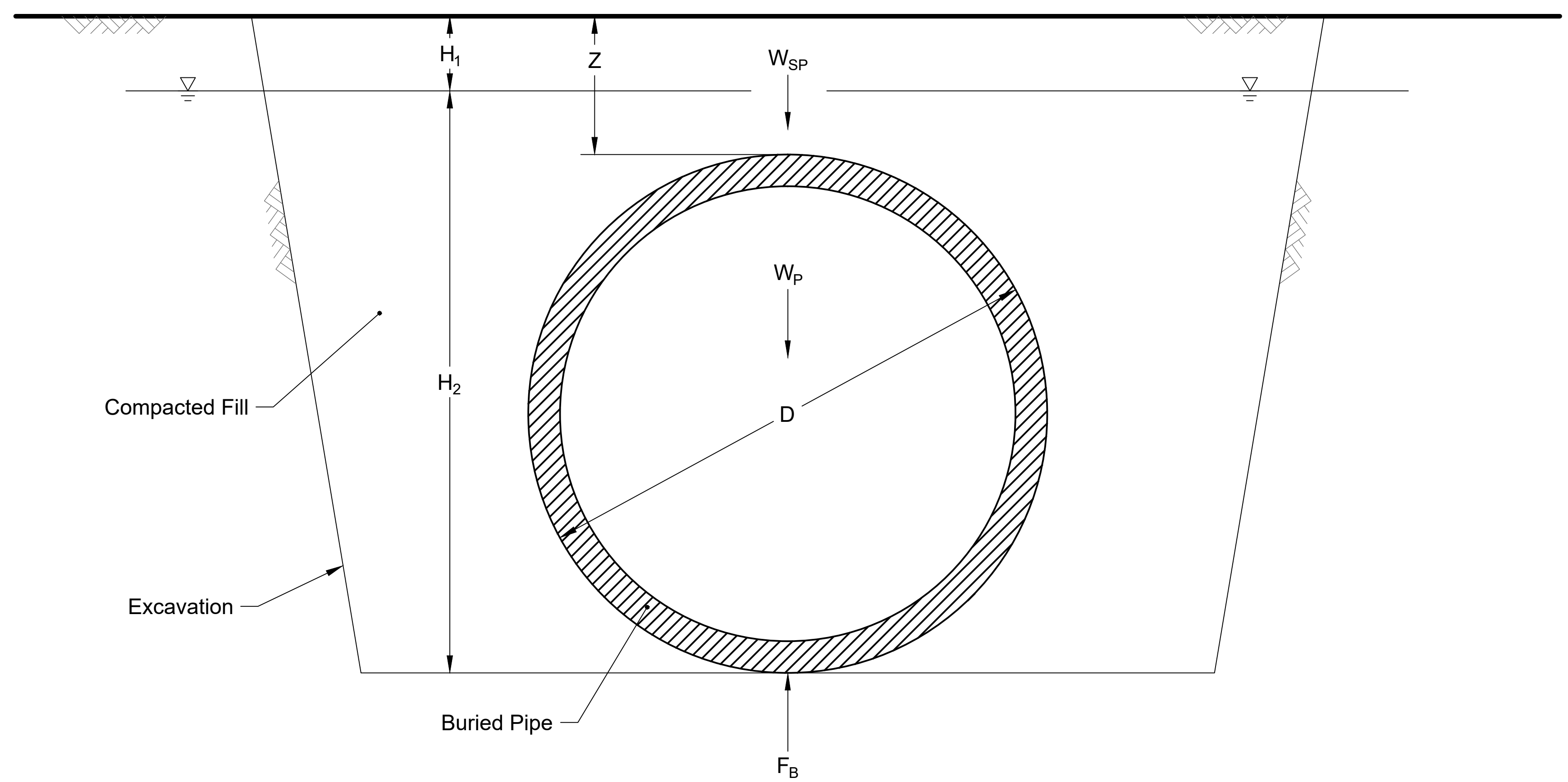
FIG. 8



Not to Scale

NOTATION

γ_T = Total Unit Weight of Soil Above Groundwater Level, γ_T = 125 pcf

γ_B = Buoyant Unit Weight of Soil Below Groundwater Level, γ_B = 62.6 pcf

γ_W = Unit Weight of Water, γ_W = 62.4 pcf (Fresh Water)

D = Outside Diameter of Pipe, Ft.

A = Area of Enclosed Pipe Below Groundwater, Ft^2. May Not Be Same Shape as Shown

A_{TOP} = Plan View Area of Pipe, DUnit Length Ft^2

Z = Depth to Top of Pipe

H_1 = Depth to Groundwater

H_2 = Depth from Groundwater to Base of Pipe

∇ = Groundwater Level

EQUATIONS

$$\text{Factor of Safety} = \frac{W_P + W_{SP}}{F_B}$$

W_P = Weight of Pipe, lb/lft

W_{SP} = Weight of Soil Above Pipe, lb/lft

$= [\gamma_T H_1 + \gamma_B (Z - H_1)] A_{Top}$

F_B = Buoyant Force, lb/lft

$= A \gamma_W$

NOTE

Permanent tiedowns could also be used to resist uplift.

Phase 2 Combined Sewer Overflow Project
Port Angeles, Washington

BURIED PIPE
UPLIFT RESISTANCE

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FIG. 9

Filename: J:\211\20617-004\21-1-20617-004 Fig 9.dwg Layout: April 2014 Date: 04-07-2014 Login: SAC

APPENDIX A

BORING AND CONE PENETRATION TEST LOGS

APPENDIX A

BORING AND CONE PENETRATION TEST LOGS

TABLE OF CONTENTS

FIGURES

Shannon & Wilson, Inc. (S&W), uses a soil classification system modified from the Unified Soil Classification System (USCS). Elements of the USCS and other definitions are provided on this and the following page. Soil descriptions are based on visual-manual procedures (ASTM D 2488-93) unless otherwise noted.

S&W CLASSIFICATION OF SOIL CONSTITUENTS

- MAJOR constituents compose more than 50 percent, by weight, of the soil. Major consituents are capitalized (i.e., SAND).
- Minor constituents compose 12 to 50 percent of the soil and precede the major constituents (i.e., silty SAND). Minor constituents preceded by "slightly" compose 5 to 12 percent of the soil (i.e., slightly silty SAND).
- Trace constituents compose 0 to 5 percent of the soil (i.e., slightly silty SAND, trace of gravel).

MOISTURE CONTENT DEFINITIONS

Dry	Absence of moisture, dusty, dry to the touch
Moist	Damp but no visible water
Wet	Visible free water, from below water table

ABBREVIATIONS

ATD	At Time of Drilling
Elev.	Elevation
ft	feet
FeO	Iron Oxide
MgO	Magnesium Oxide
HSA	Hollow Stem Auger
ID	Inside Diameter
in	inches
lbs	pounds
Mon.	Monument cover
N	Blows for last two 6-inch increments
NA	Not applicable or not available
NP	Non plastic
OD	Outside diameter
OVA	Organic vapor analyzer
PID	Photo-ionization detector
ppm	parts per million
PVC	Polyvinyl Chloride
SS	Split spoon sampler
SPT	Standard penetration test
USC	Unified soil classification
WLI	Water level indicator

GRAIN SIZE DEFINITION

DESCRIPTION	SIEVE NUMBER AND/OR SIZE
FINES	< #200 (0.08 mm)
SAND*	
- Fine	#200 to #40 (0.08 to 0.4 mm)
- Medium	#40 to #10 (0.4 to 2 mm)
- Coarse	#10 to #4 (2 to 5 mm)
GRAVEL*	
- Fine	#4 to 3/4 inch (5 to 19 mm)
- Coarse	3/4 to 3 inches (19 to 76 mm)
COBBLES	3 to 12 inches (76 to 305 mm)
BOULDERS	> 12 inches (305 mm)

* Unless otherwise noted, sand and gravel, when present, range from fine to coarse in grain size.

RELATIVE DENSITY / CONSISTENCY

COHESIONLESS SOILS		COHESIVE SOILS (FINE-GRAINED)	
N, SPT, BLOWS/FT.	RELATIVE DENSITY	N, SPT, BLOWS/FT.	RELATIVE CONSISTENCY
0 - 4	Very loose	Under 2	Very soft
4 - 10	Loose	2 - 4	Soft
10 - 30	Medium dense	4 - 8	Medium stiff
30 - 50	Dense	8 - 15	Stiff
Over 50	Very dense	15 - 30	Very stiff
		Over 30	Hard

WELL AND OTHER SYMBOLS

Bent. Cement Grout	Surface Cement Seal
Bentonite Grout	Asphalt or Cap
Bentonite Chips	Slough
Silica Sand	Bedrock
PVC Screen	
Vibrating Wire	

Phase 2 Combined Sewer Overflow Project
Port Angeles, Washington

SOIL CLASSIFICATION AND LOG KEY

April 2014 21-1-20617-011

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. A-1
Sheet 1 of 2

BORING CLASS1 21-20617.GPJ 21-09490.GPJ 4/7/14

UNIFIED SOIL CLASSIFICATION SYSTEM (USCS)
(From USACE Tech Memo 3-357)

MAJOR DIVISIONS			GROUP/GRAPHIC SYMBOL	TYPICAL DESCRIPTION
COARSE-GRAINED SOILS *(more than 50% retained on No. 200 sieve)*	Gravels *(more than 50% of coarse fraction retained on No. 4 sieve)*	Clean Gravels *(less than 5% fines)*	GW	Well-graded gravels, gravels, gravel/sand mixtures, little or no fines
			GP	Poorly graded gravels, gravel-sand mixtures, little or no fines
		Gravels with Fines *(more than 12% fines)*	GM	Silty gravels, gravel-sand-silt mixtures
			GC	Clayey gravels, gravel-sand-clay mixtures
	Sands *(50% or more of coarse fraction passes the No. 4 sieve)*	Clean Sands *(less than 5% fines)*	SW	Well-graded sands, gravelly sands, little or no fines
			SP	Poorly graded sand, gravelly sands, little or no fines
		Sands with Fines *(more than 12% fines)*	SM	Silty sands, sand-silt mixtures
			SC	Clayey sands, sand-clay mixtures
FINE-GRAINED SOILS *(50% or more passes the No. 200 sieve)*	Silts and Clays *(liquid limit less than 50)*	Inorganic	ML	Inorganic silts of low to medium plasticity, rock flour, sandy silts, gravelly silts, or clayey silts with slight plasticity
			CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
		Organic	OL	Organic silts and organic silty clays of low plasticity
	Silts and Clays *(liquid limit 50 or more)*	Inorganic	MH	Inorganic silts, micaceous or diatomaceous fine sands or silty soils, elastic silt
			CH	Inorganic clays or medium to high plasticity, sandy fat clay, or gravelly fat clay
		Organic	OH	Organic clays of medium to high plasticity, organic silts
HIGHLY-ORGANIC SOILS	Primarily organic matter, dark in color, and organic odor		PT	Peat, humus, swamp soils with high organic content (see ASTM D 4427)

NOTE: No. 4 size = 5 mm; No. 200 size = 0.075 mm

NOTES

1. Dual symbols *(symbols separated by a hyphen, i.e., SP-SM, slightly silty fine SAND)* are used for soils with between 5% and 12% fines or when the liquid limit and plasticity index values plot in the CL-ML area of the plasticity chart.

2. Borderline symbols *(symbols separated by a slash, i.e., CL/ML, silty CLAY/clayey SILT; GW/SW, sandy GRAVEL/gravelly SAND)* indicate that the soil may fall into one of two possible basic groups.

BORING_CLASS2 21-20617.GPJ 21-09490.GPJ 4/7/14

Phase 2 Combined Sewer Overflow Project
Port Angeles, Washington

SOIL CLASSIFICATION AND LOG KEY

April 2014 21-1-20617-011

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FIG. A-1
Sheet 2 of 2

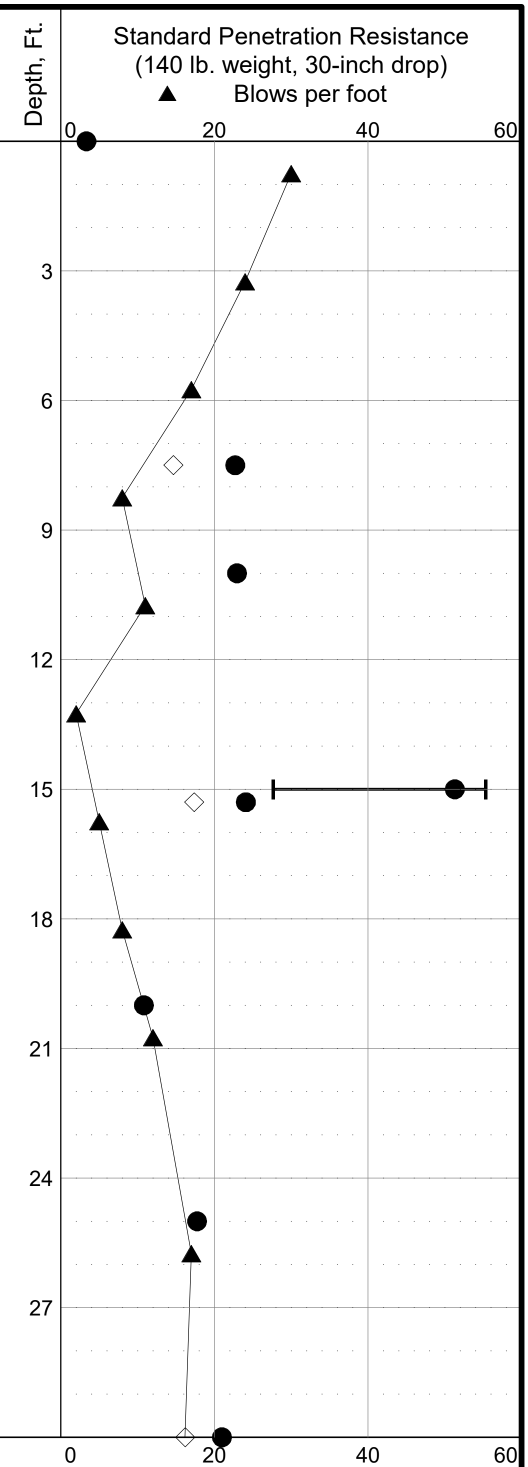
SOIL DESCRIPTION

Coordinates: N: ~ E: ~

Ground Surface Elevation: Approx. 18 Ft.

Soil Description	Depth, Ft.	Samples
Medium dense to dense, brown to gray-brown, silty, sandy GRAVEL to silty, gravelly SAND; moist; scattered shell fragments below 5 feet, scattered organics; (Hf) GM/SM.		1, 2, 3
Loose to medium dense, brown and gray, silty, fine to medium SAND and slightly fine gravelly, silty SAND; wet; trace iron-oxide staining, scattered organics, scattered shell fragments; (Hf) SM.	7.0	4 E, 5 E
Very soft, gray and brown, silty CLAY, trace of coarse sand; wet; scattered organics, scattered shell fragments; (He) CH.	12.0	6 *
Loose to medium dense, dark gray, slightly gravelly to gravelly, silty SAND to silty, sandy GRAVEL; wet; interbedded, trace to scattered shell fragments, trace organics; (Hb) SM/GM.	15.3	7 E, 8, 9, 10

Ground Water: 1/9/2014



CONTINUED NEXT SHEET

LEGEND

- * Sample Not Recovered
- E Environmental Sample Obtained
- 2" O.D. Split Spoon (SPT)
- Piezometer Screen and Sand Filter
- Bentonite-Cement Grout
- Bentonite Chips/Pellets
- Bentonite Grout
- ▼ Ground Water Level in Well

NOTES

1. The boring was performed using Mud Rotary drilling methods.
2. The stratification lines represent the approximate boundaries between soil types, and the transition may be gradual.
3. Refer to the report text for a proper understanding of the subsurface materials.
4. Groundwater level, if indicated above, is for the date specified and may vary.
5. Refer to KEY for explanation of symbols, codes and definitions.
6. USCS designation is based on visual-manual classification and selected lab testing.

Phase 2 Combined Sewer Overflow Project
Port Angeles, Washington

LOG OF BORING B-1

April 2014 21-1-20617-011

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. A-2
Sheet 1 of 2

SOIL DESCRIPTION

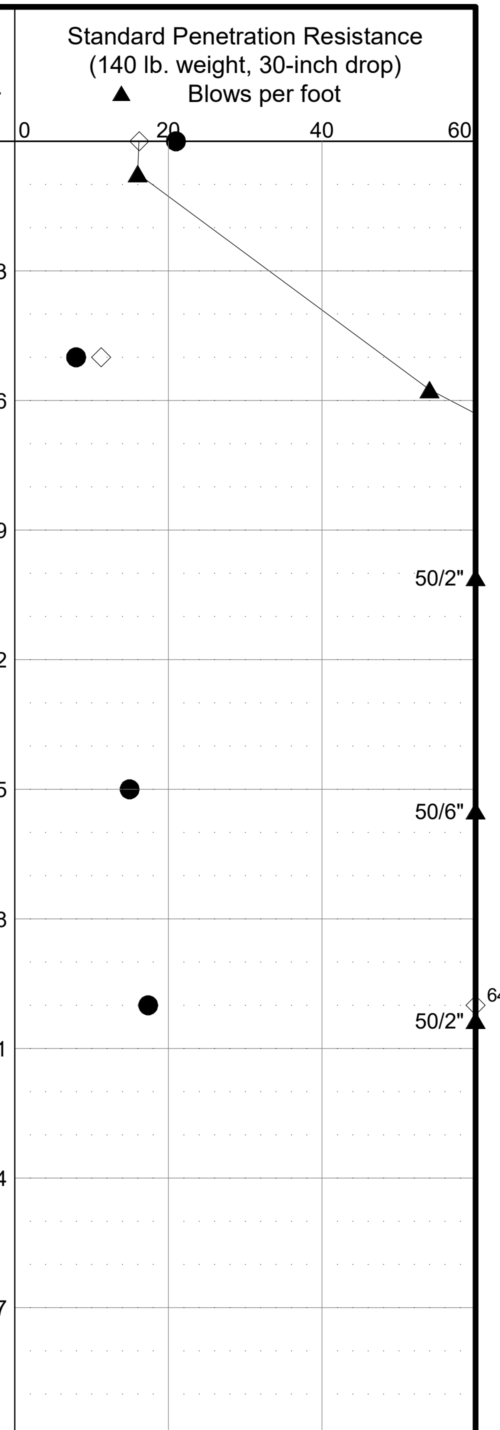
Coordinates: N: ~ E: ~

Ground Surface Elevation: Approx. 18 Ft.

Soil Description	Depth, Ft.
Very dense, gray, slightly silty to silty, sandy GRAVEL; wet; (Qvro) GW-GM/GM.	33.5
Very dense, gray-brown, trace of silt to slightly silty, fine to medium SAND; wet; (Qvro) SP-SM/SP.	41.0
Very dense, gray-brown, sandy, SILT, trace of clay, trace of fine gravel; moist; diamict; (Qvt) ML.	47.5
BOTTOM OF BORING COMPLETED 5/2/2013	50.7

Samples: 11, 12, 13, 14, 15

Depth, Ft.: 33, 36, 39, 42, 45, 48, 51, 54, 57



0 20 40 60

◇ % Fines (<0.075mm)

● % Water Content

Plastic Limit ⊢●⊣ Liquid Limit

Natural Water Content

LEGEND

- * Sample Not Recovered
- E Environmental Sample Obtained
- 2" O.D. Split Spoon (SPT)
- Piezometer Screen and Sand Filter
- Bentonite-Cement Grout
- Bentonite Chips/Pellets
- Bentonite Grout
- Ground Water Level in Well

NOTES

1. The boring was performed using Mud Rotary drilling methods.
2. The stratification lines represent the approximate boundaries between soil types, and the transition may be gradual.
3. Refer to the report text for a proper understanding of the subsurface materials.
4. Groundwater level, if indicated above, is for the date specified and may vary.
5. Refer to KEY for explanation of symbols, codes and definitions.
6. USCS designation is based on visual-manual classification and selected lab testing.

Phase 2 Combined Sewer Overflow Project
Port Angeles, Washington

LOG OF BORING B-1

April 2014 21-1-20617-011

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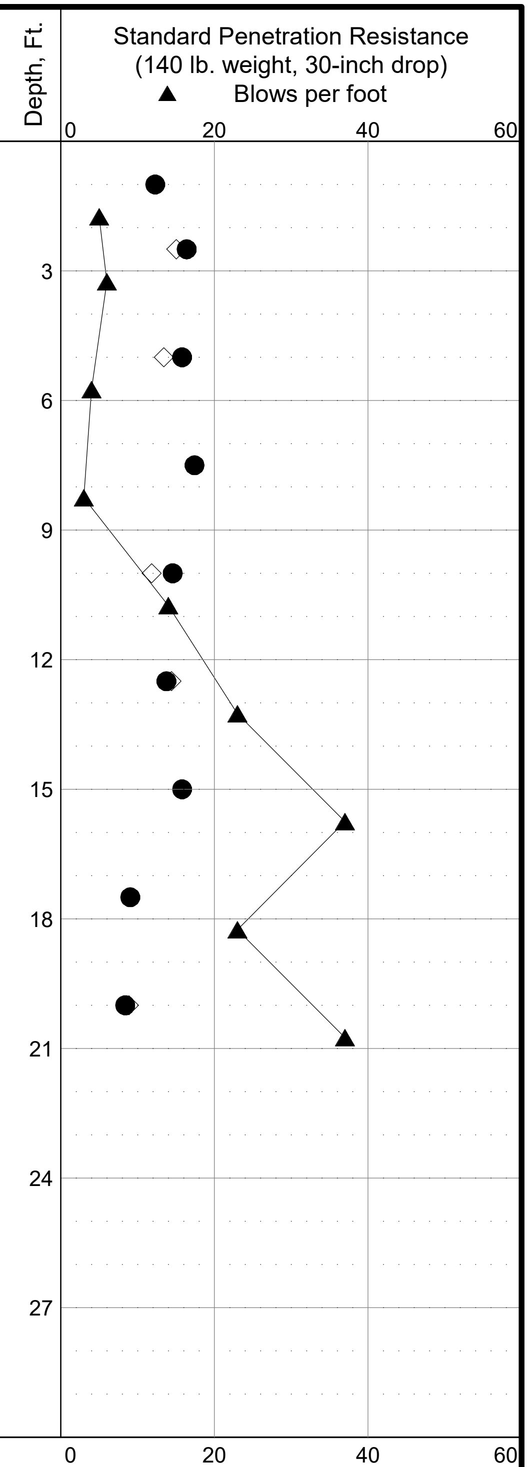
FIG. A-2
Sheet 2 of 2

Log: DPO Rev: EAS Typ: CLP

MASTER LOG FINE 21-20617.GPJ 21-09490.GPJ 4/7/14

REV 2.1

SOIL DESCRIPTION	Depth, Ft.	Symbol	Samples	Ground Water
Coordinates: N: ~ E: ~ Ground Surface Elevation: Approx. 18 Ft.				
ASPHALT	0.9			
Loose to medium dense, brown, slightly gravelly to gravelly, slightly silty to silty SAND; moist to wet at 7.5 feet; scattered pockets with iron-oxide staining at 10 feet; HF SM/SW-SM.	9.0		1, 2, 3, 4	
Medium dense, gray, slightly fine gravelly to gravelly, slight silty to silty SAND; moist to wet; (Hb) SM.	15.3		5, 6	
Medium dense to dense, gray-brown, slightly silty, gravelly SAND to slightly silty, sandy GRAVEL; wet; (Qvro) SP-SM/GP-GM.	21.5		7, 8, 9	
BOTTOM OF BORING COMPLETED 5/3/2013				



LEGEND

* Sample Not Recovered

⌶ 2" O.D. Split Spoon (SPT)

◇ % Fines (<0.075mm)

● % Water Content

Plastic Limit ├─●─┤ Liquid Limit

Natural Water Content

NOTES

1. The boring was performed using hollow stem auger drilling methods.
2. The stratification lines represent the approximate boundaries between soil types, and the transition may be gradual.
3. Refer to the report text for a proper understanding of the subsurface materials.
4. Groundwater level, if indicated above, is for the date specified and may vary.
5. Refer to KEY for explanation of symbols, codes and definitions.
6. USCS designation is based on visual-manual classification and selected lab testing.

Phase 2 Combined Sewer Overflow Project
Port Angeles, Washington

LOG OF BORING B-3

April 2014 21-1-20617-011

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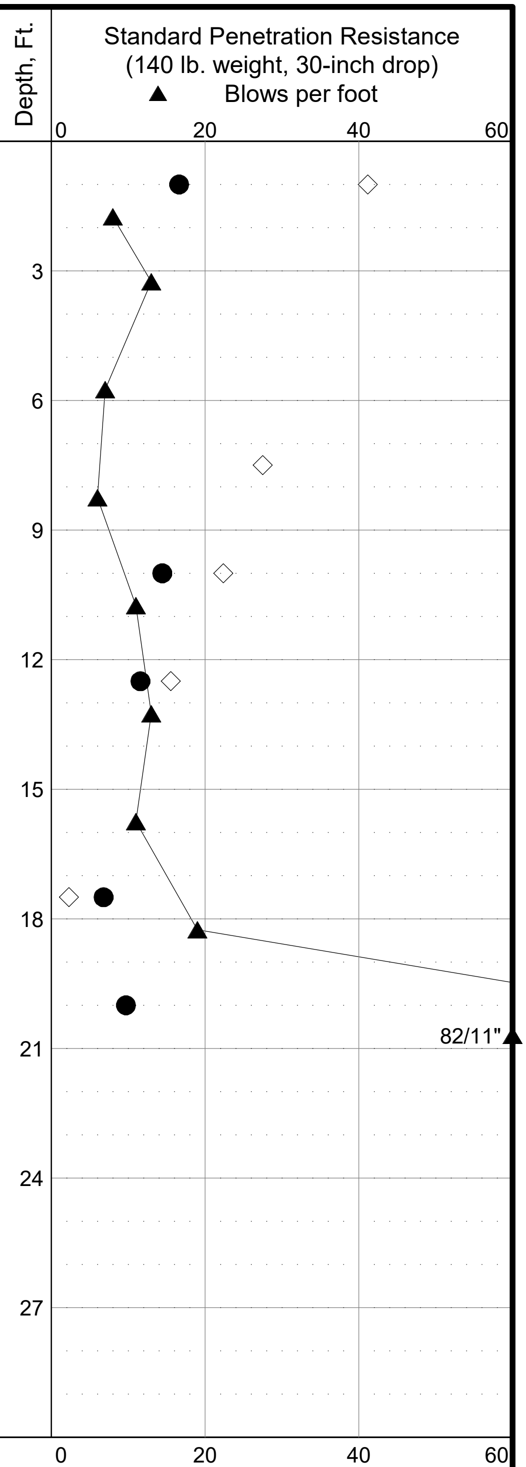
FIG. A-3

REV 2

SOIL DESCRIPTION Coordinates: N: ~ E: ~ Ground Surface Elevation: Approx. 24 Ft.	Depth, Ft.	Samples
ASPHALT		
Loose to medium dense, brown, silty, fine to medium SAND; moist; (Hf) SM.	0.9	1, 2
Loose to medium dense, gray-brown, gravelly, silty SAND; moist; trace of concrete, slight cement odor; (Hf) SM.	4.0	3, 4, 5
Medium dense, gray to dark gray, silty, sandy GRAVEL to sandy GRAVEL, trace of silt; wet; interbedded; (Hb) GM/GP.	11.5	6, 7, 8
Dense to very dense, gray, silty, sandy GRAVEL; wet; (Qvro) GM.	18.0	9
BOTTOM OF BORING COMPLETED 5/3/2013	21.4	

Symbol | Ground Water



LEGEND

* Sample Not Recovered

⌶ 2" O.D. Split Spoon (SPT)

◇ % Fines (<0.075mm)

● % Water Content

Plastic Limit ├─●─┤ Liquid Limit

Natural Water Content

NOTES

1. The boring was performed using hollow stem auger drilling methods.
2. The stratification lines represent the approximate boundaries between soil types, and the transition may be gradual.
3. Refer to the report text for a proper understanding of the subsurface materials.
4. Groundwater level, if indicated above, is for the date specified and may vary.
5. Refer to KEY for explanation of symbols, codes and definitions.
6. USCS designation is based on visual-manual classification and selected lab testing.

Phase 2 Combined Sewer Overflow Project
Port Angeles, Washington

LOG OF BORING B-4

April 2014 21-1-20617-011

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FIG. A-4

REV 2

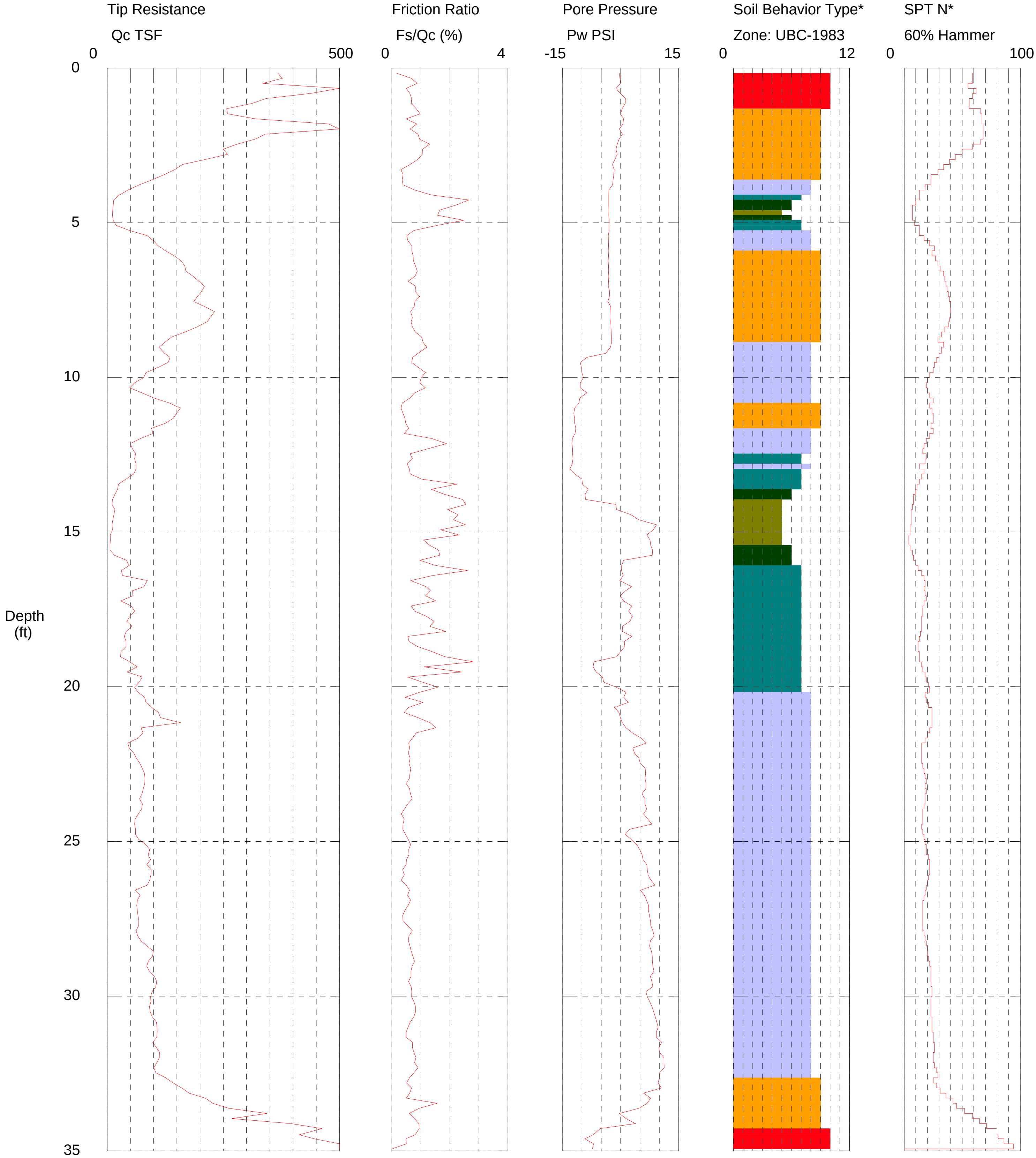
Log: DPO Rev: EAS Typ: CLP

MASTER_LOG_FINE 21-20617.GPJ 21-09490.GPJ 4/7/14

Shannon and Wilson

Operator: Gerdes
Sounding: CPT-1
Cone Used: DDG1238

CPT Date/Time: 4/26/2013 3:59:30 PM
Location: Port Angeles CSO Phase 4
Job Number: 21-1-20617-004



Maximum Depth = 34.94 feet

Depth Increment = 0.164 feet

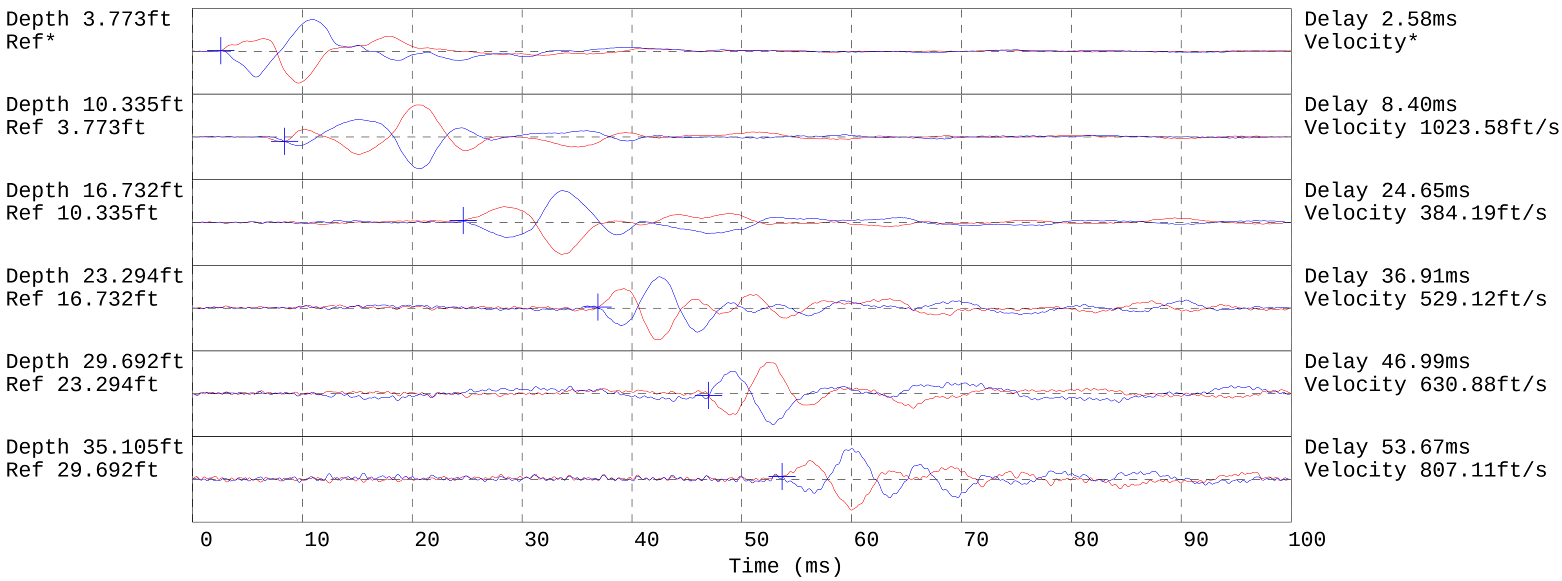
1 sensitive fine grained
2 organic material
3 clay
4 silty clay to clay
5 clayey silt to silty clay
6 sandy silt to clayey silt
7 silty sand to sandy silt
8 sand to silty sand
9 sand
10 gravelly sand to sand
11 very stiff fine grained (*)
12 sand to clayey sand (*)

InSitu Engineering

*Soil behavior type and SPT based on data from UBC-1983

FIG. A-5

Shear Wave Arrival Plots
CPT-01 Port Angeles CSO

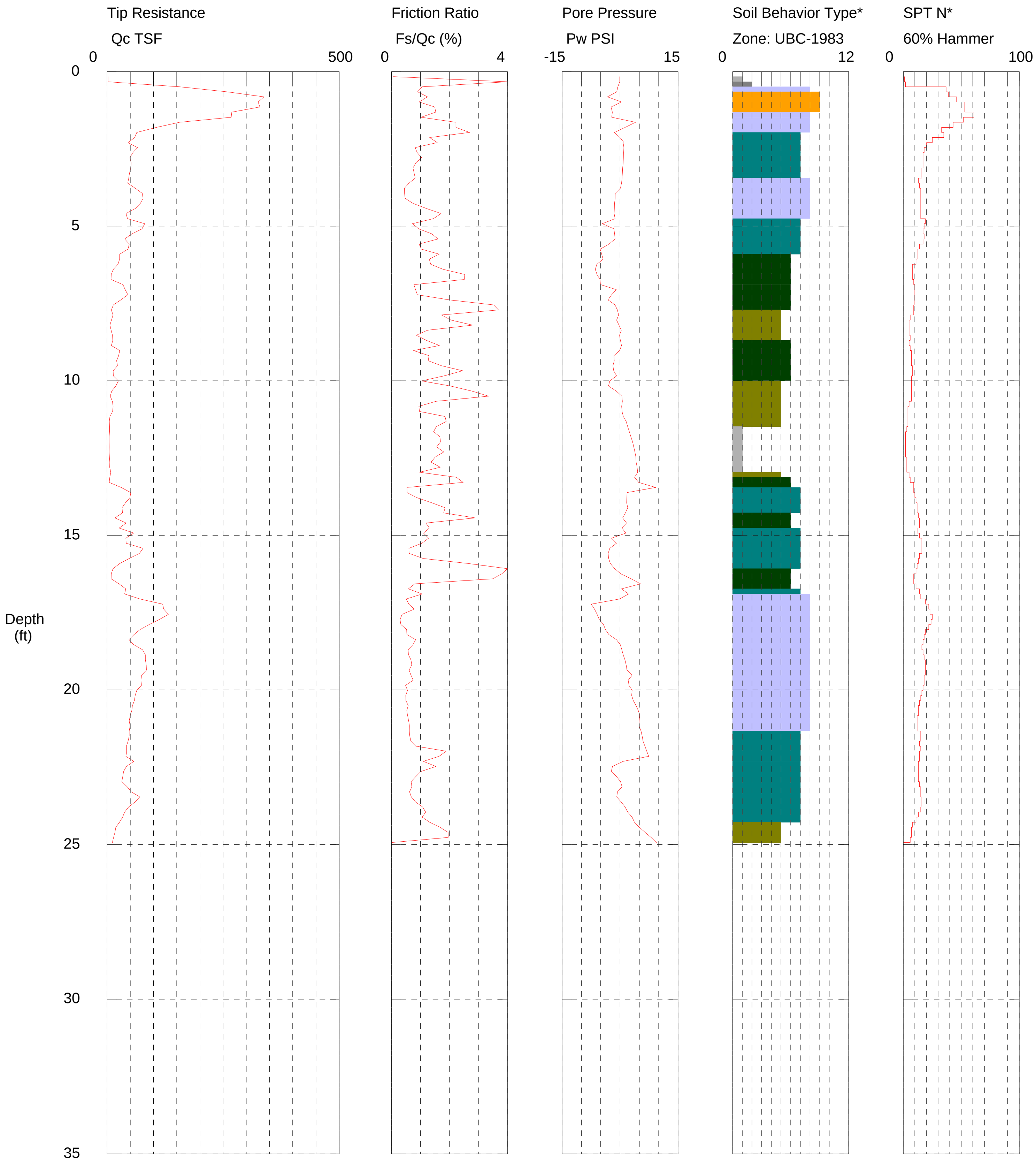


Hammer to Rod String Distance 0.9 (m)
* = Not Determined

Shannon and Wilson

Operator: Gerdes
Sounding: CPT-2
Cone Used: DDG1238

CPT Date/Time: 4/26/2013 3:12:01 PM
Location: Port Angeles CSO Phase 4
Job Number: 21-1-20617-004



Maximum Depth = 24.93 feet
Depth Increment = 0.164 feet

1 sensitive fine grained	4 silty clay to clay	7 silty sand to sandy silt	10 gravelly sand to sand
2 organic material	5 clayey silt to silty clay	8 sand to silty sand	11 very stiff fine grained (*)
3 clay	6 sandy silt to clayey silt	9 sand	12 sand to clayey sand (*)

InSitu Engineering Predrilled 1 foot

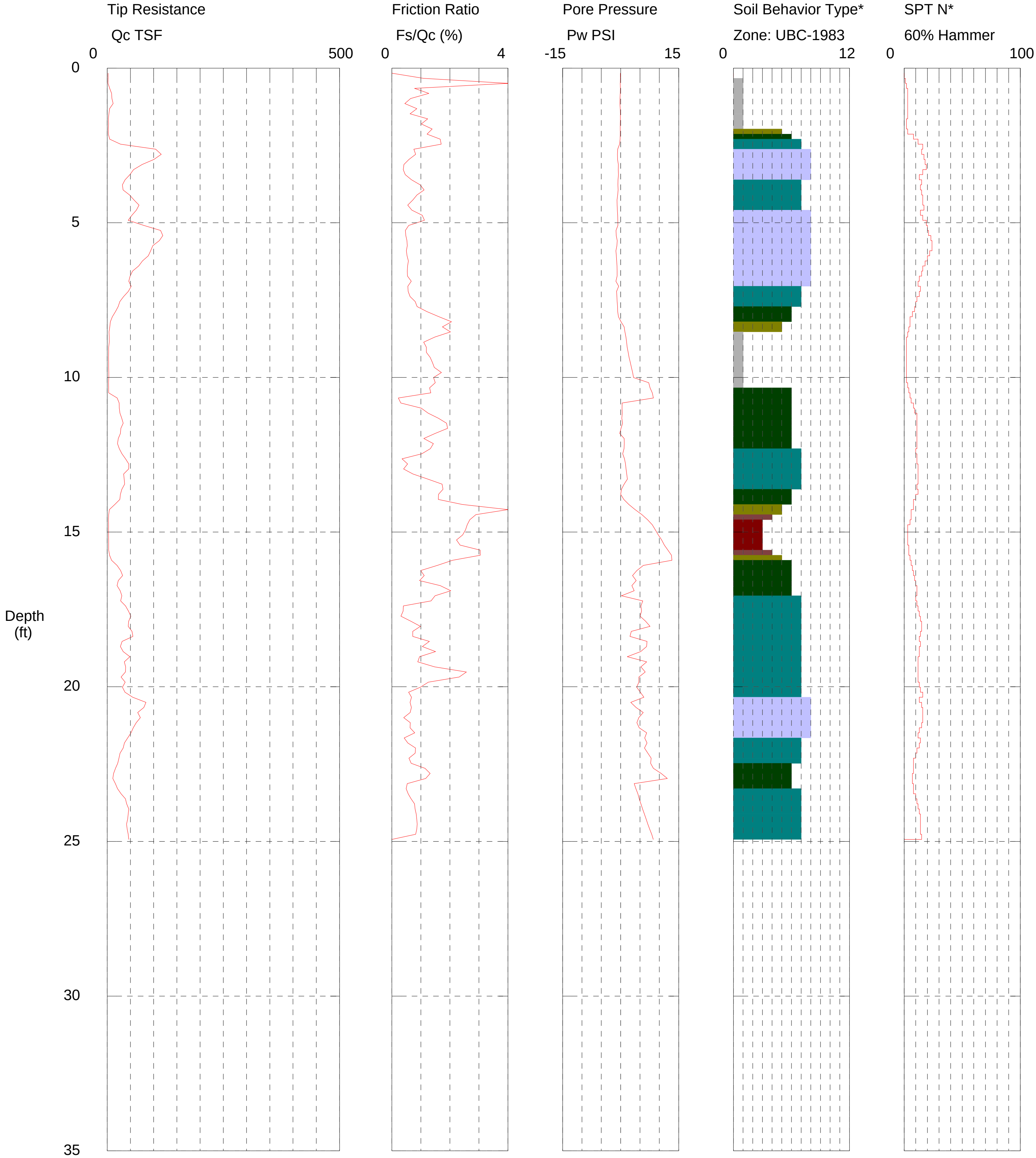
*Soil behavior type and SPT based on data from UBC-1983

FIG. A-7

Shannon and Wilson

Operator: Brown
Sounding: CPT-3
Cone Used: DDG1238

CPT Date/Time: 4/26/2013 2:41:28 PM
Location: Port Angeles CSO Phase 4
Job Number: 21-1-20617-004



Maximum Depth = 24.93 feet

Depth Increment = 0.164 feet

1 sensitive fine grained	4 silty clay to clay	7 silty sand to sandy silt	10 gravelly sand to sand
2 organic material	5 clayey silt to silty clay	8 sand to silty sand	11 very stiff fine grained (*)
3 clay	6 sandy silt to clayey silt	9 sand	12 sand to clayey sand (*)

InSitu Engineering Predrilled 2 feet

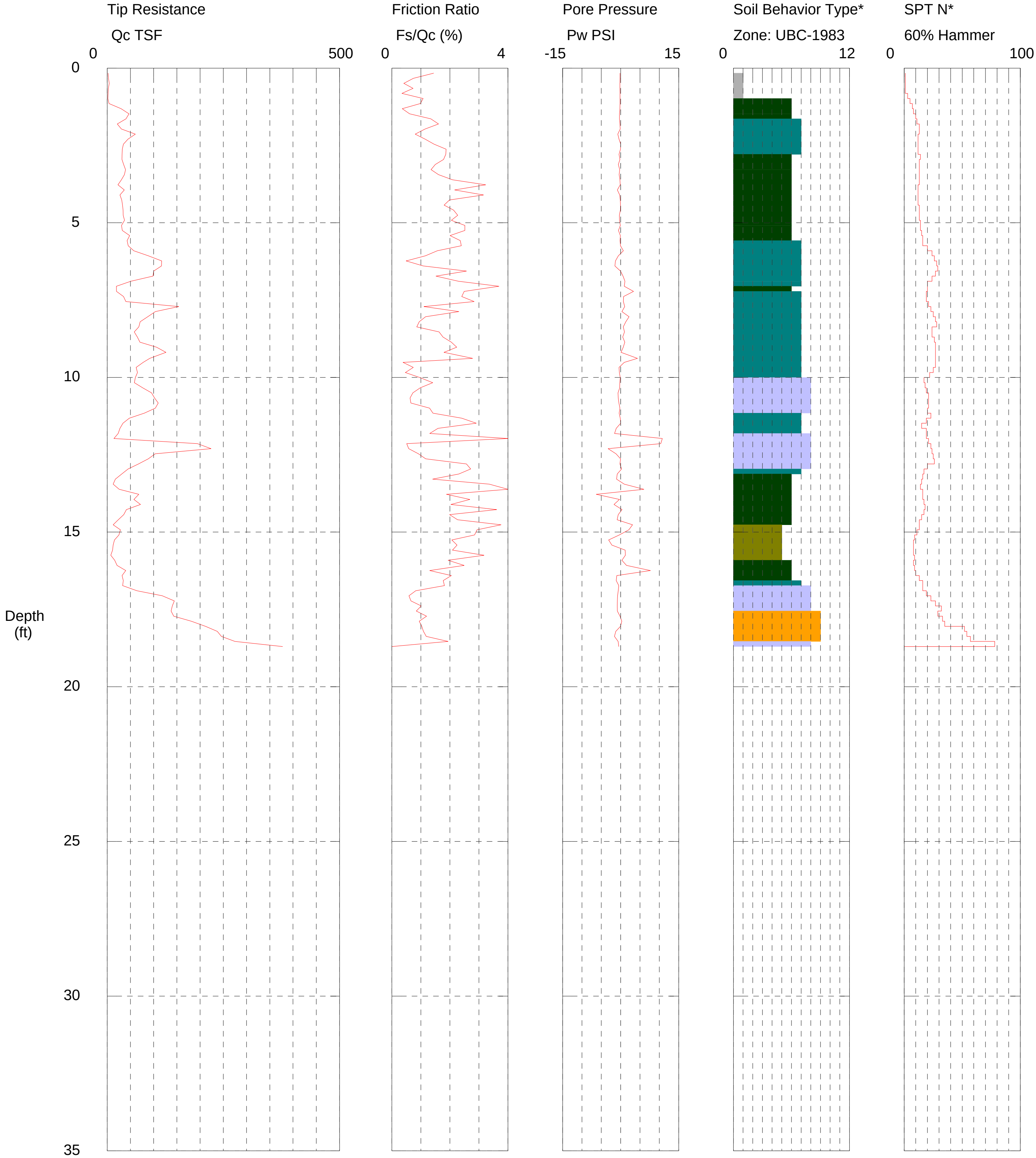
*Soil behavior type and SPT based on data from UBC-1983

FIG. A-8

Shannon and Wilson

Operator: Gerdes
Sounding: CPT-4
Cone Used: DDG1238

CPT Date/Time: 4/26/2013 12:55:41 PM
Location: Port Angeles CSO Phase 4
Job Number: 21-1-20617-004



Maximum Depth = 18.70 feet

Depth Increment = 0.164 feet

1 sensitive fine grained
2 organic material
3 clay
4 silty clay to clay
5 clayey silt to silty clay
6 sandy silt to clayey silt
7 silty sand to sandy silt
8 sand to silty sand
9 sand
10 gravelly sand to sand
11 very stiff fine grained (*)
12 sand to clayey sand (*)

InSitu Engineering Predrilled 3 feet. Refused at 19 feet.

*Soil behavior type and SPT based on data from UBC-1983

FIG. A-9

APPENDIX B

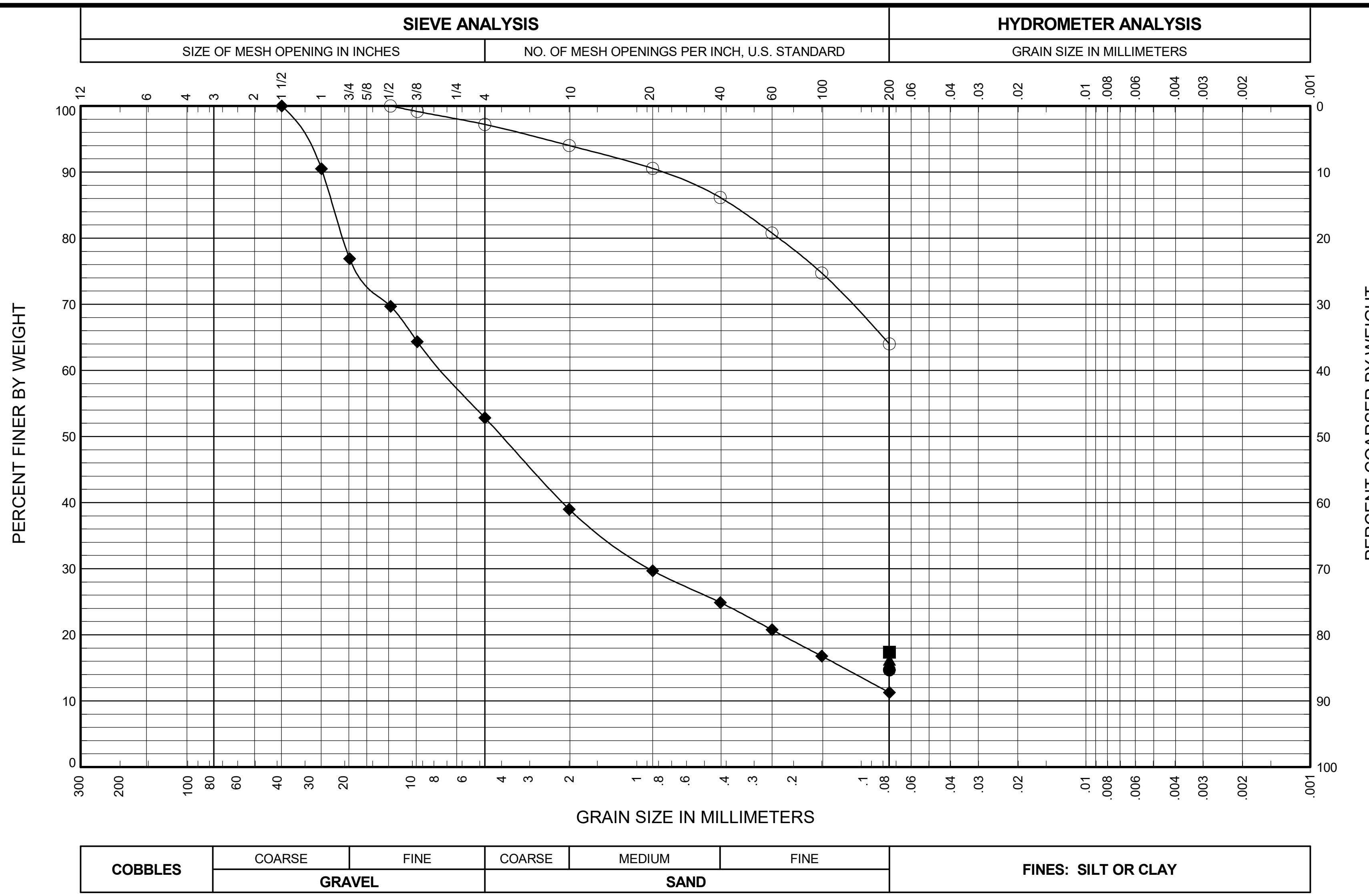
LABORATORY TESTS

APPENDIX B

LABORATORY TESTS

TABLE OF CONTENTS

FIGURES



GSAMAIN1 21-20617.GPJ 21-09490.GPJ 4/7/14

BORING AND SAMPLE NO.	DEPTH (feet)	U.S.C.S. SYMBOL	SAMPLE DESCRIPTION	FINES %	NAT. W.C. %	LL %	PL %	PI %
● B-1, S-4	7.5	SM	Brown, silty, fine to medium SAND; trace of organics	14.7	22.7			
■ B-1, S-7	15.3	SM	Dark gray, slightly gravelly, silty SAND; scattered organics and shell fragments	17.4	24.1			
▲ B-1, S-11	30.0	SM	Dark gray, silty SAND, trace of fine gravel; trace of shell fragments	16.2	21.0			
◆ B-1, S-12	35.0	GW-GM	Gray, slightly silty, sandy GRAVEL	11.3	8.0			
○ B-1, S-15	50.0	ML	Gray-brown, sandy SILT, trace of clay and fine gravel	64.0	17.4			

Phase 2 Combined Sewer Overflow Project
Port Angeles, Washington

GRAIN SIZE DISTRIBUTION
BORING B-1

April 2014 21-1-20617-011

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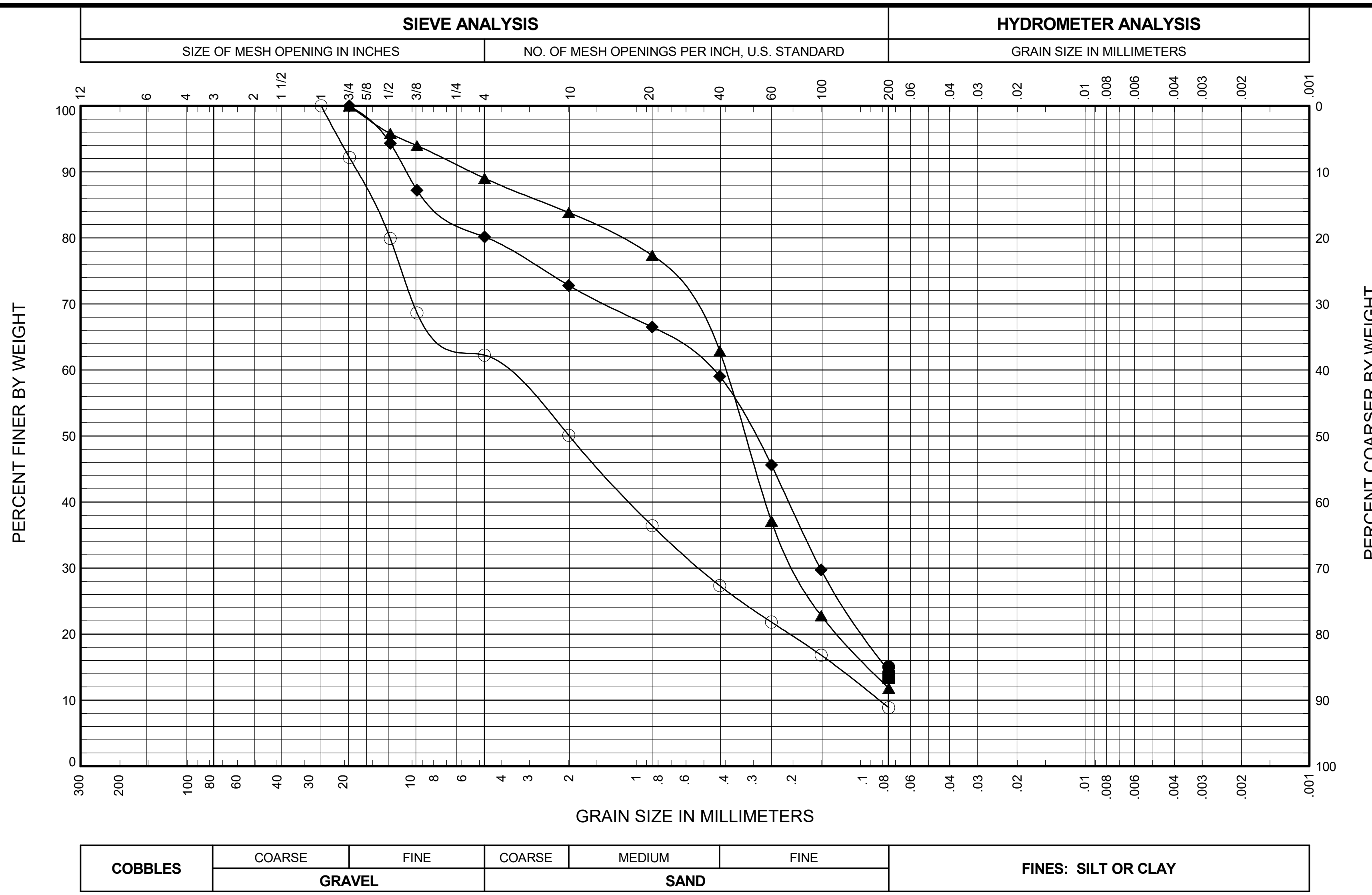
FIG. B-1

FIG. B-1



GSAMAIN1 21-20617.GPJ 21-09490.GPJ 4/7/14

BORING AND SAMPLE NO.	DEPTH (feet)	U.S.C.S. SYMBOL	SAMPLE DESCRIPTION	FINES %	NAT. W.C. %	LL %	PL %	PI %
● B-3, S-2	2.5	SM	Brown, slightly gravelly, silty SAND	15.0	16.4			
■ B-3, S-3	5.0	SM	Brown, slightly gravelly, silty SAND	13.4	15.8			
▲ B-3, S-5	10.0	SW-SM	Brown, slightly fine gravelly, slightly silty SAND	11.8	14.6			
◆ B-3, S-6	12.5	SM	Brown, silty, fine gravelly SAND	14.4	13.7			
○ B-3, S-9	20.0	SP-SM	Gray-brown, slightly silty, gravelly SAND	8.9	8.4			

Phase 2 Combined Sewer Overflow Project
Port Angeles, Washington

GRAIN SIZE DISTRIBUTION BORING B-3

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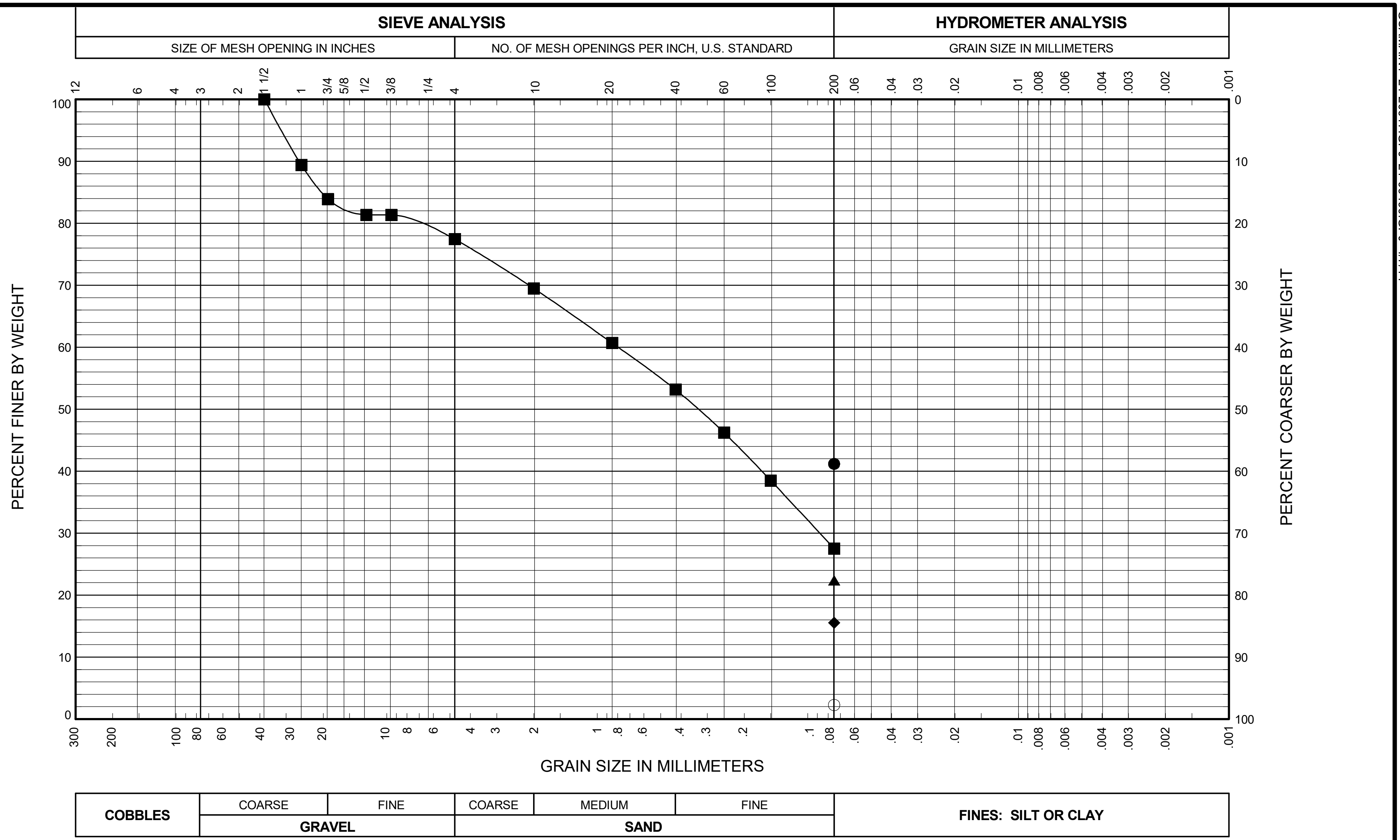
FIG. B-2

FIG. B-2



BORING AND SAMPLE NO.	DEPTH (feet)	U.S.C.S. SYMBOL	SAMPLE DESCRIPTION	FINES %	NAT. W.C. %	LL %	PL %	PI %
● B-4, S-1	1.0	SM	Brown, silty, fine to medium SAND	41.2	16.6			
■ B-4, S-4	7.5	SM	Gray-brown, gravelly, silty SAND; trace of concrete	27.5				
▲ B-4, S-5	10.0	SM	Gray-brown, silty, gravelly SAND	22.4	14.4			
◆ B-4, S-6	12.5	GM	Gray, silty, sandy GRAVEL	15.6	11.6			
○ B-4, S-8	17.5	GP	Gray, sandy GRAVEL, trace of silt	2.3	6.8			

Phase 2 Combined Sewer Overflow Project
Port Angeles, Washington

GRAIN SIZE DISTRIBUTION
BORING B-4

April 2014 21-1-20617-011

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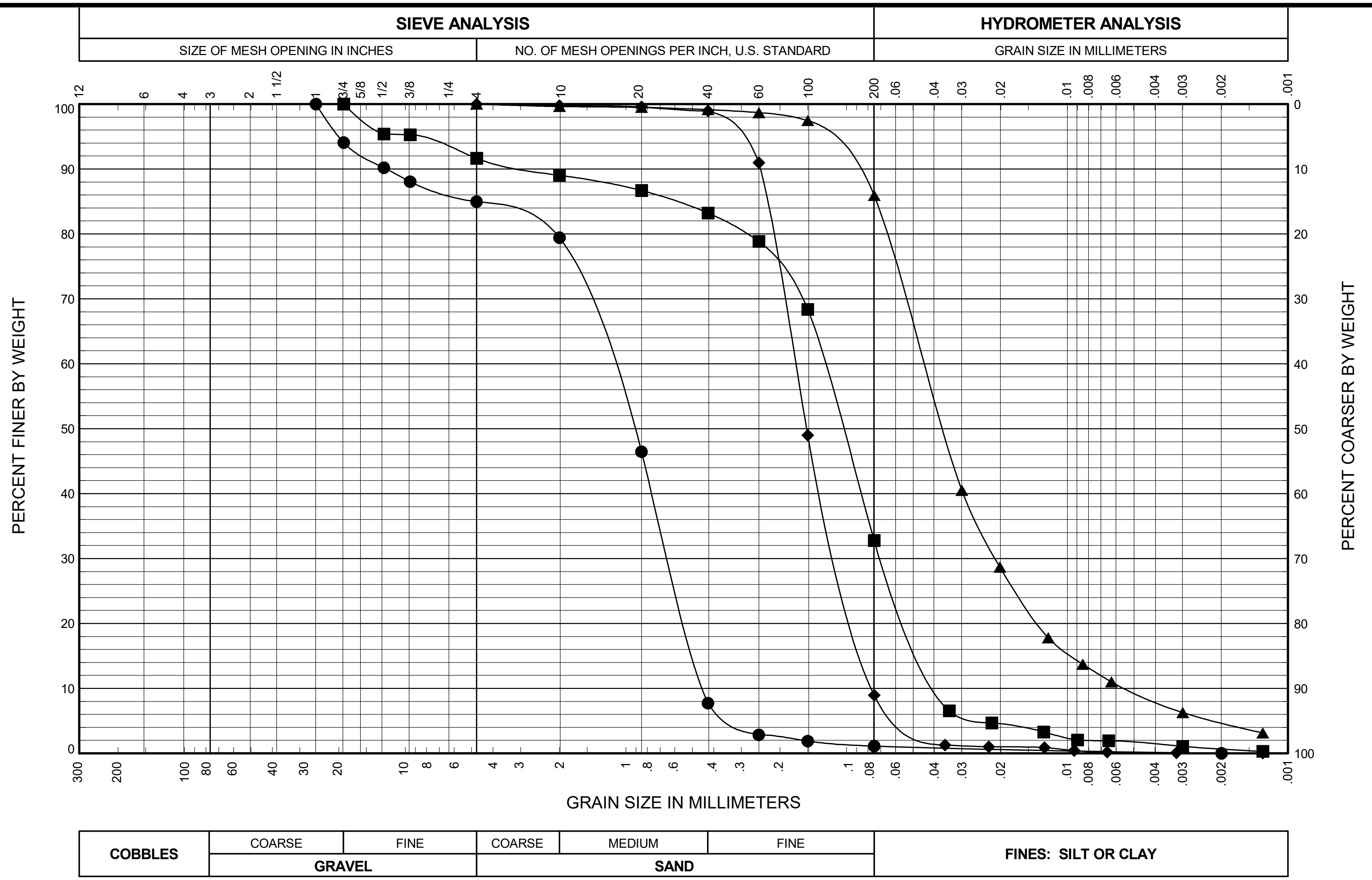
FIG. B-3

FIG. B-3



BORING AND SAMPLE NO.	DEPTH (feet)	U.S.C.S. SYMBOL	SAMPLE DESCRIPTION	FINES %	NAT. W.C. %	LL %	PL %	PI %
● TP-1, S-2	4.5	SP	Gray-brown, gravelly SAND, trace of silt	1.1	3.4			
■ TP-2, S-2	4.0	SM	Gray-brown, slightly fine gravelly, silty SAND; trace of organics	32.8	13.8			
▲ TP-2, S-3	5.5	ML	Gray, slightly fine sandy SILT	85.9	34.6			
◆ TP-2, S-6	7.5	SP-SM	Gray-brown, slightly silty, fine SAND	8.9	6.4			

Phase 2 Combined Sewer Overflow Project
Port Angeles, Washington

GRAIN SIZE DISTRIBUTION
TEST PITS TP-1 AND TP-2

April 2014 | 21-1-20617-011

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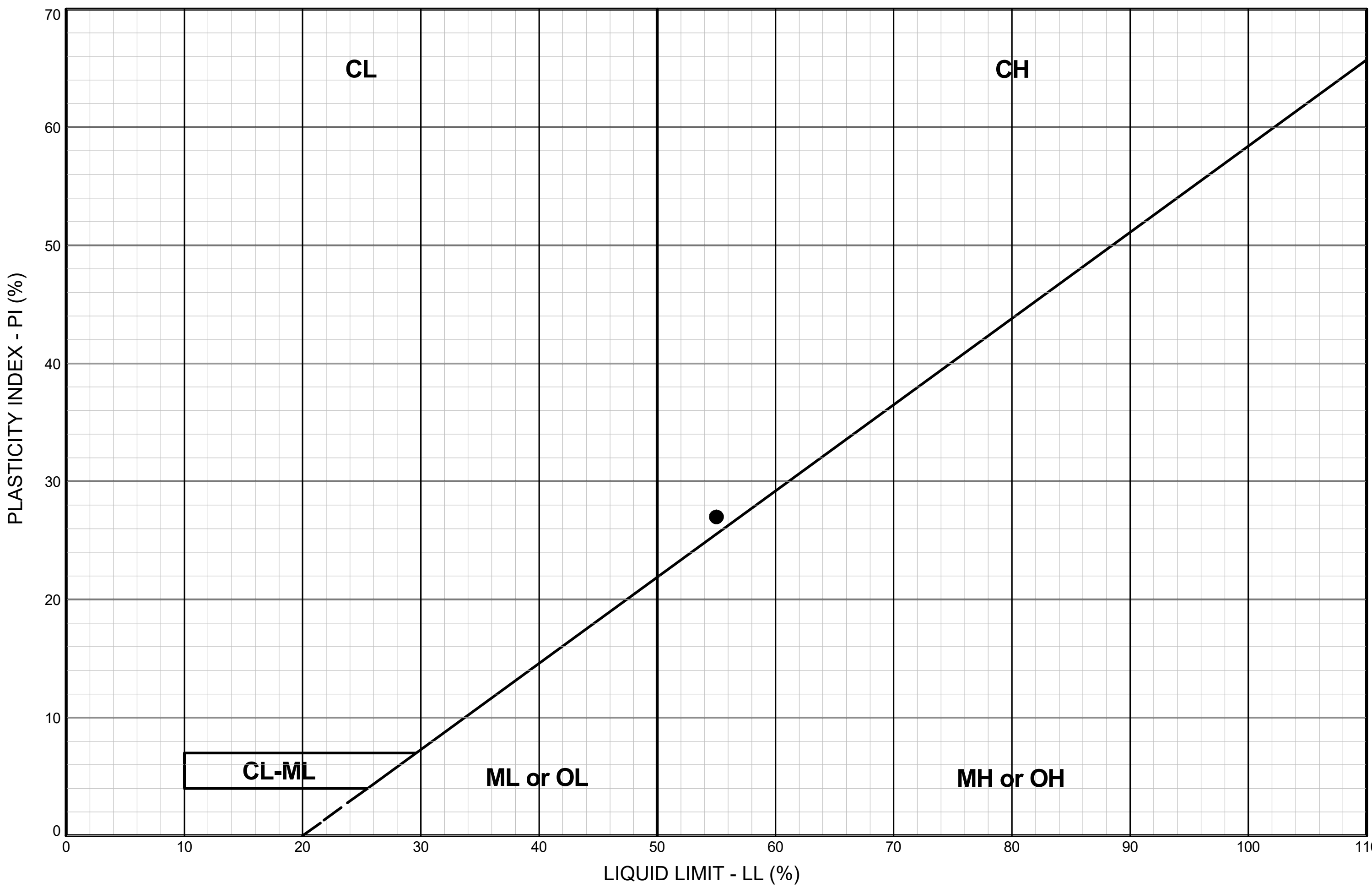
FIG. B-4

FIG. B-4



LEGEND

CL: Low plasticity inorganic clays; sandy and silty clays

CH: High plasticity inorganic clays

ML or OL: Inorganic and organic silts and clayey silts of low plasticity

MH or OH: Inorganic and organic silts and clayey silts of high plasticity

CL-ML: Silty clays and clayey silts

BORING AND SAMPLE NO.	DEPTH (feet)	U.S.C.S. SYMBOL	SOIL CLASSIFICATION	LL %	PL %	PI %	NAT. W.C. %	PASS. #200, %
● B-1, S-7	15.0	CH	Gray, silty CLAY, trace of coarse sand; scattered fine organics	55	28	27	51.3	

Phase 2 Combined Sewer Overflow Project
Port Angeles, Washington

PLASTICITY CHART
BORING B-1

April 2014 21-1-20617-011

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FIG. B-5

APPENDIX C

LOGS OF PREVIOUS BORINGS

Soil Classification System

Major Divisions			Symbol	Name
Coarse Grained Soils More Than 50% Retained on No. 200 Sieve	GRAVEL More than 50% of coarse fraction retained on No. 4 Sieve	CLEAN GRAVEL	GW	Well Graded, Fine to Coarse Gravel
			GP	Poorly graded gravel
		GRAVEL WITH FINES	GM	Silty gravel
			GC	Clayey gravel
	SAND More than 50% of coarse fraction passes No. 4 Sieve	CLEAN SAND	SW	Well graded, fine to coarse sand
			SP	Poorly graded sand
		SAND WITH FINES	SM	Silty sand
			SC	Clayey sand
Fine Grained Soils More than 50% passes No. 200 Sieve	Silt and Clay Liquid Limit Less than 50%	Inorganic	ML	Low plasticity silt
			CL	Low plasticity clay
		Organic	OL	Organic silt, organic clay
	Silt and Clay Liquid Limit greater than 50%	Inorganic	MH	High plasticity silt
			CH	High plasticity clay, fat clay
		Organic	OH	Organic clay,organic silt
Highly Organic Soils			PT	Peat

Soil Classification Guidelines

Granular Soils		Cohesive Soils		
Relative Density	Standard Penetration Resistance	Consistency	Standard Penetration Resistance	Unconfined Compressive Strength (TSF)
Very Loose	0-4	Very Soft	Less than 2	Less than .25
Loose	4-10	Soft	2-4	.25-.50
Medium Dense	10-30	Medium Stiff	4-8	.50-1.0
Dense	30-50	Stiff	8-15	1.0-2.0
Very Dense	More than 50	Very Stiff	15-30	2.0-4.0
		Hard	More than 30	More than 4.0

Grain Size Classification

		Subclassification	
Boulders	12-36 Inches		
Cobbles	3-12 Inches		Percentage of other material in sample
Gravel	3/4 - 3 Inches (coarse)	Clean	0 - 2
	1/4 - 3/4 Inches (fine)	Trace	2 - 10
Sand	No. 10-No. 4 Sieve (Coarse)	Some	10 - 30
	No. 10-No. 40 Sieve (medium)	Sandy, Silty, Clayey, ETC.	30 - 50
	No. 40 - No. 200 Sieve (fine)		

Dry = very low moisture, dry to the touch; Moist = damp, without visible moisture; Wet = saturated, with visible free water.

NTI ENGINEERING & LAND SURVEYING	SOIL CLASSIFICATION SYSTEM AND GUIDELINES
	Appendix A-1

Geotechnical Boring Log

Project Name	2010 CSO Improvments Phase I	Sheet 1 of 1	
Project No.	BRCA 1001	Date	10/14/2010
Location	City of Port Angeles, 1st Street	Elevation	Approximately 10 to 15 feet
Inspector	Steve Luxton PE, Kate O'Claire PE	Datum	
Driller/Rig Type	Boart Longyear B59 Mobile Auger	Boring Location:	
Sample Types / Core Size:	SPT test & 1 5/8" cores		B1 - At Valley and 1st Street

Sample # / Core Run #	Depth Intv./ Run Length	Inches Driven	SPT N-Value	% Recovery	Blows Per 6"	Depth (ft.)	Sample Description SOIL: Relative Density; Color: Soil Type; Moisture Content; Descritors; Hard Brown Sandy Clay, Dry with Trace Gravel, Cenentation, Air Voids etc. ROCK: Hardness, Weathering, Color, Texture, Lithology, Bedding, Foliation, Discontinuities: Orientation, Spacing, Roughness, Weathering, Aperture, Filling
						1	12" DIA Core = 2" A/C + 10" Concrete
1.0		18"	40	5%	10 23	2	Brown Sandy GRAVEL w/ Silt Rock Jammed in Sampler
					25	3	
						4	
						5	
5.0		18"	6		5 3	6	Blue-Gray Fine Clayey SILT, w/ Gravel Loose to Medium Dense, Moist
					3	7	
						8	Cuttings Are Gray Clayey SILT Gooey, Semi-Liquid
						9	
						10	
10.0		18"	13		4 5	1	Dark Gray Sandy SILT, Loose To Medium Dense, Wet
					8	2	Water Level In Auger = 10 to 12 Ft. +/- At 9:00 am - Tide at 5Ft. +/-
						3	Cuttings Are Gray Sandy SILT
						4	
15.0		18"	15		2 7	15	
					9	6	Gray Silty Fine SAND, Loose, Wet Interbedded w/ Fine Sandy GRAVEL Med. Dense Some Sand Heaving Into Auger
						7	Cuttings Are Gray Silty Very Fine SAND
						8	
						9	Water in Cuttings Is Only Slightly Brackish
						20	
20.0		18"	10		6 6	1	Dark Gray Silty Fine SAND w/ Gravel, Wet, Loose To Medium Dense, Found Wood Debris in Sampler
					6		

Boring No. B1

NTI Engineering & Surveying, Inc.
717 South Peabody, Port Angeles, WA 98362
(360) 452-8491

Geotechnical Boring Log

Project Name: 2010 CSO Improvments Phase I
Project No.: BRCA 1001
Location: City of Port Angeles, 1st Street
Inspector: Steve Luxton PE, Kate O'Claire PE
Driller/Rig Type: Boart Longyear B59 Mobile Auger
Sample Types / Core Size: SPT test & 1 5/8" cores

Sheet 1 of 1
Date: 10/14/2010
Elevation: Approximately 10 to 15 feet
Datum:
Boring Location: B2 - Near 316 1st Street

Sample # / Core Run #	Depth Intv./ Run Length	Inches Driven	SPT N-Value	% Recovery	Blows Per 6"	Depth (ft.)	Sample Description SOIL: Relative Density; Color: Soil Type; Moisture Content; Descritors; Hard Brown Sandy Clay, Dry with Trace Gravel, Cenentation, Air Voids etc. ROCK: Hardness, Weathering, Color, Texture, Lithology, Bedding, Foliation, Discontinuities: Orientation, Spacing, Roughness, Weathering, Aperture, Filling
						1	12" DIA Core = 2" A/C + 10" Concrete
1.5		18"	1		0	2	Yellow - Brown Fine Silty SAND, Moist Loose to Very Loose
					0 1	3	
						4	
						5	
5.0		18"	18		5 11	6	Yellow Brown Silty Fine SAND w/ Clay, Loose to Medium Dense, Slight Organic Odor, Moist
					7	7	
						8	
						9	
						10	
10.0		18"	17		0 5	1	Gray - Brown Silty Fine SAND, Wet Interbedded with Green-Brown Silty CLAY, Wet Both Loose to Medium Dense
					12	2	
						3	
						4	
						15	
						6	
						7	
						8	
						9	
						20	
						1	

Boring No. B2

NTI Engineering & Surveying, Inc.
717 South Peabody, Port Angeles, WA 98362
(360) 452-8491

Geotechnical Boring Log

Project Name	2010 CSO Improvments Phase I	Sheet 1 of 1	
Project No.	BRCA 1001	Date	10/14/2010
Location	City of Port Angeles, 1st Street	Elevation	Approximately 10 to 15 feet
Inspector	Steve Luxton PE, Kate O'Claire PE	Datum	
Driller/Rig Type	Boart Longyear B59 Mobile Auger	Boring Location:	
Sample Types / Core Size:	SPT test & 1 5/8" cores		B3 - At 1st Street Armory Square Entry

Sample # / Core Run #	Depth Intv./ Run Length	Inches Driven	SPT N-Value	% Recovery	Blows Per 6"	Depth (ft.)	Sample Description SOIL: Relative Density; Color: Soil Type; Moisture Content; Descritors; Hard Brown Sandy Clay, Dry with Trace Gravel, Cenentation, Air Voids etc. ROCK: Hardness, Weathering, Color, Texture, Lithology, Bedding, Foliation, Discontinuities: Orientation, Spacing, Roughness, Weathering, Aperture, Filling
						1	12" DIA Core = 2" A/C + 10" Concrete
1.5	18"		9		2	2	Brown Fine SAND, Moist, Loose
					5 4	3	
						4	Cuttings Are Fine Moist SAND
						5	
5.0	18"		6+		0 0	6	Brown Clayey SILT w/ Sand, Moist Very Loose
					6	7	
						8	
						9	
						10	
10.0	18"		4		1 2	1	Blue-Gray Fine Sandy SILT, Very Loose; Over Gray Clayey Silt w/ Gravel, Moist And Loose. Deposits Are Stratified.
					2	2	
						3	
						4	
						15	
						6	
						7	
						8	
						9	
						20	
						1	

Boring No. B3

NTI Engineering & Surveying, Inc.
717 South Peabody, Port Angeles, WA 98362
(360) 452-8491

Geotechnical Boring Log

Project Name	2010 CSO Improvments Phase I	Sheet 1 of 1	
Project No.	BRCA 1001	Date	10/14/2010
Location	City of Port Angeles, 1st Street	Elevation	Approximately 10 to 15 feet
Inspector	Steve Luxton PE, Kate O'Claire PE	Datum	
Driller/Rig Type	Boart Longyear B59 Mobile Auger	Boring Location:	B4 - 1st Street at "Lamonts"
Sample Types / Core Size:	SPT test & 1 5/8" cores		

Sample # / Core Run #	Depth Intv./ Run Length	Inches Driven	SPT N-Value	% Recovery	Blows Per 6"	Depth (ft.)	Sample Description SOIL: Relative Density; Color: Soil Type; Moisture Content; Descritors; Hard Brown Sandy Clay, Dry with Trace Gravel, Cenentation, Air Voids etc. ROCK: Hardness, Weathering, Color, Texture, Lithology, Bedding, Foliation, Discontinuities: Orientation, Spacing, Roughness, Weathering, Aperture, Filling
						1	12" DIA Core = 2" A/C + 10" Concrete
1.5		18"	5		2	2	Gray Brown Clayey SILT, Loose, Moist; Grading to Blue-Gray Silty CLAY Trace of Wood and Charcoal, Loose, Moist
					2		
					3	3	
						4	
						5	
5.0		18"	9		3		Brown Fine Sandy SILT w/ Clay, Loose to Medium Dense Interbedded w/ Fine Brown SAND, Moist
					3	6	
					6		
						7	Drill Cuttings are Brown Fine Clayey SAND Loose and Gooey, Moist Appears to be Sensitive - Reworks To Semi - Liquid State.
						8	
						9	
						10	
10.0		18"	6		3		Blue-Brown Clayey SILT, Moist and Loose Interbedded w/ Brown SILT (Lacustrine)? Both Loose to Very Loose
					3	1	
					3		
						2	
						3	
						4	
						15	
						6	
						7	
						8	
						9	
						20	
						1	

Boring No. B4

NTI Engineering & Surveying, Inc.
717 South Peabody, Port Angeles, WA 98362
(360) 452-8491

Geotechnical Boring Log

Project Name	2010 CSO Improvments Phase I	Sheet 1 of 1	
Project No.	BRCA 1001	Date	10/14/2010
Location	City of Port Angeles, 1st Street	Elevation	Approximately 10 to 15 feet
Inspector	Steve Luxton PE, Kate O'Claire PE	Datum	
Driller/Rig Type	Boart Longyear B59 Mobile Auger	Boring Location:	B5 - First Street #452 (Fiddleheads)
Sample Types / Core Size:	SPT test & 1 5/8" cores		

Sample # / Core Run #	Depth Intv./ Run Length	Inches Driven	SPT N-Value	% Recovery	Blows Per 6"	Depth (ft.)	Sample Description SOIL: Relative Density; Color: Soil Type; Moisture Content; Descritors; Hard Brown Sandy Clay, Dry with Trace Gravel, Cenentation, Air Voids etc. ROCK: Hardness, Weathering, Color, Texture, Lithology, Bedding, Foliation, Discontinuities: Orientation, Spacing, Roughness, Weathering, Aperture, Filling
						1	12" DIA Core = 2" A/C + 10" Concrete
1.0		18"	14	80%	7 9 5	2	Brown Sandy GRAVEL w/ Silt, Loose; Moist Underlain by Gray Sandy SILT, Medium Dense, Moist
						3	
						4	
						5	
5.0		18"	8	15	6 6 6	6	Blue Brown SILT w/ Clay, Moist, Medium Dense Rock Jammed in Sampler - Modified N
						7	
						8	Cuttings Are Loose And Gooey Brown SILT w/ Sand, Moist
						9	
						10	
10.0		18"	4		0 2 2	1	Brown Silty SAND w/ Silt Interbeds Very Loose, Moist
						2	
						3	
						4	
						15	
						6	
						7	
						8	
						9	
						20	
						1	

Boring No. B5

NTI Engineering & Surveying, Inc.
717 South Peabody, Port Angeles, WA 98362
(360) 452-8491

Geotechnical Boring Log

Project Name: 2010 CSO Improvments Phase I
Project No.: BRCA 1001
Location: City of Port Angeles, 1st Street
Inspector: Steve Luxton PE, Kate O'Claire PE
Driller/Rig Type: Boart Longyear B59 Mobile Auger
Sample Types / Core Size: SPT test & 1 5/8" cores

Sheet 1 of 1
Date: 10/14/2010
Elevation: Approximately 10 to 15 feet
Datum:
Boring Location: B6 - at 1st Street Fountain

Sample # / Core Run #	Depth Intv./ Run Length	Inches Driven	SPT N-Value	% Recovery	Blows Per 6"	Depth (ft.)	Sample Description SOIL: Relative Density; Color: Soil Type; Moisture Content; Descritors; Hard Brown Sandy Clay, Dry with Trace Gravel, Cenentation, Air Voids etc. ROCK: Hardness, Weathering, Color, Texture, Lithology, Bedding, Foliation, Discontinuities: Orientation, Spacing, Roughness, Weathering, Aperture, Filling
					6	1	12" DIA Core = 2 1/2 "A/C + 9" C.D.F
0.5		18"	15		7 8	2	Brown Fine Sandy SILT w/ Clay, Medium Dense to Dense, Moist
						3	
						4	
						5	Brown Sandy SILT w/ Clay, Medium Dense To Dense -
5.0		18"	35		10 9	6	
					25	7	
						8	
						9	
						10	
10.0		18"	50+		10 25	1	Brown Gravelly Coarse SAND, Moist, Dense Grades to Silty Gravel w/ Sand, To Very Dense
					25	2	
						3	
						4	
15.0		18"	50		8	15	Brown GRAVEL w/ Trace Silt, Well Graded Dense, Moist
					25 25	6	
						7	
						8	
						9	
20.0		18"	50		6	20	Brown Gravelly Coarse SAND w/ Red Mottling Moist, Found Shell Fragment at 18' +/- Very Dense
					25 25	1	

Boring No. B6

NTI Engineering & Surveying, Inc.
717 South Peabody, Port Angeles, WA 98362
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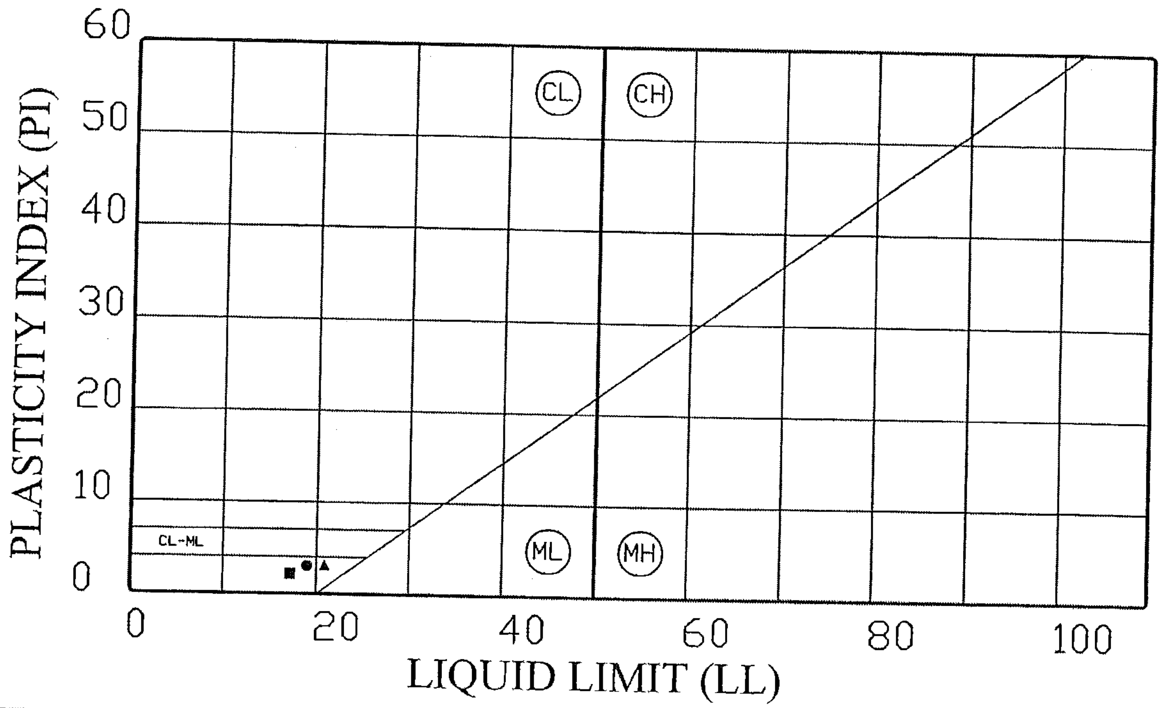
NTI ENGINEERING & SURVEYING
Engineers – Land Surveyors – Geologists
Construction Inspection – Materials Testing
NTI
717 SOUTH PEABODY, PORT ANGELES, WASHINGTON 98362, (360) 452-8491

LIQUID LIMIT, PLASTIC LIMIT AND PLASTICITY INDEX OF SOILS METHOD ASTM D4318



SYMBOL	SAMPLE	DEPTH (ft)	CLASSIFICATION	LL	PL	PI
●	B1	5.0	(ML) - Lean Silt	23	20	3
■	B2	5.0	(ML) - Lean Silt	17	13-17	0-4
▲	B3	10.0	(ML) - Lean Silt	23	20	3

APPENDIX A

ALKAI Boring Logs

Soil

Soil descriptions of exposed soil and soil samples on logs of subsurface explorations are based on ASTM D2488 Standard Practice for Description and Identification of Soils (Visual-Manual Procedure). Description includes Unified Soil Classification System (USCS) Classification, density consistency, moisture, and geologic interpretation. The criteria, descriptive terms and definitions are as follows:

Density or consistency

Density of Cohesionless soils	SPT (Blows per ft)	Consistency of Cohesive Soils	SPT (Blows per ft)
Very Loose	0-4	Very soft	0-2
Loose	5-10	Soft	3-4
Medium	11-30	Medium	5-8
Dense	31-50	Stiff	9-15
Very Dense	over 50	Very stiff	16-30
		Hard	over 30

Penetration Resistance

Standard Penetration Test (ASTM D-1586) – Number of blows required to drive a standard 2 inch O.D. split spoon sampler 6 inches with a 140 lb. Weight falling freely through 30 inches. Penetration values (N-values) are generally counted over the lower 12 inches of sampler penetration. In test pits, density or consistency is determined by probing and excavation difficulty.

Color

Basic colors and combinations: black, brown, gray, yellow-brown, etc.

Moisture Content

Dry Absence of moisture, dusty, dry to the touch.
Moist Damp but no visible water.
Wet Visible free water, usually soil is below water table.

Laboratory Testing Results

M.C. = Moisture Content
P.L. = Plastic Limit
L.L. = Liquid Limit
P.I. = Plasticity Index
Gravel: Material passing the 3-inch sieve but retained on the #4 standard sieve.
Sand: Material passing the #4 standard sieve but retained on the # 200 standard sieve.
-#200: Fines content. Material (clay or silt) passing the #200 standard Sieve.

Legend

BOE: Bottom of exploration
SPT: Split Spoon Sample
MPS: Maximum particle size
Solid line: Indicates contact between two geologic units
Dashed line: Indicates change in USCS classification of soils within the same geologic unit.

Note: In test borings sample often contains soil material 'cored' into the sampler after sampling had occurred resulting in grater recovery that the sample length. This material is incorporated into the collection sample.

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Log of Test Boring B-1

Project Name: Oak Street Development
Client: Zenovic and Associates
Project Number: ACL06-10-G102

Boring Elevation: 16'
Boring Location: See Site Plan
Depth to Groundwater: 40'

DEPTH (FT.)	USCS Classification	VISUAL PHYSICAL DESCRIPTION	SAMPLE NO.	DEPTH (FEET)	SAMPLE TYPE	BLOW COUNTS PER 6 INCHES	N VALUE	RECOVERY (INCHE)	LAB TESTING RESULTS FOR SAMPLE
0	SP-SM	Brown to gray SAND with silt and gravel (moist) (dense)	S-1	0	SPT	12 17 14	31	19	M.C.= 5% -200 = 12%
5	CH	Dark gray SAND at top of sampler (moist) (loose) Dark gray CLAY at bottom (moist) (medium stiff)	S-2	5	SPT	3 1 5	6	19	Top: M.C. = 7% -200 = 11% Bottom: M.C. = 57% -200 = 84% L.L. = 69% P.I. = 40%
10	SC	Dark gray clayey SAND with wood and crushed shells (wet) (medium stiff)	S-3	10	SPT	3 1 5	6	19	M.C. = 34% -200 = 35%
15		Same	S-4	15	SPT	1 2 3	4	19	M.C. = 28% -200 = 18%

Drill Contractor: Davies Drilling
Equipment: Mobile Track Mounted
Sampling Method: SPT
Driller: Rick

Drilling Date: 11/1/2006
ACL Representative: PZ

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Log of Test Boring B-1

Project Name: Oak Street Development
Client: Zenovic and Associates
Project Number: ACL06-10-G102

Boring Elevation:
Boring Location: Field
Depth to Groundwater: 40'

DEPTH (FT.)	USCS Classification	VISUAL PHYSICAL DESCRIPTION	SAMPLE NO.	DEPTH (FEET)	SAMPLE TYPE	BLOW COUNTS PER 6 INCHES	N VALUE	RECOVERY (INCH)	LAB TESTING RESULTS FOR SAMPLE
20		Same	S-5	20	SPT	2 3 4	7	19	M.C. = 23% -200 = 14%
25		Same	S-6	25	SPT	1 1 3	4	19	M.C. = 31% -200 = 34%
30		Same	S-7	30	SPT	2 4 4	8	19	M.C. = 30% -200 = 30%
35		Same, more gravel and shells	S-8	35	SPT	1 3 4	7	>1	
		Scattered gravels at 38'							
40									

Drill Contractor: Davies Drilling
Equipment: Mobile Track Mounted
Sampling Method: SPT
Driller: Rick

Drilling Date: 11/1/2006
ACL Representative: PZ

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Log of Test Boring B-1

Project Name: Oak Street Development
Client: Zenovic and Associates
Project Number: ACL06-10-G102

Boring Elevation:
Boring Location: Field
Depth to Groundwater: 40'

DEPTH (FT.)	USCS Classification	VISUAL PHYSICAL DESCRIPTION	SAMPLE NO.	DEPTH (FEET)	SAMPLE TYPE	BLOW COUNTS PER 6 INCHES	N VALUE	RECOVERY (INCH)	LAB TESTING RESULTS FOR SAMPLE
40	SP/GP	Gravelly SAND/sandy GRAVEL, blow count may be inflated by heave (wet) (very dense)	S-9	40	SPT	50/3"	100 +	3	
45		Same	S-10	45	SPT	50/5"	100 +	3	
		BOE 45' GW at 40' Heave at bottom of hole							
50									
55									
60									

Drill Contractor: Davies Drilling
Equipment: Mobile Track Mounted
Sampling Method: SPT
Driller: Rick

Drilling Date: 11/1/2006
ACL Representative: PZ

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Log of Test Boring B-2

Project Name: Oak Street Development
Client: Zenovic and Associates
Project Number: ACL06-10-G102

Boring Elevation: 16.25'
Boring Location: See Site Plan
Depth to Groundwater: 17'

DEPTH (FT.)	USCS Classification	VISUAL PHYSICAL DESCRIPTION	SAMPLE NO.	DEPTH (FEET)	SAMPLE TYPE	BLOW COUNTS PER 6 INCHES	N VALUE	RECOVERY (INCHE)	LAB TESTING RESULTS FOR SAMPLE
0		2" Asphaltic concrete							
5	SW-SM	Brown gravelly SAND with silt (moist) (medium dense to dense)	S-1	5	SPT	10 15 15	30	10	M.C. = 5% -200 = 9%
10	SM	Dark gray silty gravelly SAND (wet) (loose)	S-2	10	SPT	4 2 4	6	7	M.C. = 21% -200 = 24%
15	SP-SM	Gray fine SAND with silt (wet) (loose)	S-3	15	SPT	2 1 1	2	19	M.C. = 24% -200 = 9%

Drill Contractor: Davies Drilling
Equipment: Mobile Track Mounted
Sampling Method: SPT
Driller: Rick

Drilling Date: 11/1/2006
ACL Representative: PZ

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Log of Test Boring B-2

Project Name: Oak Street Development
Client: Zenovic and Associates
Project Number: ACL06-10-G102

Boring Elevation:
Boring Location: Parking lot
Depth to Groundwater: 17'

DEPTH (FT.)	USCS Classification	VISUAL PHYSICAL DESCRIPTION	SAMPLE NO.	DEPTH (FEET)	SAMPLE TYPE	BLOW COUNTS PER 6 INCHES	N VALUE	RECOVERY (INCH)	LAB TESTING RESULTS FOR SAMPLE
20	SP-SM	Dark gray gravelly SAND with silt (wet) (medium dense)	S-4	20	SPT	1 4 11	15	19	M.C. = 16% -200 = 9%
25	SM	Dark gray gravelly silty SAND with seashells (wet) (loose)	S-5	25	SPT	2 3 5	8	19	M.C. = 25% -200 = 20%
30		Same with decreasing gravel	S-6	30	SPT	1 4 6	10	19	M.C. = 25% -200 = 32%
35		Same	S-7	35	SPT	0 4 6	10	19	M.C. = 44% -200 = 44%
40									

Drill Contractor: Davies Drilling
Equipment: Mobile Track Mounted
Sampling Method: SPT
Driller: Rick

Drilling Date: 11/1/2006
ACL Representative: PZ

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Log of Test Boring B-2

Project Name: Oak Street Development
Client: Zenovic and Associates
Project Number: ACL06-10-G102

Boring Elevation:
Boring Location: Parking lot
Depth to Groundwater: 17'

DEPTH (FT.)	USCS Classification	VISUAL PHYSICAL DESCRIPTION	SAMPLE NO.	DEPTH (FEET)	SAMPLE TYPE	BLOW COUNTS PER 6 INCHES	N VALUE	RECOVERY (INCH)	LAB TESTING RESULTS FOR SAMPLE
40	SP	Brown gravelly SAND (wet) (very dense)	S-8	40	SPT	10 50/6"	100 +	6	M.C. = 9% -200 = 4%
45		Same	S-9	45	SPT	28 50/6"	100 +	9	M.C. = 11% -200 = 4%
50		Same, two large gravels in bottom of sampler	S-10	50	SPT	22 50/3"	100 +	9	M.C. = 14%
		BOE 50' GW at 17'							
55									
60									

Drill Contractor: Davies Drilling
Equipment: Mobile Track Mounted
Sampling Method: SPT
Driller: Rick

Drilling Date: 11/1/2006
ACL Representative: PZ

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Log of Test Boring B-3

Project Name: Oak Street Development
Client: Zenovic and Associates
Project Number: ACL06-10-G102

Boring Elevation: 15.75'
Boring Location: See Site Plan
Depth to Groundwater: 20'

DEPTH (FT.)	USCS Classification	VISUAL PHYSICAL DESCRIPTION	SAMPLE NO.	DEPTH (FEET)	SAMPLE TYPE	BLOW COUNTS PER 6 INCHES	N VALUE	RECOVERY (INCHE)	LAB TESTING RESULTS FOR SAMPLE
0	SP-SM	5" gravel surface Brown gravelly SAND with silt (moist) (medium dense)	S-1	0	SPT	9 8 9	17	10	M.C. = 5% -200 = 9%
5	SM	Brown silty fine SAND (moist) (loose)	S-2	5	SPT	4 4 4	8	19	M.C. = 10% -200 = 16%
		Gravel at 8'							
10	SP	Gray gravelly SAND with crushed shells (moist) (medium dense)	S-3	10	SPT	8 8 8	16	10	M.C. = 4% -200 = 4%
15	SM/ML	Dark gray silty SAND/sandy SILT (wet) (loose/very soft)	S-4	15	SPT	1 2 0	2	19	M.C. = 35% -200 = 51% L.L. = 26% P.I. = NP

Drill Contractor: Davies Drilling
Equipment: Mobile Track Mounted
Sampling Method: SPT
Driller: Rick

Drilling Date: 11/2/2006
ACL Representative: PZ

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Log of Test Boring B-3

Project Name: Oak Street Development
Client: Zenovic and Associates
Project Number: ACL06-10-G102

Boring Elevation:
Boring Location: Gravel Drive
Depth to Groundwater: 20'

DEPTH (FT.)	USCS Classification	VISUAL PHYSICAL DESCRIPTION	SAMPLE NO.	DEPTH (FEET)	SAMPLE TYPE	BLOW COUNTS PER 6 INCHES	N VALUE	RECOVERY (INCH)	LAB TESTING RESULTS FOR SAMPLE
20	SM	Dark gray gravelly silty SAND (wet) (medium dense)	S-5	20	SPT	2 6 7	13	19	M.C. = 17% -200 = 13%
25		Same with decreasing gravel	S-6	25	SPT	2 4 6	10	19	M.C. = 27% -200 = 28%
30		Grades to loose	S-7	30	SPT	1 1 4	5	19	M.C. = 26% -200 = 34%
35		Same	S-8	35	SPT	0 3 6	9	19	M.C. = 25% -200 = 41%
40									

Drill Contractor: Davies Drilling
Equipment: Mobile Track Mounted
Sampling Method: SPT
Driller: Rick

Drilling Date: 11/2/2006
ACL Representative: PZ

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Log of Test Boring B-3

Project Name: Oak Street Development
Client: Zenovic and Associates
Project Number: ACL06-10-G102

Boring Elevation:
Boring Location: Gravel Drive
Depth to Groundwater: 20'

DEPTH (FT.)	USCS Classification	VISUAL PHYSICAL DESCRIPTION	SAMPLE NO.	DEPTH (FEET)	SAMPLE TYPE	BLOW COUNTS PER 6 INCHES	N VALUE	RECOVERY (INCH)	LAB TESTING RESULTS FOR SAMPLE
40	SW-SM	Brown gravelly SAND with silt (moist) (very dense)	S-9	40	SPT	24 50/6"	100 +	9	M.C. = 9% -200 = 6%
45		Same	S-10	45	SPT	50/6"	100 +	6	
		BOE 45' GW at 20' Heaving sand toward bottom of hole Piezometer installed							
50									
55									
60									

Drill Contractor: Davies Drilling
Equipment: Mobile Track Mounted
Sampling Method: SPT
Driller: Rick

Drilling Date: 11/2/2006
ACL Representative: PZ

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Log of Test Boring B-4

Project Name: Oak Street Development
Client: Zenovic and Associates
Project Number: ACL06-10-G102

Boring Elevation: 15.25'
Boring Location: See Site Plan
Depth to Groundwater: 18'

DEPTH (FT.)	USCS Classification	VISUAL PHYSICAL DESCRIPTION	SAMPLE NO.	DEPTH (FEET)	SAMPLE TYPE	BLOW COUNTS PER 6 INCHES	N VALUE	RECOVERY (INCHE)	LAB TESTING RESULTS FOR SAMPLE
0	SP-SM	Brown SAND with silt and gravel (moist) (dense)	S-1	0	SPT	15 16 --	16	9	
5	CH	Dark gray sandy CLAY (moist) (medium stiff)	S-2	5	SPT	16 4 2	6	19	M.C. = 44% -200 = 83%
10		Dark gray CLAY (wet) (very soft)	S-3	10	SPT	1 1 0	1	19	M.C. = 96% -200 = 96% L.L. = 53% P.I. = 29%
15	SC	Dark gray clayey SAND (wet) (loose)	S-4	15	SPT	0 2 0	2	19	M.C. = 31% -200 = 32%

Drill Contractor: Davies Drilling
Equipment: Mobile Track Mounted
Sampling Method: SPT
Driller: Rick

Drilling Date: 11/2/2006
ACL Representative: PZ

ALKAI CONSULTANTS, LLC.

Environmental Engineering • Geotechnical Engineering • Wetland Consulting

Log of Test Boring B-4

Project Name: Oak Street Development
Client: Zenovic and Associates
Project Number: ACL06-10-G102

Boring Elevation:
Boring Location: Field
Depth to Groundwater: 18'

DEPTH (FT.)	USCS Classification	VISUAL PHYSICAL DESCRIPTION	SAMPLE NO.	DEPTH (FEET)	SAMPLE TYPE	BLOW COUNTS PER 6 INCHES	N VALUE	RECOVERY (INCH)	LAB TESTING RESULTS FOR SAMPLE
20	SM	Dark gray gravelly silty SAND (wet) (loose)	S-5	20	SPT	3 2 3	5	19	M.C. = 19% -200 = 13%
25		Gray silty SAND (wet) (loose)	S-6	25	SPT	0 1 2	3	19	M.C. = 31% -200 = 34%
30		Same	S-7	30	SPT	0 2 4	6	19	M.C. = 25% -200 = 24%
35	SW-SM	Brown gravelly SAND with silt (wet) (very dense)	S-8	35	SPT	8 27 50/5.5	77+	15	M.C. = 11% -200 = 5%

Drill Contractor: Davies Drilling
Equipment: Mobile Track Mounted
Sampling Method: SPT
Driller: Rick

Drilling Date: 11/2/2006
ACL Representative: PZ

40			Same **BOE 40'** GW at 18'	S-9	40	SPT	50/6"	100 +	5"	

Drill Contractor: Davies Drilling Equipment: Mobile Track Mounted Sampling Method: SPT Driller: Rick

Drilling Date: 11/2/2006 ACL Representative: PZ

APPENDIX B

Laboratory Test Reports

ALKAI Consultants, LLC
Oak Street Development
ACL06-10-G102

Moisture Contents
ASTM D-2216
Table 1

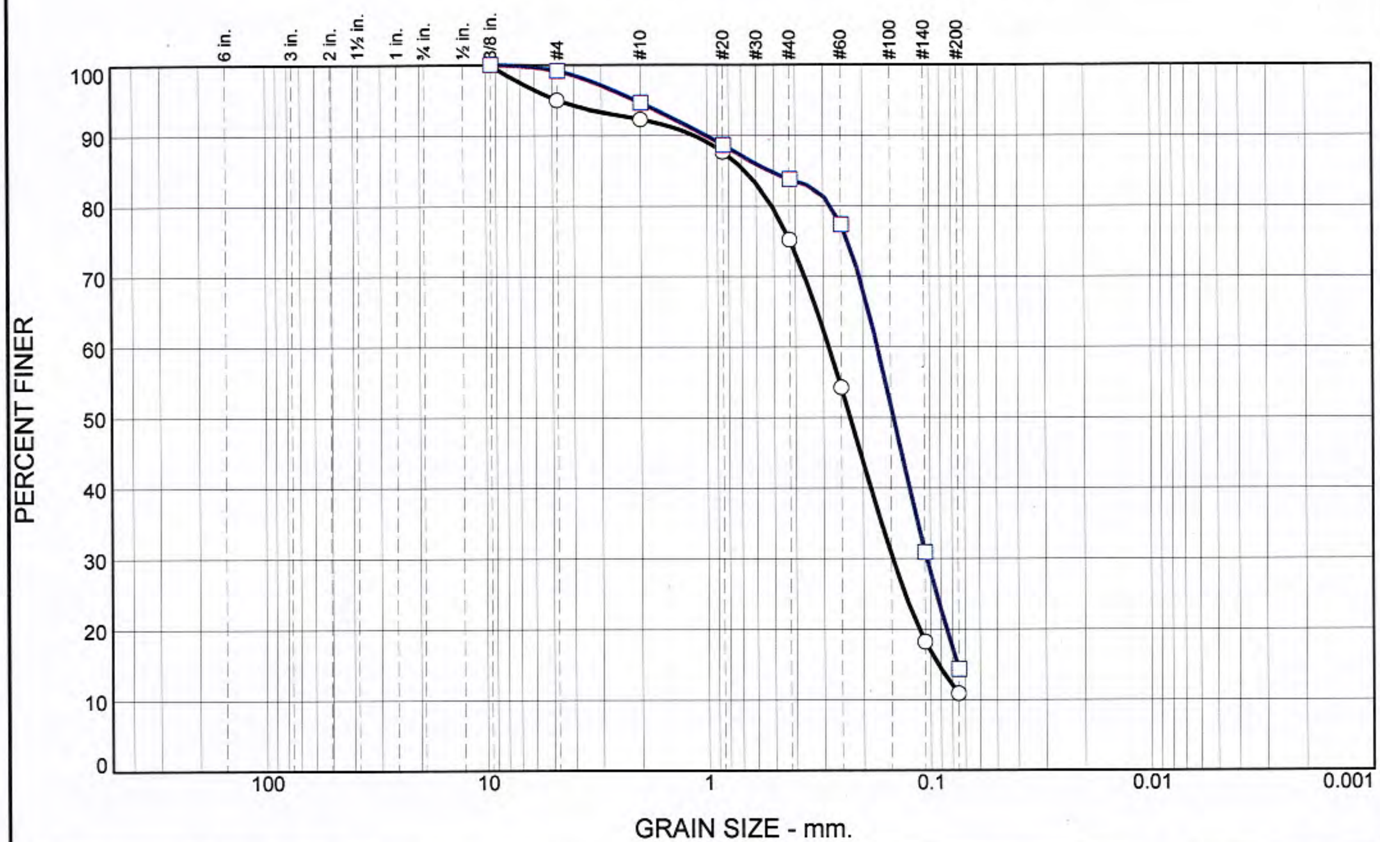
Exploration Number	Sample Number	Depth(ft)	Moisture Content %
B-1	S-1	0	5
B-1	S-2 top	5	7
B-1	S-2 bottom	5	57
B-1	S-3	10	34
B-1	S-4	15	28
B-1	S-5	20	23
B-1	S-6	25	31
B-1	S-7	30	30
B-2	S-1	5	5
B-2	S-2	10	21
B-2	S-3	15	24
B-2	S-4	20	16
B-2	S-5	25	25
B-2	S-6	30	25
B-2	S-7	35	44
B-2	S-8	40	9
B-2	S-9	45	11
B-2	S-10	50	14
B-3	S-1	0	5
B-3	S-2	5	10
B-3	S-3	10	4
B-3	S-4	15	35
B-3	S-5	20	17
B-3	S-6	25	27
B-3	S-7	30	26
B-3	S-8	35	25
B-3	S-9	40	9
B-4	S-2	5	44
B-4	S-3	10	96
B-4	S-4	15	31
B-4	S-5	20	19
B-4	S-6	25	31
B-4	S-7	30	25
B-4	S-8	35	11

ALKAI Consultants, LLC
Oak Street Development
ACL06-10-G102

Percent Passing 75 micron
ASTM D-1140
Table 2

Exploration Number	Sample Number	Depth(ft)	Percent Passing 75 Micron
B-1	S-1	0	12
B-1	S-2 bottom	5	84
B-1	S-3	10	35
B-1	S-4	15	18
B-1	S-6	25	34
B-1	S-7	30	30
B-2	S-5	25	20
B-2	S-7	35	44
B-3	S-4	15	51
B-4	S-2	5	83
B-4	S-3	10	96
B-4	S-7	30	24

Particle Size Distribution Report



	+3"	% GRAVEL	% SAND	% SILT	% CLAY	USCS	AASHTO	PL	LL
○	0.0	5.0	84.1	10.9		SP-SM	A-2-4(0)	NP	NV
□	0.0	0.9	84.8	14.3		SM	A-2-4(0)	NP	NV

SIEVE inches size	PERCENT FINER ○	□	
.375	100.0	100.0	
GRAIN SIZE			
D_{60}	0.2837	0.1724	
D_{30}	0.1474	0.1043	
D_{10}			
COEFFICIENTS			
C_c			
C_u			

SIEVE number size	PERCENT FINER ○	□	
#4	95.0	99.1	
#10	92.3	94.5	
#20	87.7	88.6	
#40	75.2	83.7	
#60	54.3	77.3	
#140	18.2	30.8	
#200	10.9	14.3	

Material Description

○ poorly graded sand with silt

□ silty sand

REMARKS:

○

□

○ Source of Sample: B-1 Depth: 5 Sample Number: S-2 top

□ Source of Sample: B-1 Depth: 20 Sample Number: S-5

Phoenix Soil Research

Kingston, WA

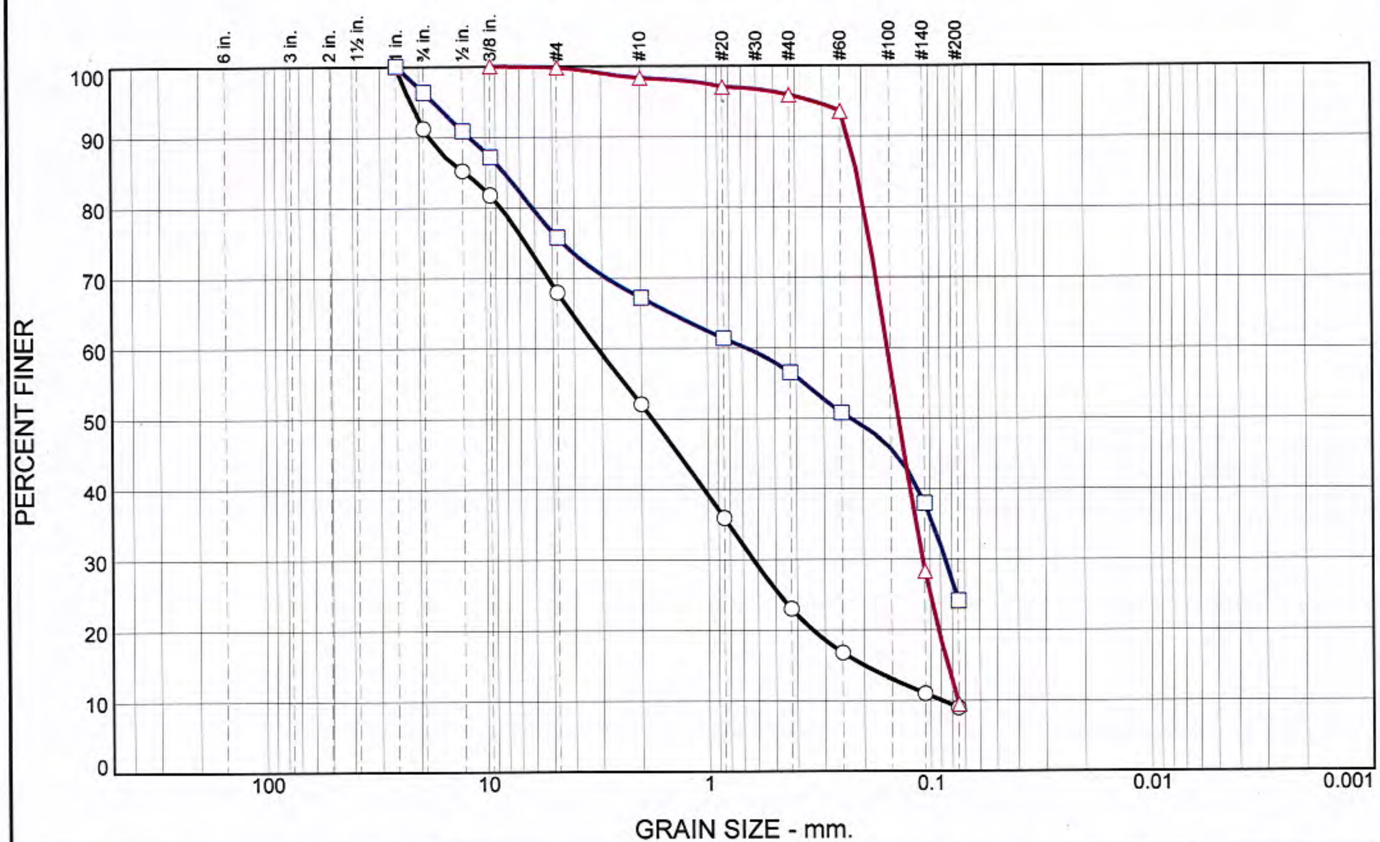
Client: Alkai Consultants, LLC

Project: Oak Street Development ACL06-10-G102

Project No.: PSR06-1-1102

Figure 1

Particle Size Distribution Report



	+3"	% GRAVEL	% SAND	% SILT	% CLAY	USCS	AASHTO	PL	LL
○	0.0	32.0	59.0	9.0		SW-SM	A-1-b	NP	NV
□	0.0	24.3	51.6	24.1		SM	A-2-4(0)	NP	NV
△	0.0	0.2	90.4	9.4		SP-SM	A-3	NP	NV

SIEVE inches size	PERCENT FINER ○	□	△
1	100.0	100.0	
.75	91.3	96.3	
.5	85.3	90.9	
.375	81.8	87.1	100.0
GRAIN SIZE			
D_{60}	3.1288	0.6749	0.1549
D_{30}	0.6289	0.0859	0.1086
D_{10}	0.0890		0.0759
COEFFICIENTS			
C_c	1.42		1.00
C_u	35.17		2.04

SIEVE number size	PERCENT FINER ○	□	△
#4	68.0	75.7	99.8
#10	52.1	67.2	98.3
#20	36.0	61.4	96.9
#40	23.1	56.5	95.8
#60	16.8	50.8	93.5
#140	11.0	37.9	28.3
#200	9.0	24.1	9.4

Material Description

○ well-graded sand with silt and gravel

□ silty sand with gravel

△ poorly graded sand with silt

REMARKS:

○

□

△

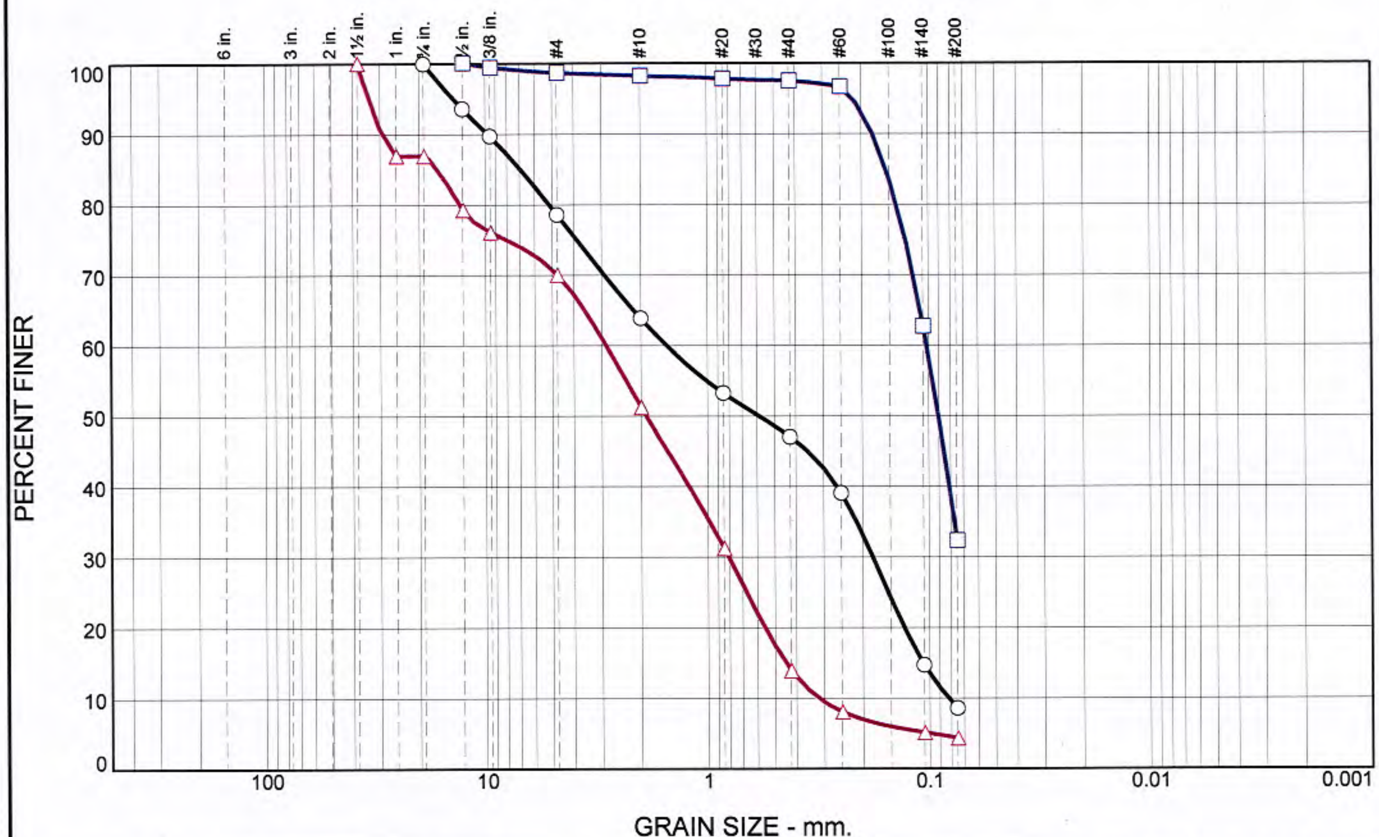
○ Source of Sample: B-2 Depth: 5 Sample Number: S-1

□ Source of Sample: B-2 Depth: 10 Sample Number: S-2

△ Source of Sample: B-2 Depth: 15 Sample Number: S-3

Phoenix Soil Research **Kingston, WA**	Client: Alkai Consultants, LLC Project: Oak Street Development ACL06-10-G102 Project No.: PSR06-1-1102 Figure 2

Particle Size Distribution Report



	+3"	% GRAVEL	% SAND	% SILT	% CLAY	USCS	AASHTO	PL	LL
○	0.0	21.4	70.0	8.6		SP-SM	A-1-b	NP	NV
□	0.0	1.4	66.3	32.3		SM	A-2-4(0)	NP	NV
△	0.0	30.0	65.7	4.3		SP			

SIEVE inches size	PERCENT FINER ○	□	△
1.5			100.0
1			86.9
.75	100.0		86.9
.5	93.7	100.0	79.2
.375	89.8	99.4	76.0
	GRAIN SIZE		
D_{60}	1.5230	0.1024	2.8741
D_{30}	0.1800		0.8114
D_{10}	0.0821		0.3206
	COEFFICIENTS		
C_c	0.26		0.71
C_u	18.55		8.97

SIEVE number size	PERCENT FINER ○	□	△
#4	78.6	98.6	70.0
#10	63.9	98.1	51.2
#20	53.3	97.7	31.2
#40	47.1	97.4	13.9
#60	39.1	96.6	8.0
#140	14.7	62.7	5.1
#200	8.6	32.3	4.3

Material Description

○ poorly graded sand with silt and gravel

□ silty sand

△ poorly graded sand with gravel

REMARKS:

○

□

△

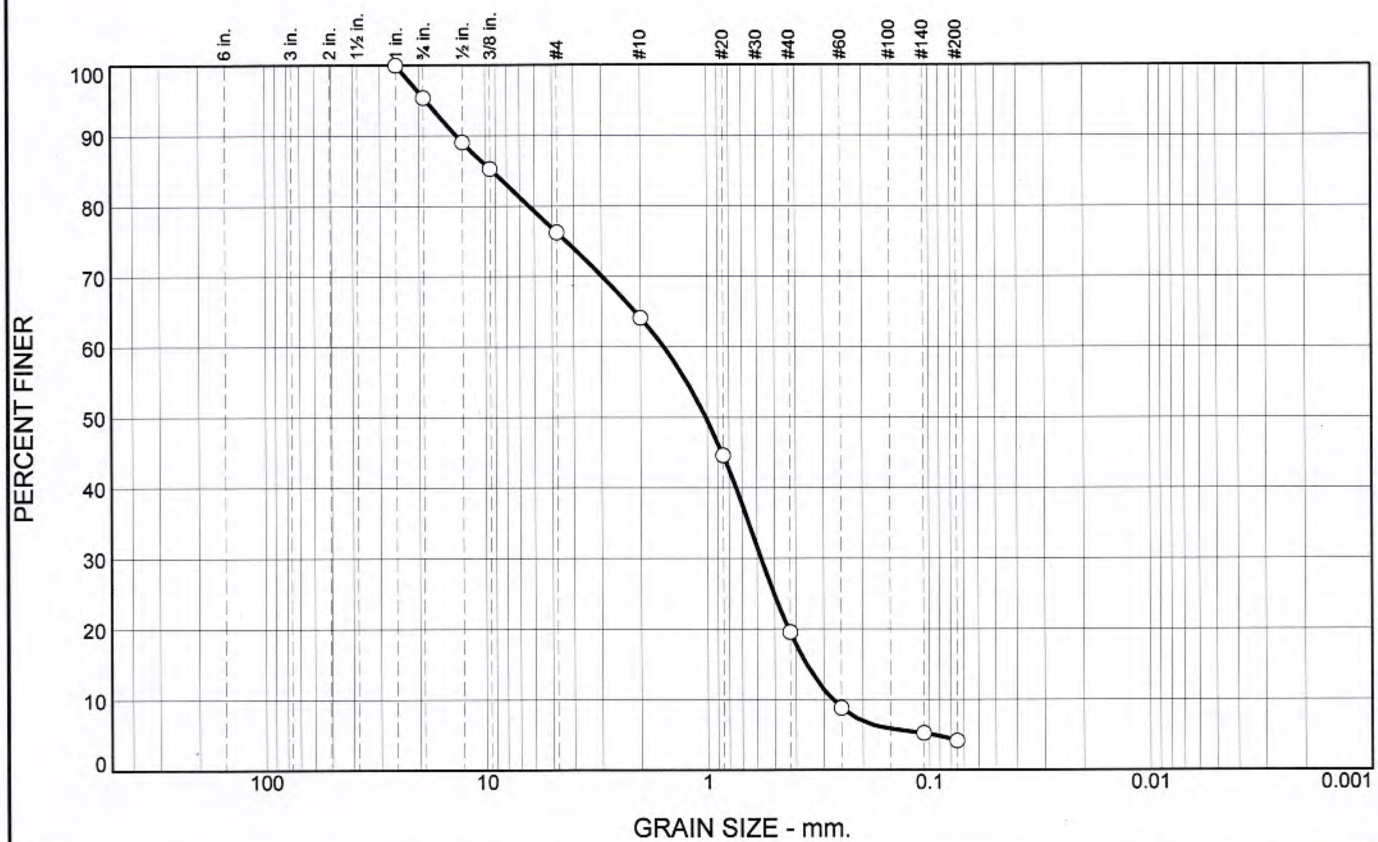
○ Source of Sample: B-2 Depth: 20 Sample Number: S-4

□ Source of Sample: B-2 Depth: 30 Sample Number: S-6

△ Source of Sample: B-2 Depth: 40 Sample Number: S-8

Phoenix Soil Research Kingston, WA	Client: Alkai Consultants, LLC Project: Oak Street Development ACL06-10-G102 Project No.: PSR06-1-1102 Figure 3

Particle Size Distribution Report



	+3"	% GRAVEL	% SAND	% SILT	% CLAY	USCS	AASHTO	PL	LL
○	0.0	23.7	72.1	4.2		SP			

SIEVE inches size	PERCENT FINER ○		
1	100.0		
.75	95.4		
.5	89.1		
.375	85.3		
	GRAIN SIZE		
D_{60}	1.5696		
D_{30}	0.5722		
D_{10}	0.2743		
	COEFFICIENTS		
C_c	0.76		
C_u	5.72		

SIEVE number size	PERCENT FINER ○		
#4	76.3		
#10	64.2		
#20	44.7		
#40	19.6		
#60	8.8		
#140	5.3		
#200	4.2		

Material Description

○ poorly graded sand with gravel

REMARKS:

○

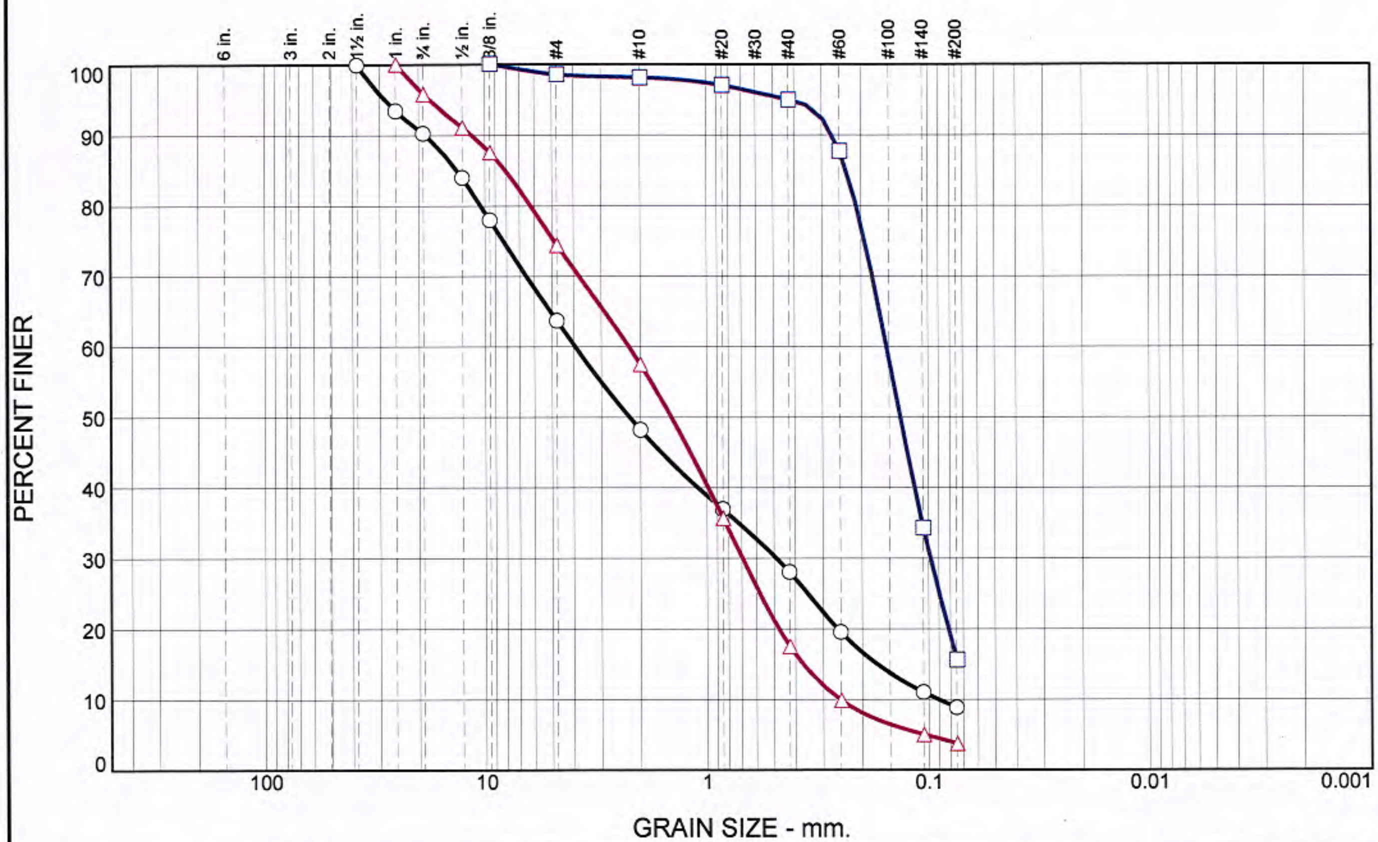
○ Source of Sample: B-2 Depth: 45 Sample Number: S-9

Phoenix Soil Research

Kingston, WA

Client: Alkai Consultants, LLC
Project: Oak Street Development
ACL06-10-G102
Project No.: PSR06-1-1102 Figure 4

Particle Size Distribution Report



	+3"	% GRAVEL	% SAND	% SILT	% CLAY	USCS	AASHTO	PL	LL
○	0.0	36.3	54.8	8.9		SP-SM	A-1-a	NP	NV
□	0.0	1.5	82.9	15.6		SM	A-2-4(0)	NP	NV
△	0.0	25.6	70.7	3.7		SP			

SIEVE inches size	PERCENT FINER ○	□	△
1.5	100.0		
1	93.5		100.0
.75	90.3		95.8
.5	84.0		91.1
.375	78.0	100.0	87.6
GRAIN SIZE			
D_{60}	3.9203	0.1543	2.2517
D_{30}	0.4841	0.0986	0.6961
D_{10}	0.0898		0.2545
COEFFICIENTS			
C_c	0.67		0.85
C_u	43.66		8.85

SIEVE number size	PERCENT FINER ○	□	△
#4	63.7	98.5	74.4
#10	48.3	98.0	57.5
#20	37.0	97.0	35.7
#40	28.1	94.9	17.5
#60	19.6	87.6	9.8
#140	11.1	34.3	5.0
#200	8.9	15.6	3.7

Material Description

○ poorly graded sand with silt and gravel

□ silty sand

△ poorly graded sand with gravel

REMARKS:

○

□

△

○ Source of Sample: B-3 Depth: 0 Sample Number: S-1
□ Source of Sample: B-3 Depth: 5 Sample Number: S-2
△ Source of Sample: B-3 Depth: 10 Sample Number: S-3

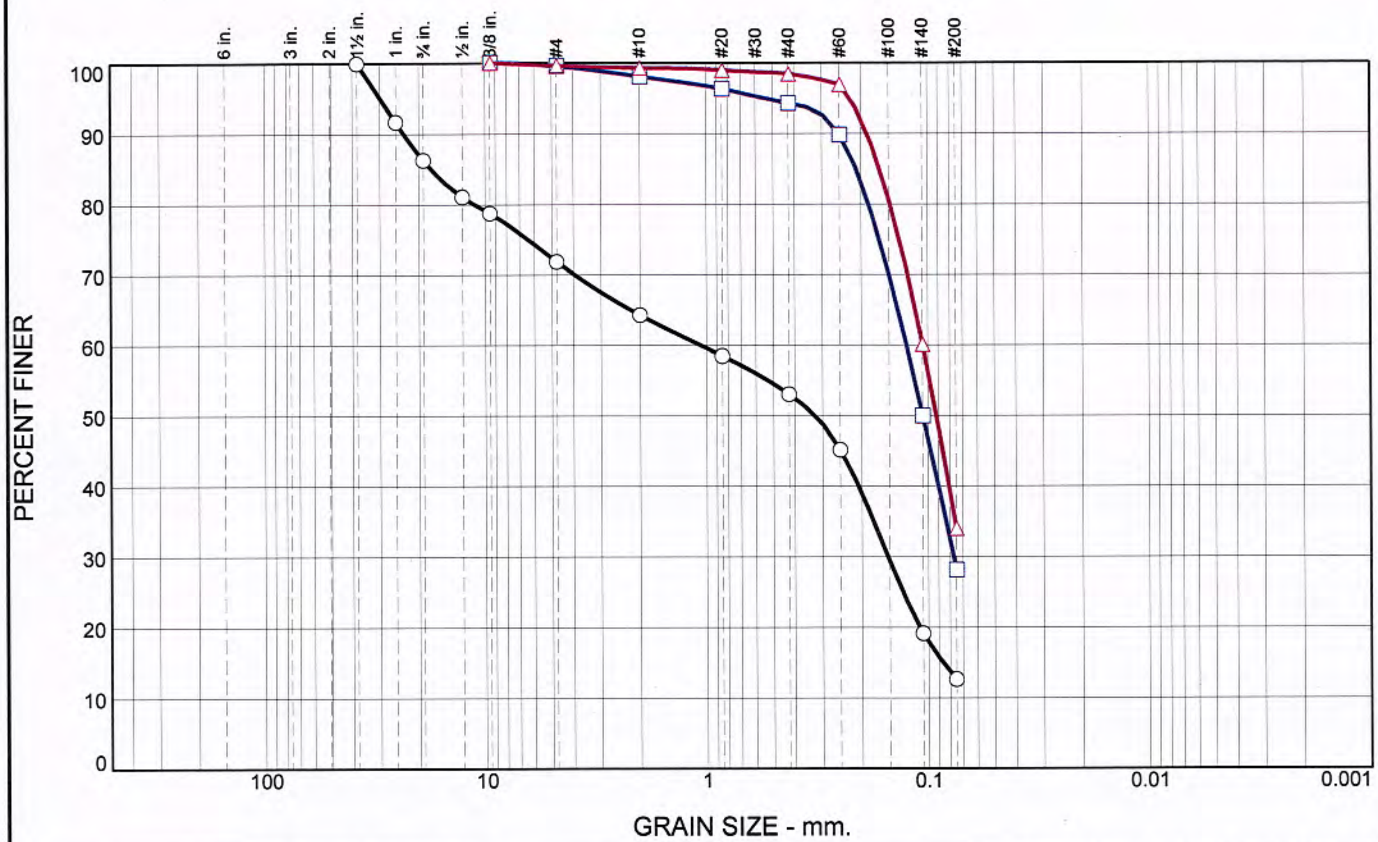
Phoenix Soil Research

Kingston, WA

Client: Alkai Consultants, LLC
Project: Oak Street Development
ACL06-10-G102
Project No.: PSR06-1-1102

Figure 5

Particle Size Distribution Report



	+3"	% GRAVEL	% SAND	% SILT	% CLAY	USCS	AASHTO	PL	LL
○	0.0	28.1	59.3	12.6		SM	A-2-4(0)	NP	NV
□	0.0	0.5	71.4	28.1		SM	A-2-4(0)	NP	NV
△	0.0	0.4	65.6	34.0		SM	A-2-4(0)	NP	NV

SIEVE inches size	PERCENT FINER ○	□	△
1.5	100.0		
1	91.7		
.75	86.3		
.5	81.1		
.375	78.8	100.0	100.0
	GRAIN SIZE		
D_{60}	1.0636	0.1254	0.1058
D_{30}	0.1522	0.0772	
D_{10}			
	COEFFICIENTS		
C_c			
C_u			

SIEVE number size	PERCENT FINER ○	□	△
#4	71.9	99.5	99.6
#10	64.3	98.0	99.2
#20	58.5	96.2	98.9
#40	53.1	94.2	98.4
#60	45.2	89.7	96.9
#140	19.2	49.9	60.1
#200	12.6	28.1	34.0

Material Description

○ silty sand with gravel

□ silty sand

△ silty sand

REMARKS:

○

□

△

○ Source of Sample: B-3 Depth: 20 Sample Number: S-5

□ Source of Sample: B-3 Depth: 25 Sample Number: S-6

△ Source of Sample: B-3 Depth: 30 Sample Number: S-7

Phoenix Soil Research

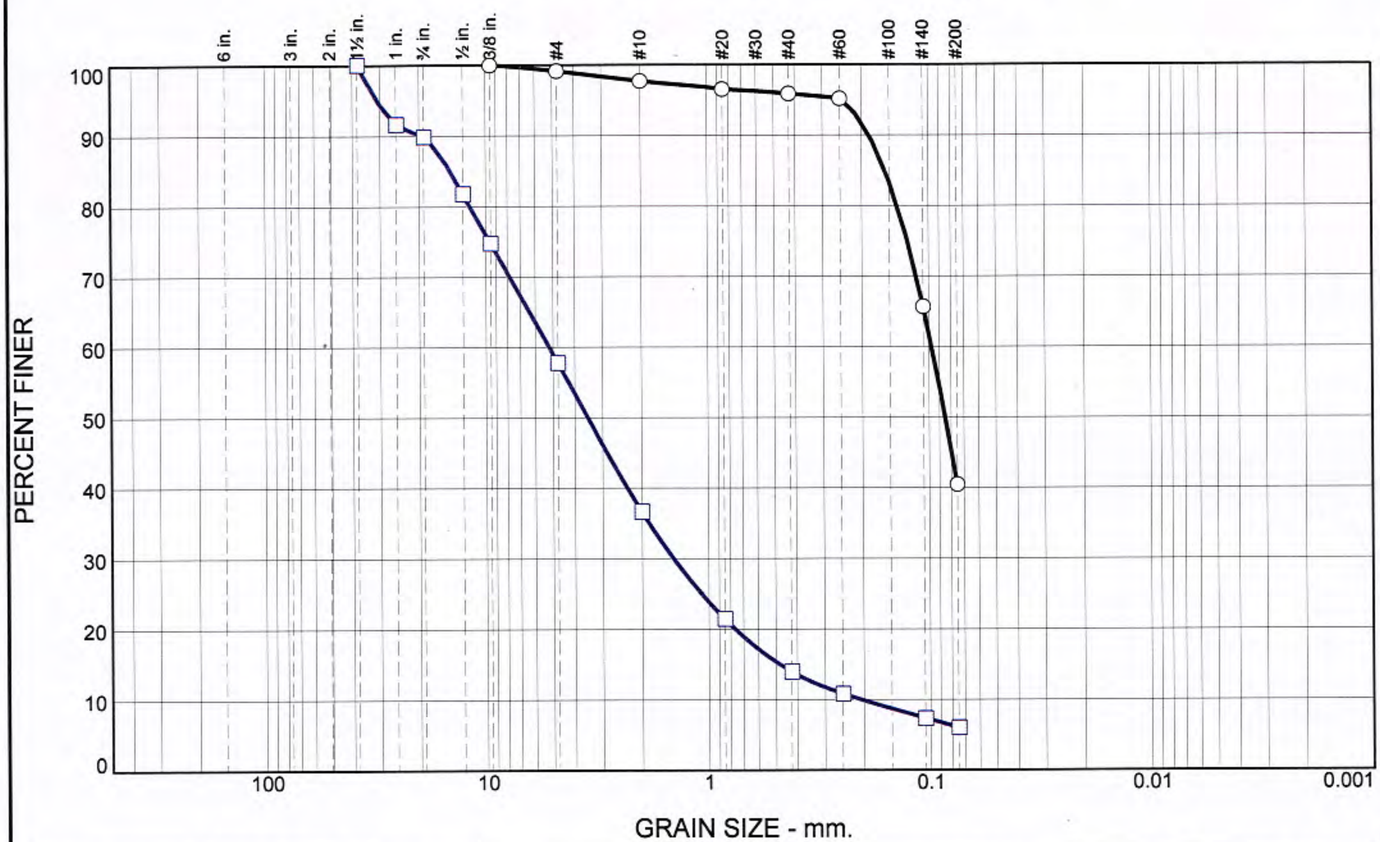
Kingston, WA

Client: Alkai Consultants, LLC

Project: Oak Street Development
ACL06-10-G102

Project No.: PSR06-1-1102 Figure 6

Particle Size Distribution Report



	+3"	% GRAVEL	% SAND	% SILT	% CLAY	USCS	AASHTO	PL	LL
○	0.0	0.8	58.7	40.5		SM	A-4(0)	NP	NV
□	0.0	42.2	51.8	6.0		SW-SM	A-1-a	NP	NV

SIEVE inches size	PERCENT FINER ○	□	
1.5		100.0	
1		91.6	
.75		89.8	
.5		81.7	
.375	100.0	74.7	
	GRAIN SIZE		
D_{60}	0.0973	5.1995	
D_{30}		1.4410	
D_{10}		0.2084	
	COEFFICIENTS		
C_c		1.92	
C_u		24.94	

SIEVE number size	PERCENT FINER ○	□	
#4	99.2	57.8	
#10	97.7	36.6	
#20	96.6	21.4	
#40	95.9	13.9	
#60	95.2	10.8	
#140	65.7	7.3	
#200	40.5	6.0	

Material Description

○ silty sand

□ well-graded sand with silt and gravel

REMARKS:

○

□

○ Source of Sample: B-3 Depth: 35 Sample Number: S-8

□ Source of Sample: B-3 Depth: 40 Sample Number: S-9

Phoenix Soil Research

Kingston, WA

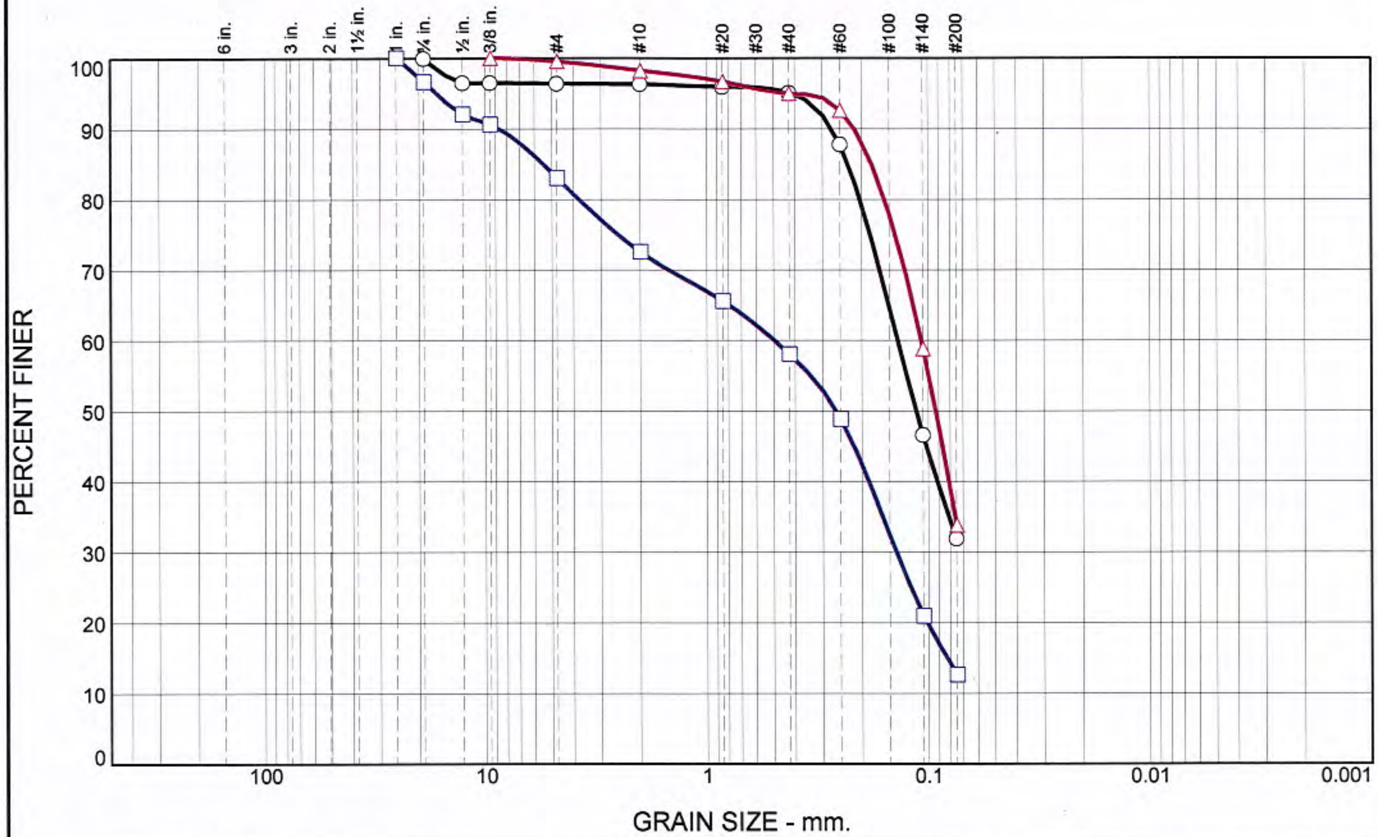
Client: Alkai Consultants, LLC

Project: Oak Street Development
ACL06-10-G102

Project No.: PSR06-1-1102

Figure 7

Particle Size Distribution Report



	+3"	% GRAVEL	% SAND	% SILT	% CLAY	USCS	AASHTO	PL	LL
○	0.0	3.6	64.4	32.0		SM	A-2-4(0)	NP	NV
□	0.0	17.0	70.4	12.6		SM	A-2-4(0)	NP	NV
△	0.0	0.5	65.7	33.8		SM	A-2-4(0)	NP	NV

SIEVE inches size	PERCENT FINER ○	□	△
1		100.0	
.75	100.0	96.6	
.5	96.5	92.1	
.375	96.5	90.6	100.0
GRAIN SIZE			
D_{60}	0.1374	0.4986	0.1079
D_{30}		0.1406	
D_{10}			
COEFFICIENTS			
C_c			
C_u			

SIEVE number size	PERCENT FINER ○	□	△
#4	96.4	83.0	99.5
#10	96.3	72.5	98.2
#20	96.0	65.5	96.7
#40	95.1	58.0	94.9
#60	87.8	48.8	92.6
#140	46.6	20.9	58.8
#200	32.0	12.6	33.8

Material Description

○ silty sand

□ silty sand with gravel

△ silty sand

REMARKS:

○

□

△

○ Source of Sample: B-4 Depth: 15 Sample Number: S-4

□ Source of Sample: B-4 Depth: 20 Sample Number: S-5

△ Source of Sample: B-4 Depth: 25 Sample Number: S-6

Phoenix Soil Research

Kingston, WA

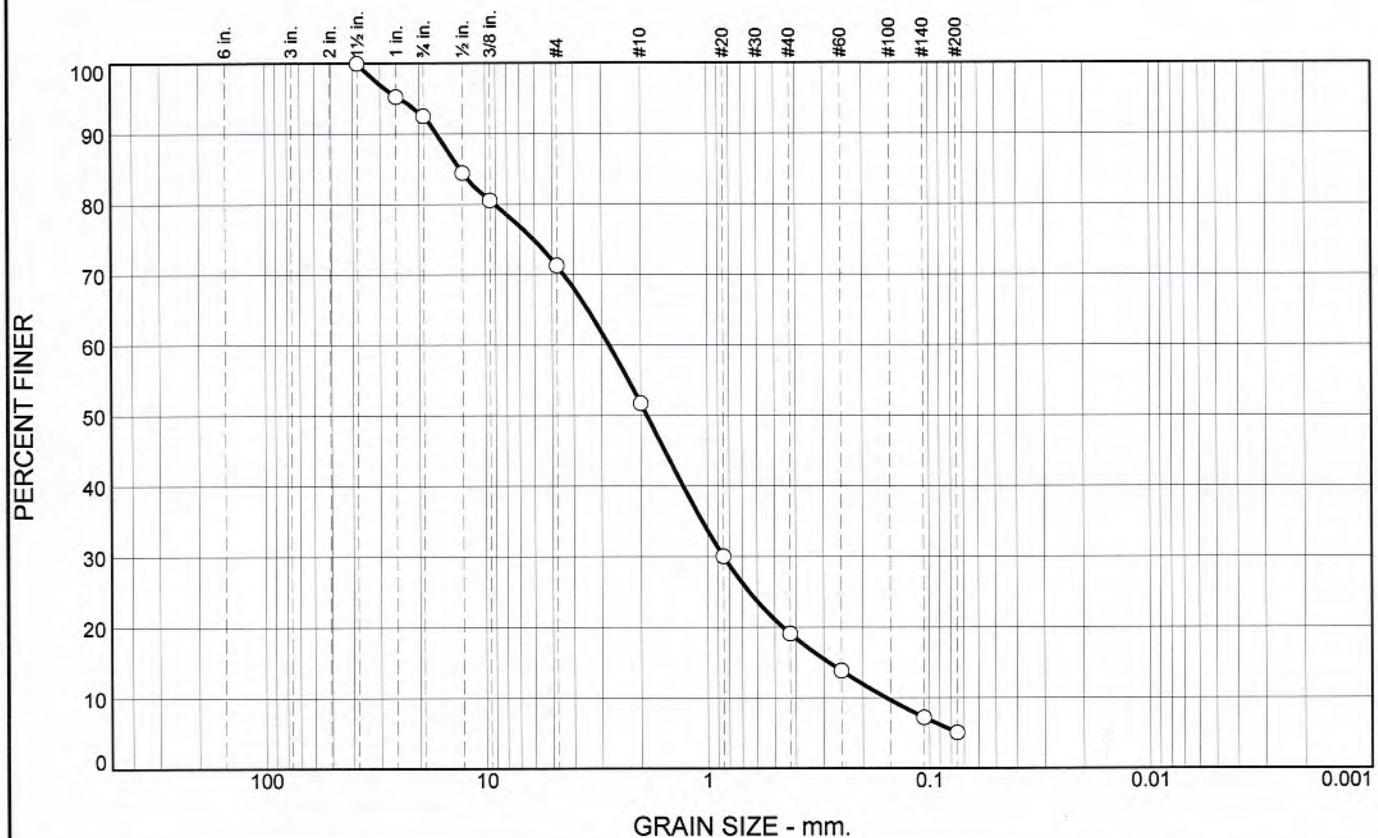
Client: Alkai Consultants, LLC

Project: Oak Street Development
ACL06-10-G102

Project No.: PSR06-1-1102

Figure 8

Particle Size Distribution Report



	+3"	% GRAVEL	% SAND	% SILT	% CLAY	USCS	AASHTO	PL	LL
○	0.0	28.7	66.2	5.1		SW-SM	A-1-b	NP	NV

SIEVE inches size	PERCENT FINER ○		
1.5	100.0		
1	95.2		
.75	92.6		
.5	84.5		
.375	80.6		
	GRAIN SIZE		
D_{60}	2.7643		
D_{30}	0.8448		
D_{10}	0.1567		
	COEFFICIENTS		
C_c	1.65		
C_u	17.65		

SIEVE number size	PERCENT FINER ○		
#4	71.3		
#10	51.8		
#20	30.1		
#40	19.1		
#60	13.9		
#140	7.2		
#200	5.1		

Material Description

○ well-graded sand with silt and gravel

REMARKS:

○

○ Source of Sample: B-4 Depth: 35 Sample Number: S-8

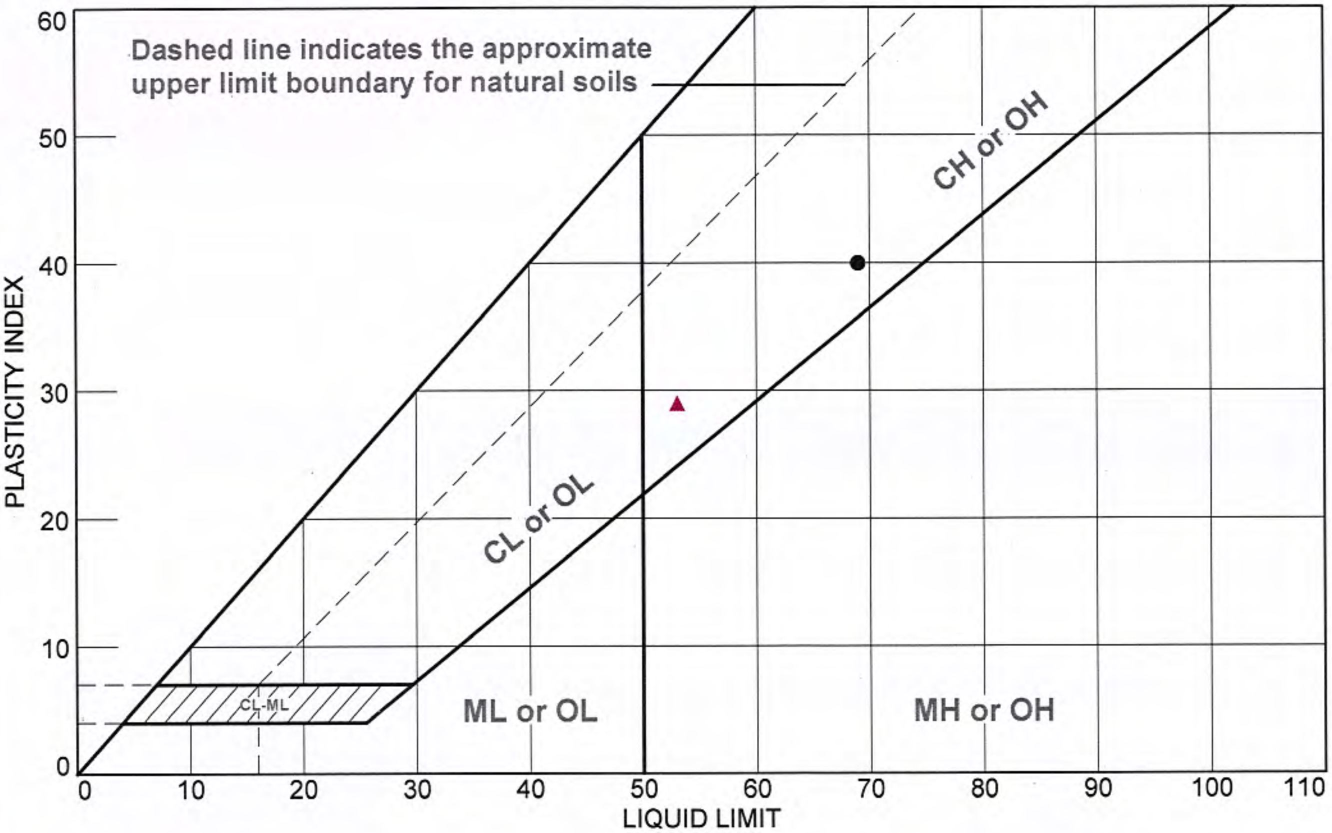
Phoenix Soil Research

Kingston, WA

Client: Alkai Consultants, LLC
Project: Oak Street Development
ACL06-10-G102
Project No.: PSR06-1-1102

Figure 9

LIQUID AND PLASTIC LIMITS TEST REPORT



	SOIL DATA							
	SOURCE	SAMPLE NO.	DEPTH	NATURAL WATER CONTENT (%)	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)	USCS
●	B-1	S-2 bottom	5	57.0	29	69	40	CH
■	B-3	S-4	15	35.0	27	26	NP	ML
▲	B-4	S-3	10	52.0	24	53	29	CH

Phoenix Soil Research **Kingston, WA**	**Client:** Alkai Consultants, LLC **Project:** Oak Street Development ACL06-10-G102 **Project No.:** PSR06-1-1102 **Figure** 10

Soil Classification System

Major Divisions			Symbol	Name
Coarse Grained Soils More Than 50% Retained on No. 200 Sieve	GRAVEL More than 50% of coarse fraction retained on No. 4 Sieve	CLEAN GRAVEL	GW	Well Graded, Fine to Coarse Gravel
			GP	Poorly graded gravel
		GRAVEL WITH FINES	GM	Silty gravel
			GC	Clayey gravel
	SAND More than 50% of coarse fraction passes No. 4 Sieve	CLEAN SAND	SW	Well graded, fine to coarse sand
			SP	Poorly graded sand
		SAND WITH FINES	SM	Silty sand
			SC	Clayey sand
Fine Grained Soils More than 50% passes No. 200 Sieve	Silt and Clay Liquid Limit Less than 50%	Inorganic	ML	Low plasticity silt
			CL	Low plasticity clay
		Organic	OL	Organic silt, organic clay
	Silt and Clay Liquid Limit greater than 50%	Inorganic	MH	High plasticity silt
			CH	High plasticity clay, fat clay
		Organic	OH	Organic clay,organic silt
Highly Organic Soils			PT	Peat

Soil Classification Guidelines

Granular Soils		Cohesive Soils		
Relative Density	Standard Penetration Resistance	Consistency	Standard Penetration Resistance	Unconfined Compressive Strength (TSF)
Very Loose	0-4	Very Soft	Less than 2	Less than .25
Loose	4-10	Soft	2-4	.25-.50
Medium Dense	10-30	Medium Stiff	4-8	.50-1.0
Dense	30-50	Stiff	8-15	1.0-2.0
Very Dense	More than 50	Very Stiff	15-30	2.0-4.0
		Hard	More than 30	More than 4.0

Grain Size Classification

		Subclassification	
Boulders	12-36 Inches		
Cobbles	3-12 Inches		Percentage of other material in sample
Gravel	3/4 - 3 Inches (coarse)	Clean	0 - 2
	1/4 - 3/4 Inches (fine)	Trace	2 - 10
Sand	No. 10-No. 4 Sieve (Coarse)	Some	10 - 30
	No. 10-No. 40 Sieve (medium)	Sandy, Silty, Clayey, ETC.	30 - 50
	No. 40 - No. 200 Sieve (fine)		

Dry = very low moisture, dry to the touch; Moist = damp, without visible moisture; Wet = saturated, with visible free water.

NTI ENGINEERING & LAND SURVEYING

SOIL CLASSIFICATION SYSTEM

Geotechnical Boring Log

Project Name	2011 CSO Improvements - Phase I	Sheet 1 of 1	
Project No.	PRTA 1107	Date	12/8/2011
Location	City of Port Angeles, Oak Street	Elevation	Approx. 10-15'
Inspector	H. Cornachione, L.G.; K. O'Claire, P.E.	Datum	
Driller/Rig Type	Boart Longyear / B50 Mobile Auger	Boring Location:	B-1
Sample Types / Core Size:	SPT test & 1 5/8" cores		S. Oak St., west side intersection with W. Railroad Ave.

Sample # / Core Run #	Depth Intv./ Run Length	Inches Driven	SPT N-value	% Recovery	Blows Per 6"	Depth (ft.)	Sample Description SOIL: Relative Density; Color: Soil Type; Moisture Content; Descritors; Hard Brown Sandy Clay, Dry with Trace Gravel, Cenentation, Air Voids etc. ROCK: Hardness, Weathering, Color, Texture, Lithology, Bedding, Foliation, Discontinuities: Orientation, Spacing, Roughness, Weathering, Aperture, Filling
						1	12" DIA core = 9" concrete tan, gravelly SAND, moist, loose
						2	
2 1/2		18"	7	85	4	3	brownish gray, gravelly SAND, dry, loose
					4 3	4	
						5	
5		18"	9	20	2 4	6	lt. brown, gravelly SAND, moist, loose, some shell fragments
					5	7	
7 1/2		18"	8	0	7 4	8	med. gray, gravelly SAND, moist, loose
					4	9	
						▼ 10	
10		18"	2	60	wh 1	1	med. gray, sandy SILT, saturated, loose; groundwater @ 10 feet
					1	2	
						3	
						4	
						15	
15		18"	2	90	1 1	6	dk. gray, silty SAND, saturated, loose with shell hash at base
					1	7	
						8	
						9	
						20	
20		18"	11	90	2 5	1	dk. gray, silty SAND, saturated, loose with some carbonaceous material and shell hash at base
					6		

Boring No. B-1

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Geotechnical Boring Log

Project Name	2011 CSO Improvements - Phase I
Project No.	PRTA 1107
Location	City of Port Angeles, Oak Street
Inspector	H. Cornachione, L.G.; K. O'Claire, P.E.
Driller/Rig Type	Boart Longyear / B50 Mobile Auger
Sample Types / Core Size:	SPT test & 1 5/8" cores

Sheet 1 of 1
Date 12/8/2011
Elevation Approx. 10-15'
Datum
Boring Location: B-2
S. Oak St., central west side between W. Front St. and W. Railroad Ave.

Sample # / Core Run #	Depth Intv./ Run Length	Inches Driven	SPT N-value	% Recovery	Blows Per 6"	Depth (ft.)	Sample Description SOIL: Relative Density; Color: Soil Type; Moisture Content; Descritors; Hard Brown Sandy Clay, Dry with Trace Gravel, Cenentation, Air Voids etc. ROCK: Hardness, Weathering, Color, Texture, Lithology, Bedding, Foliation, Discontinuities: Orientation, Spacing, Roughness, Weathering, Aperture, Filling
						1	12" DIA core = 7" concrete tan, gravelly SAND, moist, loose
						2	
2 1/2		18"	5	30	2	3	lt. brown, silty, gravelly SAND , moist, loose
					3 2	4	
						5	
5		18"	11	60	2 4	6	med. brown, gravelly (pea size), silty SAND, moist, loose
					7	7	
						8	
						9	groundwater @ 9 feet
						10	
10		18"	4	30	2 2	1	lt. brown, silty SAND, saturated, loose
					2	2	
						3	
						4	
						15	
15		18"	5	95	wh 2	6	dk. gray, silty SAND, saturated, loose with minor shell fragments
					3	7	
						8	
						9	
						20	
20		18"	11	100	4 9	1	dk. gray, silty SAND, saturated, loose with some gravel and some shell fragments and shell hash at base
					12		

Boring No. B-2

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Geotechnical Boring Log

Project Name: 2011 CSO Improvements - Phase I
Project No.: PRTA 1107
Location: City of Port Angeles, Oak Street
Inspector: H. Cornachione, L.G.; K. O'Claire, P.E.
Driller/Rig Type: Boart Longyear / B50 Mobile Auger
Sample Types / Core Size: SPT test & 1 5/8" cores

Sheet 1 of 1
Date: 12/8/2011
Elevation: Approx. 10-15'
Datum:
Boring Location: B-3
S. Oak St., west side below intersection W. Front St.

Sample # / Core Run #	Depth Intv./ Run Length	Inches Driven	SPT N-value	% Recovery	Blows Per 6"	Depth (ft.)	Sample Description SOIL: Relative Density; Color: Soil Type; Moisture Content; Descritors; Hard Brown Sandy Clay, Dry with Trace Gravel, Cenentation, Air Voids etc. ROCK: Hardness, Weathering, Color, Texture, Lithology, Bedding, Foliation, Discontinuities: Orientation, Spacing, Roughness, Weathering, Aperture, Filling
						1	12" DIA core = 7.5" concrete brown, gravelly SAND, moist, loose
						2	
						3	
						4	
						5	
5		18"	5	10	3 2 3	6	lt. brown, silty, gravelly, SAND , moist, loose
						7	
						8	
						9	
						▼ 10	
10		18"	4	50	2 2 2	1	med. gray, silty, coarse SAND, saturated, loose with some gravel at base, and sparse shell fragments; groundwater @ 10 feet
						2	
						3	
						4	
						15	
15		18"	4	0	wh 2 2	6	-Washed Out- cuttings appear to be dk. gray silty SAND, very loose with some shell fragments
						7	
						8	
						9	
						20	
20		18"	8	80	1 4 4	1	dk. gray, silty SAND, saturated, loose with some gravel note oily sheen and hydrocarbon odor @ 20.0 '; recommend for testing top 2-3" core

Boring No. B-3

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Geotechnical Boring Log

Project Name	2011 CSO Improvements - Phase I	Sheet 1 of 1	
Project No.	PRTA 1107	Date	12/7/2011
Location	City of Port Angeles, Oak Street	Elevation	Approx. 10-15'
Inspector	H. Cornachione, L.G.; K. O'Claire, P.E.	Datum	
Driller/Rig Type	Boart Longyear / B50 Mobile Auger	Boring Location:	C-4
Sample Types / Core Size:	SPT test & 1 5/8" cores		S. Oak St., approximately 4' east and 2' south of B-2

Sample # / Core Run #	Depth Intv./ Run Length	Inches Driven	SPT N-value	% Recovery	Blows Per 6"	Depth (ft.)	Sample Description SOIL: Relative Density; Color: Soil Type; Moisture Content; Descritors; Hard Brown Sandy Clay, Dry with Trace Gravel, Cenentation, Air Voids etc. ROCK: Hardness, Weathering, Color, Texture, Lithology, Bedding, Foliation, Discontinuities: Orientation, Spacing, Roughness, Weathering, Aperture, Filling
						1	12" DIA core = 9.5" concrete brown, silty, gravelly SAND, moist, loose Sample (grab) #C-4-9.5"
						2	
						3	
						4	
						5	
						6	
						7	
						8	
						9	
						10	
						1	
						2	
						3	
						4	
						15	
						6	
						7	
						8	
						9	
						20	
						1	

Boring No. C-4

NTI Engineering & Surveying, Inc.
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Geotechnical Boring Log

Project Name	2011 CSO Improvements - Phase I	Sheet 1 of 1	
Project No.	PRTA 1107	Date	12/7/2011
Location	City of Port Angeles, Oak Street	Elevation	Approx. 10-15'
Inspector	H. Cornachione, L.G.; K. O'Claire, P.E.	Datum	
Driller/Rig Type	Boart Longyear / B50 Mobile Auger	Boring Location:	C-5
Sample Types /	Core Size: SPT test & 1 5/8" cores		S. Oak St., parking along east side, just south of alley

Sample # / Core Run #	Depth Intv./ Run Length	Inches Driven	SPT N-value	% Recovery	Blows Per 6"	Depth (ft.)	Sample Description SOIL: Relative Density; Color: Soil Type; Moisture Content; Descritors; Hard Brown Sandy Clay, Dry with Trace Gravel, Cenentation, Air Voids etc. ROCK: Hardness, Weathering, Color, Texture, Lithology, Bedding, Foliation, Discontinuities: Orientation, Spacing, Roughness, Weathering, Aperture, Filling
						1	12" DIA core = 8.5" concrete brown, gravelly, silty SAND, moist, loose Sample (grab) #C-5-8.5"
						2	
						3	
						4	
						5	
						6	
						7	
						8	
						9	
						10	
						1	
						2	
						3	
						4	
						15	
						6	
						7	
						8	
						9	
						20	
						1	

Boring No. C-5

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Specimen Control #	**11061**

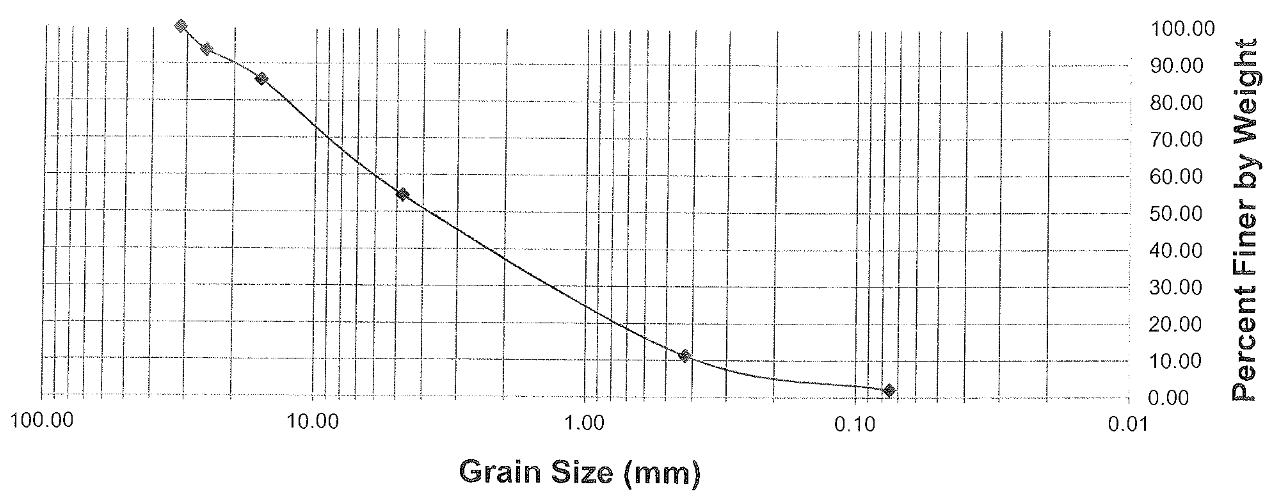
Sieve Analysis

Client:	City of PA	Date:	12/14/2011
Project:	CSO- Phase I (Oak Street)	Sample taken by:	Harriet C.
BILLING INFORMATION		Material:	B-1, 2.5'
Lab Account #:	PRTA-1107	Source:	
Project Manager:		Tested By:	SRW
Email:		Date Tested:	**12/12/2011 & 12/14/2011**
Phone#:	360-417-4808	Test requested:	**Wet / Dry Sieve:** **DRY**
Remarks:		Reviewed:	TTA

Sieve Diameter (mm)	Sieve Size	Dry Wt. (grams)	% Retained	% Passing	
31.750	**1 1/4"**	0.0	0.0%	100.0%	
25.400	**1"**	36.7	6.2%	93.8%	
15.875	**5/8"**	47.9	8.1%	85.8%	
4.750	**#4**	185.2	31.2%	54.6%	
0.425	**#40**	256.6	43.2%	11.4%	
0.075	**#200**	54.7	9.2%	2.2%	
-	**Pan**	13.2	2.2%		

Wt. Before Dry Sieve:	594.3
Wt. After Dry Sieve:	594.3
D10:	0.40
D30:	1.50
D60:	6.00
Cu:	15
Cc:	0.94
Soil Classification:	SP
Moisture Content:	-

Poorly Graded Sand



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Specimen Control # **11062**

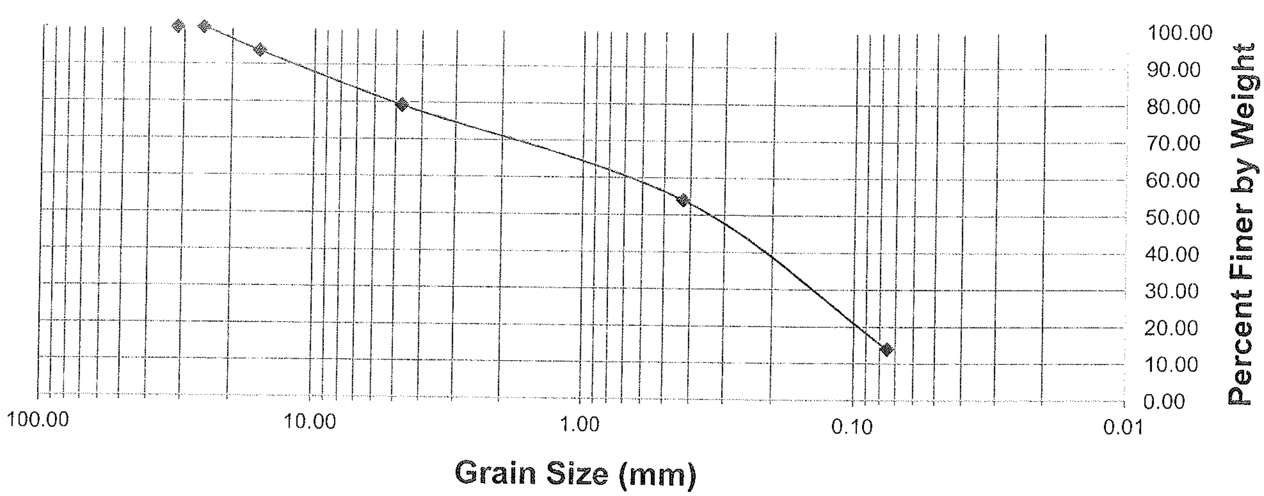
Sieve Analysis

Client:	City of PA	Date:	12/14/2011
Project:	CSO- Phase I (Oak Street)	Sample taken by:	Harriet C.
BILLING INFORMATION		Material:	B-1, 15'
Lab Account #:	PRTA-1107	Source:	
Project Manager:		Tested By:	**SRW**
Email:		Date Tested:	**12/12/2011 & 12/14/2011**
Phone#:	360-417-4808	Test requested:	**Wet / Dry Sieve:** **DRY**
Remarks:		Reviewed:	TTA

Sieve Diameter (mm)	Sieve Size	Dry Wt. (grams)	% Retained	% Passing	
31.750	**1 1/4"**	0.0	0.0%	100.0%	
25.400	**1"**	0.0	0.0%	100.0%	
15.875	**5/8"**	62.5	6.2%	93.8%	
4.750	**#4**	144.5	14.4%	79.3%	
0.425	**#40**	252.6	25.2%	54.1%	
0.075	**#200**	400.5	40.0%	14.1%	
-	**Pan**	140.6	14.1%		

Wt. Before Dry Sieve:	1000.7
Wt. After Dry Sieve:	1000.7
D10:	N/A
D30:	N/A
D60:	N/A
Cu:	N/A
Cc:	N/A
Soil Classification:	SM
Moisture Content:	-

Silty Sand



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Specimen Control # **11063**

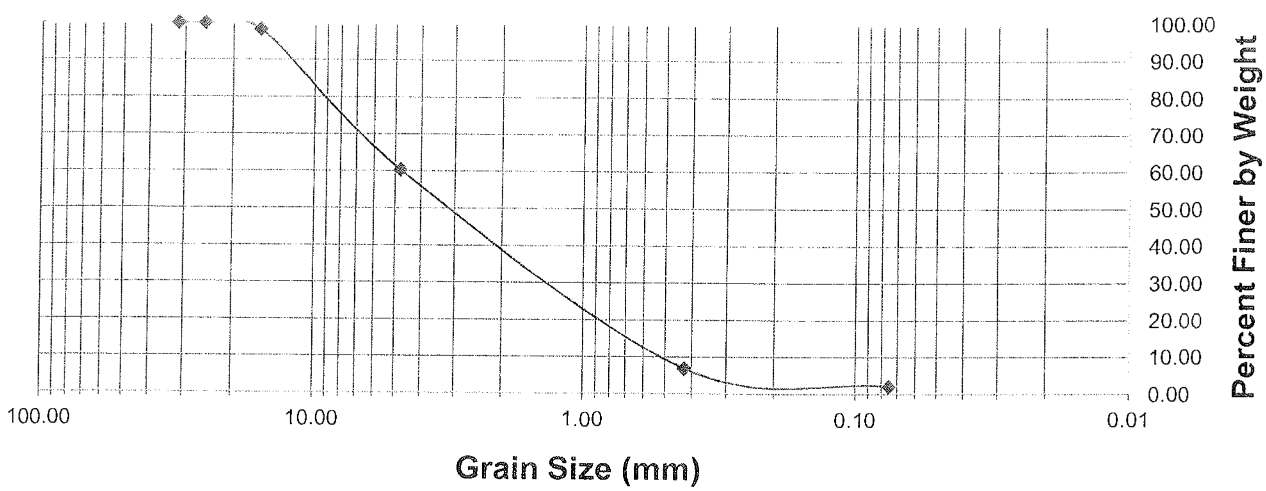
Sieve Analysis

Client:	City of PA	Date:	12/14/2011
Project:	CSO- Phase I (Oak Street)	Sample taken by:	Harriet C.
BILLING INFORMATION		Material:	B-2, 5'
Lab Account #:	PRTA-1107	Source:	
Project Manager:		Tested By:	**SRW**
Email:		Date Tested:	**12/12/2011 & 12/14/2011**
Phone#:	360-417-4808	Test requested:	**Wet / Dry Sieve:** **DRY**
Remarks:		Reviewed:	TTA

Sieve Diameter (mm)	Sieve Size	Dry Wt. (grams)	% Retained	% Passing	
31.750	**1 1/4"**	0.0	0.0%	100.0%	
25.400	**1"**	0.0	0.0%	100.0%	
15.875	**5/8"**	9.8	1.7%	98.3%	
4.750	**#4**	220.5	38.0%	60.4%	
0.425	**#40**	310.2	53.4%	7.0%	
0.075	**#200**	27.6	4.8%	2.2%	
-	**Pan**	12.9	2.2%		

Wt. Before Dry Sieve:	581.0
Wt. After Dry Sieve:	581.0
D10:	0.51
D30:	1.50
D60:	4.75
Cu:	9
Cc:	0.93
Soil Classification:	SP
Moisture Content:	-

Poorly Graded Sand



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Specimen Control #	11065

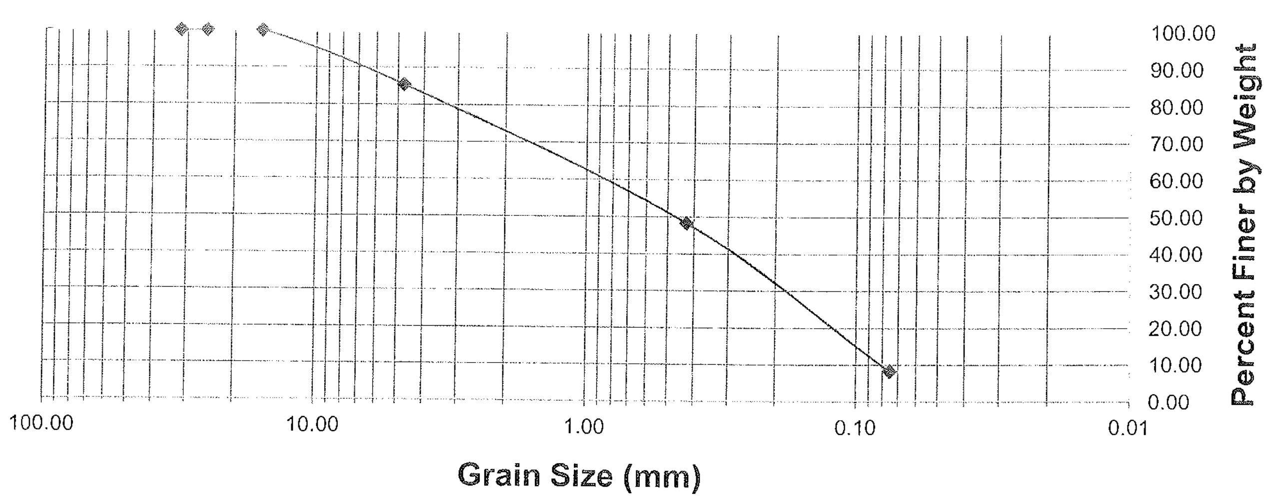
Sieve Analysis

Client:	City of PA	Date:	12/14/2011
Project:	CSO- Phase I (Oak Street)	Sample taken by:	Harriet C.
BILLING INFORMATION		Material:	B-3, 10'
Lab Account #:	PRTA-1107	Source:	
Project Manager:		Tested By:	**SRW/TTA**
Email:		Date Tested:	**12/12/2011 & 12/14/2011**
Phone#:	360-417-4808	Test requested:	**Wet / Dry Sieve: DRY**
Remarks:		Reviewed:	TTA

Sieve Diameter (mm)	Sieve Size	Dry Wt. (grams)	% Retained	% Passing	
31.750	**1 1/4"**	0.0	0.0%	100.0%	
25.400	**1"**	0.0	0.0%	100.0%	
15.875	**5/8"**	0.0	0.0%	100.0%	
4.750	**#4**	69.0	14.5%	85.5%	
0.425	**#40**	177.1	37.2%	48.4%	
0.075	**#200**	190.4	40.0%	8.4%	
-	**Pan**	40.0	8.4%		

Wt. Before Dry Sieve:	476.5
Wt. After Dry Sieve:	476.5
D10:	0.08
D30:	0.18
D60:	0.80
Cu:	10
Cc:	0.51
Soil Classification:	SP-SM
Moisture Content:	-

Poorly Graded Sand with Silt



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Specimen Control # 11069

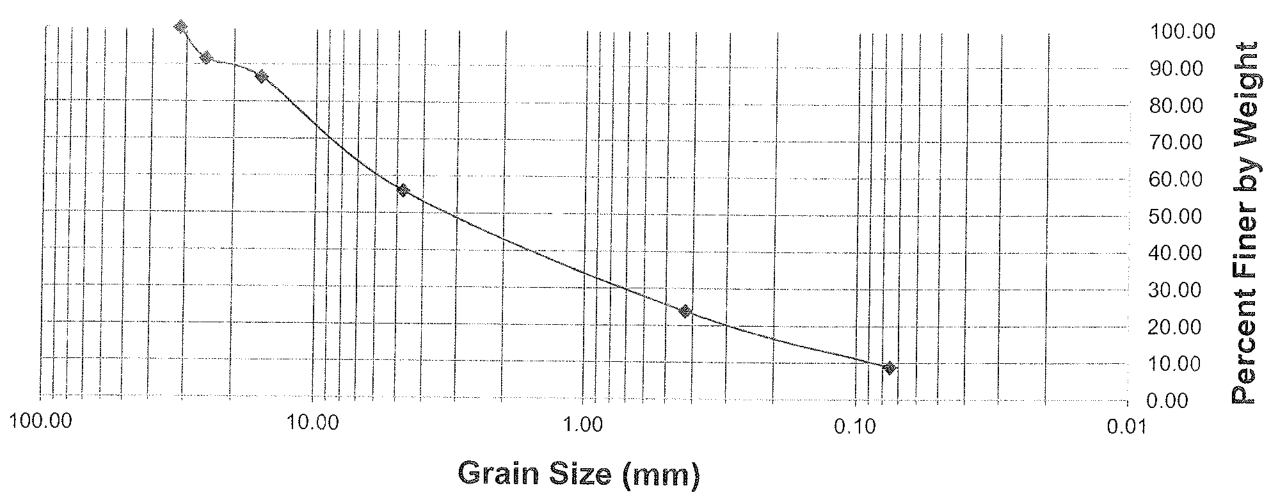
Sieve Analysis

Client:	City of PA	Date:	12/14/2011
Project:	CSO- Phase I (Oak Street)	Sample taken by:	Harriet C.
BILLING INFORMATION		Material:	B-3, 7.5"
Lab Account #:	PRTA-1107	Source:	Base below pavement
Project Manager:		Tested By:	**SRW**
Email:		Date Tested:	**12/12/2011 & 12/14/2011**
Phone#:	360-417-4808	Test requested:	**Wet / Dry Sieve:** **WET**
Remarks:		Reviewed:	TTA

Sieve Diameter (mm)	Sieve Size	Dry Wt. (grams)	% Retained	% Passing	
31.750	**1 1/4"**	0.0	0.0%	100.0%	
25.400	**1"**	142.4	8.4%	91.6%	
15.875	**5/8"**	83.5	4.9%	86.6%	
4.750	**#4**	514.8	30.5%	56.1%	
0.425	**#40**	543.8	32.2%	23.9%	
0.075	**#200**	252.5	15.0%	8.9%	
-	**Pan**	150.5	8.9%		

Wt. Before Wet Sieve:	1687.5
Wt. After Wet Sieve:	1537.0
D10:	0.09
D30:	0.75
D60:	5.70
Cu:	63
Cc:	1.10
Soil Classification:	SW-SM
Moisture Content:	-

Well Graded Sand with Silt



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Specimen Control #	11067

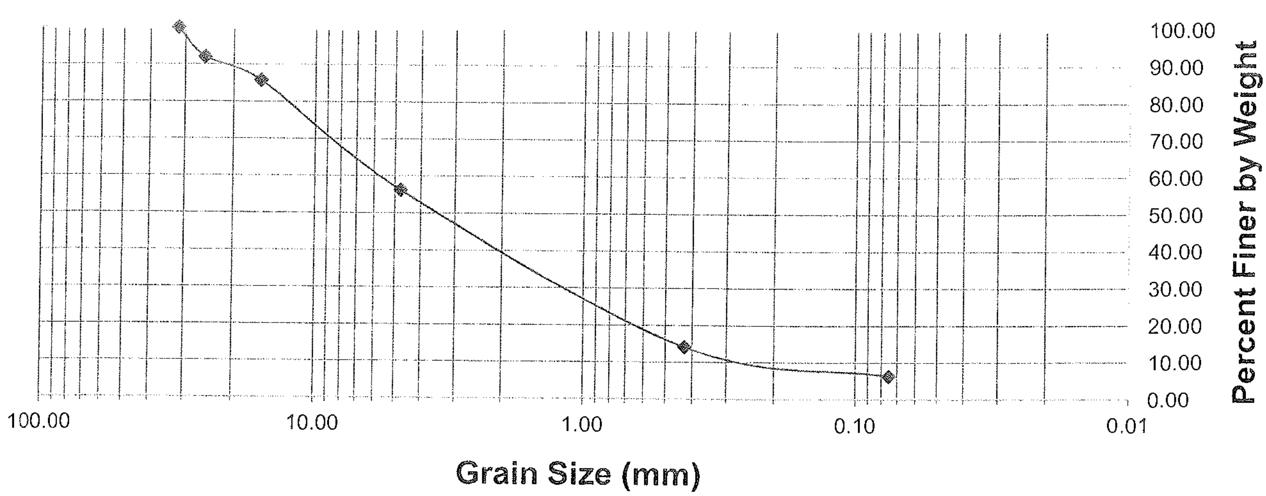
Sieve Analysis

Client:	City of PA	Date:	12/14/2011	
Project:	CSO- Phase I (Oak Street)	Sample taken by:	Harriet C.	
BILLING INFORMATION		Material:	C-5, 9.5"	
Lab Account #:	PRTA-1107	Source:	"Base" below pavement	
Project Manager:		Tested By:	**SRW/TTA**	
Email:		Date Tested:	**12/12/2011 & 12/14/2011**	
Phone#:	360-417-4808	Test requested:	**Wet / Dry Sieve:**	**WET**
Remarks:		Reviewed:	TTA	

Sieve Diameter (mm)	Sieve Size	Dry Wt. (grams)	% Retained	% Passing	
31.750	**1 1/4"**	0.0	0.0%	100.0%	
25.400	**1"**	136.2	7.9%	92.1%	
15.875	**5/8"**	107.0	6.2%	85.8%	
4.750	**#4**	505.9	29.5%	56.3%	
0.425	**#40**	720.3	42.0%	14.2%	
0.075	**#200**	133.7	7.8%	6.4%	
-	**Pan**	110.4	6.4%		

Wt. Before Wet Sieve:	1713.5
Wt. After Wet Sieve:	1617.4
D10:	0.29
D30:	1.30
D60:	5.60
Cu:	19
Cc:	1.04
Soil Classification:	SW-SM
Moisture Content:	-

Well Graded Sand with Silt



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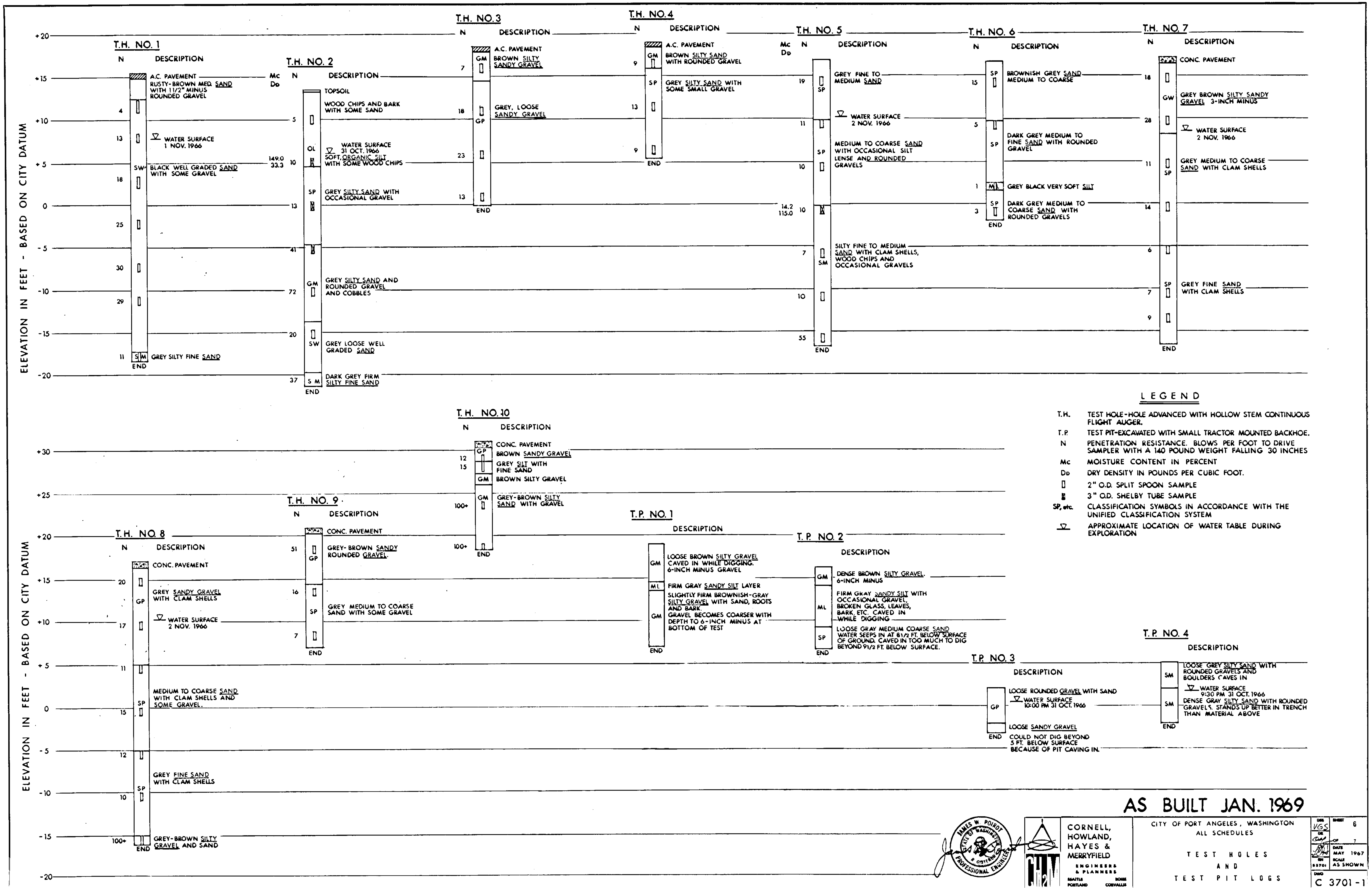

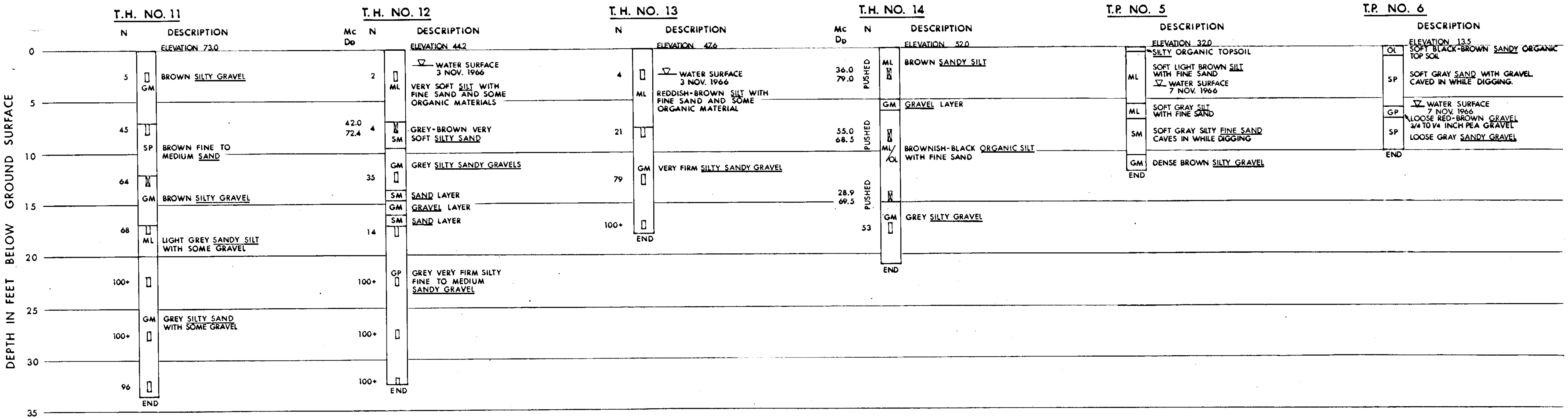

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APPENDIX D

INFILTRATION FEASIBILITY STUDY REPORT
CITY OF PORT ANGELES FRONT STREET
COMBINED SEWER OVERFLOW (PHASE 2) PROJECT
DECEMBER 12, 2013

SHANNON & WILSON, INC.
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P.O. BOX 300303
SEATTLE, WASHINGTON 98103
206•632•8020 FAX 206•695•6777

TRANSMITTAL

TO	Mr. Michael O'Neal, P.E.	DATE	December 12, 2013
COMPANY	Brown and Caldwell	PHONE	
ADDRESS	701 Pike Street, Suite 1200	FAX	
	Seattle, Washington 98101	JOB NO.	21-1-20617-005
SUBJECT	**CITY OF PORT ANGELES FRONT STREET COMBINED SEWER OVERFLOW (PHASE 2) PROJECT**		

THE FOLLOWING ITEMS ARE TRANSMITTED:

DATE	NO. COPIES	DESCRIPTION
12/12/2013	1	Infiltration Feasibility Study Report, City of Port Angeles, Front Street Combined Sewer Overflow (Phase 2) Project

☒ Per your request ☐ For your approval ☐ For your information ☐ For your files
☐ For your review ☐ For your action ☐ Return with comments ☐ Other

c: Courtney Boyle, Brown and Caldwell

By: Paul Van Horne, L.H.G. c: ______

Title: Senior Hydrogeologist ______

Infiltration Feasibility Study Report
City of Port Angeles
Front Street Combined Sewer Overflow (Phase 2) Project

December 12, 2013

SHANNON & WILSON, INC.

GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

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Submitted To:
Mr. Michael O'Neal, P.E.
Brown and Caldwell
701 Pike Street, Suite 1200
Seattle, Washington 98101

By:
Shannon & Wilson, Inc.
400 N 34th Street, Suite 100
Seattle, Washington 98103

21-1-20617-005

EXECUTIVE SUMMARY

Shannon & Wilson conducted an infiltration feasibility evaluation for the Front Street Pump Station No. 4 (PS 4) site, including a site visit, test pit logging and sampling, field infiltration testing, well construction and measurement, and laboratory testing. Our evaluation indicates:

- Approximately 10 to 12 feet of fill have been placed at the site. The highest groundwater level we have measured to date is 11.6 feet deep, in previously installed site well B-1. This well is screened in the beach deposits that underlie the fill. We previously performed water level fluctuation monitoring at this well in June 2013, which indicated about a 1-foot tidally induced groundwater level fluctuation range in the beach deposits.
- For this investigation, the City of Port Angeles (City) excavated two test pits adjacent to planned infiltration areas on the site. We logged and sampled the test pits and installed an observation well (TP-2-OW) to 9.6 feet deep in one of the test pits. This well was dry when measured on November 5 and December 9, 2013. Minor iron-oxide staining is present at approximately 8 and 8.5 feet deep (TP-1 and TP-2, respectively), which may indicate the depth to seasonally perched groundwater in the fill soils.
- We performed a small-scale pilot infiltration test (PIT) at one test pit, TP-1, in general accordance with the 2012 Low Impact Development Technical Guidance Manual (LID Manual) for Puget Sound (Puget Sound Partnership, 2012). The tested fill soil layer consisted gravelly sand (predominantly medium grained) with a trace of silt; this layer is situated at approximately 3 to 7 feet below grade at TP-1. The test pit bottom was approximately 4.3 feet below grade during the test. The PIT resulted in a measured infiltration rate for this location of about 31.1 to 21.9 inches/hour (constant head rate and falling head rate, respectively). Assuming similar soil conditions are present at the adjacent bioswale, we recommend a design subgrade infiltration rate of 7.3 inches/hour for the subgrade of the bioswale adjacent to TP-1, based on the application of an infiltration reduction factor of 0.33 (for site variability) to the observed falling head rate.
- We estimated infiltration rates based on grain size for the test pit TP-2 vicinity, using soil samples collected at depths of 4, 5.5, and 7.5 feet deep. (We also estimated infiltration rates for the TP-1 vicinity, using a sample collected at 4.5 feet deep, but we recommend using the PIT result instead.) Using the LID Manual's grain size method, we estimated the short-term infiltration rates of the tested TP-2 soils to be approximately 8.6, 0.6, and 35 inches/hour. Assuming soil conditions are similar to those encountered at TP-2, we recommend a design subgrade infiltration rate of 2.9 inches/hour for the bioswale subgrades in the TP-2 vicinity. This is based on an

infiltration reduction factor of 0.33 (for site variability) to the grain size-based infiltration rate.

- We recommend that spot excavations to at least 1 foot below the anticipated subgrade levels be performed at each bioswale. If a relatively low-permeability soil layer (such as the silt layer encountered at 5.5 to 6 feet deep at TP-2) is present within 1 foot below the subgrade, we recommend that the silt layer be excavated and replaced with sand.
- We tested two soil samples to characterize the biotreatment capability of the site soils. One sample was collected at 4.5 feet from TP-1, and the other was from 4 feet at TP-2. The cation exchange capacity (CEC) of the tested samples ranged from 6.89 to 6.26 milliequivalents (meq)/100 grams of soil, for TP-1 and TP-2, respectively. The organic content of the tested samples ranged from 0.328 to 0.994 percent, for TP-1 and TP-2, respectively. The CEC of these samples meets the LID treatment requirement of a minimum of 5 meq/100 grams, but the organic content does not meet the LID treatment requirement of 1 percent (although it is close for the TP-2 location). Also, the measured (PIT) infiltration rate of the TP-1 soils was greater than the upper limit of 9 inches/hour recommended by the Stormwater Management Manual for Western Washington (Washington Department of Ecology [Ecology], 2012). Based on these results, a composted soil mixture such as Ecology's default bioretention soil media (BSM) would be required in order to meet treatment goals for the site stormwater. We understand Ecology's default BSM will be used in the bioswales. The default short-term infiltration rate for Ecology's BSM is 6 inches/hour. We recommend application of a reduction factor of 2 to this rate, resulting in a BSM long-term design infiltration rate of 3 inches/hour.
- Based on our observations and testing, the site is generally suitable for stormwater infiltration for treatment purposes via bioretention, providing that BSM is incorporated for treatment. However, the encountered fill materials are variable in permeability, and explorations have not been performed at each proposed bioswale location. Consequently, we recommend that stormwater management should incorporate overflow facilities.
- The City's Stormwater Standard requires that infiltration facilities be set back a minimum of 10 feet from property lines and structures. The preliminary bioswale layout may need to be revised slightly in order to achieve the required setbacks, or a variance may need to be obtained from the City.
- We did not encounter evidence of soil contamination at the PS 4 site in previous boring B-1 or in either of the two test pits. Previously, we tested a sample from B-1 for metals and fuel-related constituents; this sample was collected between approximately 7.5 and 16 feet deep. Our current scope did not include testing for contaminants in the test pit soils or a detailed review of environmental records. The Ecology Facility/Site Map indicates that a voluntary cleanup was completed in 2001 at the Jackpot Food Mart gas station, located immediately west of the PS 4 site

(331 W. 1st Street). Additionally, the Port of Port Angeles Marine Trades Area (address listed as 338 W. 1st Street) is listed as a state cleanup site that is undergoing independent cleanup. The LID guidance recommends that infiltration facilities be located at least 100 feet from areas known to have deep soil contamination.

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INFILTRATION FEASIBILITY STUDY REPORT
CITY OF PORT ANGELES
FRONT STREET COMBINED SEWER OVERFLOW (PHASE 2) PROJECT
PORT ANGELES, WASHINGTON

1.0 INTRODUCTION

This infiltration feasibility study report presents the results of our subsurface explorations, laboratory testing, and hydrogeological analyses associated with the planned replacement of Pump Station No. 4 (PS 4). The PS 4 replacement is part of the Front Street Combined Sewer Overflow (CSO) (Phase 2) project and is located in Port Angeles, Washington. The replacement PS 4 site is located on a triangular parcel situated across from the existing PS 4, near the intersection of W. Front Street and Marine Drive (see Figure 1, Site and Exploration Plan).

Brown and Caldwell subcontracted Shannon & Wilson, Inc. (Shannon & Wilson) to perform an infiltration feasibility study for the new PS 4 site. The information and recommendations presented in this report are intended to provide the Brown and Caldwell design team with the information required to assist with advancing the design to 60 percent. Included in this report are a brief PS 4 site description; a discussion of the recently completed PS 4 site explorations and field and laboratory testing; the interpreted subsurface soil and groundwater conditions; and hydrogeological recommendations.

1.1 Authorization

On October 21, 2013, Brown and Caldwell authorized us to proceed with this study through acceptance of our proposal, dated October 8, 2013.

1.2 Project Background and Scope of Services

The new PS 4 will consist of a belowgrade structure containing the motor room and wet well (buried pump station) and at-grade facilities including an odor control building, generator building, and a screen wall. We understand that, if feasible, the City of Port Angeles (the City) intends to apply low-impact development (LID) principles on the site in order to treat site stormwater, through the use of bioretention features (bioswales).

Our scope of services for the project included performing an infiltration feasibility study for the site in general accordance with the Washington State Department of Ecology (Ecology)

Stormwater Management Manual for Western Washington (Ecology, 2012) and the LID Technical Guidance Manual for Puget Sound (Puget Sound Partnership, 2012).

Shannon & Wilson's scope of services for this study included the following tasks:

- Coordinating excavation and performing soil sampling at two test pits excavated by City personnel.
- Performing a small-scale pilot infiltration test (PIT) at one of the test pit locations.
- Installing and collecting a reading in a shallow observation well in one of the test pits, in order to check for shallow, perched groundwater.
- Performing laboratory analyses (visual classification and grain size analyses) of selected soil samples.
- Testing selected samples for biotreatment parameters, including cation exchange capacity (CEC) and organic content.
- Developing short- and long-term infiltration rate recommendations for the tested locations.

Our scope did not include testing for contaminants in site soils or a detailed review of environmental records.

2.0 PROJECT DESCRIPTION

As indicated in Figure 1, Site and Exploration Plan, the triangular parcel is bounded to the north by W. Front Street. It was formerly the site of a large antenna, the grounding wires for which are still present in the near-surface soils. It is nearly flat, with grade elevations ranging from about 17 to 18 feet. A detailed description of the PS 4 site and other aspects of the CSO project are presented in our draft geotechnical report for the CSO (Shannon & Wilson, 2013).

The parcel is not identified as a site of environmental concern on Ecology's Facility/Site Map. Previously, we tested a composite soil sample collected from 7.5 to 16 feet from site boring B-1. The sample results did not identify concentrations of fuel-related compounds or metals above applicable state cleanup standards.

The Ecology Facility/Site Map indicates that a voluntary cleanup was completed in 2001 at the Jackpot Food Mart gas station, located immediately west of the PS 4 site (331 W. 1st Street). Additionally, the Port of Port Angeles Marine Trades Area (address listed as 338 W. 1st Street) is listed as a state cleanup site that is undergoing independent cleanup. The LID guidance recommends that infiltration facilities be located at least 100 feet from areas known to have deep soil contamination.

Brown and Caldwell provided us and the City with a map indicating the approximate areas in which infiltration was proposed. Based on this information, City personnel identified locations on the PS 4 site for two test pits, situated near the proposed bioswale areas.

Based on information provided by Brown and Caldwell, we understand the following about the site and planned infiltration facilities:

- The contributing area to the bioswales will be approximately 0.19 acre.
- Stormwater infiltration facilities for flow control are not required.
- The minimum vertical separation from the bioswale subgrade to seasonally high groundwater or a hydraulic restrictive layer is 1 foot.
- A standard bioretention soil media, or BSM (a composted planting mix), will be placed in the bottom of each bioswale. BSM specifications are described in the LID Manual (Puget Sound Partnership, 2012).

3.0 SUBSURFACE CONDITIONS

A description of the general geologic conditions of the CSO project alignment, including the replacement PS 4 site, is included in our draft geotechnical report (Shannon & Wilson, 2013). Based on our previous review of geologic maps and geotechnical investigations, the PS 4 site is underlain by about 10 to 12 feet of recent fill that was placed over estuarine and beach deposits. Underlying the beach deposits are glacially deposited recessional outwash and till soils. The source of the fill is reportedly predominantly locally derived beach deposits, with possible engineered fill in the upper 3 to 5 feet. Based on our previous site explorations, we know that the estuarine and beach deposits underlying the fill are saturated.

4.0 FIELD EXPLORATIONS

The field exploration program included the following tasks:

- Coordinating utility location and test pit excavation with City personnel.
- Logging and sampling two test pits performed by City personnel.
- Performing hand borings within the test pits in order to log and sample deeper soil zones.

- Performing a PIT in the test pit that appeared to have the most permeable soils (TP-1), in cooperation with City personnel.
- Installing a 1-inch-diameter observation well in a hand-auger hole bored in the bottom of test pit TP-2.
- Collecting readings from the site observation wells (November 5 and December 9, 2013).

City staff excavated the test pits to their initial depths using a backhoe on October 29, 2013. On November 5, 2013, we met City personnel on the site, and we collected grab soil samples from the test pits and from the additional hand excavations that we bored within the test pits. We recorded the soil sample depth and descriptions on the test pit logs, field classifying the soils in accordance with the classification methods of ASTM International (ASTM) Designation: D 2488, Standard Recommended Practice for Description of Soil (Visual-Manual Procedure). We sealed the samples in plastic jars and returned them to our laboratory for review and testing. We did not encounter evidence of soil contamination in the two test pits.

The approximate locations of the explorations completed for this study are presented in Figure 1, Site and Exploration Plan. We estimated the locations of the test pits by measuring from mapped site features. We estimated the grade elevations of the two test pits from a site map provided by Brown and Caldwell.

Figure 2 presents a Soil Classification and Log Key that explains the terms used in the soil classifications and descriptions. The logs of the two test pits are presented as Figures 3 and 4. The log of previous site boring B-1 is presented as Figure 5. The observation well installed in this boring is screened at approximately 18.7 to 28.4 feet below grade. We based our estimates of soil density on T-probe penetration and on backhoe action.

4.1 Explorations

On October 29, 2013, City personnel excavated the test pits to their initial depths of approximately 4.3 feet (TP-1) and approximately 4 to 4.5 feet (TP-2). The City located the test pits slightly outside of the anticipated infiltration areas. We met City personnel on site on November 5, 2013, in preparation for TP-1 pilot infiltration testing.

Based on our observations, the test pits encountered fill soils to their maximum excavated depths (8.5 feet at TP-1 and 9.6 feet at TP-2). We observed shell fragments to be present in almost every soil layer encountered. The upper 2.8 to 3.5 feet of fill consisted predominantly of slightly silty to silty, sandy gravel with scattered cobbles, to trace silty to silty, gravelly sand. Both test pits encountered what City personnel identified as grounding wires for the demolished site antenna, at depths of about 1.5 to 2 feet.

Between approximately 2.8 and 7 feet deep, TP-1 encountered very loose, slightly gravelly to gravelly sand, trace of silt. We collected a sample from this layer for CEC and organic content testing. From 7 to 8.5 feet, TP-1 encountered silty, fine sand to fine sandy silt.

Between 3.5 and 5.5 feet deep, TP-2 encountered slightly fine gravelly, silty sand. We collected a sample from this layer for CEC and organic content testing. At 5.5 to 6 feet, TP-2 encountered a relatively low-permeability layer of slightly fine sandy silt. From 5.5 to 9.2 feet, TP-2 encountered slightly silty to silty, fine sand with varying amounts of gravel. Fine sandy silt was present at TP-2 from 9.2 to 9.6 feet.

We encountered no seepage in either test pit. We installed an observation well in the hand boring we performed in TP-2, designating it as TP-2-OW. The well consists of 1-inch-diameter, Schedule 40, polyvinyl chloride casing and screen with glued joints, with 0.020-inch-slot screen set at 4.8 to 9.6 feet deep. We placed a filter pack around the screen from 4 to 9.6 feet below grade, using sand collected from TP-1 as the filter material. The City used a backhoe to backfill the remainder of the test pit with TP-2 spoils.

The well we installed at TP-2 was dry when measured on November 5 and December 9, 2013. We observed iron-oxide staining at approximately 8 to 8.5 feet deep at TP-1 and TP-2, respectively. This staining may indicate the depth to seasonally perched groundwater within the fill soils.

The groundwater level in well B-1, located near TP-2, was 11.7 feet below grade on November 5, 2013. This is similar to the highest level we recorded at B-1 (11.6 feet below grade) during our previous groundwater/tidal interaction monitoring, performed on June 4 through 10, 2013. The B-1 water level was 11.8 feet deep on December 9, 2013, as measured by City personnel. The B-1 groundwater levels represent the water level in the beach deposits that underlie the fill and estuarine deposits at the site.

4.2 Pilot Infiltration Test (PIT)

With the assistance of City personnel, we performed a small-scale PIT in test pit TP-1. We ran the PIT for approximately 7 hours on October 5, 2013 (Figure 6). The PIT included 6 hours of presoaking, followed by a 1-hour constant head test. We maintained the maximum water level at about 3 feet below grade for the constant head test, using a flow rate of approximately

15.5 gallons per minute (gpm). The north, west, and south sidewalls of TP-1 slumped slightly at 3 feet deep during the test, resulting in the ponded surface area being about 6 by 8 feet during the constant head portion of the test. We calculated the observed (short-term) constant head infiltration rate of 31.1 inches/hour based on 15.5 gpm infiltrating through an area of approximately 48 square feet.

After the end of the constant head test period, we recorded the drop in water level until the test pit had completely drained. The ponded water surface area was approximately 4 by 7 feet when the water level was about 6 inches above the test pit bottom. We calculated the observed (short-term) falling head infiltration rate to be 21.9 inches/hour, based on a falling head rate from 6 to 5 inches of 1 inch in 2.75 minutes.

After the test pit had drained, City personnel immediately excavated to about 7 feet deep, and we saw no sign of ponded water to that depth. City personnel then used a backhoe to backfill TP-1 with the TP-1 spoils.

5.0 GEOTECHNICAL LABORATORY TESTING

5.1 Introduction

Our laboratory personnel performed geotechnical testing on selected samples retrieved from the test pits to evaluate index and engineering properties of the subsurface soils. Laboratory tests included visual classifications and grain size (sieve and hydrometer) analyses. We classified the soil samples according to the Unified Soil Classification System. We also classified selected samples using the U.S. Department of Agriculture (USDA) textural system. The results of these tests are incorporated in the test pit logs (Figures 3 and 4) and are presented in Figures 7 and 8.

5.2 Visual Classification

In our laboratory, we visually classified the soil samples retrieved from the explorations using a system based on ASTM Designation: D 2487, Standard Test Method for Classification of Soil for Engineering Purposes, and ASTM Designation: D 2488, Standard Recommended Practice for Description of Soil (Visual-Manual Procedure). The individual sample classifications have been incorporated into the exploration logs. The visual classifications have been incorporated into the soil descriptions presented on the test pit logs, Figures 3 and 4.

5.3 Grain Size Analysis

We performed four grain size distribution analyses on samples we collected from TP-1 and TP-2. We performed this testing in accordance with ASTM Designation: D 422, Standard Method for Particle-Size Analysis of Soils. Figure 7 presents a tabulated summary for the grain size distribution plot, including sample description, percentage of fines passing the No. 200 sieve, natural water content, and other information.

We also determined the USDA texture of these four soil samples. The USDA textural system only considers soil passing the No. 10 sieve when determining the percentages of sand, silt, and clay for use in the USDA Textural Triangle. We present the results of these analyses in Figure 8.

6.0 FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS

6.1 Infiltration Rate Recommendations

The subgrade infiltration rates discussed below are based on the soil and groundwater conditions we observed and are only applicable to the location and elevation of testing. We have assumed that the bioswale subgrade soils will not be compacted and that the subgrade depths will be 4 feet below current site grade. Compaction may require the use of lower design infiltration rates than those discussed below.

For the TP-1 vicinity, the soil tested by the PIT was gravelly sand, trace of silt. The short-term (observed) PIT falling head rate is 21.9 inches/hour. (This is greater than the 9 inches/hour maximum rate recommended by Ecology's Stormwater Management Manual for Western Washington [Ecology, 2102] for soils that can be expected to provide treatment.) Application of a correction factor for site variability and the number of locations tested (CF_v) of 0.33 results in a long-term (design) subgrade infiltration rate of 7.2 inches/hour. We understand that the standard BSM specified in the LID Manual (Puget Sound Partnership, 2012) will be placed in the proposed bioswale. The LID Manual's recommended BSM short-term infiltration rate is 6 inches/hour. The LID Manual recommends an infiltration reduction factor of 50 percent for sites with small contribution areas (like PS 4), resulting in a long-term design BSM infiltration rate of 3 inches/hour. Therefore, the bioswale infiltration rate will be governed primarily by the BSM infiltration characteristics in the TP-1 vicinity.

Table 1 presents grain size-based infiltration rate estimates for samples analyzed from TP-1 and TP-2. We developed these infiltration rate estimates using a formula presented in the LID

Manual (Puget Sound Partnership, 2012). We do not recommend using the grain size-based result for TP-1, S-2 (4.5 to 7 feet), as the PIT results indicate lower rates.

Our recommended infiltration rate for the infiltration receptor soils in the TP-2 vicinity is based on sample TP-2, S-2 (4 to 5 feet deep). This soil is slightly fine gravelly, silty sand (USDA texture "loamy sand"). The short-term rate for this soil is 8.6 inches/hour. We recommend a long-term (design) infiltration rate of 2.9 inches/hour for the TP-2 vicinity bioswale, based on applying a CF_v of 0.33.

In the TP-2 vicinity, the slightly fine sandy silt layer encountered at 5.5 to 6 feet will, if laterally extensive, retard the vertical infiltration of stormwater. The presence of iron oxide staining at 8 and 8.5 feet in the TP-1 and TP-2 locations is a potential indication of additional perching layers and seasonal high groundwater conditions at these depths. However, observation well TP-2-OW, 9.6 feet deep, has been dry to date (measured on November 5 and December 9, 2013).

6.2 Additional Recommendations

In order to check typical seasonal high groundwater levels, we recommend City personnel continue to occasionally measure and relay to us the groundwater levels at the site through the current wet season, particularly during and shortly after heavy rains. If groundwater rises to within 9 feet of grade in well TP-2-OW, we recommend we be contacted so that we may consider the need for revisions to our infiltration recommendations.

The City's stormwater standards require a 10-foot minimum setback of infiltration facilities from any structure or property line. The proposed bioswales appear to be slightly closer to the planned PS 4 structure than 10 feet, which may require either repositioning the bioswales or obtaining a variance from the City.

Because of the variable nature of the encountered fill materials, we recommend that overflows be incorporated into the bioswale designs. If soil conditions encountered at the bioswale excavations appear to differ significantly from those we observed in the test pits and previous site boring B-1, we recommend that you contact us so that we may consider the need for revising our infiltration recommendations. We recommend that spot excavations be performed in each bioswale to at least 1 foot below the subgrade level. If a relatively low-permeability layer is encountered within 1 foot of the bioswale subgrade, we recommend that the layer be excavated and replaced with sand. An example of a low-permeability soil is the silt layer encountered at 5.5 to 6 feet deep in TP-2.

We recommend that a regular and perpetual maintenance program be performed for the infiltration facilities to reduce siltation and bio-fouling.

7.0 LIMITATIONS

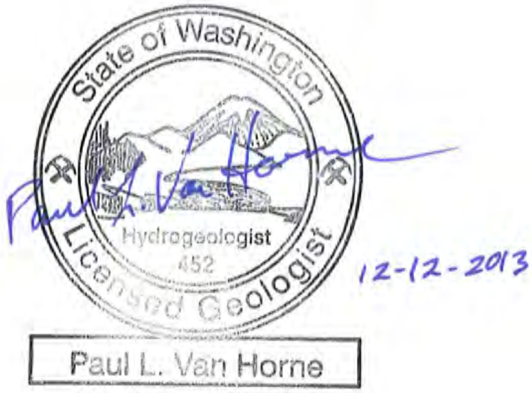
The analyses, conclusions, and recommendations contained in this report are based on site conditions as they presently exist. We further assume that the current field explorations are representative of the subsurface conditions at the proposed infiltration facility alignments; i.e., the subsurface conditions everywhere in the vicinity of the proposed infiltration facilities are not significantly different from those disclosed by the field explorations. Within the limitations of the scope, schedule, and budget, the analyses, conclusions, and recommendations presented in this report were prepared in accordance with generally accepted professional geotechnical and environmental engineering principles and practice in this area at the time this report was prepared. We make no other warranty, either express or implied. These conclusions and recommendations were based on our understanding of the project as described in this report and the site conditions as interpreted from the field explorations.

Unanticipated soil conditions are commonly encountered and cannot be fully determined by merely taking soil samples or completing test explorations. Such unexpected conditions frequently require that additional expenditures be made to attain a properly constructed project. Therefore, a contingency fund is recommended to accommodate such potential extra costs.

This report was prepared for the exclusive use of the City and the Brown and Caldwell design team. It should be made available to prospective contractors for information on factual data only, and not as a warranty of subsurface conditions such as those interpreted from the exploration logs and presented in the discussions of subsurface conditions included in this report.

Shannon & Wilson, Inc. has prepared Appendix B, "Important Information About Your Geotechnical/Environmental Report," to help you understand the use and limitations of our report. The scope of our services did not include any environmental assessment or evaluation regarding the presence or absence of wetlands or hazardous or toxic materials in the soil, surface water, groundwater, or air on or below or around the site. Shannon & Wilson, Inc. has qualified personnel to assist you with these services should they be necessary.

SHANNON & WILSON, INC.



Paul L. Van Horne, L.H.G.
Senior Hydrogeologist

PVH:JSB:MSK/pvh

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TABLE 1
GRAIN SIZE-BASED INFILTRATION ESTIMATES

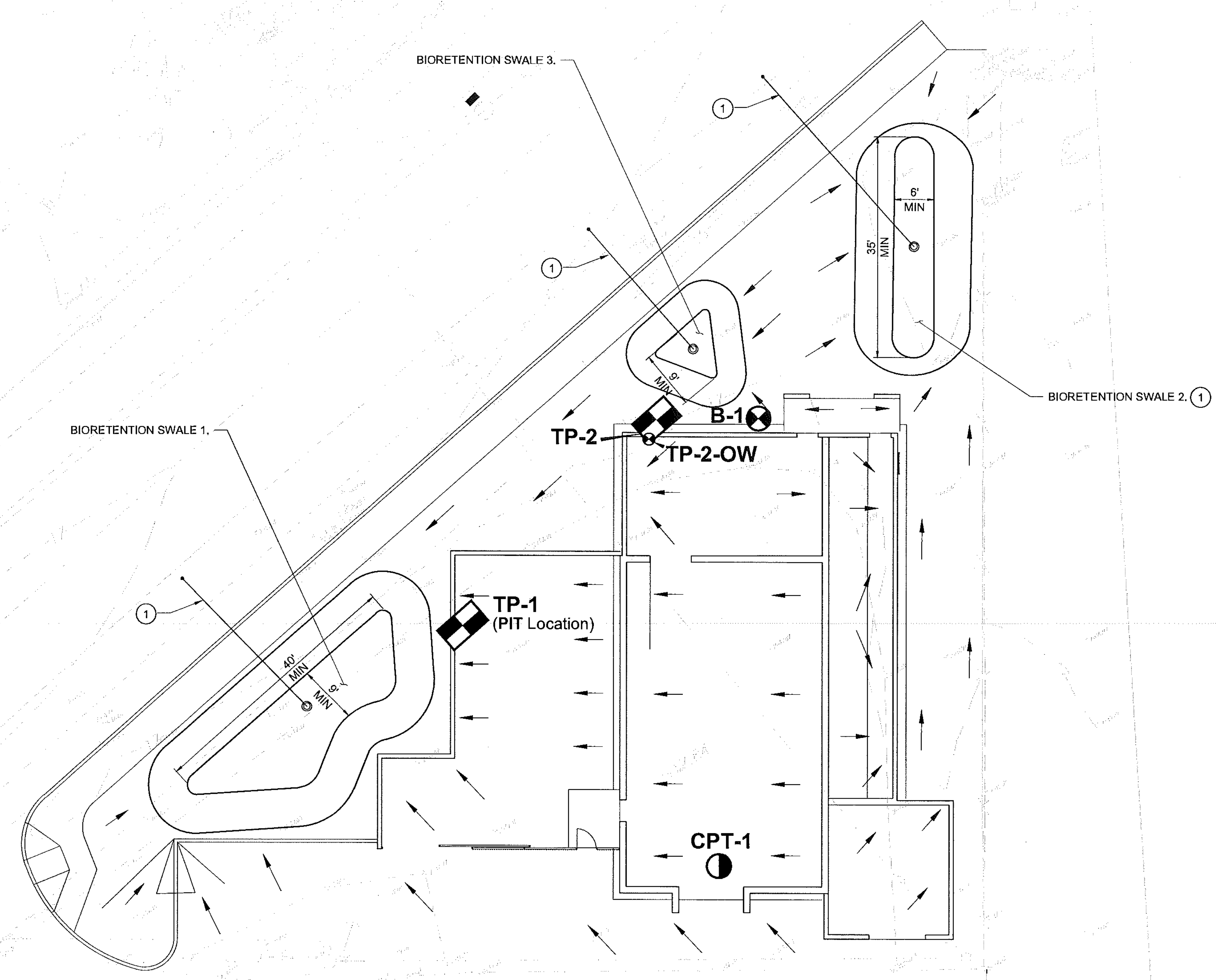
Exploration Number	Sample Number	Estimated Bioswale Subgrade Depth (feet below current grade)	Sample Top Depth (feet below current grade)	USCS	USDA Soil Texture	D_{10} (mm)	D_{60} (mm)	D_{90} (mm)	Fines (percent)	$\log_{10}(K_{sat})$	Uncompacted Short-term Grain Size-based K_{sat} (cm/sec)*	Uncompacted Short-term Grain Size-based K_{sat} (in/hr)*	Long-term (Design) Infiltration Rate, Based on CFv=0.33 (in/hr)*
TP-1	S-2**	4	4.5	SP	Sand	0.44	1.2	12	1.1	-0.89	0.13	181	59.6
TP-2	S-2	4	4	SM	Loamy Sand	0.038	0.13	2.8	32.8	-2.21	0.0061	8.6	2.9
TP-2	S-3	4	5.5	ML	Silt Loam	0.0054	0.044	0.096	85.9	-3.35	0.00045	0.6	0.21
TP-2	S-6	4	7.5	SP-SM	Sand	0.076	0.17	0.25	8.9	-1.61	0.024	35	11.4

Notes:

* Long-term (design) infiltration rates were derived using a formula provided in the Low Impact Development Technical Guidance Manual for Puget Sound (Puget Sound Partnership, 2012). The formula is as follows: $\log10(K_{sat}) = -1.57 + 1.90(D10) + 0.015(D60) - 0.013(D90) - 2.08(f_{fines})$, where D10, D60, and D90 are the grain sizes in mm for which 10, 60, and 90 percent of the sample is more fine, and f_{fines} is the fraction of the soil (by weight) that passes the number 200 sieve. K_{sat} is in cm/sec.

** Recommend using pilot infiltration test results for estimating this soil's infiltration rate.

CFv = infiltration reduction factor for site variability and number of locations tested
cm/sec = centimeters per second
in/hr = inches per hour
mm = millimeters
USCS = Unified Soil Classification System
USDA = U.S. Department of Agriculture



LEGEND

- B-1 — Boring Designation and Approximate Location (Shannon & Wilson, 2013)
- CPT-1 — Cone Penetration Test Designation and Approximate Location (Shannon & Wilson, 2013)
- TP-1 — Test Pit Designation and Approximate Location (Shannon & Wilson, 2013)
- PIT — Pilot Infiltration Test
- (1) — 12" Bioretention Overflow Line to Connect to Proposed Storm Drain

0 20 40

Scale in Feet

NOTE

This figure is adapted from AutoCAD files 144083-014-C-105.dwg, 144083-A-LSA-PLN3.dwg, 144083-C-014-XSITE.DWG, and 144083-C-WEN-SURVEY.DWG, received 11-11-2013.

Front Street CSO Phase II
Infiltration Study
Port Angeles, Washington

SITE AND EXPLORATION PLAN

December 2013 21-1-20617-005

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

FIG. 1

Filename: J:\211\20617-005\21-1-20617-005 Fig 1 Site Plan.dwg Date: 12-10-2013 Login: bac

Shannon & Wilson, Inc. (S&W), uses a soil classification system modified from the Unified Soil Classification System (USCS). Elements of the USCS and other definitions are provided on this and the following page. Soil descriptions are based on visual-manual procedures (ASTM D 2488-93) unless otherwise noted.

S&W CLASSIFICATION OF SOIL CONSTITUENTS

- MAJOR constituents compose more than 50 percent, by weight, of the soil. Major consituents are capitalized (i.e., SAND).
- Minor constituents compose 12 to 50 percent of the soil and precede the major constituents (i.e., silty SAND). Minor constituents preceded by "slightly" compose 5 to 12 percent of the soil (i.e., slightly silty SAND).
- Trace constituents compose 0 to 5 percent of the soil (i.e., slightly silty SAND, trace of gravel).

MOISTURE CONTENT DEFINITIONS

Dry	Absence of moisture, dusty, dry to the touch
Moist	Damp but no visible water
Wet	Visible free water, from below water table

ABBREVIATIONS

ATD	At Time of Drilling
Elev.	Elevation
ft	feet
FeO	Iron Oxide
MgO	Magnesium Oxide
HSA	Hollow Stem Auger
ID	Inside Diameter
in	inches
lbs	pounds
Mon.	Monument cover
N	Blows for last two 6-inch increments
NA	Not applicable or not available
NAD	North American Datum (year)
NAVD	North American Vertical Datum (year)
NGVD	National Geodetic Vertical Datum (year)
NP	Non plastic
OD	Outside diameter
OVA	Organic vapor analyzer
PID	Photo-ionization detector
ppm	parts per million
PVC	Polyvinyl Chloride
SS	Split spoon sampler
SPT	Standard penetration test
USC	Unified soil classification
WOH	Weight of hammer
WOR	Weight of drill rods

GRAIN SIZE DEFINITION

DESCRIPTION	SIEVE NUMBER AND/OR SIZE
FINES	< #200 (0.08 mm)
SAND* - Fine	#200 to #40 (0.08 to 0.4 mm)
- Medium	#40 to #10 (0.4 to 2 mm)
- Coarse	#10 to #4 (2 to 5 mm)
GRAVEL* - Fine	#4 to 3/4 inch (5 to 19 mm)
- Coarse	3/4 to 3 inches (19 to 76 mm)
COBBLES	3 to 12 inches (76 to 305 mm)
BOULDERS	> 12 inches (305 mm)

* Unless otherwise noted, sand and gravel, when present, range from fine to coarse in grain size.

RELATIVE DENSITY / CONSISTENCY

COARSE-GRAINED SOILS		FINE-GRAINED SOILS	
N, SPT, BLOWS/FT.	RELATIVE DENSITY	N, SPT, BLOWS/FT.	RELATIVE CONSISTENCY
0 - 4	Very loose	Under 2	Very soft
4 - 10	Loose	2 - 4	Soft
10 - 30	Medium dense	4 - 8	Medium stiff
30 - 50	Dense	8 - 15	Stiff
Over 50	Very dense	15 - 30	Very stiff
		Over 30	Hard

WELL AND OTHER SYMBOLS

Bent. Cement Grout	Surface Cement Seal
Bentonite Grout	Asphalt or Cap
Bentonite Chips	Slough
Silica Sand	Bedrock
PVC Screen	
Vibrating Wire	

Front Street CSO Phase II
Infiltration Study
Port Angeles, Washington

SOIL CLASSIFICATION AND LOG KEY

December 2013 21-1-20617-005

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. 2
Sheet 1 of 2

UNIFIED SOIL CLASSIFICATION SYSTEM (USCS)
(From USACE Tech Memo 3-357)

MAJOR DIVISIONS			GROUP/GRAPHIC SYMBOL	TYPICAL DESCRIPTION
COARSE-GRAINED SOILS *(more than 50% retained on No. 200 sieve)*	Gravels *(more than 50% of coarse fraction retained on No. 4 sieve)*	Clean Gravels *(less than 5% fines)*	GW	Well-graded gravels, gravels, gravel/sand mixtures, little or no fines.
			GP	Poorly graded gravels, gravel-sand mixtures, little or no fines
		Gravels with Fines *(more than 12% fines)*	GM	Silty gravels, gravel-sand-silt mixtures
			GC	Clayey gravels, gravel-sand-clay mixtures
	Sands *(50% or more of coarse fraction passes the No. 4 sieve)*	Clean Sands *(less than 5% fines)*	SW	Well-graded sands, gravelly sands, little or no fines
			SP	Poorly graded sand, gravelly sands, little or no fines
		Sands with Fines *(more than 12% fines)*	SM	Silty sands, sand-silt mixtures
			SC	Clayey sands, sand-clay mixtures
FINE-GRAINED SOILS *(50% or more passes the No. 200 sieve)*	Silts and Clays *(liquid limit less than 50)*	Inorganic	ML	Inorganic silts of low to medium plasticity, rock flour, sandy silts, gravelly silts, or clayey silts with slight plasticity
			CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
		Organic	OL	Organic silts and organic silty clays of low plasticity
	Silts and Clays *(liquid limit 50 or more)*	Inorganic	MH	Inorganic silts, micaceous or diatomaceous fine sands or silty soils, elastic silt
			CH	Inorganic clays of medium to high plasticity, sandy fat clay, or gravelly fat clay
		Organic	OH	Organic clays of medium to high plasticity, organic silts
HIGHLY-ORGANIC SOILS	Primarily organic matter, dark in color, and organic odor		PT	Peat, humus, swamp soils with high organic content (see ASTM D 4427)

NOTE: No. 4 size = 5 mm; No. 200 size = 0.075 mm

NOTES

1. Dual symbols *(symbols separated by a hyphen, i.e., SP-SM, slightly silty fine SAND)* are used for soils with between 5% and 12% fines or when the liquid limit and plasticity index values plot in the CL-ML area of the plasticity chart.
2. Borderline symbols *(symbols separated by a slash, i.e., CL/ML, silty CLAY/clayey SILT; GW/SW, sandy GRAVEL/gravelly SAND)* indicate that the soil may fall into one of two possible basic groups.

Front Street CSO Phase II
Infiltration Study
Port Angeles, Washington

SOIL CLASSIFICATION AND LOG KEY

December 2013 21-1-20617-005

SHANNON & WILSON, INC.
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FIG. 2
Sheet 2 of 2

BORING_CLASS2 21-20617-004.GPJ SWNEW.GDT 12/11/13

Filename: J:\211\20617-005\21-1-20617-005 TPs.dwg Date: 12-10-2013 Login: bac

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

LOG OF TEST PIT TP-1

JOB NO: 21-1-20617-005 DATE: 11-05-2013 LOCATION: See Site and Exploration Plan

PROJECT: W. Front Street CSO, Phase II, Infiltration

Sketch of South Pit Side

Surface Elevation: Approx. 17.5 Ft.

SOIL DESCRIPTION

(1) 0 - 0.3 feet: Asphalt pavement (Fill).

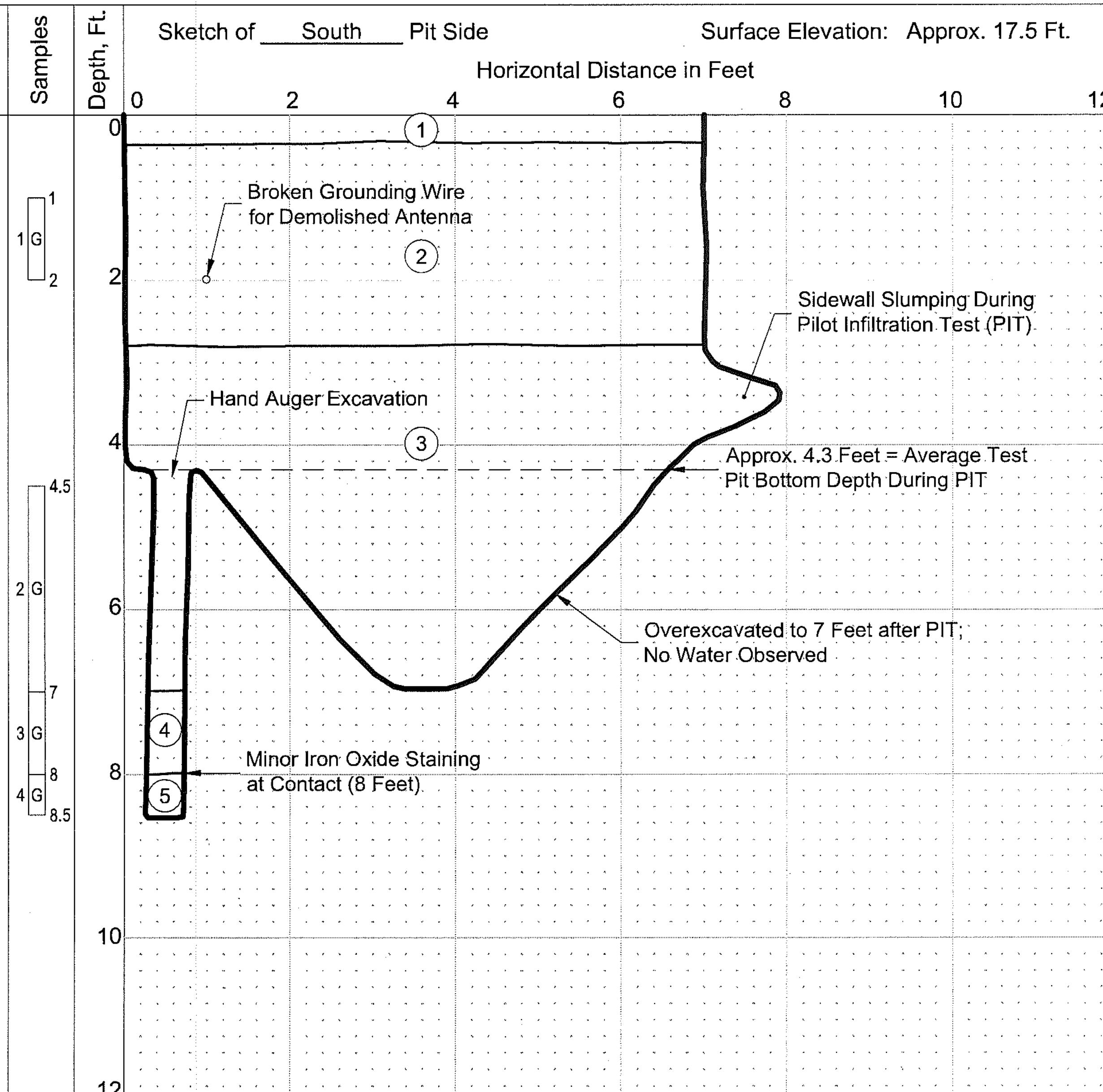
(2) 0.3 - 2.8 feet: Brown, slightly silty to silty, gravelly, fine to medium SAND; moist; scattered lean clay chunks and shell fragments; SM/SP-SM (Fill).

(3) 2.8 - 7 feet: Very loose, brown, slightly gravelly to gravelly SAND, trace of silt; moist; trace of shell fragments and organics; SP (Fill).

(4) 7 - 8 feet: Brown, silty, fine SAND; moist; scattered shell fragments and brown, sandy SILT chunks; trace of organics, iron oxide-stained at base; SM (Fill).

(5) 8 - 8.5 feet: Dark gray, fine sandy SILT; moist; scattered shell fragments; ML (Fill).

Ground Water: None Observed



NOTE

Small scale pilot infiltration test performed at approximately 4.3 feet deep.

FIG. 3

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

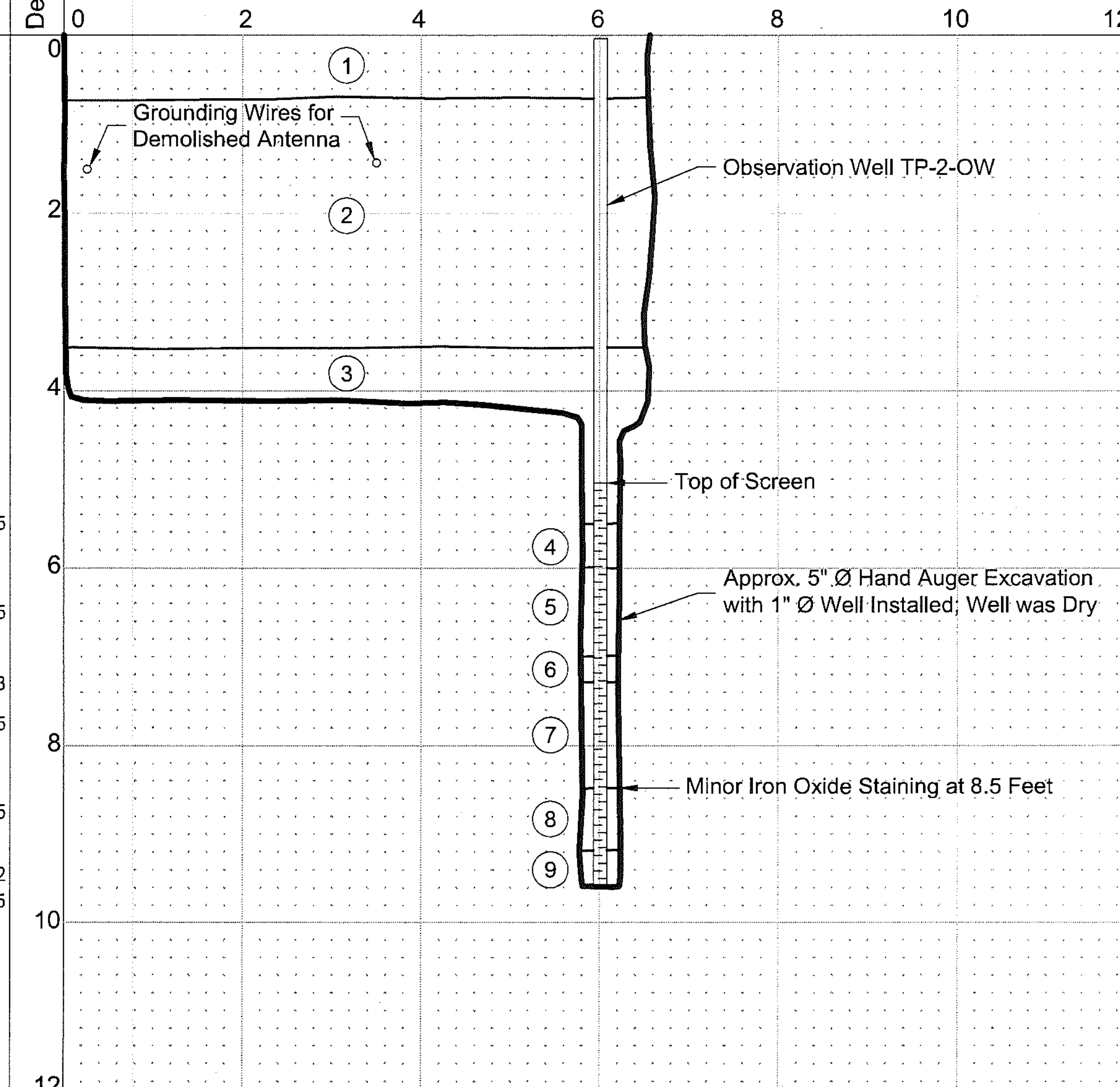
LOG OF TEST PIT TP-2

JOB NO: 21-1-20617-005 DATE: 11-05-2013 LOCATION: See Site and Exploration Plan

PROJECT: Front Street CSO, Phase II, Infiltration

Sketch of South Pit Side — Surface Elevation: Approx. 17.0 Ft.

SOIL DESCRIPTION	Ground Water	% Water Content	Samples
(1) 0 - 0.7 feet: Grass and brown, gravelly, fine to medium SAND, trace of silt; moist; SP (Fill).	None Observed		
(2) 0.7 - 3.5 feet: Brown, silty, fine to medium sandy GRAVEL; moist; with cobbles up to 9" diameter; GM (Fill).			1 G (2 - 3)
(3) 3.5 - 5.5 feet: Brown, slightly fine gravelly, silty SAND; moist; trace of organics and silt seams, scattered shell fragments; SM (Fill).			2 G (4 - 5)
(4) 5.5 - 6 feet: Dark gray, slightly fine sandy SILT; moist; ML (Fill).			3 G (5.5 - 6)
(5) 6 - 7 feet: Dark gray, slightly silty to silty, fine SAND, trace of gravel; moist; trace of wood fragments, scattered shell fragments; SM/SP-SM (Fill).			4 G (6.5 - 7)
(6) 7 - 7.3 feet: Brown, silty, gravelly, fine SAND; moist; scattered shell fragments; SM (Fill).			5 G (7 - 7.3)
(7) 7.3 - 8.5 feet: Brown, slightly silty, fine SAND; moist; trace of fine gravel and shell fragments; iron oxide-stained at base; SP-SM (Fill).			6 G (7.5 - 8)
(8) 8.5 - 9.2 feet: Dark gray, silty, fine SAND; moist; trace of shell fragments; SM (Fill).			7 G (8.5 - 9)
(9) 9.2 - 9.6 feet: Dark gray, fine sandy SILT; moist; trace of shell fragments; ML (Fill).			8 G (9.2 - 9.5)

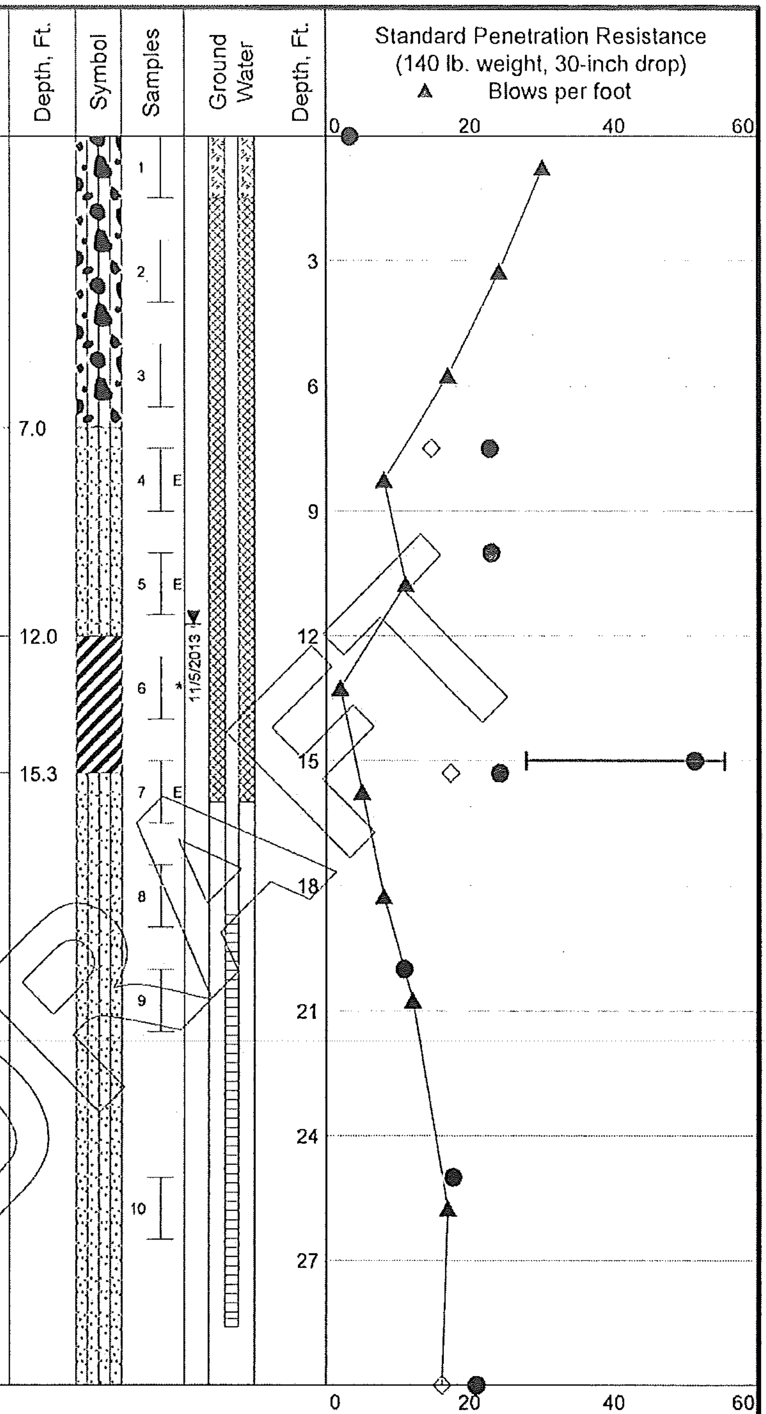


NOTE

Observation well TP-2-OW installed with 20-slot screen and perforated sump.

FIG. 4

SOIL DESCRIPTION Ground Surface Elevation: Approx. 18 Ft.	Depth, Ft.
Medium dense to dense, brown to gray-brown, silty, sandy GRAVEL to silty, gravelly SAND; moist; scattered shell fragments below 5 feet, scattered organics; (Hf) GM/SM.	
Loose to medium dense, brown and gray, silty, fine to medium SAND and slightly fine gravelly, silty SAND; wet; trace iron-oxide staining, scattered organics, scattered shell fragments; (Hf) SM.	7.0
Very soft, gray and brown, silty CLAY, trace of coarse sand; wet; scattered organics, scattered shell fragments; (He) CH.	12.0
Loose to medium dense, dark gray, slightly gravelly to gravelly, silty SAND to silty, sandy GRAVEL; wet; interbedded, trace to scattered shell fragments, trace organics; (Hb) SM/GM.	15.3



CONTINUED NEXT SHEET

LEGEND

- * Sample Not Recovered
- E Environmental Sample Obtained
- 2" O.D. Split Spoon (SPT)
- Piezometer Screen and Sand Filter
- Bentonite-Cement Grout
- Bentonite Chips/Pellets
- Bentonite Grout
- Ground Water Level in Well

◇ % Fines (<0.075mm)
● % Water Content
Plastic Limit ├──●──┤ Liquid Limit
Natural Water Content

NOTES

1. The boring was performed using Mud Rotary drilling methods.
2. The stratification lines represent the approximate boundaries between soil types, and the transition may be gradual.
3. Refer to the report text for a proper understanding of the subsurface materials.
4. Groundwater level, if indicated above, is for the date specified and may vary.
5. Refer to KEY for explanation of symbols, codes and definitions.
6. USCS designation is based on visual-manual classification and selected lab testing.

Front Street CSO Phase II
Infiltration Study
Port Angeles, Washington

LOG OF BORING B-1

December 2013 21-1-20617-005

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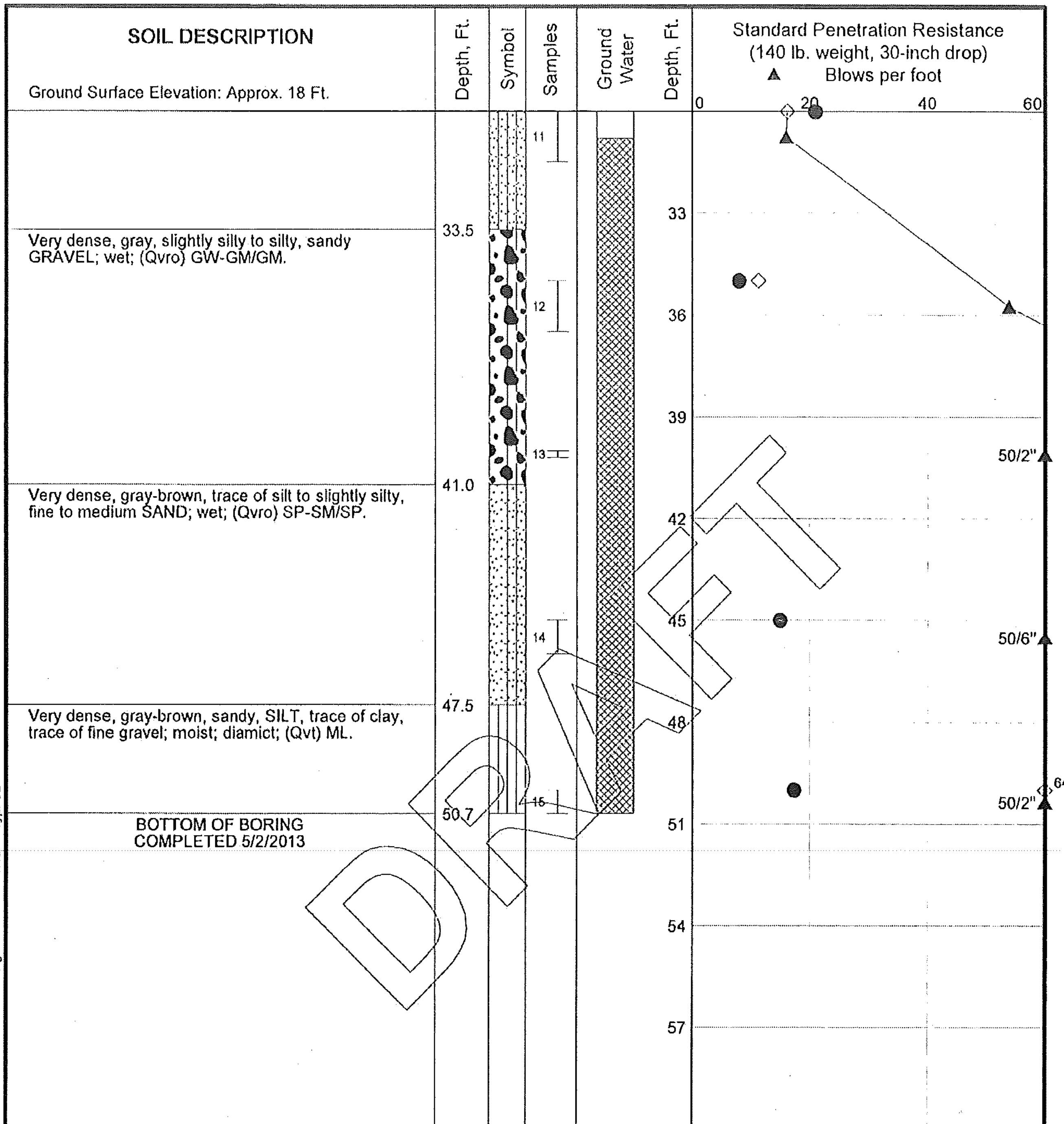
FIG. 5
Sheet 1 of 2

REV 2.1

MASTER_LOG FINE 21-20617.GPJ 21-09490.GPJ 12/11/13
Log: DPO Rev: EAS Typ: CLP



LEGEND

- * Sample Not Recovered
- E Environmental Sample Obtained
- [2" O.D. Split Spoon (SPT)
- Piezometer Screen and Sand Filter
- Bentonite-Cement Grout
- Bentonite Chips/Pellets
- Bentonite Grout
- Ground Water Level in Well

◇ % Fines (<0.075mm)
● % Water Content
Plastic Limit |—●—| Liquid Limit
Natural Water Content

NOTES

1. The boring was performed using Mud Rotary drilling methods.
2. The stratification lines represent the approximate boundaries between soil types, and the transition may be gradual.
3. Refer to the report text for a proper understanding of the subsurface materials.
4. Groundwater level, if indicated above, is for the date specified and may vary.
5. Refer to KEY for explanation of symbols, codes and definitions.
6. USCS designation is based on visual-manual classification and selected lab testing.

Front Street CSO Phase II
Infiltration Study
Port Angeles, Washington

LOG OF BORING B-1

December 2013 21-1-20617-005

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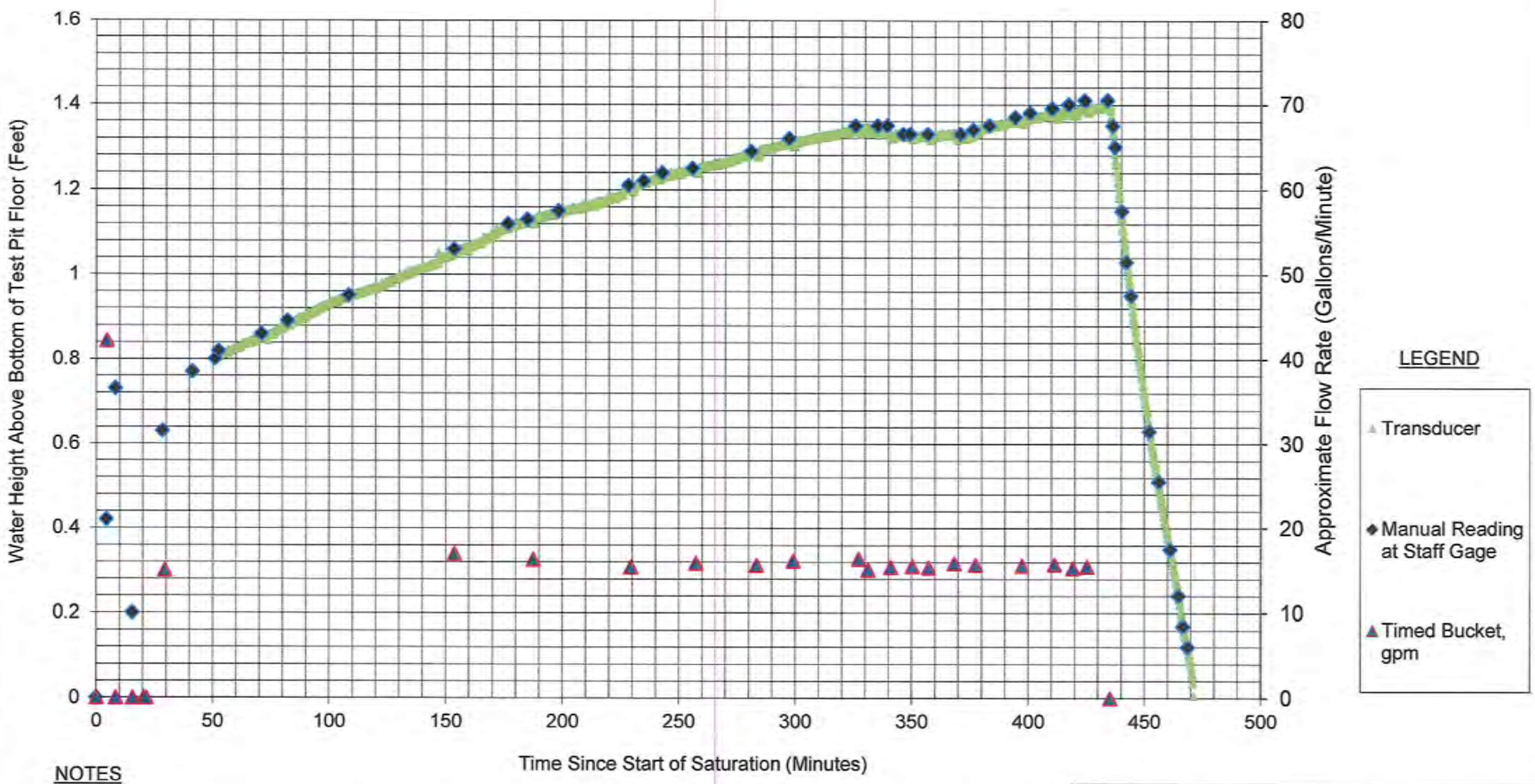
FIG. 5
Sheet 2 of 2

Log: DPO Rev: EAS Typ: CLP

MASTER LOG FINE 21-20617.GPJ 21-09490.GPJ 12/11/13

REV 2.1



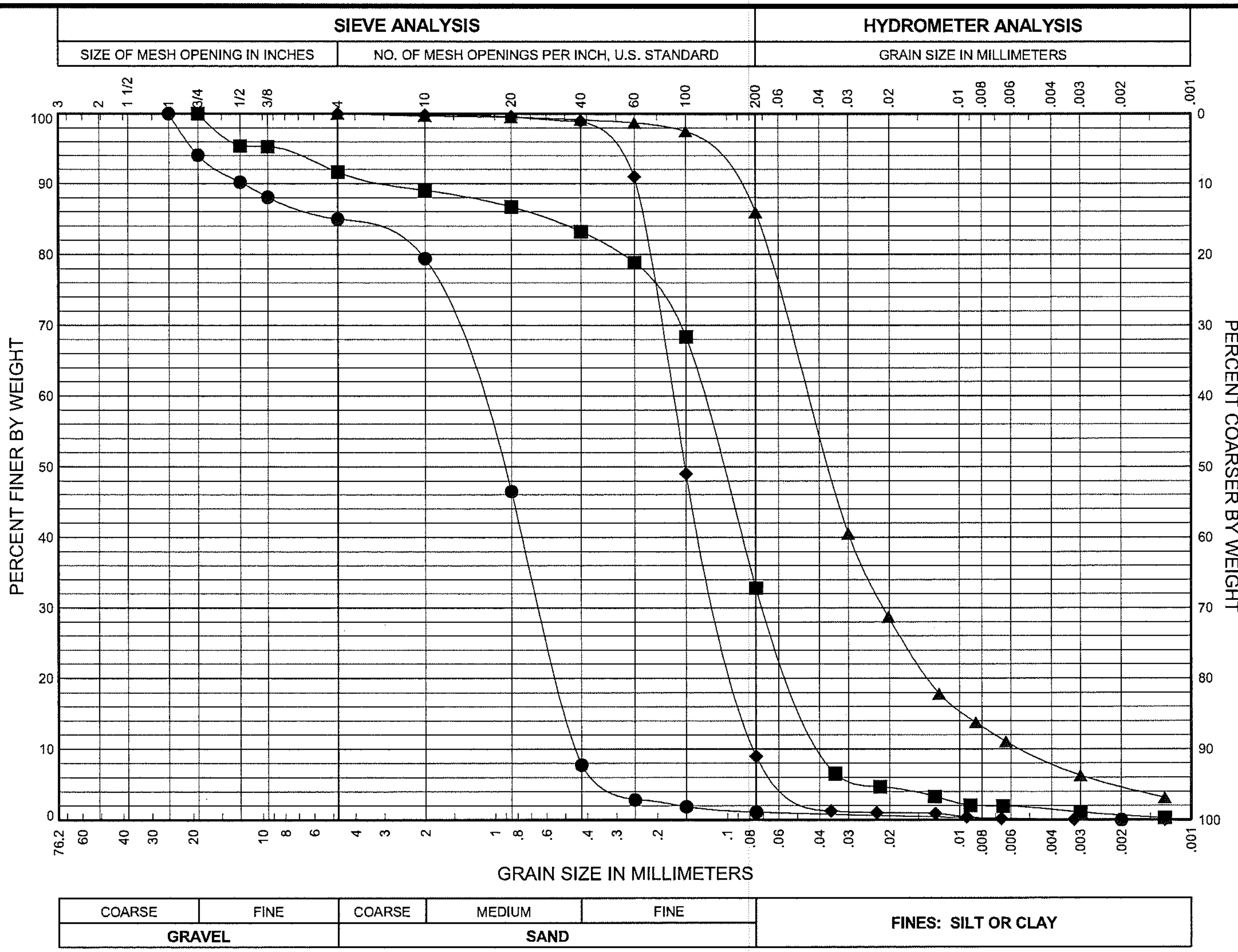
NOTES

1. This small-scale Pilot infiltration test (PIT) was performed on November 5, 2013. Saturation began at 8:43. The TP-1 floor was at approximately elevation 13.2 feet during the test, or 4.3 feet deep. The initial TP-1 surface dimensions were approximately 4 feet wide by 7 feet long. At approximately 3 feet deep, the north, south, and west sidewalls caved slightly, resulting in an approximate ponded surface area of 6 feet by 8 feet at the contant head test ponded water level.
2. A relatively constant flow rate of 15.2 to 15.7 gpm (average 15.5 gpm) was maintained for 60 minutes, (elapsed time 375 to 435 minutes after the start of saturation). The water level during the constant head portion of the test was maintained at approximately 1.3 to 1.4 feet above the test pit bottom (3.0 to 2.9 feet below grade).
3. The ponded surface area was approximately 4 feet by 7 feet during the falling head period (residual head of approximately 0.5 feet).

FIG. 6

Front Street CSO Phase II Infiltration Study Port Angeles, Washington	
MEASURED WATER LEVEL PILOT INFILTRATION TEST TEST PIT TP-1	
December 2013	21-1-20617-005
SHANNON & WILSON, INC. Geotechnical and Environmental Consultants	**FIG. 6**

TP-1 PIT-Fig 6 TP-1 PIT Plot-12/11/2013-pvh



LEGEND

USCS: Unified Soil Classification System

COBBLE REM %: Percentage of cobbles removed from specimen; based on pre-removal total dry mass

SG: Specific gravity of soil solids < No. 4 sieve per ASTM D854

NAT WC %: Natural water content

Cu: Coefficient of uniformity

Cc: Coefficient of curvature

ASTM DES: ASTM International test standard designation

++: ***Clay-size percentage estimated from grain size distribution curve - actual clay-size percentage may vary.***

BORING AND SAMPLE NO.	DEPTH (feet)	USCS SYMBOL	SOIL CLASSIFICATION	GRAVEL %	SAND %	FINES %	COBBLE REM %	SG	NAT WC %	Cu	Cc	TEST BY	REVIEW BY	ASTM DES
● TP-1, S-2++	4.5	SP	Gray-brown, gravelly SAND, trace of silt	15	84	1.1			3.4	2.7	0.7	AKV	JFL	D422
■ TP-2, S-2	4.0	SM	Gray-brown, slightly fine gravelly, silty SAND; trace of organics	8	59	32.8			13.8			AKV	JFL	D422
▲ TP-2, S-3	5.5	ML	Gray, slightly fine sandy SILT		14	85.9			34.6			AKV	JFL	D422
◆ TP-2, S-6	7.5	SP-SM	Gray-brown, slightly silty, fine SAND		91	8.9			6.4	2.2	0.9	AKV	JFL	D422

Front Street CSO Phase II
Infiltration Study
Port Angeles, Washington

GRAIN SIZE DISTRIBUTION

December 2013 21-1-20617-004

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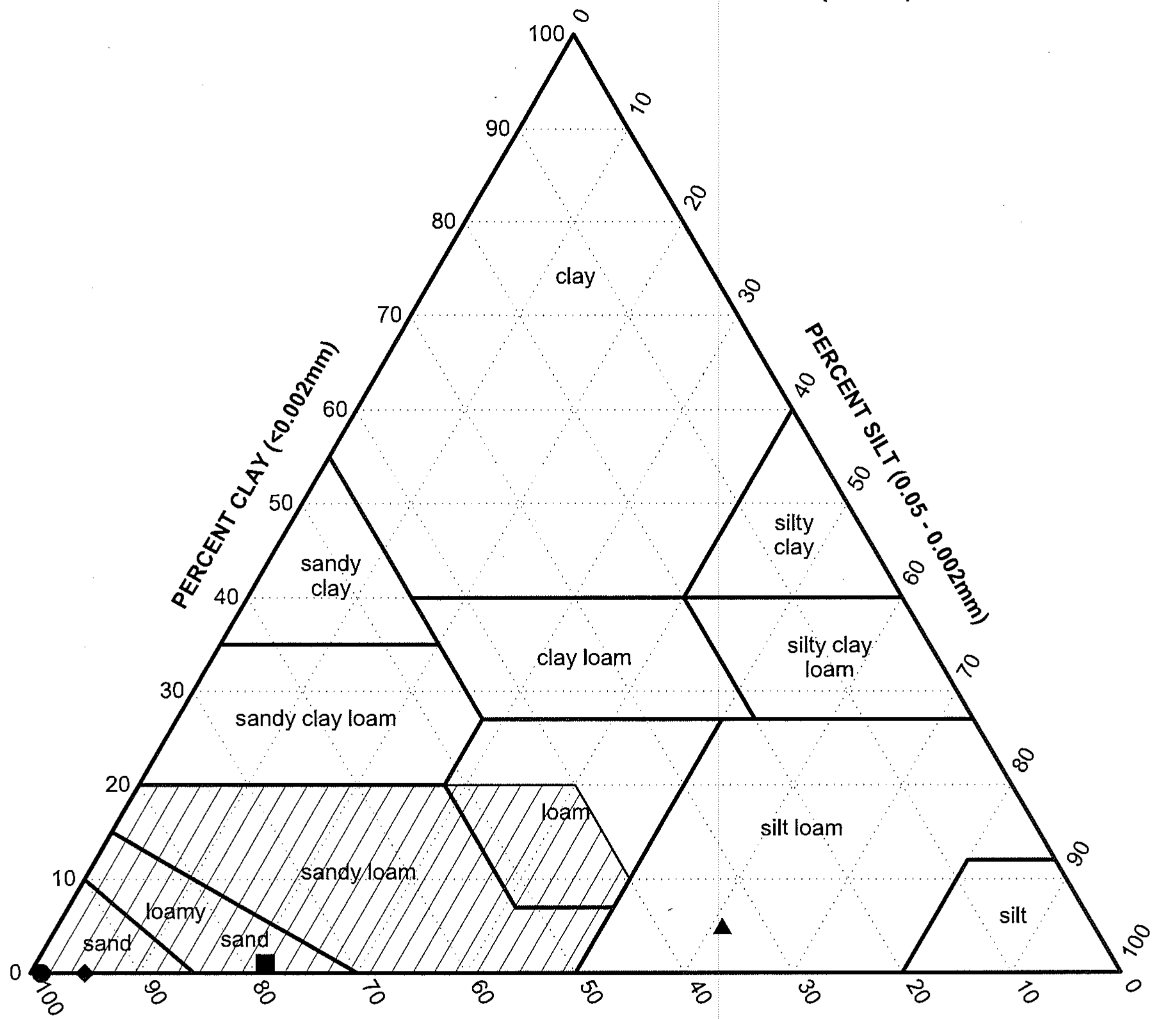
FIG. 7
Sheet 1 of 1

FIG. 7

FRACTIONS NORMALIZED TO 100% PASSING THE 2mm (NO. 10) SIEVE



LEGEND

USCS: Unified Soil Classification System

LL: Liquid Limit

PL: Plastic Limit

PI: Plasticity Index = (LL-PL)

NAT WC: Natural Water Content

ASTM DES: ASTM International test standard designation

//////: Cross-hatched area of plot represents soil generally suitable for infiltration, when soil is normally consolidated.

BORING AND SAMPLE NO.	DEPTH (feet)	USDA CLASSIFICATION	SAND %	SILT %	CLAY %	NAT WC %	USCS SYMBOL	LL %	PL %	PI %	TEST BY	REVIEW BY	ASTM DES
● TP-1, S-2	4.5	SAND	98.7	1.3	0.0*	3.4	SP				AKV	JFL	D422
■ TP-2, S-2	4.0	LOAMY SAND	78.5	20.8	0.8	13.8	SM				AKV	JFL	D422
▲ TP-2, S-3	5.5	SILT LOAM	33.9	61.3	4.8	34.6	ML				AKV	JFL	D422
◆ TP-2, S-6	7.5	SAND	95.2	4.7	0.1	6.4	SP-SM				AKV	JFL	D422

Front Street CSO Phase II
Infiltration Study
Port Angeles, Washington

USDA TEXTURAL CHART

December 2013 21-1-20617-004

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FIG. 8
Sheet 1 of 1

** Clay-size percentage estimated from grain size distribution curve - actual clay-size percentage may vary.*

FIG. 8

APPENDIX A

FREMONT ANALYTICAL LABORATORY DATA REPORT
LAB ID: 1311042 (7 PAGES)

3600 Fremont Ave. N.
Seattle, WA 98103
T: (206) 352-3790
F: (206) 352-7178
info@fremontanalytical.com

Shannon & Wilson
Paul Van Horne
400 N. 34th Street, Suite 100
Seattle, WA 98103

RE: W. Front St CSO
Lab ID: 1311042

November 15, 2013

Attention Paul Van Horne:

Fremont Analytical, Inc. received 4 sample(s) on 11/6/2013 for the analyses presented in the following report.

Cation Exchange Capacity
Organic Matter of Organic Soils by ASTM D2974
Sample Moisture (Percent Moisture)

This report consists of the following:

- Case Narrative
- Analytical Results
- Applicable Quality Control Summary Reports
- Chain of Custody

All analyses were performed consistent with the Quality Assurance program of Fremont Analytical, Inc. Please contact the laboratory if you should have any questions about the results.

Thank you for using Fremont Analytical.

Sincerely,

Michael Dee
Sr. Chemist / Principal

Fremont Analytical

Date: *11/15/2013*

CLIENT: Shannon & Wilson
Project: W. Front St CSO
Lab Order: 1311042

Work Order Sample Summary

Lab Sample ID	Client Sample ID	Date/Time Collected	Date/Time Received
1311042-001	TP-1:4.5	11/05/2013 8:05 AM	11/06/2013 11:36 AM
1311042-002	TP-2:4.0	11/05/2013 10:20 AM	11/06/2013 11:36 AM
1311042-003	TP-1:7.0	11/05/2013 8:15 AM	11/06/2013 11:36 AM
1311042-004	TP-2:7.5	11/05/2013 10:50 AM	11/06/2013 11:36 AM

Note: If no "Time Collected" is supplied, a default of 12:00AM is assigned

Case Narrative

WO#: **1311042**
Date: **11/15/2013**

CLIENT: Shannon & Wilson
Project: W. Front St CSO

I. SAMPLE RECEIPT:
Samples receipt information is recorded on the attached Sample Receipt Checklist.

II. GENERAL REPORTING COMMENTS:
Results are reported on a wet weight basis unless dry-weight correction is denoted in the units field on the analytical report ("mg/kg-dry" or "ug/kg-dry").

Matrix Spike (MS) and MS Duplicate (MSD) samples are tested from an analytical batch of "like" matrix to check for possible matrix effect. The MS and MSD will provide site specific matrix data only for those samples which are spiked by the laboratory. The sample chosen for spike purposes may or may not have been a sample submitted in this sample delivery group. The validity of the analytical procedures for which data is reported in this analytical report is determined by the Laboratory Control Sample (LCS) and the Method Blank (MB). The LCS and the MB are processed with the samples and the MS/MSD to ensure method criteria are achieved throughout the entire analytical process.

III. ANALYSES AND EXCEPTIONS:
Exceptions associated with this report will be footnoted in the analytical results page(s) or the quality control summary page(s) and/or noted below.

Fremont Analytical

Analytical Report

WO#: **1311042**
Date Reported: **11/15/2013**

CLIENT: Shannon & Wilson
Project: W. Front St CSO

Lab ID: 1311042-001
Client Sample ID: **TP-1:4.5**
Collection Date: 11/5/2013 8:05:00 AM
Matrix: Soil

Analyses	Result	RL	Qual	Units	DF	Date Analyzed
Sample Moisture (Percent Moisture)				Batch ID: R10921		Analyst: JS
Percent Moisture	2.62			wt%	1	11/6/2013 1:17:23 PM
Cation Exchange Capacity				Batch ID: R11061		Analyst: MC
Cation Exchange Capacity	6.89	1.00		meq/100g	1	11/14/2013 9:10:53 AM
Organic Matter of Organic Soils by ASTM D2974				Batch ID: R11069		Analyst: GH
Organic Matter	0.328	0.500	J	%	1	11/15/2013 7:06:04 AM

Lab ID: 1311042-002
Client Sample ID: **TP-2:4.0**
Collection Date: 11/5/2013 10:20:00 AM
Matrix: Soil

Analyses	Result	RL	Qual	Units	DF	Date Analyzed
Sample Moisture (Percent Moisture)				Batch ID: R10921		Analyst: JS
Percent Moisture	13.1			wt%	1	11/6/2013 1:17:23 PM
Cation Exchange Capacity				Batch ID: R11061		Analyst: MC
Cation Exchange Capacity	6.26	1.00		meq/100g	1	11/14/2013 9:10:53 AM
Organic Matter of Organic Soils by ASTM D2974				Batch ID: R11069		Analyst: GH
Organic Matter	0.994	0.500		%	1	11/15/2013 7:06:04 AM

Qualifiers:

B	Analyte detected in the associated Method Blank	D	Dilution was required
E	Value above quantitation range	H	Holding times for preparation or analysis exceeded
J	Analyte detected below quantitation limits	ND	Not detected at the Reporting Limit
RL	Reporting Limit	S	Spike recovery outside accepted recovery limits

Fremont Analytical

Date: 11/15/2013

Work Order: 1311042
CLIENT: Shannon & Wilson
Project: W. Front St CSO

QC SUMMARY REPORT

Cation Exchange Capacity

Sample ID: **MB-R11061** SampType: **MBLK** Units: **µg/L** Prep Date: **11/14/2013** RunNo: **11061**
Client ID: **MBLKS** Batch ID: **R11061** Analysis Date: **11/14/2013** SeqNo: **220838**

Analyte	Result	RL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Barium	ND	1.00									J

Sample ID: **LCS-R11061** SampType: **LCS** Units: **µg/L** Prep Date: **11/14/2013** RunNo: **11061**
Client ID: **LCSS** Batch ID: **R11061** Analysis Date: **11/14/2013** SeqNo: **220839**

Analyte	Result	RL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Barium	107	1.00	100.0	0	107	75	125				

Sample ID: **1311042-001ADUP** SampType: **DUP** Units: **meq/100g** Prep Date: **11/14/2013** RunNo: **11061**
Client ID: **TP-1:4.5** Batch ID: **R11061** Analysis Date: **11/14/2013** SeqNo: **220843**

Analyte	Result	RL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Cation Exchange Capacity	9.26	1.00						6.890	29.3	30	

Qualifiers:

B	Analyte detected in the associated Method Blank	D	Dilution was required	E	Value above quantitation range
H	Holding times for preparation or analysis exceeded	J	Analyte detected below quantitation limits	ND	Not detected at the Reporting Limit
R	RPD outside accepted recovery limits	RL	Reporting Limit	S	Spike recovery outside accepted recovery limits

Fremont Analytical

Sample Log-In Check List

Client Name:	SW	Work Order Number:	1311042
Logged by:	Chelsea Ward	Date Received:	11/6/2013 11:36:00 AM

Chain of Custody

1. Is Chain of Custody complete? — Yes ☑ No ☐ Not Present ☐
2. How was the sample delivered? — Client

Log In

3. Coolers are present? — Yes ☑ No ☐ NA ☐
4. Shipping container/cooler in good condition? — Yes ☑ No ☐
5. Custody seals intact on shipping container/cooler? — Yes ☐ No ☐ Not Required ☑
6. Was an attempt made to cool the samples? — Yes ☑ No ☐ NA ☐
7. Were all coolers received at a temperature of >0°C to 10.0°C — Yes ☑ No ☐ NA ☐
8. Sample(s) in proper container(s)? — Yes ☑ No ☐
9. Sufficient sample volume for indicated test(s)? — Yes ☑ No ☐
10. Are samples properly preserved? — Yes ☑ No ☐
11. Was preservative added to bottles? — Yes ☐ No ☑ NA ☐
12. Is the headspace in the VOA vials? — Yes ☐ No ☐ NA ☑
13. Did all samples containers arrive in good condition(unbroken)? — Yes ☑ No ☐
14. Does paperwork match bottle labels? — Yes ☑ No ☐
15. Are matrices correctly identified on Chain of Custody? — Yes ☑ No ☐
16. Is it clear what analyses were requested? — Yes ☑ No ☐
17. Were all holding times able to be met? — Yes ☑ No ☐

Special Handling (if applicable)

18. Was client notified of all discrepancies with this order? — Yes ☐ No ☐ NA ☑

Person Notified: ______ Date: ______
By Whom: ______ Via: ☐ eMail ☐ Phone ☐ Fax ☐ In Person
Regarding: ______
Client Instructions: ______

19. Additional remarks:

Item Information

Item #	Temp °C	Condition
Cooler	5.7	Good
Sample	4.1	Good

1311042

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

400 N. 34th Street, Suite 100, Seattle, WA 98103, (206) 632-8020
11500 Olive Blvd., Suite 276, St. Louis, MO 63141, (314) 872-8170
2055 Hill Road, Fairbanks, AK 99709, (907) 479-0600
5430 Fairbanks Street, Suite 3, Anchorage, AK 99518, (907) 561-2120
303 Wellsian Way, Richland, WA 99352, (509) 946-6309

CHAIN OF CUSTODY RECORD

Page 1 of 1
Laboratory Fremont
Attn: Mike

Analysis Parameters/Sample Container Description (include preservative if used) (NH)

Sample Identity	Lab No.	Time	Date Sampled	Comp	Grab	Cation Exchange Capacity (EPA 9081)		Organic Content (ASTM D 2974)				Total Number of Containers	Remarks/Matrix
TP-1: 4.5		0805	11/5/13		X	X		X				3	3-8oz GJ/Soil
TP-2: 4.0		1020	↓		X	X		X				3	" "
TP-1: 7.0		0815	↓		X	Hold		Hold				3	" "
TP-2: 7.5		1050	↓		X	Hold		Hold				3	2-8oz 4 1-4oz GJ/Soil

Project Information	Sample Receipt	
Project Number: 21-1-20617-005	Total Number of Containers	
Project Name: W. Frout St CSO	COC Seals/Intact? Y/N/NA (NA)	
Contact: PVH	Received Good Cond./Cold	
Ongoing Project? Yes ☐ No ☒	Delivery Method: S+W Personnel (attach shipping bill, if any)	
Sampler: PVH		

Instructions

Requested Turn Around Time: standard

Special Instructions:

Relinquished By: 1.	Relinquished By: 2.	Relinquished By: 3.
Signature: Paul Van Horne Time: 1156	Signature: Time:	Signature: Time:
Printed Name: Paul Van Horne Date: 11/6/13	Printed Name: Date:	Printed Name: Date:
Company: S+W	Company:	Company:

Received By: 1.	Received By: 2.	Received By: 3.
Signature: [signature] Time: 1134	Signature: Time:	Signature: Time:
Printed Name: Clare Griggs Date: 11-6-13	Printed Name: Date:	Printed Name: Date:
Company: FAI	Company:	Company:

Distribution: White - w/shipment - returned to Shannon & Wilson w/ Laboratory report
Yellow - w/shipment - for consignee files
Pink - Shannon & Wilson - Job File

F-19-91/UR

No. 25925

APPENDIX B

IMPORTANT INFORMATION ABOUT
YOUR GEOTECHNICAL/ENVIRONMENTAL REPORT

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

Attachment to and part of Report 21-1-20617-005

Date: December 12, 2013
To: Mr. Michael O'Neal, P.E.
Brown and Caldwell

IMPORTANT INFORMATION ABOUT YOUR GEOTECHNICAL/ENVIRONMENTAL REPORT

CONSULTING SERVICES ARE PERFORMED FOR SPECIFIC PURPOSES AND FOR SPECIFIC CLIENTS.

Consultants prepare reports to meet the specific needs of specific individuals. A report prepared for a civil engineer may not be adequate for a construction contractor or even another civil engineer. Unless indicated otherwise, your consultant prepared your report expressly for you and expressly for the purposes you indicated. No one other than you should apply this report for its intended purpose without first conferring with the consultant. No party should apply this report for any purpose other than that originally contemplated without first conferring with the consultant.

THE CONSULTANT'S REPORT IS BASED ON PROJECT-SPECIFIC FACTORS.

A geotechnical/environmental report is based on a subsurface exploration plan designed to consider a unique set of project-specific factors. Depending on the project, these may include: the general nature of the structure and property involved; its size and configuration; its historical use and practice; the location of the structure on the site and its orientation; other improvements such as access roads, parking lots, and underground utilities; and the additional risk created by scope-of-service limitations imposed by the client. To help avoid costly problems, ask the consultant to evaluate how any factors that change subsequent to the date of the report may affect the recommendations. Unless your consultant indicates otherwise, your report should not be used: (1) when the nature of the proposed project is changed (for example, if an office building will be erected instead of a parking garage, or if a refrigerated warehouse will be built instead of an unrefrigerated one, or chemicals are discovered on or near the site); (2) when the size, elevation, or configuration of the proposed project is altered; (3) when the location or orientation of the proposed project is modified; (4) when there is a change of ownership; or (5) for application to an adjacent site. Consultants cannot accept responsibility for problems that may occur if they are not consulted after factors which were considered in the development of the report have changed.

SUBSURFACE CONDITIONS CAN CHANGE.

Subsurface conditions may be affected as a result of natural processes or human activity. Because a geotechnical/environmental report is based on conditions that existed at the time of subsurface exploration, construction decisions should not be based on a report whose adequacy may have been affected by time. Ask the consultant to advise if additional tests are desirable before construction starts; for example, groundwater conditions commonly vary seasonally.

Construction operations at or adjacent to the site and natural events such as floods, earthquakes, or groundwater fluctuations may also affect subsurface conditions and, thus, the continuing adequacy of a geotechnical/environmental report. The consultant should be kept apprised of any such events, and should be consulted to determine if additional tests are necessary.

MOST RECOMMENDATIONS ARE PROFESSIONAL JUDGMENTS.

Site exploration and testing identifies actual surface and subsurface conditions only at those points where samples are taken. The data were extrapolated by your consultant, who then applied judgment to render an opinion about overall subsurface conditions. The actual interface between materials may be far more gradual or abrupt than your report indicates. Actual conditions in areas not sampled may differ from those predicted in your report. While nothing can be done to prevent such situations, you and your consultant can work together to help reduce their impacts. Retaining your consultant to observe subsurface construction operations can be particularly beneficial in this respect.

A REPORT'S CONCLUSIONS ARE PRELIMINARY.

The conclusions contained in your consultant's report are preliminary because they must be based on the assumption that conditions revealed through selective exploratory sampling are indicative of actual conditions throughout a site. Actual subsurface conditions can be discerned only during earthwork; therefore, you should retain your consultant to observe actual conditions and to provide conclusions. Only the consultant who prepared the report is fully familiar with the background information needed to determine whether or not the report's recommendations based on those conclusions are valid and whether or not the contractor is abiding by applicable recommendations. The consultant who developed your report cannot assume responsibility or liability for the adequacy of the report's recommendations if another party is retained to observe construction.

THE CONSULTANT'S REPORT IS SUBJECT TO MISINTERPRETATION.

Costly problems can occur when other design professionals develop their plans based on misinterpretation of a geotechnical/environmental report. To help avoid these problems, the consultant should be retained to work with other project design professionals to explain relevant geotechnical, geological, hydrogeological, and environmental findings, and to review the adequacy of their plans and specifications relative to these issues.

BORING LOGS AND/OR MONITORING WELL DATA SHOULD NOT BE SEPARATED FROM THE REPORT.

Final boring logs developed by the consultant are based upon interpretation of field logs (assembled by site personnel), field test results, and laboratory and/or office evaluation of field samples and data. Only final boring logs and data are customarily included in geotechnical/environmental reports. These final logs should not, under any circumstances, be redrawn for inclusion in architectural or other design drawings, because drafters may commit errors or omissions in the transfer process.

To reduce the likelihood of boring log or monitoring well misinterpretation, contractors should be given ready access to the complete geotechnical engineering/environmental report prepared or authorized for their use. If access is provided only to the report prepared for you, you should advise contractors of the report's limitations, assuming that a contractor was not one of the specific persons for whom the report was prepared, and that developing construction cost estimates was not one of the specific purposes for which it was prepared. While a contractor may gain important knowledge from a report prepared for another party, the contractor should discuss the report with your consultant and perform the additional or alternative work believed necessary to obtain the data specifically appropriate for construction cost estimating purposes. Some clients hold the mistaken impression that simply disclaiming responsibility for the accuracy of subsurface information always insulates them from attendant liability. Providing the best available information to contractors helps prevent costly construction problems and the adversarial attitudes that aggravate them to a disproportionate scale.

READ RESPONSIBILITY CLAUSES CLOSELY.

Because geotechnical/environmental engineering is based extensively on judgment and opinion, it is far less exact than other design disciplines. This situation has resulted in wholly unwarranted claims being lodged against consultants. To help prevent this problem, consultants have developed a number of clauses for use in their contracts, reports and other documents. These responsibility clauses are not exculpatory clauses designed to transfer the consultant's liabilities to other parties; rather, they are definitive clauses that identify where the consultant's responsibilities begin and end. Their use helps all parties involved recognize their individual responsibilities and take appropriate action. Some of these definitive clauses are likely to appear in your report, and you are encouraged to read them closely. Your consultant will be pleased to give full and frank answers to your questions.

The preceding paragraphs are based on information provided by the
ASFE/Association of Engineering Firms Practicing in the Geosciences, Silver Spring, Maryland

APPENDIX E

IMPORTANT INFORMATION ABOUT YOUR GEOTECHNICAL/ENVIRONMENTAL REPORT

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

Attachment to and part of Report 21-1-20617-004

Date: April 7, 2014
To: Mr. Michael O'Neal, P.E.
Brown and Caldwell

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The preceding paragraphs are based on information provided by the
ASFE/Association of Engineering Firms Practicing in the Geosciences, Silver Spring, Maryland

Appendix C
Site Photographs

Site Photographs

Photograph 1
Project Site (Upland), Facing East

Photograph 2
Project Site (Upland), Facing South

Photograph 3
Project Site (Upland), Facing Southwest

Photograph 4
Project Site (Shoreline), Facing East

Photograph 5
Project Site (Shoreline), View of Existing Pier Structure, Facing Northeast

Appendix D
Biological Assessment

(Submitted with this report under separate cover)