Geotechnical Engineering Report

Post Point Wastewater Treatment
Plant Improvements
Bellingham, Washington

for
Carollo Engineers

October 6, 2010

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October 6, 2010

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Attention: Brian Matson, PE

Subject: Geotechnical Engineering Services
Post Point Wastewater Treatment Plant Improvements
Bellingham, Washington
File No. 003562-106-00

We are pleased to submit 11 copies of our report, "Geotechnical Engineering Services, Post Point Wastewater Treatment Plant Improvements, Bellingham, Washington." Our geotechnical services were completed in general accordance with our proposal dated May 2, 2010. Our services were authorized by Brian Matson of Carollo Engineers on May 28, 2010.

We appreciate the opportunity to work with Carollo Engineers on this project. Please call if you have any questions regarding this report.

Sincerely,

GeoEngineers, Inc.

J. Robert Gordon, PE
Principal

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https://projects.geoengineers.com/sites/00356-106-00/Finals/Report

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Post Point Wastewater Treatment Plant Improvements Bellingham, Washington

File No. 0356-106-00

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Table of Contents

1.0 INTRODUCTION AND SCOPE OF SERVICES 1

2.0 PROJECT DESCRIPTION 1

3.0 SITE BACKGROUND AND RESEARCH 2

4.0 SITE CONDITIONS 3

4.1. Surface Conditions 3
4.2. Geologic Setting 3
4.3. Geologically Hazardous Areas 4
4.3.1. Erosion Hazard Areas 4
4.3.2. Landslide Hazard Areas 4
4.3.3. Seismic Hazard Areas 5
4.3.4. Mine Hazard Areas 5
4.4. Subsurface Conditions 6
4.4.1. Subsurface Exploration 6
4.4.2. Soil Conditions 6
4.4.3. Groundwater Conditions 7

5.0 CONCLUSIONS AND RECOMMENDATIONS 8

5.1. Summary of Geotechnical Considerations 8
5.1.1. Secondary Clarifier No. 4 (Facility No. 330) 8
5.1.2. Activated Sludge Basin No. 4 (Facility 311) and Odor Control Facility (Facility 312) 9
5.1.3. Blower Building (Facility 325) 9
5.1.4. Selector/Activated Sludge Basin No. 1 (Facility 305) and Odor Control Facility (Facility 306) 10
5.1.5. Chemically Enhanced Primary Treatment Facility (Facility 240) 10
5.2. Geologic Hazards and Mitigation 11
5.2.1. Erosion Hazard Considerations 11
5.2.2. Seismic Hazard Considerations 11
5.2.3. Seismic Ground Motion Design Values 12
5.2.4. Liquefaction and Lateral Spreading 12
5.2.5. Surface Fault Rupture 13
5.2.6. Tsunami Hazard Areas 13
5.3. Pile Foundation Recommendations 13
5.3.1. Augercast Piles 14
5.3.2. Vertical Axial Capacities 14
5.3.3. Lateral Capacities 15
5.3.4. Settlement 16
5.3.5. Construction Considerations 16
5.4. Shallow Foundation Recommendations 18
5.4.1. General 18
5.4.2. Footing Design 18
5.4.3. Mat Foundation Recommendations 19
5.4.4. Overexcavation for Selector/Activated Sludge Basin No. 1 19
5.4.5. Lateral Resistance 20

5.4.6. Shallow Foundation Settlement 20
5.5. Slab-On-Grade Support 20
5.6. Additional Design for Below Grade Structures 21
5.6.1. Lateral Earth Pressures 21
5.6.2. Buoyancy and Uplift 22
5.6.3. Drainage for Activated Sludge Basin No. 1 (Facility 305) 22
5.6.4. Buried Slabs 22
5.7. Pipe Design Considerations 23
5.7.1. General 23
5.7.2. Pipeline Support 23
5.7.3. Structural and Trench Backfill 24
5.7.4. Pipe Settlement 24
5.8. Corrosion Potential 25
5.9. Earthwork 26
5.9.1. General 26
5.9.2. Site Preparation 26
5.9.3. Base Preparation 27
5.9.4. Temporary Excavations 27
5.9.5. Temporary Cut Slopes 28
5.9.6. Temporary Shoring 30
5.9.7. Wet Weather Earthwork and Erosion Control 31
5.10. Construction Dewatering 32
5.10.1. General 32
5.10.2. Open Pumping 32
5.10.3. Pumped Wells 33
5.10.4. Wellpoints 33
5.10.5. Dewatering Qualifications and Experience 33
5.10.6. Dewatering Limitations 34
5.11. Pavement 34
6.0 CONSTRUCTION OBSERVATION SERVICES 35
7.0 LIMITATIONS 35
8.0 REFERENCES 35

List Of Figures

Figure 1. Vicinity Map
Figure 2. Site and Exploration Plan
Figure 3. Subsurface Cross-Section A-A'
Figure 4. Subsurface Cross-Section B-B'
Figure 5. Subsurface Cross-Section C-C'
Figure 6. Subsurface Cross-Section D-D'
Figure 7. Subsurface Cross-Section E-E'
Figure 8. 5% Damped Site Specific MCE Response Spectra, 2475 YR EQ Event
Figures 9 to 12. Plots of LPILE Analysis Results
Figure 13. Schematic of Overexcavation at Selector/Activated Sludge Basin No. 1

Figures 14 and 15. Earth Pressure Diagrams for Tempoarary Shoring

APPENDICES

Appendix A. Field Explorations and Laboratory Testing
Figure A-1 – Key to Exploration Logs
Figures A-2 through A-15 – Logs of Borings
Figures A-16 through A-18 – Logs of Test Pits
Figures A-19 and A-20 – Log of CPT and Shear Wave Velocity Plot (In Situ Engieering)

Appendix B. Laboratory Testing
Figures B-1 through B-14 – Sieve Analysis Results
Figures B-15 through B-18 – Atterberg Limits Test Results
Figures B-19 through B-24 – Corrosion Potential Test Results (ALS Group)

Appendix C. Previous Site Explorations

Appendix D. Site Specific Seismic Response Analysis
Figure D-1 – 5% Damped Response Spectra of Scaled Input Ground Motions
Figure D-2 – Design Shear Wave Velocity Profile
Figure D-3 – 5% Damped MCE Response Spectra at Surface
Figure D-4 – 5% Damped MCE Amplification Factor at Surface
Figure D-5 – 5% Damped Site Specific MCE Response Spectra

Appendix E. Report Limitations and Guidelines for Use

1.0 INTRODUCTION AND SCOPE OF SERVICES

This report presents the results of our design level geotechnical engineering services for the proposed Wastewater Treatment Plant (WWTP) expansion at the existing City of Bellingham facility at Post Point in Bellingham, Washington. The generalized location of the WWTP site is shown in the Vicinity Map, Figure 1.

The purpose of our services was to explore subsurface soil and groundwater conditions at the locations of the new facilities to provide geotechnical engineering recommendations for design. Our scope of services included:

- Research and review of available geotechnical information;
- Completing geotechnical explorations including fourteen geotechnical borings, three test pits, and one cone penetrometer test (CPT) with seismic shear wave velocity measurements;
- Completing laboratory testing on samples obtained from the borings and test pits;
- Performing engineering analyses and providing geotechnical conclusions and recommendations for design and construction of the proposed expansion elements;
- Preparing this geotechnical engineering report.

Our specific scope of services is described in Task Order No. 2, Agreement between Carollo Engineers and GeoEngineers, City of Bellingham Contract Number 2008-0669 dated May 3, 2010 (which supersedes Task Order No. 1 dated March 2, 2009), and Task Order No. 3 for Additional Site Investigations.

2.0 PROJECT DESCRIPTION

We understand that the original design for the WWTP was completed in 1971 with an expansion that occurred in 1989. Our understanding of this proposed expansion project is based on information provided by Carollo Engineers, including communications with Brian Matson and Susanna Leung. Figure 2, attached, shows the existing WWTP including the 1989 expansion, with proposed locations of the structures identified for these improvements.

As currently envisioned, the WWTP expansion will include five primary components as described below:

- Secondary Clarifier No. 4 (Facility No. 330) – The Secondary Clarifier No. 4 will be located in the western portion of the site, south and west of existing clarifiers. The structure will be approximately 120 feet in diameter with an inside base elevation ranging from about Elevation 7.6 feet at the perimeter to about Elevation +0 feet at the center. Foundation loads are anticipated to be 1,500 pounds per square foot (psf) across the base of the foundation with a concentrated 3,000 psf load at the perimeter wall.
- Activated Sludge Basin No. 4 (Facility 311) and Odor Control (Facility 312) – The Activated Sludge Basin No. 4 will be located in the southern portion of the site, immediately south of the existing Oxygen Activated Sludge Basin. The sludge basin will be approximately 150 feet long

and 50 feet wide. The activated sludge basin will have an inside base elevation at about Elevation 12.1 feet with an anticipated foundation load of 1,840 psf. Odor control for the new sludge basin will be provided by an aerobic biofilter (if needed) with equipment supported on an approximately 35 foot by 60 foot slab on grade structure at the existing ground surface (near Elevation 20 feet).

- **Blower Building (Facility 325)** – The Blower Building will be an approximately 60-foot by 80-foot slab on grade structure with concrete tilt-up walls and metal roof deck and open-web steel joists. Top of slab elevation for the structure will be similar to the adjacent driveway, at about Elevation 22 feet, which will require cuts on the eastern portion of the structure up to about 5 feet. Total perimeter wall loads will be on the order of 4,000 pounds per lineal foot. The building will house five blowers, a generator, and other miscellaneous equipment.
- **Selector/Activated Sludge Basin No. 1 (Facility 305) and Odor Control (Facility 306)** – The Selector/Activated Sludge Basin No. 1 will be located in the southeastern portion of the site, south of the existing Headworks Building (Facility 120) Screenings Facility (Facility 110) and east of the existing Oxygen Activated Sludge Basins (Facility 310). This basin will be approximately 105 feet by 155 feet in plan dimension with an inside base elevation at about Elevation 14 feet. Anticipated foundation loads for this structure are on the order of 1,920 psf. Odor control for the new sludge basin will be provided by an aerobic biofilter with equipment supported on an approximately 35-foot by 60-foot slab-on-grade structure at the existing ground surface, near Elevation 22 feet.
- **Chemically Enhanced Primary Treatment Facility (Facility 240)** – The Chemically Enhanced Primary Treatment Facility (CEPT building) will be located in the northeast portion of the site, near the existing headworks. This facility will be an approximately 30 feet by 82 feet slab on grade structure with concrete tilt-up walls and metal roof deck and open-web steel joists. The structure will house fluid tanks supported at/near existing site grades, typically on 1-foot thick concrete pads in a slab-on-grade structure with perimeter footing. Total perimeter wall loads will be on the order of 4,000 pounds per lineal foot.

3.0 SITE BACKGROUND AND RESEARCH

The site of the existing Post Point WWTP is an area of historic ground modification, including excavation of peat and organic soils and backfill with structural fill and some excavation of granular borrow soils in select areas of the site. The approximate extent of previous peat removal (based on our review of the documents below) is shown in Figure 2. In addition to local geologic maps, we have reviewed available subsurface information from the previous phases of site development, including the following sources:

- CH2M Hill, "Post Point Wastewater Treatment Plant Upgrade Geotechnical Design Report," September 1971.
- CH2M Hill, "Post Point Wastewater Treatment Plant Upgrade Geotechnical Data Report," September 1989.
- CH2M Hill, "Post Point Wastewater Treatment Plant Upgrade, Initial Design Review Submittal – Design Guidelines," September 1989.

4.0 SITE CONDITIONS

4.1. Surface Conditions

The project site is located in Fairhaven area of south Bellingham, southwest of the intersection of McKenzie Avenue and 4th Street. The site is bounded by Bellingham Bay, an intertidal lagoon and Burlington Northern Santa Fe railroad tracks and embankment to the west and northwest. An industrial/transportation district is located to the north and northeast. A residential neighborhood is located to the southeast, south and southwest, primarily on the raised bluffs above the site.

The site grades slope gently downward to the northwest towards Bellingham Bay with open grassy areas present in the southwest and southeast corners of the site. Steeper slopes are present on the margins of the site toward the south and east with heavier wooded vegetation on the bluff to the southwest.

4.2. Geologic Setting

We reviewed various geologic maps for the project area (Easterbrook 1976, Lapen 2000, and Department of Ecology 1977). The maps indicate that the site is underlain by the Chuckanut Formation bedrock, Frasier drift, alluvium and artificial fill.

The Chuckanut Formation consists of sandstone, conglomerate, shale, and coal deposits. The bedrock typically encountered in the study area consists of sandstone or siltstone. Bedrock was mapped at/near the ground surface in both the Easterbrook and Lapen maps, although no surface exposures of bedrock are present in the immediate project vicinity, and bedrock was not encountered in the site explorations.

The Department of Ecology (Costal Zone Atlas) maps soils in the project vicinity as Frasier drift, an undifferentiated glacial deposit composed of various glacial sources including glacial outwash, terrace deposits, glaciomarine drift, and glacial till. The soil types in this unit will depend on the depositional environment.

One predominant soil unit within the Frasier drift is a glaciomarine deposit locally referred to as Bellingham (glaciomarine) Drift. This glaciomarine deposit consists of unsorted, unstratified silt and clay with varying amounts of sand, gravel, cobbles and occasional boulders. Some discrete but likely discontinuous sand layers were also encountered. Glaciomarine drift is derived from sediment melted out of floating glacial ice that was deposited on the sea floor. Glaciomarine drift was deposited during the Everson Interstade approximately 11,000 to 12,000 years ago while the land surface was depressed 500 to 600 feet from previous glaciations. This unit is predominantly medium stiff to soft and possesses relatively low shear strength and moderate to high compressibility characteristics in a lowland environment. Glacial till, a subset of the Frasier drift, is typically dense as a result of being overridden by glaciers, with resultant high hear strength and low compressibility characteristics.

Alluvium typically consists of sand, gravel and silt with areas of clayey and organic soil, deposited on beaches, spits, and modern flood plains, and may include some nearshore inter-tidal deposits.

The artificial fill identified at the site is the result of historical ground modification. The WWTP has been located at the site since 1971. It appears that historically excavation likely occurred into the hillside along the east side of the site. The lower portion of the site is located in an alluvial environment with significant peat deposits. During previous site development, some of the peat has been removed and fill has been brought into the site to raise grades to present elevations.

4.3. Geologically Hazardous Areas

Geologically hazardous areas are designated by the City of Bellingham Critical Areas Ordinance (CAO) per Bellingham Municipal Code 16.55.410 – 16.55.460. In addition to the definition of the geologically hazardous areas in the CAO, the City has developed a folio of maps that identify these areas in their database. In general, the CAO requires that a qualified professional assess the geologic hazards based on review of available information and field studies, evaluate the specific project proposal with respect to relationship and impact on the hazard area and adjacent sites if appropriate, provide minimum buffers and setbacks and provide mitigation strategies where appropriate for specific geologic hazards. The geologically hazardous areas include erosion, landslide, seismic and mines.

4.3.1. Erosion Hazard Areas

Erosion hazard areas are defined by the CAO as areas prone to soil erosion including:

- Areas identified in soil unit maps of the U.S. Department of Agriculture Soil Conservation Services Soil Survey of Whatcom County rated as “severe” due to “slope, wetness, ponding, flooding, cutbanks cave” or any combination thereof.
- Upland areas immediately adjacent to Bellingham Bay.
- Any area where soil type is predominantly sand, clay, silt and/or organic matter and slopes greater than 30 percent.

The soils mapping by the Soil Conservation Service Soil Survey of Whatcom County (SCS) does not indicate if an erosion hazard is present at the project location; the site is mapped as urban land and does not indicate the soil type. The site is not identified as an erosion hazard in the Geologic Hazard Areas Map Folio. However, the site is adjacent to Bellingham Bay and does have soil types that would be defined as an erosion hazard area by the CAO. Additionally, an erosion hazard would exist where soils are disturbed during the earthwork phase of construction. Erosion hazard mitigation is presented in a subsequent section of this report.

4.3.2. Landslide Hazard Areas

Landslide hazard areas are defined by the CAO as those susceptible to landslides and/or subsidence that could include movement of soil, fill materials, rock or other geologic strata. Specific landslide designations as defined by the CAO include:

- Areas identified in soil unit maps of the U.S. Department of Agriculture Soil Conservation Services Soil Survey of Whatcom County rated as “severe” due to “slope” and/or “subsides”.
- Slopes equal to or greater than 40 percent grade (2.5H:1V [Horizontal:Vertical] or 22 degrees) with an elevation change of at least 10 feet.

- Slopes that are parallel or subparallel to planes of weakness in subsurface materials.
- Current and historic marine bluffs along present and historical shorelines including Bellingham Bay.
- Areas depicted as landslide hazards by the Geologic Hazard Areas Map Folio, Bellingham, Washington, 1991.

The soils mapping by the Soil Conservation Service Soil Survey of Whatcom County does not indicate that a landslide hazard is present at the project location. The site does not currently have slopes greater than 40 percent grade with at least 10 feet of vertical relief. The site is not identified as a landslide hazard in the Geologic Hazard Areas Map Folio. Accordingly, the area does not meet the definition of a landslide hazard area and landslide hazards will not be addressed further in this report.

4.3.3. Seismic Hazard Areas

Seismic hazard areas are defined by the CAO as those areas subject to severe risk of damage as a result of earthquake induced ground shaking, slope failure, settlement, soil liquefaction, lateral spreading, or surface rupture. Specific areas of very high response to seismic shaking include:

- All landfills placed waterward of the historic 1850 natural coastline of Bellingham Bay.
- All alluvial deposits near the mouth (delta) of Whatcom Creek.
- All marine and stream course bluffs greater than 10 feet in vertical relief and steeper than 100%.
- All rock outcrops greater than 10 feet in vertical relief.

The site is identified in the Geologic Hazard Areas Map Folio as exhibiting a low response to seismic shaking, however, some of the soils encountered in our explorations exhibit a moderate to high potential response to seismic shaking. Although the site does not appear to meet the criteria for definition as a seismic hazard area according to the CAO, it is located near the shoreline in an area of modified land overlying a soft soil profile, and therefore is in a similar environment as a recognized seismic hazard area. Accordingly, potential impacts and mitigation strategies have been identified and are discussed in the subsequent sections of this report.

4.3.4. Mine Hazard Areas

Mine hazard areas are defined by the CAO as those areas underlain by or affected by historical mine workings. Specific hazard areas include:

- Areas depicted within the as *Coal Mine Hazard Areas* within the Geologic Hazard Areas Map Folio, Bellingham, Washington, 1991.

The project site is located approximately 1,600 feet west of the Union Mine portal location based on the Map Folio. No known mine workings are mapped at the project site. Accordingly, the area does meet the definition of a mine hazard area and mine hazards will not be addressed further in this report.

4.4. Subsurface Conditions

4.4.1. Subsurface Exploration

The subsurface exploration completed by GeoEngineers for this project consisted of fourteen borings, three test pits, and a seismic cone penetration test (CPT). Borings GEI-1 through GEI-14 were completed on April 27, April 28, and July 15, 2010 using a hollow stem auger and were advanced to depths ranging from 21.5 to 36.5 feet below existing ground surface (bgs). GeoEngineers conducted three test pits at the site on May 4, 2010 to depths ranging from 8 to 9 feet bgs using a small tracked excavator. The CPT was advanced to a depth of 81.2 feet bgs on April 26, 2010 with a track-mounted rig. All explorations were subcontracted to GeoEngineers. The approximate locations of the explorations are shown in Figure 2, as well as the explorations from previous studies completed at the site. Details of the field exploration program and the exploration logs are presented in Appendix A. Details of the laboratory testing program completed for this evaluation are presented in Appendix B. Relevant logs from previous site explorations in the vicinity of the proposed WWTP expansion are provided in Appendix C.

4.4.2. Soil Conditions

Subsurface soils were classified as fill, alluvium/peat, undifferentiated glacial drift, and glacial till. A description of each geologic unit is presented below. Representative subsurface cross-sections are presented in Figures 3 through 7.

FILL. Fill of variable soil types and density/consistency was encountered in all our explorations, except GEI-7, GEI-8, and TP-2, which were completed outside of the existing WWTP facility. The fill was typically medium dense/stiff in the upper portion of the fill, grading to decreased density/consistency with depth. The fill thickness ranged from 2 to 19.5 feet below ground surface (bgs). Fill consisted of sand with gravel, sandy silt, silty/clayey sand, and sand with silt/clay. Some scattered organic material was also encountered in the fill soils.

PEAT. A layer of soft to medium stiff peat over organic silt was encountered in GEI-1 from 9.5 to 15.5 feet bgs. We understand that extensive areas of peat were removed and replaced with structural and non-structural fill during previous site development. The approximate extents of previous peat removal at the site based on our research are shown in Figure 2. Peat was also identified in previous explorations by others where we assume overexcavation was not performed including boring B-9, B-10, and B-13.

ALLUVIUM. Soil interpreted to be alluvium was encountered in the southern and southwest portions of the site in areas outside of the developed WWTP facility. Alluvium was encountered underlying fill and/or sod in borings GEI-6, GEI-7, GEI-8, GEI-9, GEI-10, and GEI-14, and test pits TP-2, and TP-3. The alluvial deposits encountered generally consisted of loose to medium dense and soft to medium stiff sand with silt, silty sand and sandy silt with lesser amount of clayey soil. The alluvium extended to depths ranging from 7 to 14 feet bgs. Test pits TP-2 and TP-3 terminated in this unit.

UNDIFFERENTIATED GLACIAL DRIFT. Undifferentiated glacial drift, primarily interpreted to be a glaciomarine deposit, was encountered in all our boring locations except GEI-11. The glacial drift encountered generally consists of soft to medium stiff silty and sandy clay with some clayey silt and sand with variable gravel content. In the eastern portion of the site, near the proposed Blower

Building and CEPT Building, the glacial drift was medium stiff to stiff with some medium dense silty sand. The glacial drift encountered in our explorations has a higher sand content than is typical for glaciomarine deposits in upland areas. Based on the CPT data and our review of previous deeper explorations, this unit has some interbedding/layering with more granular soils. All GEI borings terminated in this unit except GEI-10 through GEI-14, which terminated in glacial till.

GLACIAL TILL. Glacial till, distinguished from the remainder of the undifferentiated glacial drift soil units because of its higher density and lower moisture content, was encountered in borings GEI-10 through GEI-14 at depths of 3 to 24 feet bgs and during previous site exploration at variable depths, up to 123 feet bgs. The glacial till encountered is typically dense to very dense silty sand with gravel, with very stiff to hard sandy silt and clay at some locations.

4.4.3. Groundwater Conditions

Relatively shallow groundwater conditions were observed at the project site, consistent with the nearshore location of the WWTP facility. Three piezometers were installed for this project at GEI-1, GEI-2, and GEI-5 boring locations. Groundwater was generally encountered between Elevation 13 and 15 feet in the southern portion of the site and slightly lower, between about Elevation 10 and 12 feet in the western portion of the site. Similar groundwater elevations were measured during exploration and monitoring for previous expansion, with groundwater ranging from Elevation 11.5 to 13 feet near B-9 and B-10 to Elevation 8 to 9 feet near Boring B-13 and B-14 (elevations adjusted from City of Bellingham datum to NAVD). Groundwater levels should be expected to fluctuate in response to rainfall, seasonal variations, possibly tidal variations, and other factors.

TABLE 1. GROUNDWATER CONDITIONS

Exploration No.	Approximate Surface Elevation (ft)	Depth to Groundwater Seepage at Time of Drilling (ft)	Groundwater Seepage Elevation at Time of Drilling (ft)	Measured Depth to Groundwater in Piezometer (ft)(1)	Groundwater Elevation in Piezometer (ft)(1)
GEI-1	13	17	-4	2.7	10.3
GEI-2	17	6	11	4.5	12.5
GEI-3	18	NE	NE	--	--
GEI-4	17.5	20.5	3	--	--
GEI-5	20	12	8	4.9	15.1
GEI-6	21	6	15	--	--
GEI-7	23	9	14	--	--
GEI-8	21	5.5	15.5	--	--
GEI-9	18.5	5.5	13	--	--
GEI-10	22	NE	NE	--	--
GEI-11	27	NE	NE	--	--
GEI-12	34	NE(2)	NE(2)	--	--
GEI-13	24	20	4	--	--
GEI-14	21	5	16	--	--

Exploration No.	Approximate Surface Elevation (ft)	Depth to Groundwater Seepage at Time of Drilling (ft)	Groundwater Seepage Elevation at Time of Drilling (ft)	Measured Depth to Groundwater in Piezometer (ft)(1)	Groundwater Elevation in Piezometer (ft)(1)
TP-1	15	8	7	--	--
TP-2	20	6.5	13.5	--	--
TP-3	23	NE	NE	--	--

NE – Not encountered

(1) – Measured June 11, 2010

(2) –Perched groundwater seepage was observed at a depth of 1 foot within the fill over the glaciomarine drift and is not representative of the local water table at this location.

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1. Summary of Geotechnical Considerations

Based on our evaluation, construction of the WWTP expansion is feasible as proposed. The site conditions include fill, peat, and naturally occurring compressible soils which must be carefully considered to achieve desirable foundation performance of the various project components. Additionally, a relatively shallow groundwater table is present that affects both design and construction of below grade structures. This report section includes a preliminary summary of geotechnical considerations for the proposed WWTP expansion. The recommendations in this report section should only be used in conjunction with the full text of this report.

5.1.1. Secondary Clarifier No. 4 (Facility No. 330)

The proposed Secondary Clarifier No. 4 is located in area overlying compressible peat and a significant differential thickness of soft to medium stiff clay (Figure 3). The adjacent clarifier settled several inches differentially across the width of the structure and required post construction mitigation to maintain system performance. The foundation loads are not fully compensated by the excavation and similar settlement and performance would occur if the new structure was supported on a shallow mat foundation. Accordingly, a pile supported mat foundation has been selected by the design team as the preferred foundation alternative for the Secondary Clarifier No. 4. Pile supporting this structure will limit total and differential settlement within the desired respective 1½ inch total and ¾ inch differential tolerances.

- Piles will consist of 18- or 24-inch augercast piles primarily deriving support from side friction in the glacial drift; some piles may reach dense glacial till. Recommendations for augercast pile axial and lateral capacity are presented in Section 5.3 of this report.
- Excavation to the foundation subgrade will likely extend through existing fill and reach loose alluvium, peat, and/or soft clay in places. Some additional subgrade stabilization may be required to support equipment for pile installation as described in Section 5.9.3 of this report.
- The depth of excavation for this structure will likely require temporary shoring and dewatering. We recommend temporary shoring consisting of sheetpiles that also provide groundwater cutoff and will limit construction dewatering. Recommendations for earth pressures for

temporary shoring are presented in Section 5.9.6 of this report. Recommendations for dewatering are discussed in Section 5.10.

5.1.2. Activated Sludge Basin No. 4 (Facility 311) and Odor Control Facility (Facility 312)

These facilities are also located in an area underlain by loose alluvium and soft to medium stiff clay (Figures 4 and 5). Peat was encountered in a nearby boring completed by others and could be encountered, although it appears unlikely based on our exploration program. The loads for the basin are higher than the weight of soil removed and are not fully compensated. Differential settlement and seismic response would be problematic if constructed with shallow foundations. Accordingly, a pile supported mat foundation has also been selected as the preferred foundation support for this structure. The lighter, at-grade odor control facility may be constructed with shallow foundations.

- Piles will consist of 18- or 24-inch augercast piles primarily deriving support from end bearing in the underlying dense glacial till. Recommendations for augercast pile axial and lateral capacity are presented in Section 5.3 of this report.
- Excavation to the foundation subgrade will likely extend through existing fill and reach loose alluvium and/or soft clay in places. Some additional subgrade stabilization may be required to support equipment for pile installation as described in Section 5.9.3 of this report.
- The depth of excavation for this structure and adjacent infrastructure will likely require temporary shoring. We recommend temporary shoring consisting of sheetpiles that also provide groundwater cutoff and will limit construction dewatering. Recommendations for earth pressures for temporary shoring are presented in Section 5.9.6 of this report. Recommendations for dewatering are discussed in Section 5.10.
- The odor control facility is a light facility. We recommend that the structure be supported by a structural slab on grade with thickened edges for footings. Shallow foundation recommendations are presented in Section 5.4.

5.1.3. Blower Building (Facility 325)

The proposed Blower Building will be constructed as a slight cut up to about 5 feet below existing site grades in an area with a shallow thickness of fill overlying alluvium (Figure 6). The groundwater table is not expected within the depth of excavation. The walls of the structure are anticipated to be concrete tilt-up or concrete masonry unit (CMU). Because of variability in underlying soils, site history of excavation and fill, and presence of a limited thickness of liquefiable soils, some differential settlement could occur with traditional shallow foundations. We recommend a mat foundation or tying internal foundations together with grade beams to help limit differential settlement.

- We recommend a mat foundation or slab-on grade with continuous perimeter grade-beam style foundation with top and bottom steel reinforcement. We recommend any internal footings also be tied together with grade beams, or possibly by placing some steel in the slab-on-grade and connecting the slabs to the footings. The footings can be designed for an allowable bearing pressure of 2,000 psf if supported on 12 inches of compacted structural fill. Mat foundations may be designed with a subgrade modulus of about 30 pounds per cubic inch (pci). Shallow foundation recommendations are presented in Section 5.4.

5.1.4. Selector/Activated Sludge Basin No. 1 (Facility 305) and Odor Control Facility (Facility 306)

The Selector/Activated Sludge Basin No. 1 is in an area of sloping ground and will be excavated between 10 and 20 feet below existing site grades to reach the slab elevation of +14 feet (Figure 7). If constructed as a mat foundation at Elevation 14 feet, the western portion of the mat foundation would bear directly on dense glacial till while the eastern portion would be supported medium stiff to stiff clayey glacial drift. The portion of the structure founded on glacial till will not experience any appreciable settlement, with an increasing settlement magnitude toward the west; therefore, any settlement that does occur will be differential across the basin. For planning purposes, we recommend that the glacial drift in the western portion of the building footprint be overexcavated down to dense glacial till and backfilled with densely compacted structural fill. Alternatively, it may be more cost effective to use a series of slots or piers backfilled with controlled density fill (CDF) or rammed aggregate piers (RAPs) that penetrate through the drift and bear on/in the glacial till. We have provided recommendations for the overexcavation at this time, and suggest re-evaluating alternatives once the project design is further along.

- Based on explorations near the western building corners, overexcavation and replacement to about Elevation +0 to -2 could be required to reach the dense glacial till.
- Relatively steep temporary construction slopes will be feasible in the dense glacial till, and likely in the glacial drift. Flatter slopes or shoring will be required for the cut in alluvium. Recommendations for temporary slopes are provided in Section 5.9.5.
- Excavation of the glacial till in the eastern portion of the basin will encounter very dense soil that may be very difficult to excavate and require larger equipment or "ripping" to reach the proposed subgrade elevation.
- Even with overexcavation and replacement with structural fill, some potential for differential settlement will remain. We recommend that the transition between cut into dense glacial till and fill be spaced in steps over approximately 30 feet as described in Section 5.4.4.
- If the RAP option is pursued further, noise generated during installation could be a factor for protection of adjacent wildlife habitat. Excavated slots or piers backfilled with CDF would have construction noise similar to other planned site activities.
- The mat foundation on dense glacial till or structural fill placed and compacted directly over glacial till, may be designed with a subgrade modulus of about 200 pci. A discussion of mat foundations is presented in Section 5.4.3.
- The odor control facility is a light facility. We recommend that the structure be supported by a structural slab on grade with thickened edges for footings. Shallow foundation recommendations are presented in Section 5.4.

5.1.5. Chemically Enhanced Primary Treatment Facility (Facility 240)

The proposed CEPT Facility will be constructed near existing site grades in an area with a shallow thickness of fill overlying alluvium (Figure 6). The walls of the structure are anticipated to be concrete tilt-up or concrete masonry unit (CMU). Because of variability in underlying soils, site history of excavation and fill, and presence of a limited thickness of liquefiable soils, some differential settlement could occur and we have recommend a mat foundation or structural slab with perimeter grade beam type design to help limit differential settlement.

- We recommend a mat foundation or structural slab-on grade with continuous perimeter grade-beam style foundation with top and bottom steel reinforcement for support of the walls. The perimeter footing can be designed for an allowable bearing pressure of 2,000 psf if supported on 12 inches of compacted structural fill. Mat foundations may be designed with a subgrade modulus of about 30 pci. Details of shallow foundation support are presented in Section 5.4.

5.2. Geologic Hazards and Mitigation

5.2.1. Erosion Hazard Considerations

The area of the proposed construction includes relatively flat or gently sloping areas of historical fill or native alluvium and glacial drift. As currently envisioned, earthwork construction for the WWTP expansion will require significant excavation to the proposed foundation elevations and construction of the new structures. The primary erosion hazard at the site is from temporary conditions created during construction. Temporary erosion control measures and Best Management Practices (BMPs) are required during construction under current regulations to mitigate on-site and off-site erosion potential, which is standard of practice.

In our opinion, provided typical erosion and sedimentation controls are implemented during construction, the site does not present a significant erosion hazard. Stormwater should be prevented from flowing across disturbed areas and not directed toward the slopes during construction. Temporary erosion control measures should be used during construction depending on the weather, location, soil/rock type, and other factors. Temporary erosion protection (e.g., straw, plastic, or rolled erosion control products [RECPs]) may be necessary to reduce sediment transport until vegetation is established or permanent surfacing applied. Appropriate best management practices (BMPs) should be incorporated into the temporary erosion and sediment control plan by the civil engineer. All finished slopes should be protected and/or vegetated before the rainy season. Provided that proper grading practices are used and BMPs incorporated into the grading plans, we conclude that the erosion hazard will be adequately mitigated during site development. During construction, the contractor would be subject to Ecology regulations which require performance based testing of turbidity at all discharge points. Proper construction practices and monitoring procedures will manage the risks to the standard of practice.

5.2.2. Seismic Hazard Considerations

5.2.2.1. SITE SEISMICITY

The site is located within the Puget Sound region, which is seismically active. Seismicity in this region is attributed primarily to the interaction between the Pacific, Juan de Fuca and North American plates. The Juan de Fuca plate is subducting beneath the North American plate. It is thought that the resulting deformation and breakup of the Juan de Fuca plate might account for the deep focus earthquakes in the region. Hundreds of earthquakes have been recorded in the Puget Sound area. In recent history, four of these earthquakes were large events: (1) in 1946, a Richter magnitude 7.2 earthquake occurred in the Vancouver Island, British Columbia area; (2) in 1949, a Richter magnitude 7.1 earthquake occurred in the Olympia area; (3) in 1965, a Richter magnitude 6.5 earthquake occurred between Seattle and Tacoma; and (4) in 2001, a Richter magnitude 6.8 earthquake occurred near Olympia.

Research has concluded that historical large magnitude subduction-related earthquake activity has occurred along the Washington and Oregon coasts. Evidence suggests several large magnitude

earthquakes (Richter magnitude 8 to 9) have occurred in the last 1,500 years, the most recent of which occurred about 300 years ago. No earthquakes of this magnitude have been documented during the recorded history of the Pacific Northwest. Local design practice in Puget Sound and local building codes now include the possible effect of a very large subduction earthquake and local known faults in the design of structures.

5.2.3. Seismic Ground Motion Design Values

The 2009 International Building Code (IBC) mapped acceleration parameters, S_s and S_1 (Site Class B), are determined using the 2002 United States Geological Survey (USGS) National Seismic Hazard Map, as presented in Table 2 below.

TABLE 2. 2009 IBC ACCELERATION PARAMETERS

Soil Site Class B
Spectral Response Acceleration at Short Periods (S_S) = 0.993
Spectral Response Acceleration at 1 Second Periods (S_1) = 0.333

The acceleration parameters presented in Table 2 above are only appropriate for a rock site. Because the project area is a soil site, these parameters will need to be adjusted to account for the soil effect prior to being used in the design of the WWTP structures. For this project, a site-specific seismic response analysis was completed to develop the ground surface design response spectra for use in the structural analyses. Figure 8 presents the recommended ground surface design response spectra for use in design of the WWTP structures for this project. Details of the site-specific seismic response analysis are provided in Appendix D.

5.2.4. Liquefaction and Lateral Spreading

Liquefaction is a phenomenon where soils experience a rapid loss of internal strength as a consequence of strong ground shaking. Loss of bearing support, ground settlement, lateral spreading and/or sand boils may result from liquefaction. Conditions favorable to liquefaction occur in very loose to medium dense, clean to moderately silty sand that is below the groundwater level. Dense soils or soils that exhibit cohesion are less likely to be susceptible to liquefaction. Soils considered susceptible to liquefaction underlying the project site include a limited thickness a granular alluvium and some layers/lenses of granular soil within the generally fine-grained glaciomarine drift.

The results of our analyses indicate that portions of the loose to medium dense native alluvium and granular portions of the glacial drift have a moderate potential for liquefaction during a design earthquake event with 2 percent probability of exceedance in 50 years (i.e. an earthquake with 2,475 year recurrence interval with magnitude 6.4 and a PGA of 0.44g). Our analyses indicate that settlements caused by liquefaction of the saturated portions of these layers during a design earthquake could be on the order of 2 to 3 inches. The variability of site conditions suggests that liquefaction and subsequent settlement will be sporadic across the site and differential settlement over short distances could equal the total anticipated liquefaction settlement. Pile foundations discussed subsequently in this report will effectively mitigate liquefaction induced settlement.

In addition to settlement, there is the possibility that lateral spreading of the soils could occur as a result of soil liquefaction. Lateral spreading involves lateral displacement of large, surficial blocks of non-liquefied soil, as well as the liquefied soil itself, as the underlying soil layer liquefies. Lateral spreading generally develops in areas where sloping ground is present or near a free face, such as a river or slough. If liquefaction were to occur within the granular layers at the site we anticipate that, because of the sporadic nature of the liquefiable soils, there would be a relatively low potential for lateral spreading to occur. During a design earthquake, lateral spreading displacements, characterized by movement of the soils towards Bellingham Bay, are estimated to be on the order of 1 to 2 inches, with perhaps little to no lateral spreading occurring depending on the level of ground shaking.

The complexity and variability of the subsurface conditions, variable loading and elevations of the various facilities, connections between facilities make a detailed analysis of the ground motion and affect on facilities very difficult. This is typical of WWTP facilities construction along Puget Sound shorelines. In this case, the predicted seismic induced subsidence from liquefaction is relatively limited. A mitigation measure for the structures is to make the foundations sufficiently rigid to resist the differential settlement that could occur.

5.2.5. Surface Fault Rupture

There are no known faults located at the site. The closest active faults identified include the Vedder Mountain Fault, Sumas Mountain Fault, and the Boulder Creek Fault complex including the Kendal Fault. The closest fault to the site is approximately 10 miles northwest of Bellingham. Therefore, the site is not considered to be at risk of surface rupture.

5.2.6. Tsunami Hazard Areas

Large subduction zone earthquakes are commonly followed by a tsunami. A tsunami is a large ocean wave typically caused by rapid vertical seafloor movements associated with earthquakes. The 1960 Chile, 1964 Alaska and 2006 Indonesia events are examples of the relationship between subduction zone earthquakes and tsunamis. Predicting the size of a tsunami is complicated and relies on several factors, including size of the earthquake, seafloor topography and tides. The tsunami in Puget Sound originates at the coast and must travel through Juan de Fuca Straits. The Whatcom County Geologically Hazardous Areas map identifies a tsunami maximum wave height of about 8 to 10 feet in the project vicinity; however, no significant inundation is expected at the site (WDNR 2004). Additionally, the new structures are at the same elevation as the existing structure and much of the surrounding areas, including McKenzie Avenue. As such, the new construction does not represent increased tsunamis hazard beyond the existing condition.

5.3. Pile Foundation Recommendations

Pile foundations have been selected by the design team for certain project elements to reduce anticipated total and differential settlements within tolerable levels and avoid liquefaction induced subsidence to the structures. As currently envisioned, augercast piles will be used to support the proposed Secondary Clarifier No. 4 (Facility 330) and the Activated Sludge Basin No. 4 (Facility 311) because of deeper soft soil profiles under these structures and heavier loads applied that are not compensated with foundation excavation.

5.3.1. Augercast Piles

Augercast piles are the preferred pile type because they are a relatively economical type of deep foundation, there is minimal disturbance of adjacent structures during installation, the equipment provides a cased hole for installation of the pile, and because there is a lower level of construction noise (i.e. no pile driving) with lesser impacts to adjacent wildlife habitat. Drilled shafts would require temporary casings because of the soft soils. Other pile types, such as driven steel pipe or H-piles are also be feasible, but with greater noise impacts. Recommended capacities for these pile types can be provided if requested.

Augercast piles are constructed using a continuous flight hollow stem auger attached to a set of leads supported by a crane. The first step in the pile casting process consists of drilling the auger into the ground to the specified tip elevation of the pile. Grout is then pumped through the hollow stem auger upon steady withdrawal of the auger and replaces the soils removed on the flights of the auger. The final step is to install a steel reinforcing cage and typically a center bar into the column of fresh grout. The benefit of using augercast piles in this environment is that the auger provides support for the soils during the pile installation process, thus eliminating the need for temporary casing or drilling fluid.

5.3.2. Vertical Axial Capacities

We have estimated the vertical axial load capacities of 18-inch and 24-inch diameter augercast piles. Axial pile capacity in compression will be developed from a combination of frictional resistance in the medium stiff to stiff clayey glacial drift soils underlying the site, and in some cases end bearing in the dense glacial till. Because of the greater thickness of medium stiff glacial drift underlying the clarifier, the augercast piles at this location will develop most of their capacity from side friction because the glacial till is too deep. The till surface is variable as shown in Figure 3. At Sludge Basin No. 4, the augercast piles will extend to dense glacial till and will derive most of their support from end bearing in this unit. Uplift pile capacity at both locations will be developed from frictional resistance in the glacial drift and glacial till.

Allowable pile capacities are provided for Allowable Stress Design (ASD). The allowable capacities are for combined dead plus long term live loads and may be increased by one-third when considering design loads of short duration such as seismic forces. The allowable capacities are based on the strength of the supporting soils for the depths below the existing ground surface and include a factor of safety of about three for end bearing and two for shaft friction. The capacities apply to single piles. If piles are spaced at least three pile diameters on center as recommended, no reduction for group action is needed. Provided site grades are not raised significantly from existing conditions, we anticipate limited effects and reduction in axial capacity resulting from downdrag. We recommend that we be consulted if surrounding grades within about 15 feet of the structure are raised by more than 3 to 4 feet.

The structural characteristics of pile materials and structural connections may impose limitations on pile capacities and should be evaluated by the structural engineer. For example, steel reinforcing will be needed for augercast piles subjected to uplift or large bending moments.

Table 3 below presents a summary of the allowable axial pile capacity (compression and uplift) for the Secondary Clarifier No. 4. To achieve suitable bearing at this location, we recommend a

minimum pile length of 30 feet into the underlying clayey glacial drift soils, with total design length based on the required capacity. Based on our subsurface explorations, we anticipate that some piles may reach the dense glacial till within the depths shown. Piles reaching glacial till prior to the design depth can be terminated 5 feet into that layer and will achieve the minimum capacities presented in the table, and do not need to extend the full design depth.

TABLE 3. AXIAL PILE CAPACITIES – SECONDARY CLARIFIER NO. 4

	Allowable Pile Capacity (kips)			
	18-inch Augercast		24-inch Augercast	
Depth (ft)	Compression	Uplift	Compression	Uplift
30	60	60	80	80
40	80	80	100	100
50	100	100	130	130
60	125	125	160	160
70	150	150	190	190

Table 4 below presents a summary of the allowable axial pile capacity (compression and uplift) for the Sludge Basin No. 4. To achieve suitable bearing at this location, we recommend a minimum embedment of about 5 feet into the dense glacial till. Based on our subsurface explorations, pile lengths on the order of 30 to 45 feet are anticipated to achieve the desired embedment.

TABLE 4. AXIAL PILE CAPACITIES – SLUDGE BASIN NO. 4

	Allowable Pile Capacity (kips)			
	18-inch Augercast		24-inch Augercast	
Embedment Depth in Glacial Till (ft)	Compression	Uplift	Compression	Uplift
5	170	60	280	80

5.3.3. Lateral Capacities

Lateral loads can be resisted by the skin friction and passive soil pressure on the vertical piles and by the passive soil pressures on pile caps. Because of the potential separation between the pile-supported foundation components and the underlying soil from settlement, base friction on pilecaps should not be included in calculations for lateral capacity.

We analyzed the ultimate lateral load capacity of 18-inch and 24-inch augercast piles with the pile head fixed against rotation. We evaluated the lateral capacity for ¼-inch, ½-inch, and 1-inch deflection at the top of the pile. The results of our analyses are summarized in Tables 5 and 6 for the Secondary Clarifier No. 4 and Sludge Basin No. 4 respectively. The results represent ultimate values and do not include a factor of safety. Plots of the lateral pile analysis are presented at the end of this report in Figures 9 through 14.

TABLE 5. ULTIMATE LATERAL PILE CAPACITY – AUGERCAST PILES AT SECONDARY CLARIFIER NO. 4

Pile Diameter	Lateral Deflection (in)	Fixed Head Condition	
		Lateral Load (kip)	Maximum Bending Moment (in-kip)
18-inch	¼	12.5	830
	½	18	1,320
	1	26	2,130
24-inch	¼	19	1,570
	½	28	2,580
	1	41.5	4,280

TABLE 6. ULTIMATE LATERAL PILE CAPACITY – AUGERCAST PILES AT SLUDGE BASIN NO. 4

Pile Diameter	Lateral Deflection (in)	Fixed Head Condition (at Basin)	
		Lateral Load (kip)	Maximum Bending Moment (in-kip)
18-inch	¼	12.5	830
	½	18	1,320
	1	26	2,130
24-inch	¼	19.5	1,620
	½	28.5	2,640
	1	42	4,330

5.3.4. Settlement

We estimate that the post-construction settlement of pile foundations, designed and installed as recommended, will be on the order of ¾-inch or less. Maximum differential settlement should be less than about one-half the post-construction settlement. Most of this settlement will occur rapidly as loads are applied. Pile foundations will effectively mitigate the liquefaction induced settlement discussed in the Seismic Hazard Considerations section of this report.

5.3.5. Construction Considerations

The augercast piles should be installed to the recommended depth or tip embedment using a continuous-flight, hollow-stem auger. We recommend that the augercast piles be installed by a contractor experienced in their placement and using suitable equipment. Excavation to the

subgrade will likely reach loose/soft soil that will easily become disturbed and may not adequately support construction equipment without mitigation. Subgrade performance will be improved with appropriate dewatering. Additionally, a gravel working mat about 24 inches thick, or other measures to distribute equipment loads may be required to support equipment during pile installation.

5.3.5.1. DRILLING AND GROUTING

The augercast piles generate cuttings as the soil is removed. As is standard practice, the pile grout must be pumped under pressure through the hollow stem as the auger is withdrawn. Maintenance of adequate grout pressure at the auger tip is critical to reduce the potential for encroachment of adjacent native soils into the grout column. Grout pumps must be fitted with a volume-measuring device and pressure gauge so that the volume of grout placed in each pile and the pressure head maintained during pumping can be observed. A minimum grout line pressure of 100 pounds per square inch (psi) should be maintained.

The action of the auger may tend to disturb the soil at the bottom of the drilled hole, which would result in decreased end-bearing capacity. In order to minimize the negative effects of this disturbance, we recommend that the pile contractor be required to rotate the auger following pumping of the first few cubic feet of grout and prior to auger withdrawal. This will mix any loose cuttings at the bottom of the hole with the grout; thus, developing the required end-bearing capacity.

The glacial drift soil can have occasional cobbles and boulders and even clusters. It may be necessary to relocate some piles if refusal is encountered above the recommended tip elevation.

5.3.5.2. AUGER WITHDRAWL

The rate of withdrawal of the auger must remain constant throughout the installation of the piles in order to reduce the potential for necking of the piles. The rate of auger withdrawal should be controlled during grouting such that the volume of grout pumped is equal to at least 115 percent of the theoretical pile volume. A minimum head of 10 feet of grout should be maintained above the auger tip during withdrawal of the auger to maintain a full column of grout and prevent hole collapse. Failure to maintain a constant rate of withdrawal of the auger will result in immediate rejection of that pile. Reinforcing steel for bending and uplift should be placed in the fresh grout column as soon as possible after withdrawal of the auger. Centering devices should be used to provide concrete cover around the reinforcing steel.

5.3.5.3. CONSTRUCTION SEQUENCING

We recommend that there be a waiting period of at least 12 hours between the installation of piles spaced closer than 8 feet, center-to-center. This waiting period is necessary to avoid disturbing the curing concrete in previously cast piles.

5.3.5.4. VERIFICATION AND TESTING

It should be noted that no direct information regarding the capacity of augercast piles (e.g., driving resistance data) can be obtained while this type of pile is being installed. Therefore, we recommend that pile installation operations be monitored by the Geotechnical Engineer or his representative. The Geotechnical Engineer will observe the drilling operations, monitor grout injection procedures, record the volume of grout placed in each pile relative to the calculated

volume of the hole, and evaluate the adequacy of individual pile installations. We also strongly recommend that a pre-construction meeting take place with the pile contractor, the owner and the Geotechnical Engineer to discuss pile construction techniques.

Federal Highway Administration (FHWA) Geotechnical Engineering Circular No. 8 – Design and Construction of Continuous Flight Auger Piles outlines guidelines for pre-production, verification load testing, and integrity testing. Testing could include pre-production static load testing, rapid dynamic test (RDT) or dynamic load test (DLT) for verification, and sonic echo testing for integrity. In our experience, this type of testing is uncommon except for large projects or projects of a critical nature. We recommend that this document be consulted and an appropriate testing program selected. At a minimum, we recommend that geotechnical observations described above along with appropriate materials testing to verify quality of grout and steel materials.

5.4. Shallow Foundation Recommendations

5.4.1. General

In general, shallow foundations will be suitable for project elements that do not impose large aerial loads that could induce unacceptable settlement in the underlying soft soil profile. Shallow foundations are anticipated for the Blower Building (Facility 325), CEPT Facility (Facility 240), and other miscellaneous lightly loaded structures such as the Odor Control Equipment (Facilities 306 and 312). This may include footing design in Section 5.4.2 and Slab on Grade section 5.5. We anticipate that these structures will be constructed near existing site grades. Based on the results of our study, these locations are underlain by fill, alluvium and glacial drift; it does not appear that the structures would be located in areas with peat or very soft compressible soil.

The proposed Activated Sludge Basin No. 1 (Facility 305) will also be supported on a shallow foundation, consisting of a mat foundation and retaining walls since this structure will be approximately 10 to 20 feet below grade. This structure is located in an area underlain at shallower depths by dense glacial till and glacial drift. Mat foundation recommendations are presented in Section 5.4.3 below. Some overexcavation and replacement below this structure will be required as discussed in Section 5.4.4 below.

5.4.2. Footing Design

The subgrade soils for the at-grade foundations could be somewhat variable and will most likely consist of existing fill from previous peat removal activities or native loose to medium dense alluvium. Deeper foundation elements could extend through the alluvium and into the underlying glacial drift. The lightly loaded structures as described above can be adequately supported on spread footings or continuous foundations bearing on the native soils.

We suggest a continuous grade-beam style foundation with top and bottom steel reinforcement to the footing together and help limit differential settlement for the Blower Building, CEPT Building, or other structures with taller concrete tilt up or CMU walls. We suggest a minimum of 12 inches of structural fill under shallow foundations with a contingency (because of potentially variable fill soils) to overexcavate and replace an additional 12 inches as necessary to achieve uniform bearing. We recommend that the slab include some steel to tie the building together, or internal continuous footings that act as grade beams where internal footings will occur.

Exterior footings should be founded at least 18 inches below adjacent grade for frost protection in accordance with local codes. We recommend that continuous wall footings and individual column footings have minimum widths of 18 and 24 inches, respectively. Footings can be designed for an allowable bearing capacity of 2,000 pounds per square foot (psf) for the combination of dead and long-term live loads. This allowable bearing capacity may be increased by one-third to account for short-term live loads such as induced by wind or seismic forces.

We recommend that all completed footing excavations be observed by geotechnical engineer prior to reinforcing steel and structural concrete placement, to confirm that the bearing surface has been prepared in a manner consistent with our recommendations and that the subsurface conditions are as expected.

It may be cost effective and efficient to design the smaller odor buildings with a structural floor and thickened edge footings as a monolithic pour. This procedure would tie the floor and perimeter footings together and minimize differential settlement and differential movement during seismic events.

5.4.3. Mat Foundation Recommendations

The modulus of subgrade reaction can be used for design and analysis of mat foundations that are not supported on piles. The subgrade modulus, k, is not a fundamental soil property and depends on many other factors including the width, shape, and depth below the ground surface of the loaded area, position under the foundation, and time (Coduto 2001). Because it is difficult to develop accurate k values, it may be appropriate to conduct a parametric study to evaluate its effect on the foundation design. ACI (1993) suggests varying k from about one-half of the value to five or ten times the value.

Mat foundations designed as beams on an elastic foundation, will require the soil subgrade modulus for design. Where the mat foundations bear on existing fill, alluvium and/or medium stiff glacial drift, the subgrade may be assumed to have a subgrade modulus on the order of 30 pci. This value has been reduced to account for the soft clay soils encountered in our explorations. This is likely the condition for the Blower Building and CEPT Building. It is likely that theses foundations will bear on variable subgrade soils including loose sandy alluvium and soft to medium stiff clay soils. Therefore, we recommend that these foundations be underlain by a minimum 12 inches of sand and gravel or crushed rock as described in the “Base Preparation” section of this report. The sand and gravel or crushed rock will serve as a clean working surface during construction.

Where mat foundations bear on dense glacial till, or compacted structural fill placed directly over glacial till, the compacted subgrade may be assumed to have a subgrade modulus on the order of 200 pci. This condition occurs at Activated Sludge Basin No. 1.

5.4.4. Overexcavation for Selector/Activated Sludge Basin No. 1

As previously described, the eastern end of Selector/Activated Sludge Basin No. 1 will be located on essentially incompressible glacial till and the western end of this facility is located in an area underlain by moderately compressible glacial drift. At this time, we recommend that the glacial drift be removed from the foundation support prism of this structure, which can be assumed by extending a 1:1 plane out from the edge of the mat foundation to the top of the till. To limit a

sharp break in settlement between the structural fill and the excavation into the dense glacial soils, we recommend that the overexcavation be transitioned over an approximately 30 foot horizontal distance in approximately 10 foot wide and one foot high steps. The overexcavation should be backfilled with granular structural fill compacted to at least 95 percent of the maximum dry density (MDD) based on ASTM D 1557 test procedure as described in the Earthwork section of this report.

A generalized depiction of the foundation soils is shown in Figure 7. The depth of the glacial drift below the foundation elevation is up to 16 feet based on the two westerly borings (GEI-10 and GEI-13). A schematic of the overexcavation is presented in Figure 13.

It is likely that a ground improvement technique such as CDF slot trenches, CDF piles or RAPs will be a more cost effective way to support the mat foundation. These alternatives can be evaluated at a later time, if appropriate. As discussed previously, if the RAP option is pursued further, noise generated during installation could be a factor for protection of adjacent wildlife habitat. Excavated slots or piers backfilled with CDF would have construction noise similar to other planned site activities.

5.4.5. *Lateral Resistance*

Lateral loads can be resisted by a combination of friction between the footing and the supporting soil, and by the passive lateral resistance of the soil surrounding the embedded portions of the footings. A passive lateral resistance corresponding to an equivalent fluid density of 275 pounds per cubic foot (pcf) may be used for design above the groundwater table. Below the groundwater table an equivalent fluid density of 150 pcf may be used. The upper 12 inches of passive resistance should be ignored. A coefficient of friction of 0.40 may be used between the concrete and soil. This value assumes that the subgrade soils will consist of a minimum 12-inch-thick working surface of sand and gravel or crushed rock placed over the native site soils. These values include a safety factor of approximately 1.5.

5.4.6. Shallow Foundation Settlement

We estimate that the post construction settlement of structures supported on shallow foundations may be on the order of ½ to 1 inch, depending on loads and locations. Differential settlements measured over a distance of approximately 25 feet may be on the order of 1/2 inch. We expect that settlements for these conditions will be a combination of elastic in nature (tending to occur rapidly after the loads are applied) and consolidation of clayey soils (tending to occur slowly over a period of months or years).

Immediately prior to placing concrete, all debris and soil slough that accumulated in the footings during forming and reinforcing steel placement must be removed. Debris or loose soil not removed from the footing excavations will result in increased settlement.

5.5. Slab-On-Grade Support

The slab subgrade soils for the near surface structures should be prepared in accordance with the site preparation recommendations provided in the "Earthwork" section of this report. We recommend that the exposed slab subgrades be compacted to a firm and non-yielding condition and approved by the geotechnical engineer during construction. We recommend that the slab-on-

grade be supported on a layer of structural fill serving as capillary break material with a minimum thickness of 12 inches for the structures.

The capillary break material should consist of a well-graded sand and gravel or crushed rock with a maximum particle size of 1 inch and have less than 3 percent fines. A suitable WSDOT *Standard Specification* is coarse aggregate for Portland cement concrete, AASHTO Grading No. 67 [9-03.1(4)C].

Where moisture content in the slab is critical (i.e., if tile or carpeting is glued to the slab), we recommend a vapor barrier be placed between the floor slab and the capillary break material. The vapor barrier should consist of polyethylene sheeting with bonded seams.

All fill placed beneath the building slab to meet the proposed grade should be in accordance with our recommendations for structural fill provided in the "Earthwork" section of this report. Structural fill in slab areas should be compacted to at least 95 percent of the MDD in accordance with ASTM D 1557.

5.6. Additional Design for Below Grade Structures

The Secondary Clarifier No. 4 (Facility 330), Activated Sludge Basin No. 4 (Facility 311), and Activated Sludge Basin No. 1 (Facility 305) will have below grade portions of the structure that will be subject to lateral earth pressures, hydrostatic pressures, buoyancy and uplift.

5.6.1. Lateral Earth Pressures

Lateral soil pressures acting on the retaining walls will depend on the nature and density of soil behind the wall, the amount of lateral wall movement which occurs as backfill is placed, and the inclination of the backfill surface. For walls free to yield at the top at least one thousandth of the wall height (i.e., wall height times 0.001), soil pressures will be less than if wall movement is restrained. We recommend that walls free to yield at the top and supporting horizontal backfill be designed using an equivalent fluid density of 35 pcf. We recommend that walls deeper than 5 feet bgs be designed using an equivalent fluid density of 80 pcf to account for hydrostatic pressures. If the walls will be restrained against movement, we recommend using an equivalent fluid density of 55 pcf above the water table and 90 pcf below the water table. We conclude that the Selector/Activated Sludge Basin No. 1 does not need to be designed with hydrostatic earth pressures (based on the proposed base Elevation of 14 feet) provided that the design includes a drainage layer with positive drainage by gravity or sump and pump.

We also recommend a uniformly distributed seismic surcharge of 9H psf (H = Height of wall) be applied to the wall with a corresponding reduction in the factors of safety to 1.1 or greater. Lateral pressure resulting from seismic surcharge loading is additive to lateral soil pressures computed as recommended above. Surcharge loading should be added to all walls where appropriate. If traffic can be within about 10 feet of the top of the wall, we recommend that the walls be designed for a 250 psf surcharge load. For design purposes, this is equivalent to assuming approximately two additional feet of soil above site grades using the equivalent fluid densities described above. Temporary surcharge loading during construction resulting from equipment and soil stockpiles should be evaluated by the contractor.

In order to prevent overstressing the concrete retaining walls and causing bulging or rotation, we recommend that structural fill placed against the back of the wall be compacted with lighter weight hand-operated equipment and within the range of 90 to 92 percent of the MDD. Backfill should be placed after the concrete has had sufficient time to cure and develop the necessary strength.

5.6.2. Buoyancy and Uplift

We recommend that the structures that extend below the groundwater table be designed to resist hydrostatic uplift, based on a groundwater level at Elevation +12 feet for the Secondary Clarifier No. 4 (Facility 330) and +15 feet for the Sludge Basin No. 4 (Facility 311). The Activated Sludge Basin No. 1 (Facility 305) is located in an area almost exclusively underlain by glacial till and glacial drift. This effectively is a boundary condition for the groundwater conditions in the alluvium and we conclude that this structure does not need to be designed for buoyancy or uplift; however, we recommend positive drainage below the basin. Without drainage provisions, the excavation backfill could have the potential to collect water in the lower permeability native soil "bathtub". This basin could alternatively be designed for hydrostatic uplift based on a groundwater level at about Elevation +17 feet.

Resistance to uplift can be developed by the dead weight of the structure, friction along the sides of the structure, and pile side friction where pile foundations are used. Frictional resistance can be computed using a coefficient of friction of 0.35 applied to the lateral soil pressures. This coefficient of friction is an allowable value and includes a factor of safety of approximately 1.5. We recommend that lateral soil pressures for uplift resistance be computed using an equivalent fluid density of 35 pcf above the groundwater table and 18 pcf below the groundwater table. In addition to the above means of resisting uplift, the structure may be constructed with a base that extends beyond the structure walls so that the weight of overlying soil resists a portion of the uplift. For this purpose the overlying backfill may be assumed to have a submerged unit weight of 60 pcf.

5.6.3. Drainage for Activated Sludge Basin No. 1 (Facility 305)

The Activated Sludge Basin No. 1 site is located in an area underlain by glacial till and glacial drift. The only water encountered in this area was perched within a thin veneer of fill overlying these relatively impermeable soil units. We recommend that this basin be underlain by at least 1 foot of free draining sand and gravel (such as Gravel Backfill for Walls, Washington State Department of Transportation *Standard Specification* (hereafter referred to as WSDOT *Standard Specifications*) Section 9-03.12(2)) or washed gravel. Depending on conditions encountered during construction, a perimeter footing drain may also provide suitable drainage. We recommend that the subgrade be graded toward a sump with a pump or a gravity drain. Without drainage provisions, the structure should be designed for hydrostatic uplift as described above.

5.6.4. Buried Slabs

Buried slabs, such as for the tops of utility vaults or tunnel roofs, should be designed for a uniform pressure of 130 psf per foot of fill placed above the slab. Other loading, such as traffic surcharge should also be applied to these slabs.

5.7. Pipe Design Considerations

5.7.1. General

Various piping and utility corridors will be required to connect the new facilities to the existing infrastructure. Notable utilities include new piping that will connect the Activated Sludge Basin No. 1 and Activated Sludge Basin No. 4 in the southeast portion of the site. This piping will include three 48-inch diameter pipes and one 72-inch diameter pipe, all with inverts generally ranging between about Elevation 0 feet and 5 feet. Reinforced concrete pipe (RCP) will be used for these installations.

Within the areas of identified peat removal, variable quality structural fill could be encountered. Where piping extends outside of the identified areas of peat removal, there is a possibility that peat will be encountered, particularly in the western portion of the site. The groundwater table, or zones of groundwater seepage, will likely be encountered at relatively shallow depths throughout the site. The contractor should anticipate, at a minimum, all utility excavations will require a trenchbox for sidewall support and sumps and pumps to control groundwater seepage. At some locations, where nearby infrastructure must be protected, shoring that limits lateral movement of soil and more aggressive dewatering, as described in this report, may be necessary.

The work areas should be cleared of all surface and subsurface deleterious matter, including debris, vegetation and root wads; and stripped of any organic soil, if present. The cleared/stripped material will not be suitable for use as structural fill, which includes trench backfill.

5.7.2. Pipeline Support

Because of the variable geologic conditions and site history, the soils expected to be encountered at the subgrade level will be highly variable depending on location at the site, pipe depth, previous overexcavation of peat soils, and other factors. In general, the native alluvium, glacial drift, glacial till, and most previously placed fill will provide adequate support for proposed piping throughout the site. If the subgrade soils are organic, become disturbed, or are otherwise unsuitable, it may be necessary to over-excavate the unsuitable material and backfill with pipe bedding or crushed surfacing material as discussed below. Portions of the site piping may be below the groundwater table. In these cases, we recommend that dewatering occur prior to excavation as discussed subsequently in this report.

We recommend a minimum of 12 inches of foundation material be placed for leveling and support of new piping. Depending on conditions encountered it may be helpful to place a geotextile fabric as separation between the native subgrade and foundation imported material. Based on the explorations general recommendations for pipe bedding support are presented below:

- Pipe bedding material, placement, compaction, and shaping should be in accordance with the project specifications, the pipe manufacturer's recommendations, and Section 7-09 of the most recent WSDOT *Standard Specifications.* At a minimum, the pipe bedding should meet the gradation requirements for Gravel Backfill for Pipe Zone Bedding Section 9-03.12(3) of the *Standard Specifications*, unless otherwise stated by the project specifications.

- If the trench bottom encounters any extremely soft or organic-rich subgrade soils, it may be necessary to over-excavate the unsuitable material and backfill with pipe bedding material. In wet conditions, 1½-inch minus granular fill meeting the gradation requirements for Gravel Backfill for Pipe Zone Bedding, as previously described, should be used to backfill the over-excavated portion of the trench.
- Pipe bedding material should be used as backfill up to at least the spring line of the pipe or in accordance for with the WSDOT standard plans for the type of pipe chosen.
- Prior to the installation of the pipe, the pipe bedding should be shaped to fit the lower part of the pipe exterior with reasonable closeness to provide continuous support along the pipe.
- Pipe bedding material and/or backfill around the pipe should be placed in layers and tamped around the pipe to obtain complete contact per the project plans. In areas where a trench box is used, the bedding material should be placed before the trench box is advanced.
- We understand that the large diameter RCP described above will be bedded in flowable CDF to ensure full support of the pipe. The CDF will be backfilled to about 1 foot above the crown of the pipe bell. In our opinion this will provide suitable bedding for the pipe. If very soft or organic subgrade soils are encountered, it may be necessary to first stabilize the subgrade as described above prior to placing the pipe or CDF bedding, or an initial lift of CDF can be use as a base stabilization.

5.7.3. Structural and Trench Backfill

We recommend that trench backfill consist of structural fill as described in the subsequent earthwork section of this report. The suitability of the native, on-site material as structural fill is discussed below. During placement of the initial lifts, the backfill material should not be bulldozed into the trench or dropped directly on the pipe. Furthermore, heavy vibratory equipment should not be permitted to operate directly over the pipe until a minimum of 2 feet of backfill has been placed. Backfill should be placed in lifts to achieve the required compaction using the mechanical equipment chosen by the contractor. We recommend that the MDD be determined based on ASTM D 1557 or in accordance with WSDOT *Standard Specification* 2-03.3(14)D.

- In non-settlement sensitive areas, such as landscape areas, we recommend that the backfill be compacted to at least 85 percent of its MDD.
- In settlement sensitive areas, such as existing or future roadways and driveways, backfill placed at depths greater than 2 feet below the ground surface should be compacted to at least 90 percent of the MDD. The upper 2 feet of backfill should be compacted to at least 95 percent of the MDD in existing/future pavement areas. This is consistent with Method B of WSDOT Standard Specification 2-03.3(14)C.

5.7.4. Pipe Settlement

The likely mechanisms for pipe settlement are from poor bearing support immediately below the pipe, consolidation of underlying compressible soils under new loads, or liquefaction induced settlement. For smaller diameter and shallower pipes, the increased weight of the structural backfill will be negligible and will not lead to significant settlement. Structural backfill for the large diameter RCP trenches will be heavier than the native site soils; however, the increased weight will

be partially offset by the pipe voids/difference in weight between pipe contents and soil. The net increase will be low, such that settlement from increased soil stress will be on the order of ½ to ¾ inch or less. If settlement in this range is unacceptable, the increased loading and resulting settlement could be reduced by backfilling with clean uniform sand, with MDD on the order of 100 pcf.

The design and construction procedures discussed in this report will not mitigate the possible liquefaction effects and associated damage to the utilities caused by differential settlements. Infrastructure supported by or within liquefiable zones is at higher risk, however, oftentimes buried pipes will move with the soil and not experience significant damage. The proposed CDF backfill will increase the likelihood that the pipe will move as a unit and reduce differential settlement over short distances along the pipe length. The pipeline/infrastructure areas at most significant risk are transitions from non-liquefiable soils to liquefiable areas (such as transitions from the dense glacial till near Aeration Basin No. 1 to areas of alluvium) and transitions of liquefiable areas to pipe supported structures (such as pipes connected to Secondary Clarifier No. 4 and Aeration Basin No. 4). The most significant design issue in this regard is the piping transitions.

In order to minimize the risk of potential damage from liquefaction from a large design event, it would be necessary to support the utilities on piles or improve the ground such that the soils below the corridor do not liquefy. However, in our experience, these measures are not considered feasible for this type of project because of the significant expense. The simplest and most cost-effective mitigation strategy is to include restrained joints (which allow movement but not separation) and flexible connections at these risk areas, although some of the piping for this project is likely too big for flexible connections. It may not even be practical/possible to completely mitigate the large scale differential movements from a large design event; however, some flexibility will provide resistance to smaller earthquakes.

5.8. Corrosion Potential

Corrosion potential of soil samples selected by Carrollo Engineers was conducted based on laboratory chemical testing subcontracted to ALS Group of Everett, Washington. Laboratory testing included pH, chloride, sulfate, sulfide, redox potential, and resistivity, the results of which are summarized in Table7 below, with the full laboratory results presented in Appendix B. The results of the chemical testing were compared to critical values presented in FHWA-RD-89-186 (FHWA 1990) for evaluating aggressiveness of soil environment for steel reinforcement.

TABLE 7 – RESULTS OF LABORATORY TESTING FOR CORROSION POTENTIAL

Boring No.	Sample No. (Depth)	pH	Chloride (mg/kg)	Sulfate (mg/kg)	Sulfide (mg/L)	Redox Potential (mV)	Resistivity (Ohm/cm)
GEI-2	S-5 (15')	7.2	180	340	ND	480	2500
GEI-4	S-3 (7.5')	8.3	32	410	ND	400	6500

GEI-6	S-4 (10')	7.5	23	190	ND	380	4350
GEI-9	S-4 (10')	7.7	21	190	ND	380	4350

Based on the referenced document, soils with a redox potential between 380 to 480 mV are considered slightly to non-corrosive. Soils with a resistivity between 2,500 and 6,500 ohm/cm are considered moderately to mildly corrosive. The same document presents the following recommended electrochemical limits for fill soils:

pH	greater than 4.5 and less than 9.5
chlorides	less than 100 ppm
sulfates	less than 200 ppm
resistivity	greater than 5,000 ohm/cm

Based on these limits, all the samples tested have at least some limited corrosion potential to steel reinforcement. We recommend further corrosion evaluation during final design.

5.9. Earthwork

5.9.1. General

Significant excavation will be required for the proposed improvements at the site. Temporary shoring is anticipated to reduce dewatering requirements. The site soils that will be excavated generally consist of various fill soils, loose to medium dense silty sand (alluvium), medium stiff silt and clay (glacial drift), and dense silty sand and gravel (glacial till). These are moisture-sensitive soils and are susceptible to disturbance by construction equipment during wet weather. We expect that stormwater would be contained in the excavations, especially after the sheet pile wall is installed.

Temporary erosion control measures should be used during construction depending on the water, location, soil type and other factors. Temporary erosion protection (for example, straw, plastic or rolled erosion control products [RECPs]) may be necessary to reduce sediment transport until vegetation is established or permanent surfacing applied. Appropriate best management practices (BMPs) should be incorporated into the temporary erosion and sediment control plan developed by the civil engineer. We are available to provide input if requested.

5.9.2. Site Preparation

The proposed improvements will be constructed in areas currently surfaced with field grass, small trees/shrubs, gravel, and pavement. We recommend that any existing vegetation and topsoil or other surfacing be stripped from all new building and pavement areas. For planning purposes, the results of our explorations indicate stripping depth in vegetated areas within the existing facility will be in the range of 3 to 6 inches, and outside the existing WWTP footprint, in the range of 12 to 24 inches. Roots should be grubbed to a diameter less than 1 inch. The stripped material should be wasted off-site. We recommend that the existing pavement be removed from the existing

driveway area where necessary and a uniform subgrade be prepared in all areas for support of the new pavement section.

The prevailing site soils are moisture-sensitive and will be difficult to operate on and very difficult to compact during wet weather. Rubber-tired vehicles can easily disturb this type of soil. It has moderate erosion potential in-place and is easily transported by running water when disturbed. Therefore, silt fences and other measures will be necessary to control erosion and sediment transport during construction.

We recommend that the subgrade be evaluated by a representative of GeoEngineers to confirm the subgrade is adequate for structural support. After site preparation activities have been completed in pavement areas, we recommend that the subgrade for structural areas be thoroughly proofrolled with heavily loaded rubber-tired construction equipment if site preparation is done during extended dry weather conditions. The proofrolling should be observed by one of our geotechnical engineers, who will evaluate the subgrade. In areas where adequate compaction cannot be achieved, additional overexcavation of soft, organic or deleterious materials may be required as directed by the field engineer.

5.9.3. Base Preparation

The base of Secondary Clarifier No. 4 and Activated Sludge Basin No. 4 excavations will be disturbed, wet and very soft and difficult to work on. The subgrade soils for the at-grade foundations could be somewhat variable and will most likely consist of existing fill from previous peat removal activities or native loose to medium dense alluvium. We therefore recommend that a minimum 12 inch layer of clean sand and gravel (Select Import Fill as described in this report) be placed over the subgrade, however a thicker layer, up to 24 inches, or other means of distributing equipment loads, may be required to support pile installation equipment.

For pile supported mat foundations we recommend that the sand and gravel be uniformly compacted with a smooth drum roller to at least 90 percent of the MDD in accordance with ASTM D 1557 or in accordance with the geotechnical field engineer's recommendations. For conventional shallow mat foundations and footings we recommend that the structural fill be compacted to at least 95 percent of the MDD. We also recommend placing a lightweight nonwoven geotextile fabric (e.g., Mirafi 140NS, Layfield LP4) between fine-grained subgrades soils and the imported material to help subgrade performance and minimize intrusion of the medium stiff silt/clay subgrade soils. It will likely be necessary to install a series of sumps through the sand and gravel and into the underlying material to capture and pump groundwater and rainwater that will flow into the excavation through the sheet pile joints.

5.9.4. _Temporary Excavations

All excavation activities must be completed in accordance with applicable county, state and federal safety standards. The on-site soils can generally be excavated using conventional earthmoving equipment, although some large cobbles should be expected. Excavation of the glacial till in the eastern portion of the basin will encounter very dense soil that may be very difficult to excavate and require larger equipment or "ripping" to reach the proposed subgrade elevation. Regardless of the soil type encountered in the excavation shoring, trench boxes, or sloped sidewalls will be required for excavations deeper than 4 feet under Washington State Administrative Code (WAC)

296-155, Part N. The stability of open-cut slopes is a function of soil type, groundwater level, slope inclination and nearby surface loads. The use of inadequately designed open cuts could impact the stability of adjacent structures and existing utilities and endanger personnel. We expect that much of the trench excavations will be made as open cuts in conjunction with the use of sloped sidewalls and/or a trench box for shielding workers.

The stability of open-cut slopes is a function of soil type, groundwater level, slope inclination and nearby surface loads. The use of inadequately designed open cuts could impact the stability of adjacent roadway surfaces, nearby structures and existing utilities, and endanger personnel. In our opinion, the contractor will be in the best position to observe subsurface conditions continuously throughout the construction process and to respond to variable soil and groundwater conditions. Therefore, we recommend that the contractor have the primary responsibility for deciding whether or not to use an open-cut slope rather than some form of temporary excavation support and/or dewatering strategies. Temporary excavation considerations for the various project elements are discussed below:

- We expect that excavations for the Secondary Clarifier No. 4 and Activated Sludge Basin No. 4 will **not** remain open below the groundwater table absent significant dewatering. The saturated loose to medium dense sand will run into the excavation. It is our opinion that aggressive dewatering will be required while the excavation is open. Alternatively, a cutoff wall (such as a continuous sheetpile cofferdam) extending a minimum of 10 feet into the underlying clayey glacial drift would effectively cut off the groundwater allowing conventional sumps and pumps dewatering inside the cofferdam.
- Soil and groundwater conditions within the areas of previous peat removal could be extremely variable. If significant quantities of clean granular fill were used as backfill, groundwater flow into excavations could be rapid. Groundwater seepage may also occur where layers/lenses of granular material occur within finer grained fill.

  We suggest that the contractor "pothole" the areas of excavation and alignment of the utility trenches in advance of opening the excavation to put an excavation strategy/dewatering plan together as appropriate. Dewatering considerations are provided in a subsequent section of this report.

5.9.5. Temporary Cut Slopes

The state regulations allow temporary slopes for excavations less than 20 feet deep, from 0.75H:1V (Horizontal:Vertical) to 1.5H:1V depending upon soil type. The regulations assume that surface loads such as construction equipment and storage loads will be kept a sufficient distance away from the top of the cut so that the stability of the excavation is not affected. Based on our explorations, the site soils are considered to be as follows:

- The existing fill and loose to medium dense granular alluvial soils are considered to be a "Type C" soil by the regulations, which has an allowable temporary maximum slope angle of 1.5H:1V.
- The soft clay (glacial drift) is considered to be a "Type B" soil by the regulations, which has an allowable temporary maximum slope angle of 1H:1V.
- The medium stiff to stiff glacial drift dense glacial till is considered to be a "Type C" soil by the regulations, which has an allowable temporary maximum slope angle of 0.75H:1V.

The regulations and maximum slope angles presented assume that groundwater seepage is not present in these soils. Therefore, the soils must be above the groundwater level and/or in a dewatered condition.

If temporary cut slopes experience excessive sloughing or raveling during construction, it may become necessary to modify the cut slopes to maintain safe working conditions and protect adjacent facilities or structures. Slopes experiencing excessive sloughing or raveling can be flattened, regraded to add intermediate slope benches, or additional dewatering can be provided if the poor slope performance is related to groundwater seepage. Berms, hay bales or other provisions should be installed along the top of excavations to intercept surface runoff to reduce the potential for sloughing and erosion of cut slopes during wet weather.

5.9.6. Temporary Shoring – Trench Boxes

We recommend that a shoring system be used where excavations are located adjacent to existing utilities, roadways or structures where soil movement or ground loss could result in damage to these facilities. Generally, a trench box is not considered appropriate in areas where soil movement adjacent to the trench is unacceptable. Typically, a trench box is used to protect workers from injury should the sidewall collapse. If a sidewall collapses, a contractor typically will backfill the void space in the trench box to the extent practical. Upon completion of the work the contractor will then pull the trench box out and the sidewalls cave and surface distress or disruption occurs.

A trench box can be used where sidewall support is required provided that it is (1) designed for anticipated earth pressures and hydrostatic pressures if appropriate and (2) the installation, moving and backfilling can be accomplished in such a manner that significant yielding does not occur. Braced or unbraced shoring (several types of adjustable braced trench shoring systems are available) of various types could be used where protection of existing infrastructure is necessary.

If a trench box is used and the soils are dewatered below the base of the excavation (prior to excavation), yielding/movement of the sidewalls is unlikely to occur beyond a 1.5H:1V slope as measured from the bottom of the excavation. If the soils are not dewatered to at least 1 foot below the bottom of the trench prior to and during excavation, the area of disturbance could be significantly greater. The following should be implemented for the shoring systems for the project:

- At locations where settlement could be detrimental to adjacent structures, utilities, or pavements, the shoring system should be designed to prevent significant lateral movement of the existing soils.
- Precautions should be taken during removal of the shoring or sheeting materials to minimize disturbance of the pipe, underlying bedding materials, and natural soils.
- Trench boxes should be of sufficient size, both vertically and horizontally, to support the excavation without excessive deformation of the natural soils.
- The open excavations should be backfilled as soon as practical after the shoring has been removed.

- Heavy construction equipment, construction materials, and excavated soil should not be allowed within a distance, measured from the edge of the excavation, equal to half the depth of the excavation, unless the shoring system has been designed for the additional lateral pressure.

Because of the diversity of available shoring systems and construction techniques, the design of temporary shoring is most appropriately left up to the contractor proposing to complete the installation. We recommend that the shoring be designed by an engineer licensed in Washington, and the PE stamped shoring plans and calculations be submitted to the engineer prior to construction.

5.9.7. Temporary Shoring – Sheet Pile Walls

5.9.7.1. GENERAL

We anticipate that construction of the Secondary Clarifier No. 4 (Facility 330) and Activated Sludge Basin No. 4 (Facility 311) will be completed using a shored excavation due to the depth of the excavation and the presence of groundwater. A sloped excavation may be feasible at some locations provided that aggressive dewatering is completed concurrently and space constraints will not prohibit relatively flat temporary slopes. A sheet pile system extending into the underlying clayey glacial drift at the site will retain the soils and serve as a groundwater cutoff to minimize the quantity of water that will need to be pumped and discharged. For deeper excavations, where the wall is greater than about 10 feet high, it may be necessary to use a row of tieback anchors or deadmen to resist the additional pressure due to hydrostatic pressures. We recommend that the shoring be designed by an engineer licensed in Washington, and the PE stamped shoring plans and calculations be submitted to the Engineer prior to construction. The following paragraphs present suggested design parameters based on conditions encountered at the site; however, as stated before, the contractor will be responsible for shoring design.

5.9.7.2. SHEET PILE DESIGN PARAMETERS

The soil conditions encountered within our explorations generally consist of existing fill and alluvium with some remaining peat overlying generally clayey glacial drift. Groundwater is assumed to be approximately Elevation 12 feet near the Secondary Clarifier No. 4, and approximately Elevation 15 feet near the Sludge Basin No. 4. Our preliminary analysis indicate that that the loose/soft soil profile may not be capable of supporting tall cantilever sheet pile walls and that tie-back anchors or deadmen may be required for excavations greater than about 10 feet.

Earth pressure diagrams for sheet pile shoring are provided in Figure 14 for the Secondary Clarifier No. 4 for areas inside the previous peat removal area (Case 1) and for areas outside the previous peat removal area (Case 2). Earth pressure diagrams for sheet pile shoring are provided in Figure 15 for the Activated Sludge Basin No. 4 (Case 3).

5.9.8. Structural Fill

Structural fill materials should be free of debris, organic contaminants and rocks or rock fragments larger than 6 inches or half the lift thickness, whichever is smaller. All fill placed within the building and pavement areas should be placed as structural fill. Structural fill should be placed in horizontal lifts not exceeding 10 inches in loose thickness or that necessary to obtain the specified

compaction with the equipment used. Each lift must be thoroughly and uniformly compacted as previously recommended.

As the amount of fines (material passing the U.S. No. 200 sieve) increases in a soil it becomes more sensitive to small changes in moisture content. During wet conditions, adequate compaction becomes more difficult to achieve. Generally, soils containing more than about 5 percent fines by weight cannot be properly compacted when the moisture content is more than a few percent from optimum.

Sufficient earthwork monitoring and a sufficient number of in-place density tests should be performed to evaluate fill placement and compaction operations and to confirm that the required compaction is being achieved.

5.9.8.1. Suitability of On-Site Materials

The on-site materials within much of the proposed excavation depth for below grade structures consist fill of variable composition including sand, silt and clay, with limited quantities of cleaner sand (SP-SM and SP). Material excavated from below the water table will not be suitable for use as backfill unless the sand is allowed to drain. The fine-grained soils encountered during our explorations typically had a moisture content well above the optimum moisture content. Since these soils are highly moisture sensitive and have a high natural water content, it will be very difficult to compact these soils to dry densities greater than 90 percent of the MDD as specified. Therefore, we recommend that the silt and clay be considered not suitable for use as structural fill.

Silty sand fill and native soils (including glacial till), encountered during our explorations had moisture contents ranging from slightly above, to well above optimum moisture content. This material is also highly moisture sensitive. In our opinion the silty sand encountered may be used at the time of construction if approved by the geotechnical engineer based on the field moisture content and intended use. If significant quantities of native or previously imported sand with silt (SP-SM) or sand (SP) are encountered, this material will likely be suitable for general backfill. This material will likely need to be moisture conditioned to achieve suitable compaction. It may be necessary for the contractor to segregate materials in order to use on-site soils for backfill. For planning purposes in structural support areas, we recommend a select import fill where structural fill is required.

5.9.8.2. SELECT IMPORT FILL

If wet weather or the moisture content precludes the use of onsite materials structural fill, we recommend using a select import fill to complete the backfilling site excavations. The select import fill should consist of sand and gravel with a fines content less than 5 percent based on that portion passing the ¾-inch sieve. Suitable *Standard Specifications* include Gravel Borrow (9-03.14).

5.9.9. Wet Weather Earthwork and Erosion Control

General recommendations relative to earthwork performed in wet weather or in wet conditions are presented below. These recommendations should be incorporated into the contract specifications.

- Earthwork should be performed to limit exposure to wet weather. Excavation or the removal of unsuitable soil should be followed promptly by the placement and compaction of clean fill. The size and type of construction equipment used may need to be limited to prevent soil disturbance.

- The ground surface within the construction area should be sealed by a smooth drum vibratory roller, or equivalent, and under no circumstances should soil be left uncompacted and exposed to moisture that can erode off the jobsite.
- Excavation and placement of structural fill and trench backfill material should be performed under sufficient observation and testing to confirm that the work is completed in accordance with the project specifications and the recommendations contained herein.
- Soil stockpiles should be covered with plastic sheeting if wet weather conditions are anticipated.
- Silt fences should be installed between the work area and sensitive areas to prevent transport of sediment beyond the work area.

5.10. Construction Dewatering

5.10.1. General

The excavations for the Secondary Clarifier No. 4, Activated Sludge Basin No. 4, and some excavations for utility piping will likely be below groundwater during most times of the year. Zones of seepage will likely be encountered in other shallower excavations and for excavation of the Activated Sludge Basin No. 1. As discussed previously, we recommend sheetpile shoring/cutoff walls be considered for Clarifier No. 4 and Sludge Basin No. 4 excavations to limit dewatering requirements. Where temporary construction slopes with open cuts will be used, we expect that a combination of open pumping, pumped wells, and/or well points will be required to adequately dewater site soils. Deep wells will not provide efficient dewatering based on the typical conditions of limited thicknesses of more granular soils overlying clay. It is likely that sumps and pumps with limited shoring will be sufficient to dewater if the water level needs to be lowered only a few feet. Extensive dewatering of compressible soils can increase effective stresses in the soil and induce settlement.

The Contractor should have the responsibility to determine the dewatering measures needed for the project. The monitoring wells installed are still in place and we expect will be available for additional monitoring during the design for the project and by the contractor prior to construction. A general discussion of the dewatering methods anticipated for the project is discussed below.

5.10.2. Open Pumping

This dewatering method involves removing water that has seeped into the excavation by pumping from a sump that has been excavated at one end of the excavation or trench. Drainage ditches that are connected to the sump are typically excavated along the sidewalls at the base of the excavation or trench. The excavation for the sump and the drainage ditches should be backfilled with gravel or crushed rock to reduce the amount of erosion and associated sediment in the water pumped from the sump. In our experience, a slotted casing, perforated 5-gallon bucket or 55-gallon drum that is installed in the sump backfill provides a suitable housing for a submersible pump.

The amount of water removed from the excavation by open pumping should be minimized because of high turbidity levels. Temporary storage of dewatering effluent from the sumps in a settlement tank or basin may be required to meet NPDES construction storm water discharge permit requirements and reduce sediment content prior to discharging the water to surface water courses.

5.10.3. Pumped Wells

Pumped wells that have been properly installed and developed in highly permeable sand deposits are capable of producing the high discharge rates that are necessary to dewater these coarse grained units. Pumped wells are generally the most effective dewatering method in areas where dewatering to deeper than about 15 feet below the ground surface is necessary. In our opinion, pumped wells will have limited effectiveness in most areas of the site due to the relatively high fines content of the most of the site soils and underlying unit clayey glacial drift.

We recommend that all dewatering wells installed for this project be properly developed to remove fine sediment from the immediate vicinity of the well screens. Proper development is essential for producing efficient wells and greatly reduces the turbidity of the water discharged from the well. Filter packs consisting of properly graded sand, should be installed around the well screens in areas where the aquifer contains a high percentage of fine sand and silt.

5.10.4. Wellpoints

Wellpoints are effective for dewatering all types of soils, whether pumping small amounts of water from silt or large quantities of water from coarse sand and gravel. The volume of water generated by a wellpoint system is typically less than the volume generated by a corresponding system of pumped wells because the wellpoints are generally completed at a shallower depth. Because of the shallower completion depth, the volume of aquifer that contributes water to a wellpoint system is less than for a comparable deep well system. In our opinion, well points will be a more effective dewatering system than pumped wells, given the site conditions.

Wellpoint systems are most suitable for dewatering shallow excavations where the water table must be lowered no more than about 15 feet below ground surface or the header surface. Multiple wellpoint stages are generally required beyond that depth because of the physical limitations of suction lift. Dewatering can be accomplished at depths greater than 15 feet where the excavation can be open cut to permit installation of the wellpoint header system below original grade. This technique increases the depth to which the water table can be lowered with wellpoints.

The wellpoints would likely need to be installed on less than 10-foot centers (typically 4 to 8 feet) to be effective and as close as possible to the edge of the excavation. The wellpoint screens should be filter packed with graded sand, or sand and fine gravel to improve pumping efficiency and minimize the discharge of turbid water. Wellpoints must be sealed to a depth of at least 8 feet with hydrated bentonite chips forming a surface seal to encourage the development of a partial vacuum around each wellpoint.

5.10.5. Dewatering Qualifications and Experience

We strongly recommend that dewatering, where used, be performed by a contractor or subcontractor with dewatering experience. If necessary to use well points, we recommend an experienced dewatering specialist contractor with competent and experienced staff who can demonstrate successful deployment and operation of vacuum wellpoint systems in the Pacific Northwest over the past 10 years, and who can install systems that use high capacity electronically controlled and monitored vacuum pumps. If active dewatering using wells or wellpoints will be used, we recommend a Dewatering Plan be required as a submittal from the contractor at least

two weeks prior to dewatering, that fully describes the dewatering approach, including material and equipment specifications, calculations and supporting assumptions to ensure that dewatering is achieved to not less than 1 foot below excavation subgrade. The Dewatering Plan should include an appropriate survey program identifying critical infrastructure that will be monitored, schedule of survey times, and appropriate action plans if subsidence is observed. The Dewatering Plan should be prepared by or under the direct supervision of a Professional Engineer and/or Licensed hydrogeologist registered in the State of Washington and having at least 5 years of demonstrated experience in the design and operation of vacuum wellpoint dewatering systems.

5.10.6. Dewatering Limitations

Our services were provided to assist in the assessment of construction dewatering requirements for the planned wastewater treatment plant expansion project. Our dewatering recommendations are based on evaluation of the available geotechnical information. Groundwater can create a safety threat and can seriously compromise arrangements for shoring excavations. Also, given the potential for natural variation in geologic formations, differing site conditions may be encountered that could lead to substantially different groundwater inflows and dewatering challenges than are presented in this evaluation. We did not perform pumping tests or other detailed hydrogeologic evaluations and this information is presented for use by the contractor but is not intended to dictate designs.

5.11. Pavement

New pavement will be constructed primarily as driveways and access roads for the proposed facilities. The access roads will typically support lightweight traffic; however, larger equipment or trucks will also use the driveways occasionally. Accordingly, we recommend a minimum pavement section consisting of the following layers in new pavement areas:

- 3 to 4 inches of AC surface course. It is our opinion that 4 inches of AC will better support the construction traffic. The surface course may consist of either of the following mix designs:
  - Hot Mix Asphalt (HMA), Class ½ inch, PR 64-22 per the most recent *WSDOT Standard Specifications* (5-04 and 9-03.8) for the ESAL interval from 0.3 to 3 million;
  - Class B Asphalt Concrete per the 2002 *WSDOT Standard Specifications* (5-04 and 9-03.8).
- 4 inches of crushed surfacing base course per *WSDOT Standard Specifications* 9-03.9(3).
- 12 inch thick subbase course consisting of gravel base (*WSDOT Standard Specifications*, 9-03.10). We recommend the base course have at least 30 percent retained on the U.S. No. 4 sieve.
- A woven geotextile placed directly over the prepared subgrade with a minimum grab tensile strength (ASTM 4632) of 200 pounds (such as Mirafi 500X or equivalent).

It is imperative that the subgrade surface be prepared in accordance with the "Subgrade Preparation" recommendations provided in this report to provide the desired pavement performance.

6.0 CONSTRUCTION OBSERVATION SERVICES

The project has variable subsurface conditions and some complex geotechnical issues. We recommend that GeoEngineers provide consultation and monitoring during construction. It is our experience that providing geotechnical support to the design team during bidding, preconstruction meetings and during construction facilitates the contractor, progress and schedule, and helps protect the owner from change orders. On this project, we recommend geotechnical involvement in at least the following aspects of the project:

- Review of pile foundation plan and observation of pile installation
- Review of shoring submittal and observation during construction
- Review of dewatering plan and consultation during construction
- Evaluation of subgrade conditions for shallow foundation
- Evaluation of subgrade conditions for pipeline, pavement, and other infrastructure
- Approval of backfill materials and sources
- Monitor and test backfill in the trenches, as appropriate
- General consultation to the owner, design team and contractor, as requested.

7.0 LIMITATIONS

We have prepared this report for use by the City of Bellingham, Carollo Engineers, and their authorized agents for the proposed Post Point WWTP Expansion Project located in Bellingham, Washington.

Within the limitations of scope, schedule and budget, our services have been executed in accordance with generally accepted practices in the field of geotechnical engineering in this area at the time this report was prepared. No warranty or other conditions, express or implied, should be understood.

Any electronic form, facsimile or hard copy of the original document (email, text, table, and/or figure), if provided, and any attachments are only a copy of the original document. The original document is stored by GeoEngineers, Inc. and will serve as the official document of record. Please refer to the appendix titled Report Limitations and Guidelines for Use for additional information pertaining to use of this report.

8.0 REFERENCES

American Concrete Institute (ACI). 1993. Suggested Analysis and Design Procedures for Combined Footings and Mats. ACI 336.2R-88 (Reapproved 1993), American Concrete Institute.

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Notes:
1. The locations of all features shown are approximate.
2. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. can not guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.
3. It is unlawful to copy or reproduce all or any part thereof, whether for personal use or resale, without permission.

Data Sources: ESRI Data & Maps, Street Maps 2005

Transverse Mercator, Zone 10 N North, North American Datum 1983
North arrow oriented to grid north

Vicinity Map

Post Point WWTP Improvements
Bellingham, Washington

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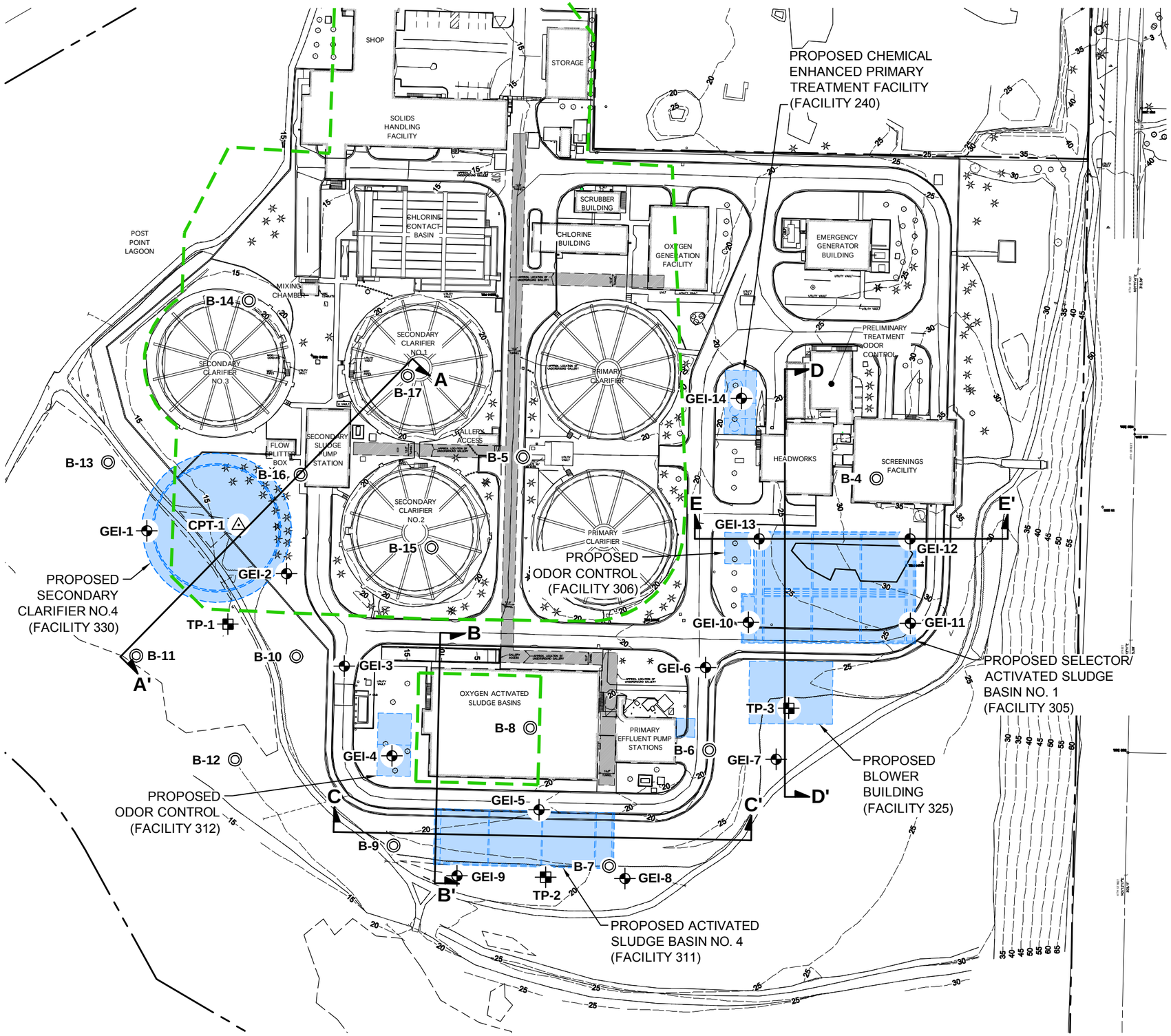
Figure 1

Office: BELL Path: P:\0\00356-106\00\GIS\35610600 VM F1.mxd SWC:IMS 07/1/2010



Legend

- GEI-1 — Approximate Boring Location (GeoEngineers 2010)
- TP-1 — Approximate Test Pit Location (GeoEngineers 2010)
- CPT-1 — Approximate Cone Penetration Test Location (GeoEngineers 2010)
- B-1 — Approximate Previous Boring Location (CH2M Hill 1989)
- Proposed Building Location
- Approximate Boundary of Documented Areas of Historic Peat Removal
- A — A' Cross-Section Location

N W E S

100 0 100
FEET

Notes

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2. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. can not guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Reference: Base topographic survey CAD file "08079S01.dwg" by Wilson Engineering, LLC dated May 2009.

Site and Exploration Plan

Post Point WWTP Improvements
Bellingham, Washington

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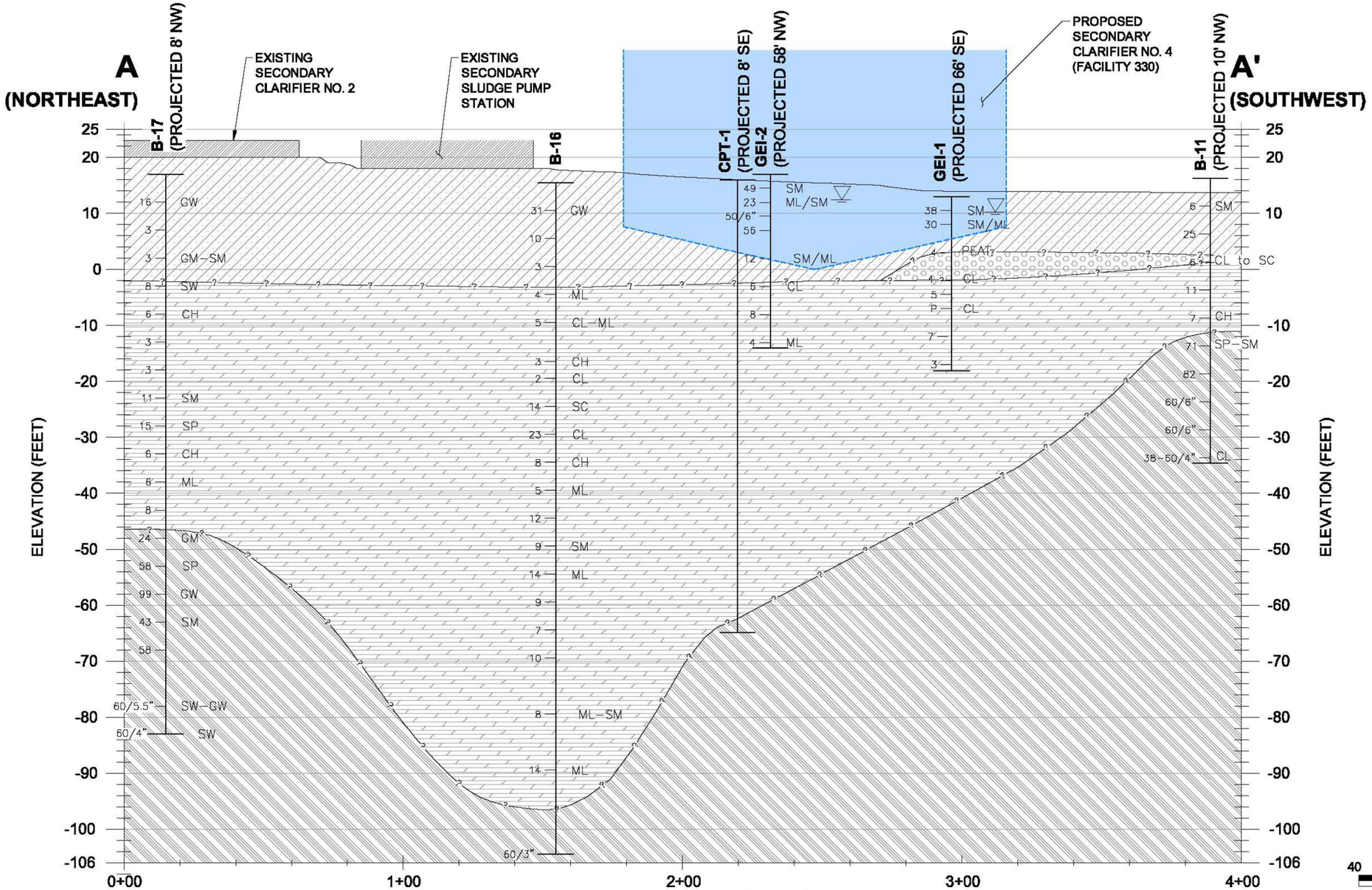
Figure 2

W:\BELLINGHAM\PROJECTS\0\0356106\00\CAD\0356106 00 FIG 2.DWG\TAB:LANDSCAPE MODIFIED BY TMICHAUD ON OCT 04, 2010 - 15:45



HORIZONTAL SCALE: 1"= 40'
VERTICAL SCALE: 1"= 20'
VERTICAL EXAGGERATION: 2X

40 0 40
FEET

Legend

FILL: Variable soil types including sand with gravel, sandy silt and silty/clayey sand (medium dense to dense/ stiff to very stiff)

PEAT: Fibrous peat and organic silt (soft to medium stiff)

GLACIAL DRIFT: Silty and sandy clay with some clayey silt and sand lenses (soft to stiff)

GLACIAL TILL: Silty sand with gravel and some sandy silt and clay (dense to very dense/very stiff to hard)

B-1 — Boring

? — Inferred Soil Contact

Groundwater Level Observed in Piezometer

ML — Soil Classification

25 — Blow Count

Notes

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Cross-Section A-A'

Post Point WWTP Improvements
Bellingham, Washington

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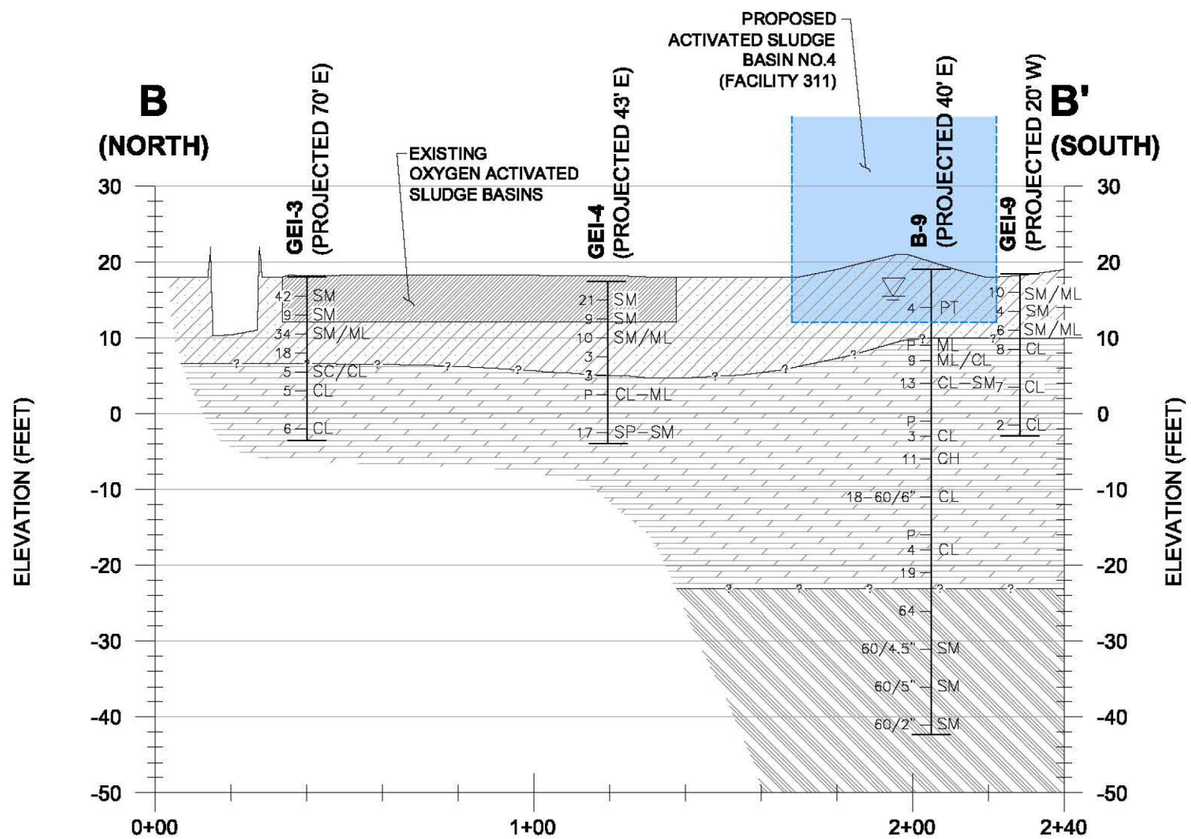
Figure 3

W:\BELLINGHAM\PROJECTS\0\03561\06\00\CAD\035610600 X-SECTIONS.DWG\TAB:AA MODIFIED BY THICHAUD ON OCT 05, 2010 - 9:40



HORIZONTAL SCALE: 1"= 40'
VERTICAL SCALE: 1"= 20'
VERTICAL EXAGGERATION: 2X

40 0 40
FEET

Legend

FILL: Variable soil types including sand with gravel, sandy silt and silty/clayey sand (medium dense to dense/ stiff to very stiff)

PEAT: Fibrous peat and organic silt (soft to medium stiff)

GLACIAL DRIFT: Silty and sandy clay with some clayey silt and sand lenses (soft to stiff)

GLACIAL TILL: Silty sand with gravel and some sandy silt and clay (dense to very dense/very stiff to hard)

B-1 Boring

? Inferred Soil Contact

Groundwater Level Observed in Piezometer

ML Soil Classification

25 Blow Count

Notes

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2. Peat unit at B-6 not Shown.

Cross-Section B-B'

Post Point WWTP Improvements
Bellingham, Washington

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Figure 4

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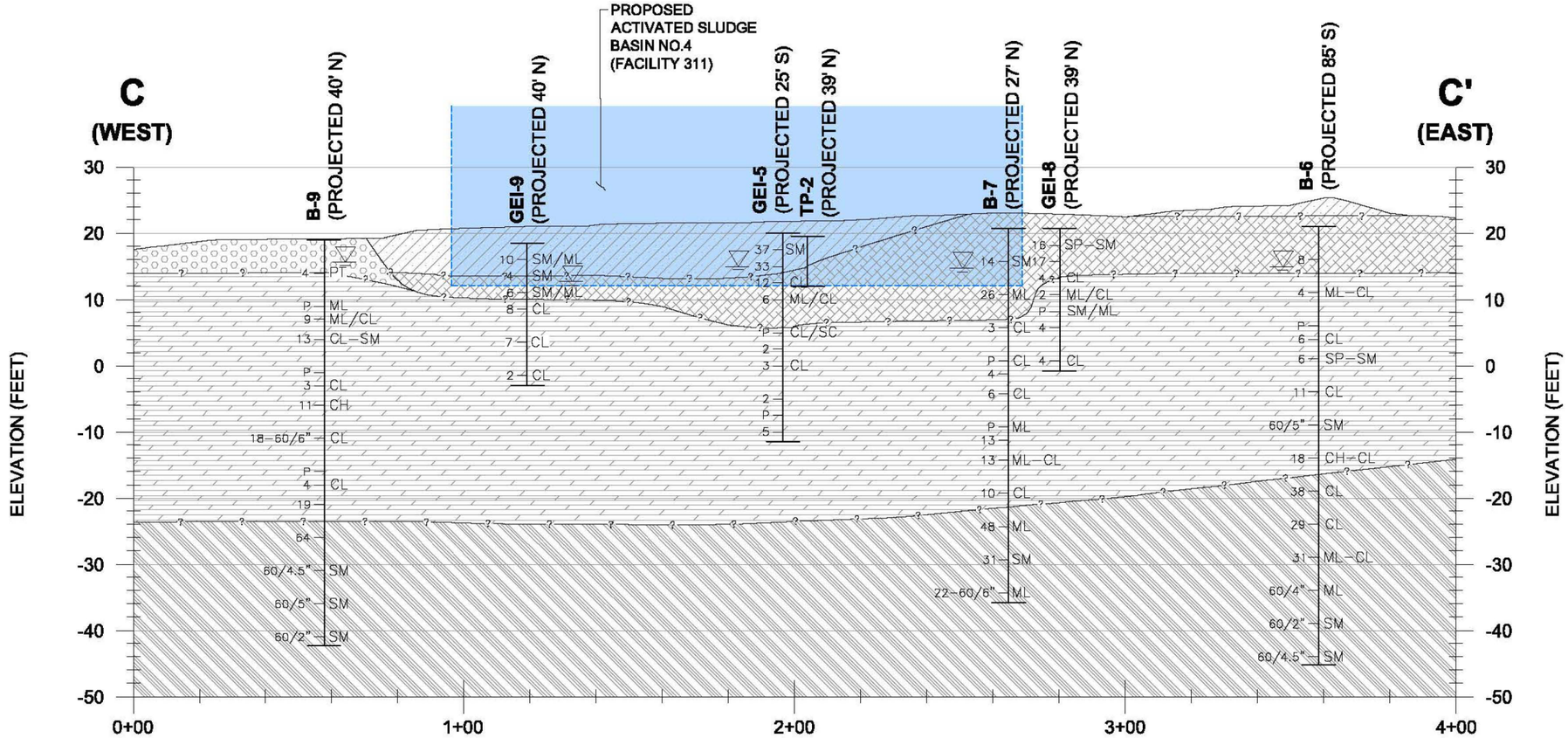

Legend

- FILL: Variable soil types including sand with gravel, sandy silt and silty/clayey sand (medium dense to dense/ stiff to very stiff)
- PEAT: Fibrous peat and organic silt (soft to medium stiff)
- ALLUVIUM: Sand with silt, silty sand and sandy silt with some clay (loose to medium dense/soft to medium stiff)
- GLACIAL DRIFT: Silty and sandy clay with some clayey silt and sand lenses (soft to stiff)
- GLACIAL TILL: Silty sand with gravel and some sandy silt and clay (dense to very dense/very stiff to hard)

B-1 — Boring

? — Inferred Soil Contact

Groundwater Level Observed in Piezometer

ML — Soil Classification

25 — Blow Count

HORIZONTAL SCALE: 1"= 40'
VERTICAL SCALE: 1"= 20'
VERTICAL EXAGGERATION: 2X

40 0 40
FEET

Notes

1. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. can not guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.
2. Fill at GEI-5 extends to elevation +6 feet.

Cross-Section C-C'

Post Point WWTP Improvements
Bellingham, Washington

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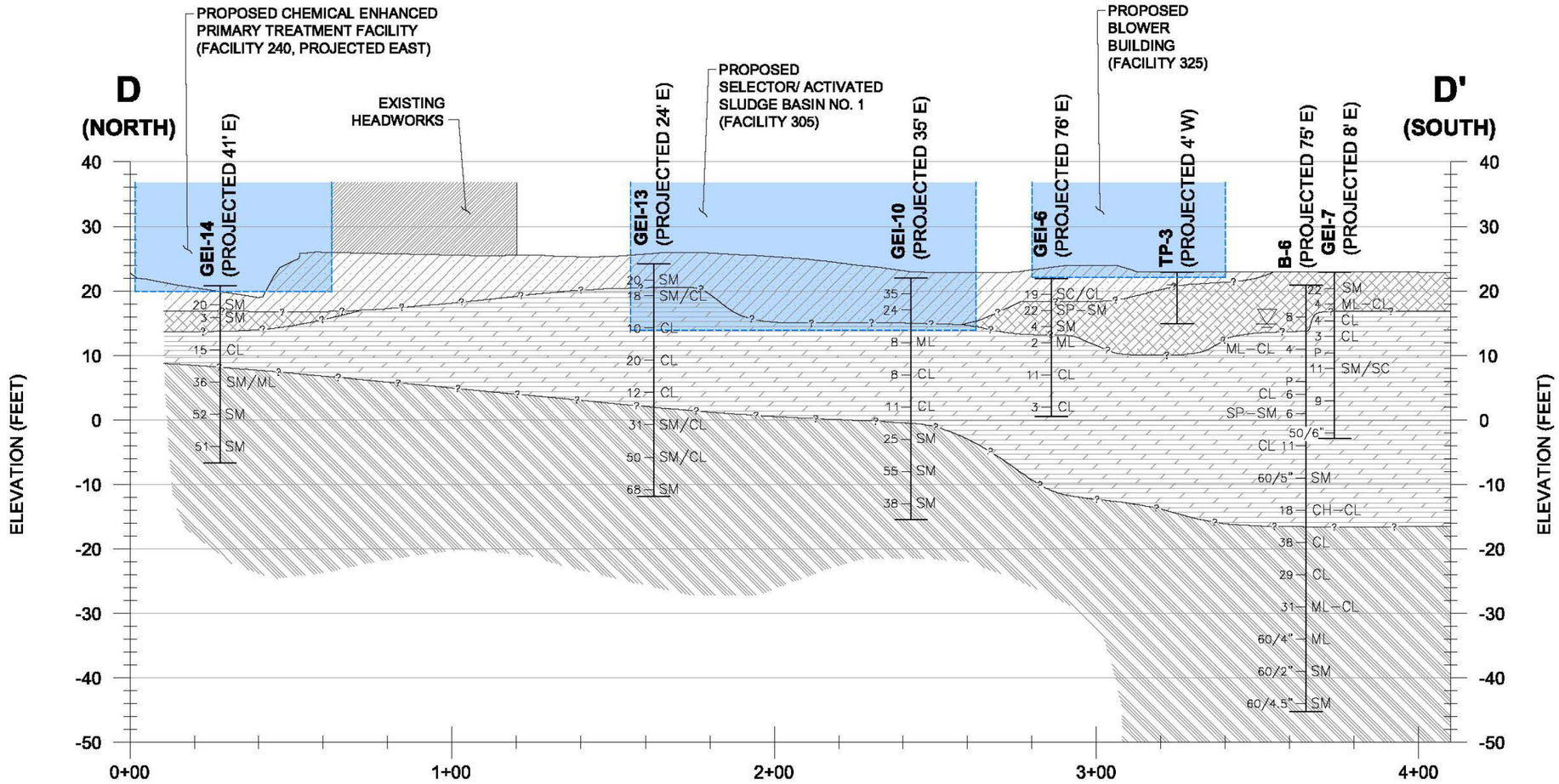
Figure 5

W:\BELLINGHAM\PROJECTS\01\0356\06\00\CAD\0356\0600 X-SECTIONS.DWG\TAB:CC MODIFIED BY TMICHAUD ON OCT 05, 2010 - 9:42



Legend

FILL: Variable soil types including sand with gravel, sandy silt and silty/clayey sand (medium dense to dense/ stiff to very stiff)

ALLUVIUM: Sand with silt, silty sand and sandy silt with some clay (loose to medium dense/soft to medium stiff)

GLACIAL DRIFT: Silty and sandy clay with some clayey silt and sand lenses (soft to stiff)

GLACIAL TILL: Silty sand with gravel and some sandy silt and clay (dense to very dense/very stiff to hard)

B-1 — Boring

? — Inferred Soil Contact

Groundwater Level Observed in Piezometer

ML — Soil Classification

25 — Blow Count

HORIZONTAL SCALE: 1"= 40'
VERTICAL SCALE: 1"= 20'
VERTICAL EXAGGERATION: 2X

40 0 40
FEET

Notes

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Cross-Section D-D'

Post Point WWTP Improvements
Bellingham, Washington

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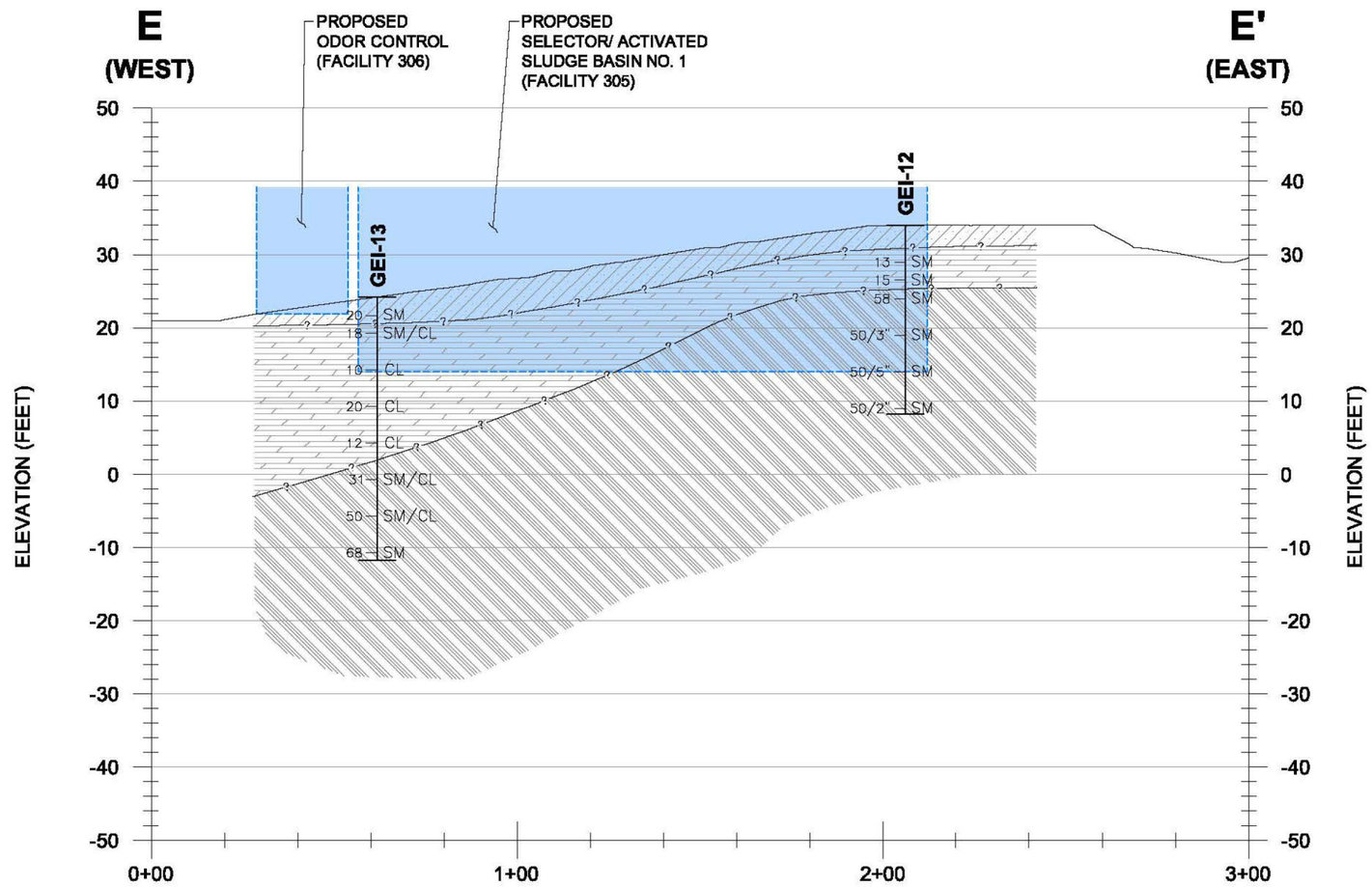
Figure 6



HORIZONTAL SCALE: 1"= 40'
VERTICAL SCALE: 1"= 20'
VERTICAL EXAGGERATION: 2X

40 0 40
FEET

Legend

FILL: Variable soil types including sand with gravel, sandy silt and silty/clayey sand (medium dense to dense/ stiff to very stiff)

GLACIAL DRIFT: Silty and sandy clay with some clayey silt and silty sand (medium dense/ stiff to very stiff)

GLACIAL TILL: Silty sand with gravel and some sandy silt and clay (dense to very dense/very stiff to hard)

B-1 Boring

? Inferred Soil Contact

Groundwater Level Observed in Piezometer

ML Soil Classification

25 Blow Count

Notes

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Cross-Section E-E'

Post Point WWTP Improvements
Bellingham, Washington

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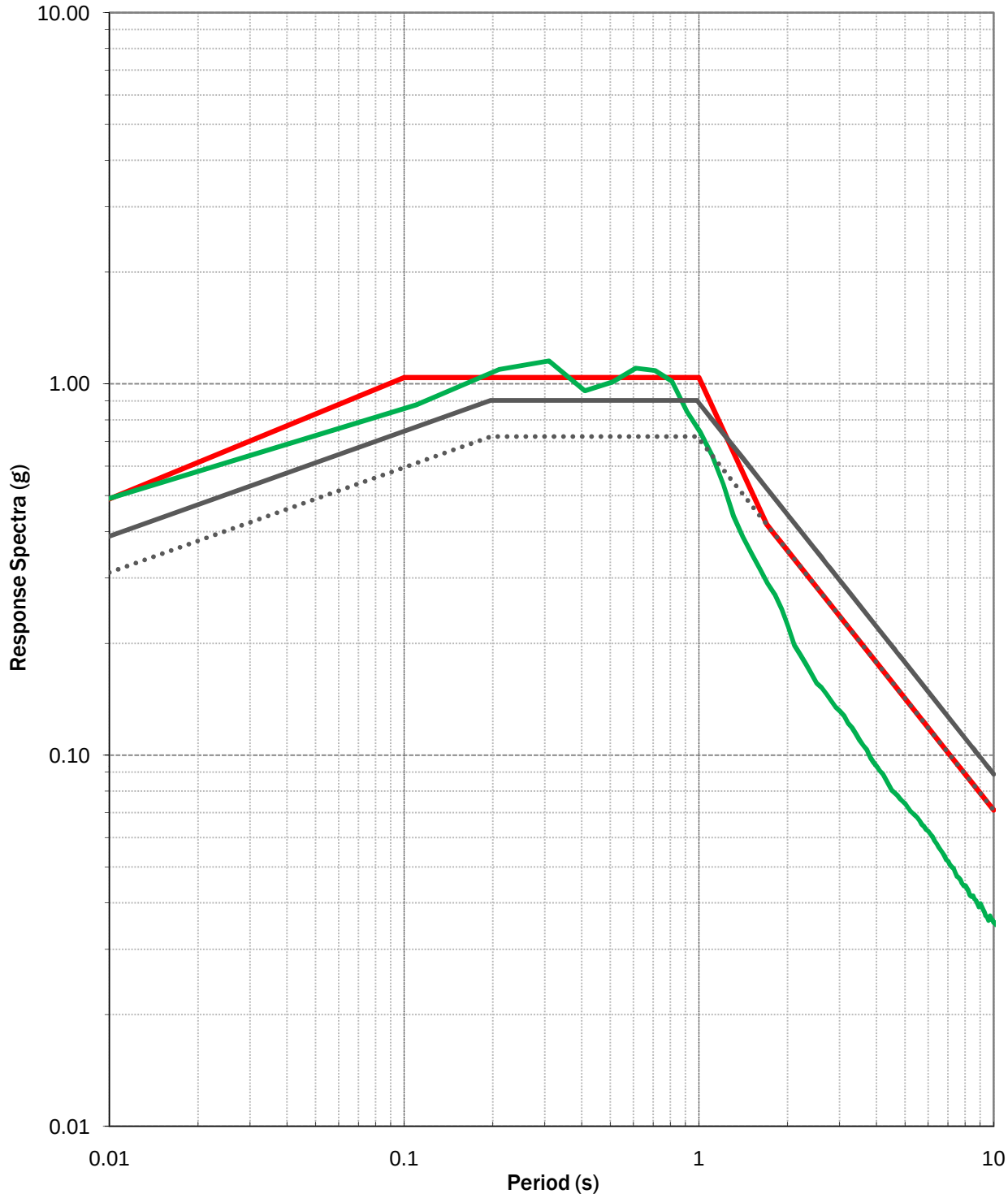
Figure 7



MCE Response Spectrum for 2475 year Event

Average Best Estimate AF X Rock Outcrop (ASCE 7 Approach)

Site Class E General Response Spectrum (ASCE 7 Approach)

0.8 x Site Class E General Response Spectrum (ASCE 7 Approach)

5% Damped Site Specific MCE Response Spectra, 2475 YR EQ Event

Post Point WWTP Improvements
Bellingham, Washington

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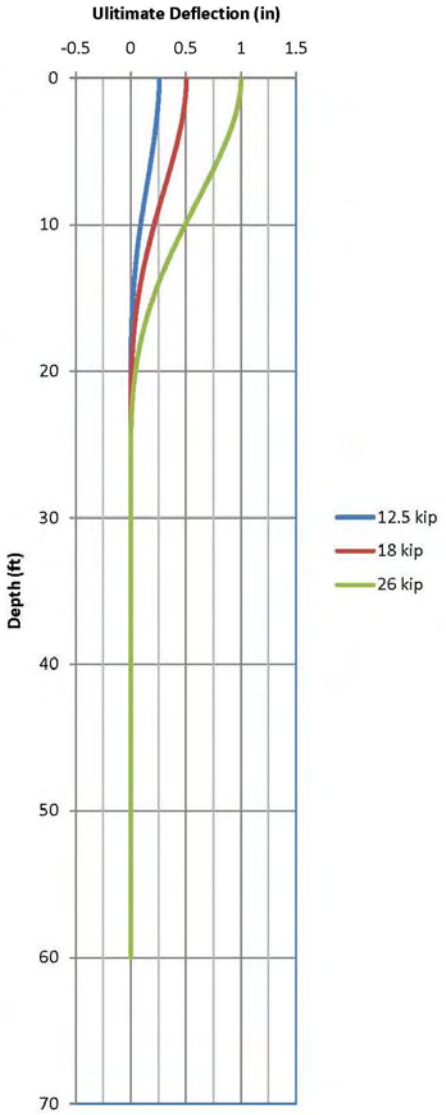
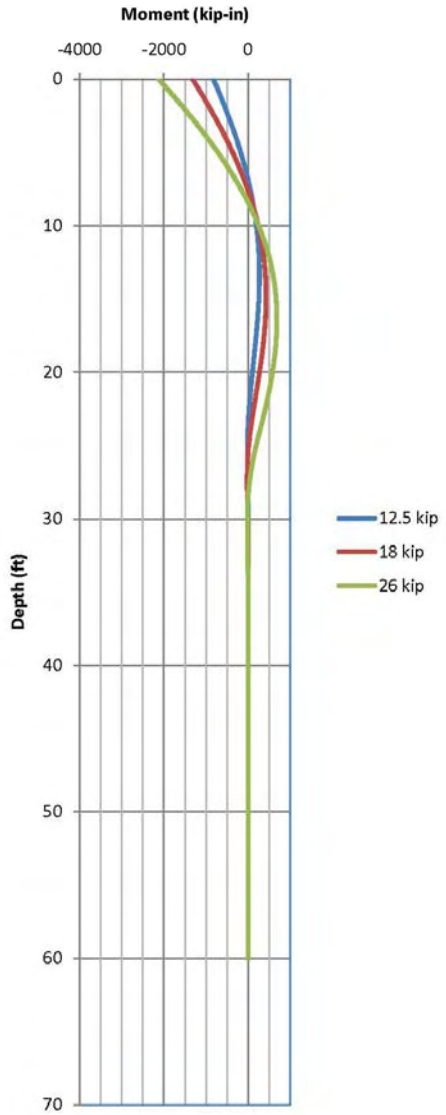
Figure 8

SharePoint: 03561060\Technical Analysis\Seismic Site Response Analysis\Bham_WWTP- Design Response Spectra.xlsx NCS:khc

Secondary Clarifier No. 4 (Facility 330)
18-Inch Augercast Pile





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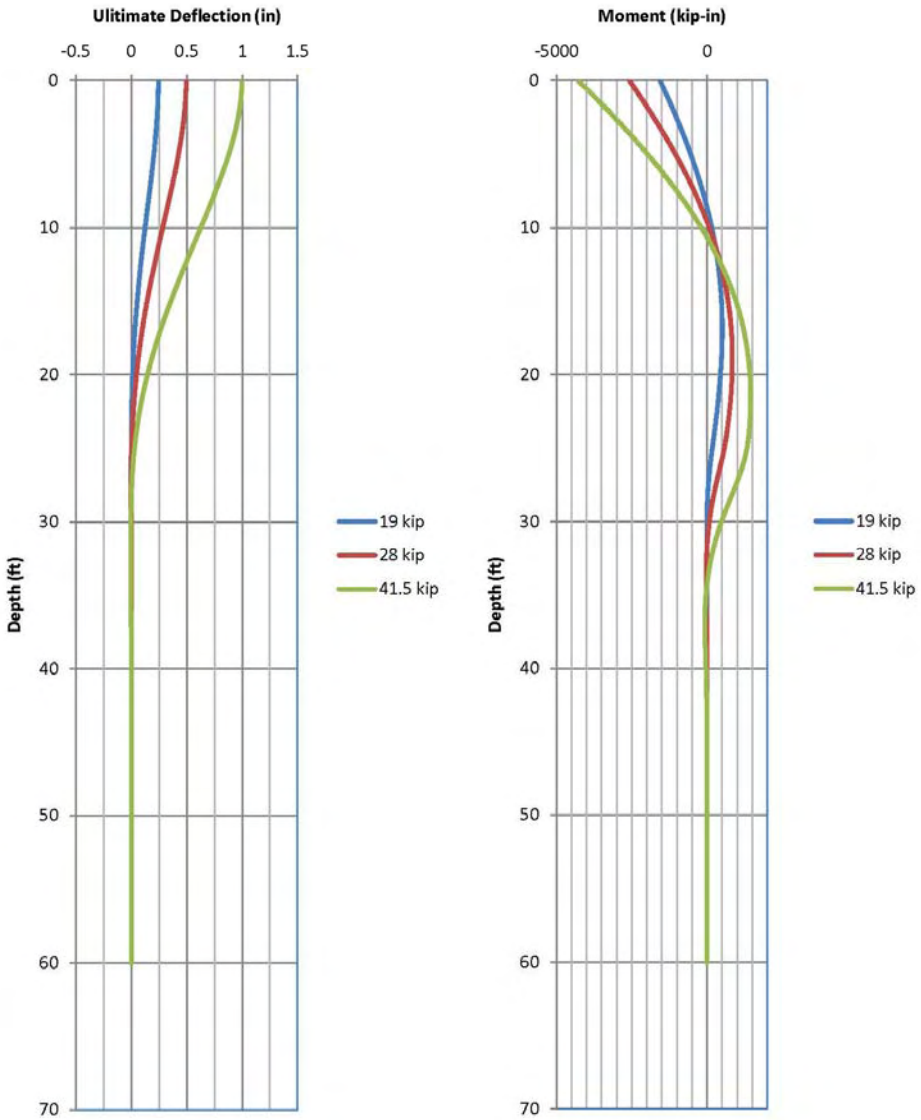
Post Point WWTP Improvements

LPILE Analysis Results - FIGURE 9

Secondary Clarifier No. 4 (Facility 330)
24-Inch Augercast Pile



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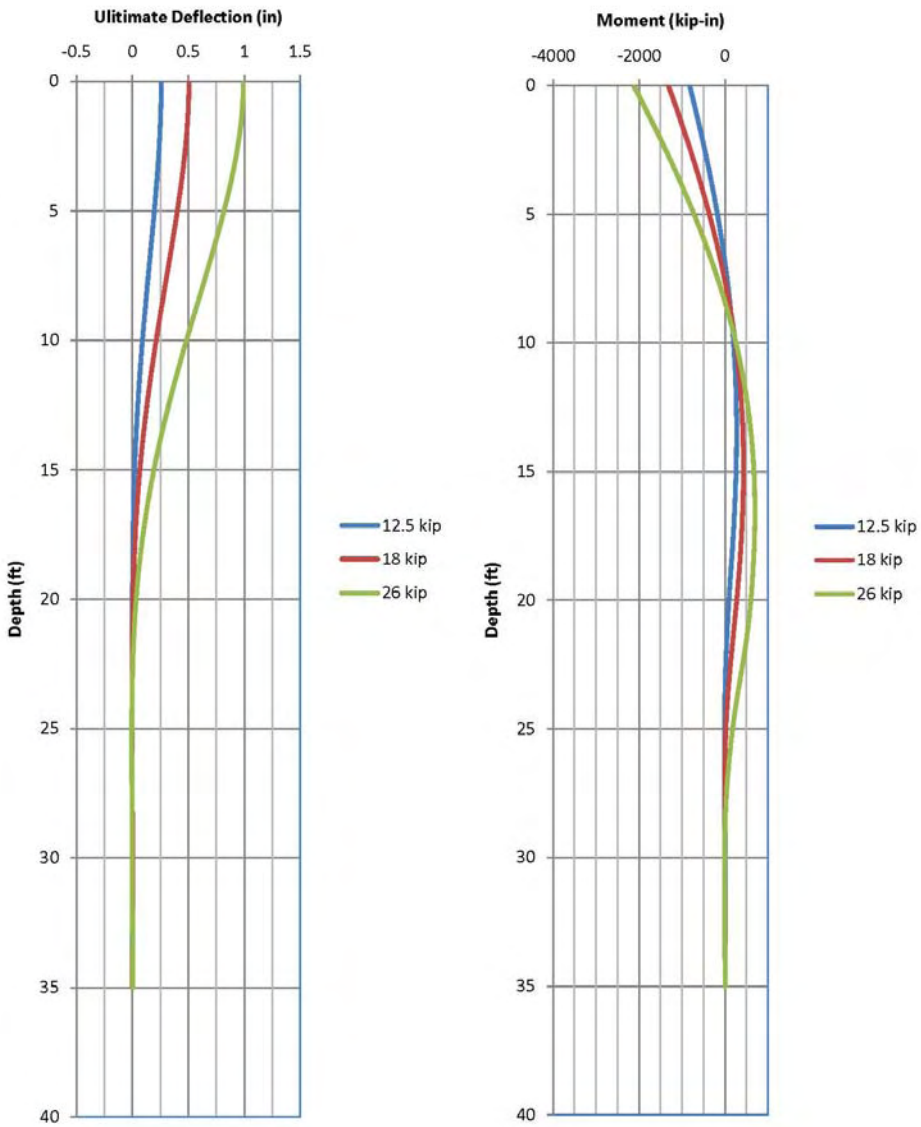
Post Point WWTP Improvements

LPILE Analysis Results - FIGURE 10

Activated Sludge Basin No. 4 (Facility 311)
18-Inch Augercast Pile



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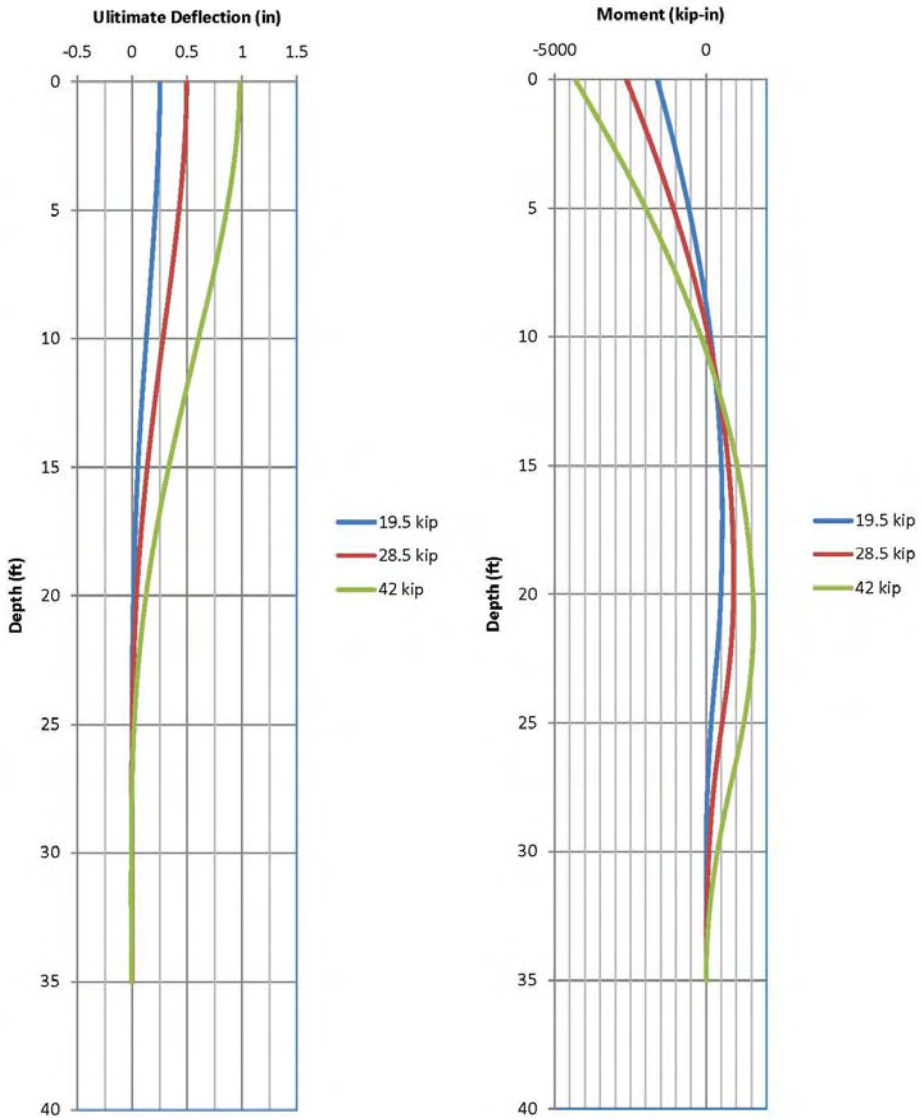
Post Point WWTP Improvements

LPILE Analysis Results - FIGURE 11

Activated Sludge Basin No. 4 (Facility 311)
24-Inch Augercast Pile



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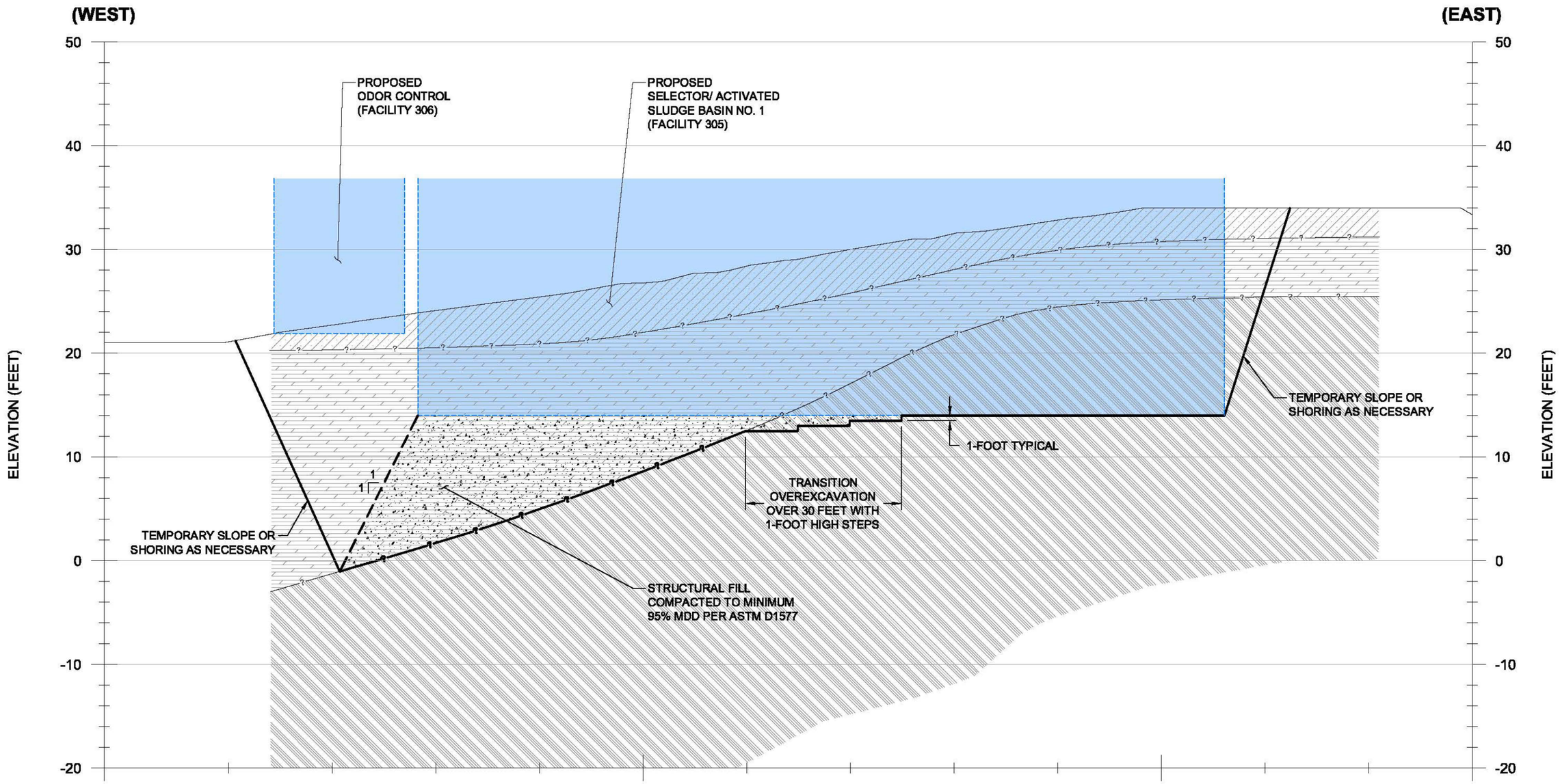
Post Point WWTP Improvements

LPILE Analysis Results - FIGURE 12



Legend

FILL: Variable soil types including sand with gravel, sandy silt and silty/clayey sand (medium dense to dense/ stiff to very stiff)

GLACIAL DRIFT: Silty and sandy clay with some clayey silt and silty sand (medium dense/ stiff to very stiff)

GLACIAL TILL: Silty sand with gravel and some sandy silt and clay (dense to very dense/very stiff to hard)

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HORIZONTAL SCALE: 1"= 20'
VERTICAL SCALE: 1"= 10'
VERTICAL EXAGGERATION: 2X

20 0 20
FEET

Schematic of Overexcavation at Selector / Activated Sludge Basin No. 1

Post Point WWTP Improvements
Bellingham, Washington

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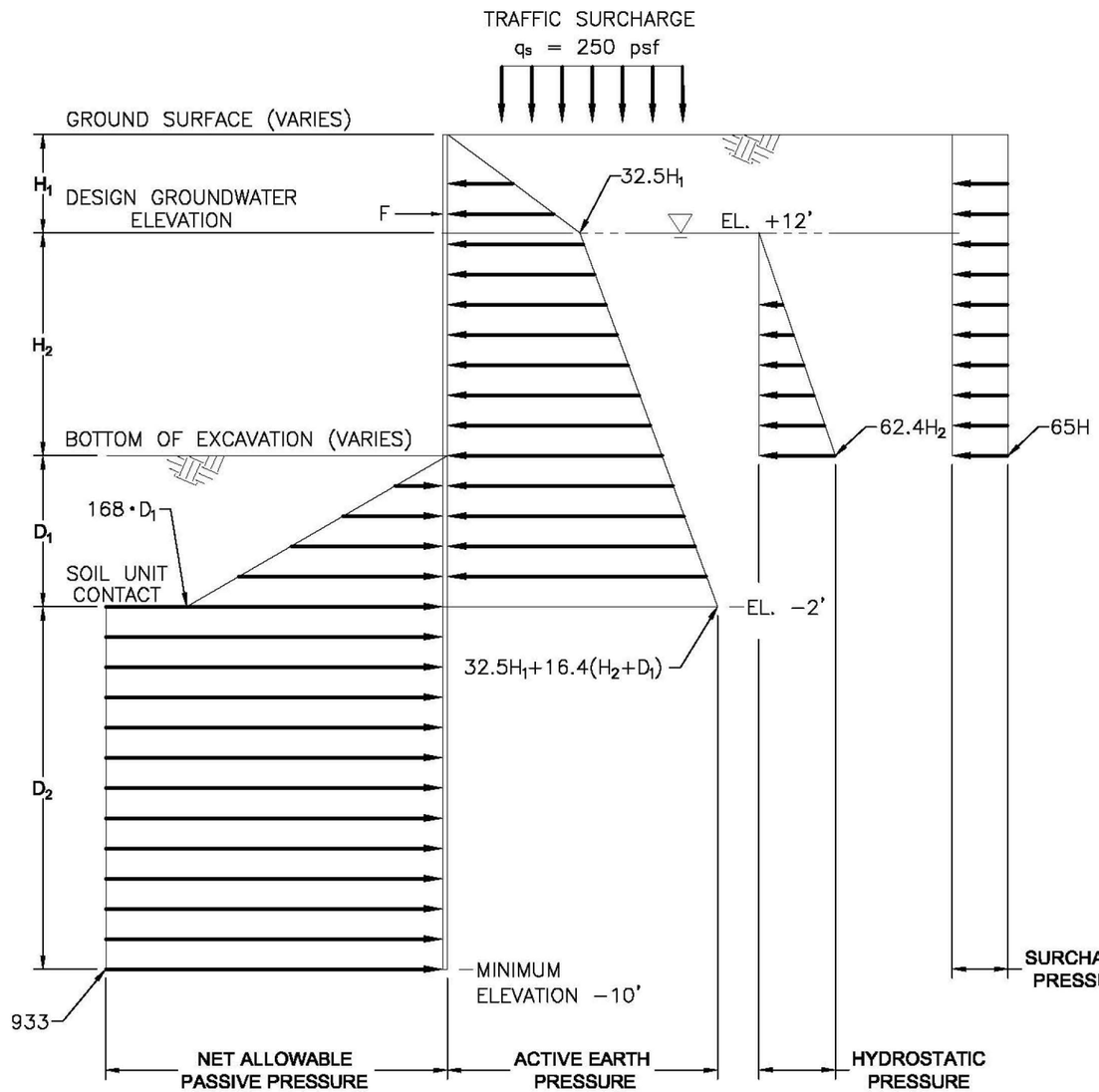
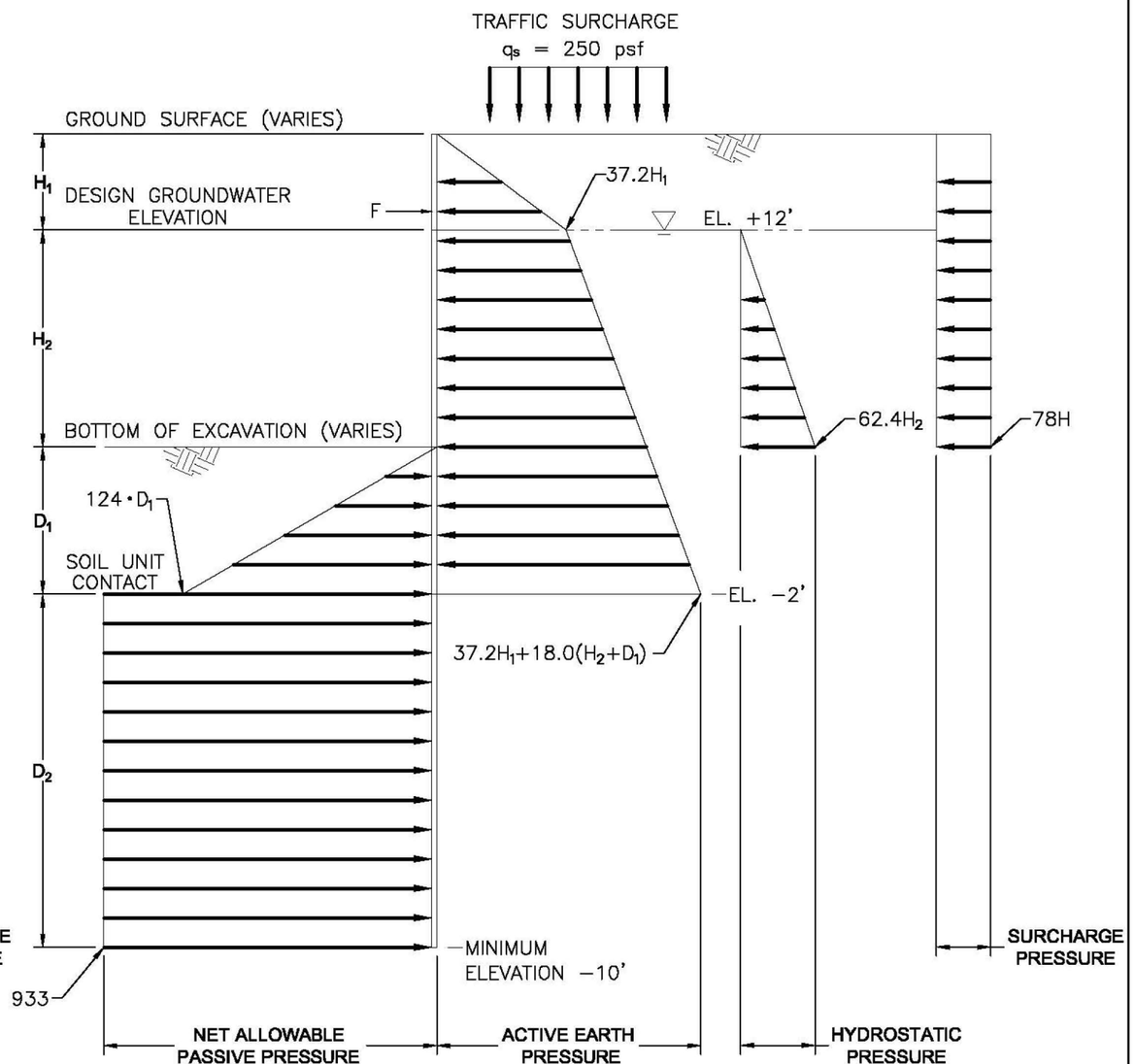
Figure 13

TEMPORARY SHEETPILE SHORING - CASE 1
SECONDARY CLARIFIER NO.4 (FACILITY 330)
INSIDE PREVIOUS PEAT REMOVAL AREA



NOT TO SCALE

TEMPORARY SHEETPILE SHORING - CASE 2
SECONDARY CLARIFIER NO.4 (FACILITY 330)
OUTSIDE PREVIOUS PEAT REMOVAL AREA



NOT TO SCALE

Notes

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Legend

- ▽ Design Groundwater Elevation
- H_1 = Height of excavation above design groundwater elevation
- H_2 = Height of excavation below design groundwater elevation
- D_1 = Depth of sheet pile embedment between bottom of excavation and soil unit contact
- D_2 = Depth of sheet pile embedment soil unit contact and bottom of sheet pile

Earth Pressure Diagram
Temporary Sheet Pile Wall

Post Point WWTP Improvements
Bellingham, Washington

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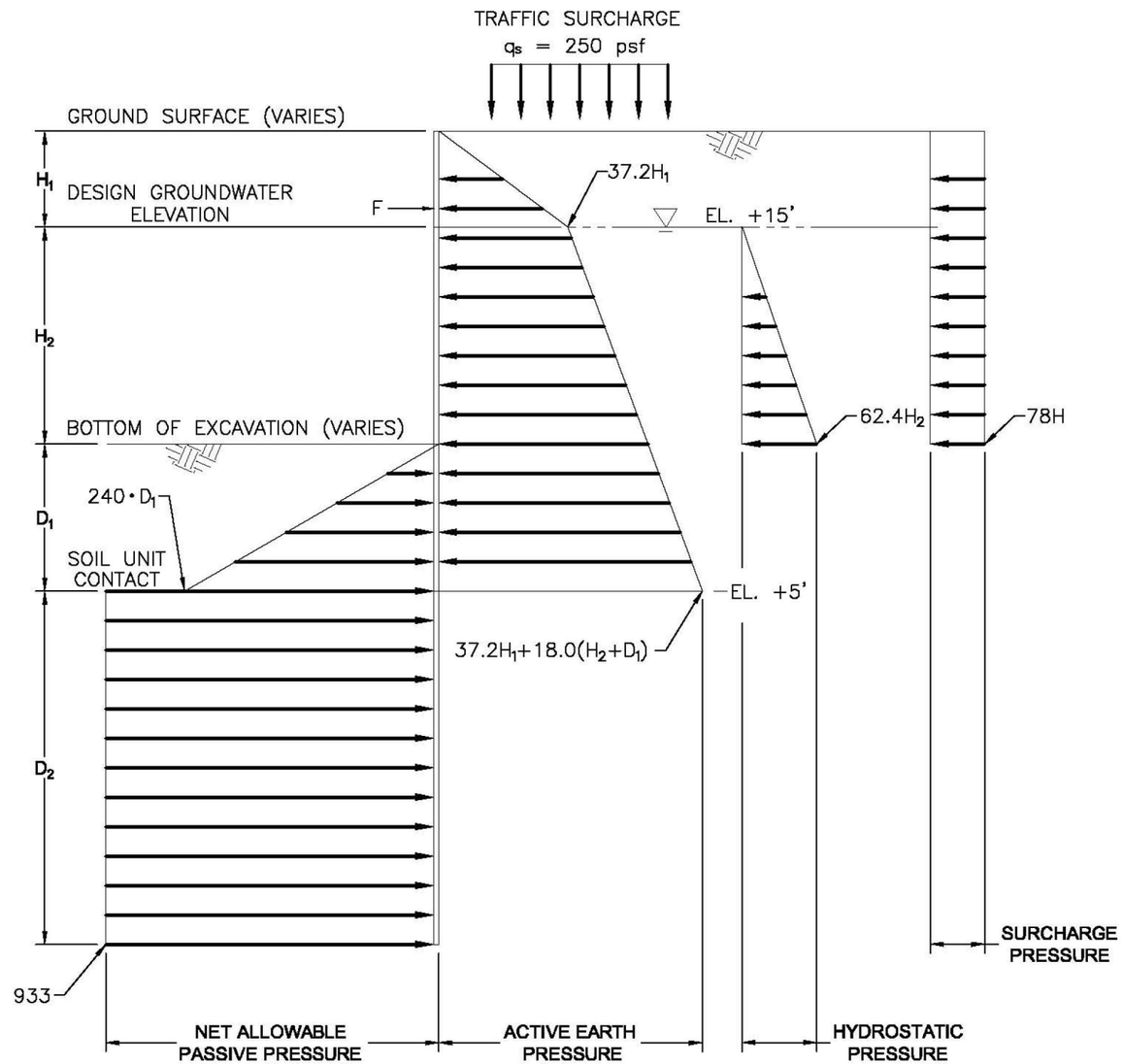
Figure 14

W:\BELLINGHAM\PROJECTS\0\0356\06\00\CAD\0356\0600 EPDs.DWG\TAB:IA MODIFIED BY TMICHAUD ON OCT 04, 2010 - 16:29

TEMPORARY SHEETPILE SHORING - CASE 3
ACTIVATED SLUDGE BASIN NO. 4 (FACILITY 311)



NOT TO SCALE

Notes

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Legend

- ▽ Design Groundwater Elevation
- H_1 = Height of excavation above design groundwater elevation
- H_2 = Height of excavation below design groundwater elevation
- D_1 = Depth of sheet pile embedment between bottom of excavation and soil unit contact
- D_2 = Depth of sheet pile embedment soil unit contact and bottom of sheet pile

Earth Pressure Diagram
Temporary Sheet Pile Wall

Post Point WWTP Improvements
Bellingham, Washington

GEOENGINEERS

Figure 15

W:\BELLINGHAM\PROJECTS\0\0356106\00\CAD\0356106600 EPDs.DWG\TAB:I5 MODIFIED BY TMICHAUD ON OCT 04, 2010 - 16:30

APPENDIX A
Field Explorations

APPENDIX A
FIELD EXPLORATIONS

Subsurface soil and groundwater conditions were evaluated by drilling fourteen borings (GEI-1 through GEI-14), excavating three test pits (TP-1 through TP-3), and advancing one seismic cone penetration test (CPT-1) at the site. The borings were drilled to depths from 21.5 to 36.5 feet below the existing ground surface (bgs) and were completed on April 27, April 28, and July 15 2010, using a track-mounted drill rig operated by Boretec, Inc. The test pits were excavated to depths from 8 to 9 feet bgs and were completed on May 4, 2010 with a backhoe operated by Ram Construction, Inc. The CPT was advanced to a depth of 81.2 feet bgs on April 26, 2010 with a track-mounted rig operated by In-Situ, Inc. All explorations were subcontracted to GeoEngineers. The locations and elevations of the explorations were determined in the field based on taping and pacing from relevant site features shown in a site survey drawing by Wilson Engineering. The approximate exploration locations are shown in the Site and Exploration Plan, Figure 2.

The soils encountered in the borings were generally sampled at 2½ or 5-foot vertical intervals with a 2-inch outside diameter split-barrel standard penetration test (SPT) sampler. The samples were obtained by driving the sampler 18 inches into the soil with a 140-pound automatic hammer free-falling 30 inches. The number of blows required for each 6 inches of penetration was recorded. The blow count ("N-value") of the soil was calculated as the number of blows required for the final 12 inches of penetration. This resistance, or N-value, provides a measure of the relative density of granular soils and the relative consistency of cohesive soils. Where very dense soil conditions preclude driving the full 18-inches, the penetration resistance for the partial penetration was entered on the logs. The blow counts are shown on the boring logs at the respective sample depths. Selected samples were attempted with a thin-walled tube “Shelby” sampler, as noted in the logs.

The explorations were continuously monitored by a geotechnical engineer from our firm who examined and classified the soils encountered, obtained representative soil samples, observed groundwater conditions and prepared a detailed log of each exploration. Soils encountered were classified visually in general accordance with ASTM D-2488-90, which is described in Figure A-1. An explanation of our boring log symbols is also shown in Figure A-1.

The logs of the borings are presented in Figures A-2 through A-15. The exploration logs are based on our interpretation of the field and laboratory data and indicate the various types of soils encountered. They also indicate the depths at which these soils or their characteristics change, although the change might actually be gradual. If the change occurred between samples in the boring, it was interpreted.

The log of the CPT sounding is presented in Figure A-16. A seismic shear wave velocity profile is presented in Figure A-17.

SOIL CLASSIFICATION CHART

MAJOR DIVISIONS			SYMBOLS GRAPH	SYMBOLS LETTER	TYPICAL DESCRIPTIONS
COARSE GRAINED SOILS MORE THAN 50% RETAINED ON NO. 200 SIEVE	GRAVEL AND GRAVELLY SOILS MORE THAN 50% OF COARSE FRACTION RETAINED ON NO. 4 SIEVE	CLEAN GRAVELS (LITTLE OR NO FINES)		GW	WELL-GRADED GRAVELS, GRAVEL - SAND MIXTURES
				GP	POORLY-GRADED GRAVELS, GRAVEL - SAND MIXTURES
		GRAVELS WITH FINES (APPRECIABLE AMOUNT OF FINES)		GM	SILTY GRAVELS, GRAVEL - SAND - SILT MIXTURES
				GC	CLAYEY GRAVELS, GRAVEL - SAND - CLAY MIXTURES
	SAND AND SANDY SOILS MORE THAN 50% OF COARSE FRACTION PASSING NO. 4 SIEVE	CLEAN SANDS (LITTLE OR NO FINES)		SW	WELL-GRADED SANDS, GRAVELLY SANDS
				SP	POORLY-GRADED SANDS, GRAVELLY SAND
		SANDS WITH FINES (APPRECIABLE AMOUNT OF FINES)		SM	SILTY SANDS, SAND - SILT MIXTURES
				SC	CLAYEY SANDS, SAND - CLAY MIXTURES
FINE GRAINED SOILS MORE THAN 50% PASSING NO. 200 SIEVE	SILTS AND CLAYS	LIQUID LIMIT LESS THAN 50		ML	INORGANIC SILTS, ROCK FLOUR, CLAYEY SILTS WITH SLIGHT PLASTICITY
				CL	INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS
				OL	ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY
	SILTS AND CLAYS	LIQUID LIMIT GREATER THAN 50		MH	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS SILTY SOILS
				CH	INORGANIC CLAYS OF HIGH PLASTICITY
				OH	ORGANIC CLAYS AND SILTS OF MEDIUM TO HIGH PLASTICITY
HIGHLY ORGANIC SOILS				PT	PEAT, HUMUS, SWAMP SOILS WITH HIGH ORGANIC CONTENTS

NOTE: Multiple symbols are used to indicate borderline or dual soil classifications

ADDITIONAL MATERIAL SYMBOLS

SYMBOLS GRAPH	SYMBOLS LETTER	TYPICAL DESCRIPTIONS
	CC	Cement Concrete
	AC	Asphalt Concrete
	CR	Crushed Rock/ Quarry Spalls
	TS	Topsoil/ Forest Duff/Sod

Measured groundwater level in exploration, well, or piezometer

Groundwater observed at time of exploration

Perched water observed at time of exploration

Measured free product in well or piezometer

Graphic Log Contact

Distinct contact between soil strata or geologic units

Approximate location of soil strata change within a geologic soil unit

Material Description Contact

Distinct contact between soil strata or geologic units

Approximate location of soil strata change within a geologic soil unit

Sampler Symbol Descriptions

2.4-inch I.D. split barrel

Standard Penetration Test (SPT)

Shelby tube

Piston

Direct-Push

Bulk or grab

Blowcount is recorded for driven samplers as the number of blows required to advance sampler 12 inches (or distance noted). See exploration log for hammer weight and drop.

A "P" indicates sampler pushed using the weight of the drill rig.

Laboratory / Field Tests

%F	Percent fines
AL	Atterberg limits
CA	Chemical analysis
CP	Laboratory compaction test
CS	Consolidation test
DS	Direct shear
HA	Hydrometer analysis
MC	Moisture content
MD	Moisture content and dry density
OC	Organic content
PM	Permeability or hydraulic conductivity
PP	Pocket penetrometer
SA	Sieve analysis
TX	Triaxial compression
UC	Unconfined compression
VS	Vane shear

Sheen Classification

NS	No Visible Sheen
SS	Slight Sheen
MS	Moderate Sheen
HS	Heavy Sheen
NT	Not Tested

NOTE: The reader must refer to the discussion in the report text and the logs of explorations for a proper understanding of subsurface conditions. Descriptions on the logs apply only at the specific exploration locations and at the time the explorations were made; they are not warranted to be representative of subsurface conditions at other locations or times.

KEY TO EXPLORATION LOGS

GEOENGINEERS

FIGURE A-1

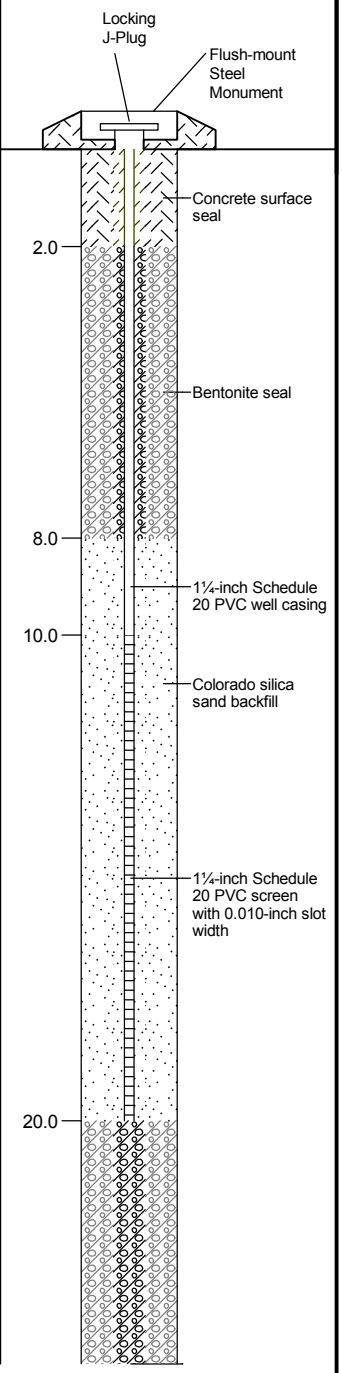
Drilled Start 4/27/2010 End	Total Depth (ft) 31.5	Logged By AF2 Checked By SWC	Driller Boretec, Inc.	Drilling Method Hollow-stem Auger
Hammer Data 140 (lbs) / 30 (in) Drop		Drilling Equipment EC-55B Tracked Rig	Licencing agency well number: **BBB-906** A 2 (in) well was installed on 4/27/2010 to a depth of 30 (ft).	
Surface Elevation (ft) Vertical Datum 13.0		Top of Casing Elevation (ft)	Groundwater Date Measured / Depth to Water (ft) / Elevation (ft) Undetermined	
Easting (X) 10 Northing (Y) 0		System Datum		

Notes:

FIELD DATA

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Blows/foot	Collected Sample	Sample Name	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Water Content, %	Dry Density, (pcf)
	0								TS	Dark brown fine sandy silt with organic matter (soft to medium stiff, moist) (topsoil)		
									SM	Gray-brown fine to coarse sand with gravel; mottled iron staining (dense, moist) (fill)		
10			12	38		1					10	
	5		18	30		2			SM/ML	Brown-gray silty fine to medium sand to sandy silt with occasional organic matter (medium dense to dense/very stiff, moist)		
5												
	10		18	4		3			PEAT	Brown fibrous peat (soft to medium stiff, moist)	220	
0												
									OL	Brown organic silt (soft to medium stiff, moist)		
	15		18	4		4a					83	
						4b			CL	Blue-gray clay with lenses of silty fine to medium sand and occasional shell fragments (medium stiff, moist to wet) (glacial drift) - slight seepage within sand lenses	27	
5			18	5		5					37	
	20		24	P		6				AL		
10									CL	Brown-gray clay (medium stiff, moist)		
	25											

WELL LOG



Notes: See Figure A-1 for explanation of symbols.
The depths on the test pit logs are based on an average of measurements across the test pit and should be considered accurate to 0.5 foot.

Log of Boring GEI-1

GeoEngineers

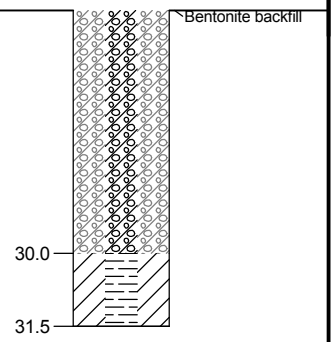
Project: Post Point WWTP Expansion
Project Location: Bellingham, Washington
Project Number: 356-106-00

Figure A-2
Sheet 1 of 2

Bellingham: Date:6/15/10 Path:P:\0\0356106\GINT\35610600 BORINGS.GPJ DBTemplate/LibTemplate:GEOENGINEERS8.GDT/GEI8_GEOTECH_WELL

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Blows/foot	Collected Sample	Sample Name	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Water Content, %	Dry Density, (pcf)
	25		18	7		7					34	
15									CL	Gray clay; trace shell fragments (soft, moist to wet)		
	30		18	3		8				AL	33	

WELL LOG



Notes: See Figure A-1 for explanation of symbols.
The depths on the test pit logs are based on an average of measurements across the test pit and should be considered accurate to 0.5 foot.

Log of Boring GEI-1 (continued)

GEOENGINEERS

Project: Post Point WWTP Expansion
Project Location: Bellingham, Washington
Project Number: 356-106-00

Figure A-2
Sheet 2 of 2

Bellingham: Date:6/15/10 Path:P:\0\0356106\GINT\35610600 BORINGS.GPJ DBTemplate/LibTemplate:GEOENGINEERS8.GDT/GEI8_GEOTECH_WELL

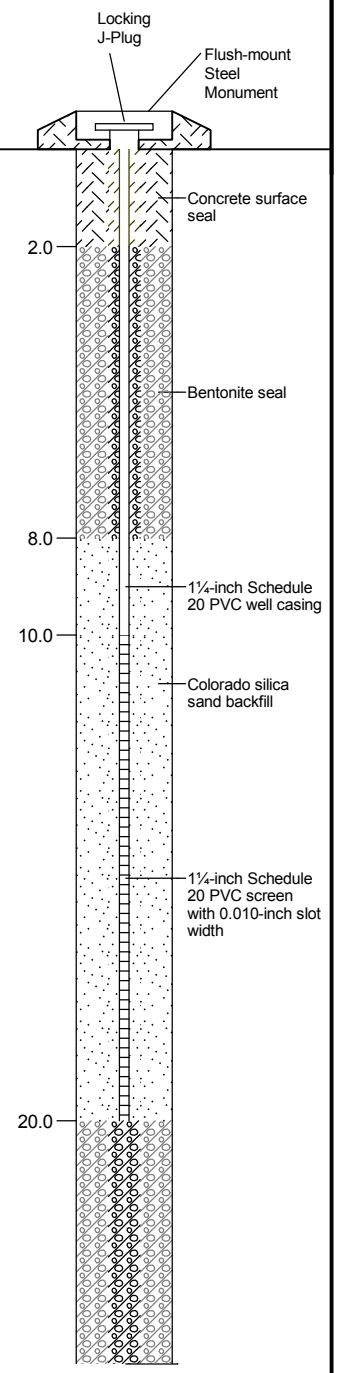
Drilled Start 4/27/2010 End	Total Depth (ft) 31.5	Logged By AF2 Checked By SWC	Driller Boretec, Inc.	Drilling Method Hollow-stem Auger
Hammer Data 140 (lbs) / 30 (in) Drop		Drilling Equipment EC-55B Tracked Rig	Licencing agency well number: **BBB-905** A 2 (in) well was installed on 4/27/2010 to a depth of 30 (ft).	
Surface Elevation (ft) Vertical Datum 17.0		Top of Casing Elevation (ft)	Groundwater: Date Measured / Depth to Water (ft) 30.5 / Elevation (ft) -13.50	
Easting (X) 20 Northing (Y) 0		System Datum		

Notes:

FIELD DATA

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Blows/foot	Collected Sample	Sample Name	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Water Content, %	Dry Density, (pcf)
	0								SOD	6 inches of sod		
									SM	Brown to gray silty fine to coarse sand with gravel (dense, moist) (fill)		
			12	49		1						
	5		6	23		2			ML/SM	Brown to gray silty fine sand to sandy silt (medium dense, moist) - slight seepage along sandy seams	12	
			0	50/6"		3						
	10		6	56		4				- with roots and organic matter	19	
									SM/ML	Dark gray silty fine to coarse sand to sandy silt with gravel (medium dense/stiff, moist) (fill)		
	15		18	12		5				SA; %F=30	12	
	20		18	6		6a			CL	Blue-gray clay with fine sand (medium stiff, moist) (glacial drift)		
						6b			CL	Brown gray clay with fine sand (medium stiff to stiff, moist)		
	25											

WELL LOG



Notes: See Figure A-1 for explanation of symbols.
The depths on the test pit logs are based on an average of measurements across the test pit and should be considered accurate to 0.5 foot.

Log of Boring GEI-2

GEOENGINEERS

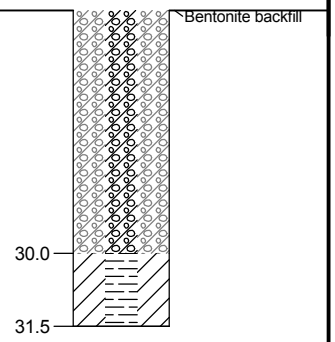
Project: Post Point WWTP Expansion
Project Location: Bellingham, Washington
Project Number: 356-106-00

Figure A-3
Sheet 1 of 2

Bellingham: Date:6/15/10 Path:P:\0\0356106\GINT\35610600 BORINGS.GPJ DBTemplate/LibTemplate:GEOENGINEERS8.GDT/GEI8_GEOTECH_WELL

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Blows/foot	Collected Sample	Sample Name	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Water Content, %	Dry Density, (pcf)
	25		18	8		7					40	
-10									ML	Gray sandy silt with pockets/lenses of clay (medium stiff, moist to wet)		
	30		18	4		8	▽			%F=76	26	

WELL LOG



Notes: See Figure A-1 for explanation of symbols.
The depths on the test pit logs are based on an average of measurements across the test pit and should be considered accurate to 0.5 foot.

Log of Boring GEI-2 (continued)

GEOENGINEERS

Project: Post Point WWTP Expansion
Project Location: Bellingham, Washington
Project Number: 356-106-00

Figure A-3
Sheet 2 of 2

Bellingham: Date:6/15/10 Path:P:\0\0356106\GINT\35610600 BORINGS.GPJ DBTemplate/LibTemplate:GEOENGINEERS8.GDT/GEI8_GEOTECH_WELL

Drilled Start 4/27/2010 End	Total Depth (ft) 21.5	Logged By AF2 Checked By SWC	Driller Boretec, Inc.	Drilling Method Hollow-stem Auger
Surface Elevation (ft) Vertical Datum 18.0	Hammer Data 140 (lbs) / 30 (in) Drop	Drilling Equipment EC-55B Tracked Rig		
Easting (X) Northing (Y)	System Datum	Groundwater Date Measured / Depth to Water (ft) / Elevation (ft)		
Notes:		Undetermined		

Elevation (feet)	Depth (feet)	Interval Recovered (in)	Blows/foot	Collected Sample Sample Name Testing	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
	0						AC	6 inches of asphalt concrete			
							SP-SM	Dark gray fine to coarse sand with silt and gravel (medium dense to dense, moist) (fill)			
15		6	42	1			SM	Gray silty fine to medium sand with gravel (loose, moist to wet)	9		
	5	6	9	2			SM	Gray-brown silty fine to coarse sand with occasional gravel (medium dense, moist)			
10		6	34	3			SM/ML	Gray-brown silty fine to coarse sand to sandy silt with gravel (medium dense/stiff, moist)	10		blowcount likely overstated
	10	9	18	4					9		SA; %F=27
5		16	5	5			SC/CL	Brown clayey fine to coarse sand to sandy clay with occasional gravel (loose/medium stiff, moist) (glacial drift)	13		
	15	18	5	6			CL	Blue-gray silty sandy clay with occasional organic matter (medium stiff, moist to wet)	24		AL; %F=56
0							CL	Brown-gray clay with iron mottling (medium stiff, moist to wet)			
	20	18	6	7					33		

Notes: See Figure A-1 for explanation of symbols.
The depths on the test pit logs are based on an average of measurements across the test pit and should be considered accurate to 0.5 foot.

Log of Boring GEI-3

GeoEngineers

Project: Post Point WWTP Expansion
Project Location: Bellingham, Washington
Project Number: 356-106-00

Figure A-4
Sheet 1 of 1

Bellingham: Date:9/23/10 Path:P:\0\0356106\GINT\35610600 BORINGS.GPJ DBTemplate/LibTemplate:GEOENGINEERS8.GDT/GEI8_GEOTECH_STANDARD

Drilled Start 4/27/2010 End	Total Depth (ft) 21.5	Logged By AF2 Checked By SWC	Driller Boretec, Inc.	Drilling Method Hollow-stem Auger
Surface Elevation (ft) Vertical Datum 17.5		Hammer Data 140 (lbs) / 30 (in) Drop	Drilling Equipment EC-55B Tracked Rig	
Easting (X) Northing (Y)		System Datum	Groundwater Date Measured	Depth to Water (ft) 20.5 / Elevation (ft) -3.0
Notes:				

Elevation (feet)	Depth (feet)	Interval Recovered (in)	Blows/foot	Collected Sample	Sample Name Testing	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
	0							SOD	4 inches of sod			
								SM/ML	Brown silty fine to coarse sand to sandy silt with clay and occasional gravel (medium dense/stiff, moist) (fill)			
15		9	21		1					12		
	5	4	9		2							
10		12	10		3							
	10	18	3		4			SM/SC	Brown fine to coarse silty and clayey sand with gravel (very loose, moist)	12		SA; %F=24
5		18	3		5a					15		
					5b			CL-ML	Blue-gray silty clay with fine sand (soft, moist to wet) (glacial drift)	22		AL
	15	18	P		6							
0								SP-SM	Gray to brown fine to coarse sand with silt and gravel (medium dense, wet)			
	20	18	17		7	▽				20		SA; %F=7

Notes: See Figure A-1 for explanation of symbols.
The depths on the test pit logs are based on an average of measurements across the test pit and should be considered accurate to 0.5 foot.

Log of Boring GEI-4

GeoEngineers

Project: Post Point WWTP Expansion
Project Location: Bellingham, Washington
Project Number: 356-106-00

Figure A-5
Sheet 1 of 1

Bellingham: Date:9/23/10 Path:P:\0\0356106\GINT\35610600 BORINGS.GPJ DBTemplate/LibTemplate:GEOENGINEERS8.GDT/GEI8_GEOTECH_STANDARD

Drilled Start 4/28/2010 End	Total Depth (ft) 31.5	Logged By AF2 Checked By SWC	Driller Boretec, Inc.	Drilling Method Hollow-stem Auger
Surface Elevation (ft) Vertical Datum 20.0		Hammer Data 140 (lbs) / 30 (in) Drop	Drilling Equipment EC-55B Tracked Rig	
Easting (X) Northing (Y)		System Datum	Groundwater Date Measured	Depth to Water (ft) 12.0 / Elevation (ft) 8.0
Notes:				

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Blows/foot	Collected Sample	Sample Name Testing	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
	0								AC	3 inches of asphalt concrete			
									SP-SM	Gray fine to coarse sand with gravel and silt (medium dense, moist) (fill)			
									SM	Gray silty fine to medium sand with occasional gravel (medium dense, moist)			
			10	37		1							
15	5		9	33		2					9		
			6	12		3					15		
										- increased moisture			
10	10		12	6		4			SM	Gray silty fine to coarse sand with clay (loose, moist)			
									SC/CL	Gray-brown clayey fine sand with occasional gravel to sandy clay (very loose/very soft, wet) (glacial drift)			
5	15		0	P		5							
			18	2		6				SA; %F=32	23		
									CL	Gray clay with lenses of fine to medium sand and occasional shell fragments (soft, wet)			
0	20		16	3		7					22		
-5	25												

Notes: See Figure A-1 for explanation of symbols.
The depths on the test pit logs are based on an average of measurements across the test pit and should be considered accurate to 0.5 foot.

Log of Boring GEI-5

GEOENGINEERS

Project: Post Point WWTP Expansion
Project Location: Bellingham, Washington
Project Number: 356-106-00

Figure A-6
Sheet 1 of 2

Bellingham: Date:9/23/10 Path:P:\0\0356106\GINT\35610600 BORINGS.GPJ DBTemplate/LibTemplate:GEOENGINEERS8.GDT/GEI8_GEOTECH_STANDARD

Elevation (feet)	Depth (feet)	FIELD DATA: Interval	Recovered (in)	Blows/foot	Collected Sample	Sample Name / Testing	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
	25		18	2		8				- soft to very soft			
			24	P		9							
-10	30		18	5		10				- becomes medium stiff	41		

Notes: See Figure A-1 for explanation of symbols.
The depths on the test pit logs are based on an average of measurements across the test pit and should be considered accurate to 0.5 foot.

Log of Boring GEI-5 (continued)

GEOENGINEERS

Project: Post Point WWTP Expansion
Project Location: Bellingham, Washington
Project Number: 356-106-00

Figure A-6
Sheet 2 of 2

Bellingham: Date:9/23/10 Path:P:\0\0356106\GINT\35610600 BORINGS.GPJ DBTemplate/LibTemplate:GEOENGINEERS8.GDT/GEI8_GEOTECH_STANDARD

Drilled Start 4/28/2010 End	Total Depth (ft) 21.5	Logged By AF2 Checked By SWC	Driller Boretec, Inc.	Drilling Method Hollow-stem Auger
Surface Elevation (ft) Vertical Datum 21.0	Hammer Data 140 (lbs) / 30 (in) Drop	Drilling Equipment EC-55B Tracked Rig		
Easting (X) Northing (Y)	System Datum	Groundwater Date Measured	Depth to Water (ft) 6.0	Elevation (ft) 15.0
Notes:				

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Blows/foot	Collected Sample	Sample Name Testing	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
	0								AC	3 inches of asphalt concrete			
20									SM	Brown silty fine to coarse sand with gravel (medium dense, moist) (fill)			
			18	19		1			SC/CL	Brown-gray clayey fine to coarse sand to sandy clay with occasional gravel (medium dense/very stiff, moist)	13		
	5		6	22		2			SP-SM	Gray fine to coarse sand with silt (medium dense, wet) (alluvium)			
15			18	4		3			SM	Brown silty fine sand with iron staining (loose, wet)	27		SA; %F=28
	10		18	2		4			ML	Brown fine sandy silt with iron staining (very soft to soft, wet) (glacial drift)	26		
10									CL	Brown fine sandy clay (stiff, wet)			
	15		18	11		5					27		
5													
	20		18	3		6				- becomes gray, soft with occasional gravel	21		
0													

Notes: See Figure A-1 for explanation of symbols.
The depths on the test pit logs are based on an average of measurements across the test pit and should be considered accurate to 0.5 foot.

Log of Boring GEI-6

GeoEngineers

Project: Post Point WWTP Expansion
Project Location: Bellingham, Washington
Project Number: 356-106-00

Figure A-7
Sheet 1 of 1

Bellingham: Date:9/23/10 Path:P:\0\0356106\GINT\35610600 BORINGS.GPJ DBTemplate/LibTemplate:GEOENGINEERS8.GDT/GEI8_GEOTECH_STANDARD

Drilled Start 4/27/2010 End	Total Depth (ft) 26	Logged By AF2 Checked By SWC	Driller Boretec, Inc.	Drilling Method Hollow-stem Auger
Surface Elevation (ft) Vertical Datum 23.0	Hammer Data 140 (lbs) / 30 (in) Drop	Drilling Equipment EC-55B Tracked Rig		
Easting (X) Northing (Y)	System Datum	Groundwater Date Measured	Depth to Water (ft) 9.0	Elevation (ft) 14.0
Notes:				

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Blows/foot	Collected Sample	Sample Name Testing	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
	0								SOD	Sod			
									SM	Brown silty fine to coarse sand with gravel (medium dense, moist) (alluvium)			
20			12	22		1					11		
	5		18	4		2			ML/SC	Brown fine sandy silt with clay to silty, clayey fine sand (medium stiff/loose, moist)	28		%F=50
15			18	4		3			CL	Light gray silty clay with iron staining, interbedded with silty fine to coarse sand layers (medium stiff, moist to wet) (glacial drift)			
							▽			- wet sand layers			
	10		18	3	↔	4a			CL	Gray clay with fine sand and occasional gravel (soft, wet)	33		
					↔	4b					22		
10			24	P		5							
	15		18	11		6			SM/SC	Gray silty, clayey fine to coarse sand with gravel (stiff, moist to wet)	16		SA; %F=46 AL
5													
	20		18	9		7					22		
0										- increased gravel content			
	25												

Notes: See Figure A-1 for explanation of symbols.
The depths on the test pit logs are based on an average of measurements across the test pit and should be considered accurate to 0.5 foot.

Log of Boring GEI-7

GEOENGINEERS

Project: Post Point WWTP Expansion
Project Location: Bellingham, Washington
Project Number: 356-106-00

Figure A-8
Sheet 1 of 2

Bellingham: Date:9/23/10 Path:P:\0\0356106\GINT\356106\00 BORINGS.GPJ DBTemplate/LibTemplate:GEOENGINEERS8.GDT/GEI8_GEOTECH_STANDARD

Elevation (feet)	Depth (feet)	FIELD DATA: Interval	Recovered (in)	Blows/foot	Collected Sample	Sample Name / Testing	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
	25		6	50/6"		8							Blowcount overstated on gravel

Notes: See Figure A-1 for explanation of symbols.
The depths on the test pit logs are based on an average of measurements across the test pit and should be considered accurate to 0.5 foot.

Log of Boring GEI-7 (continued)

GEOENGINEERS

Project: Post Point WWTP Expansion
Project Location: Bellingham, Washington
Project Number: 356-106-00

Figure A-8
Sheet 2 of 2

Bellingham: Date:9/23/10 Path:P:\0\0356106\GINT\35610600 BORINGS.GPJ DBTemplate/LibTemplate:GEOENGINEERS8.GDT/GEI8_GEOTECH_STANDARD

Drilled Start 4/27/2010 End	Total Depth (ft) 21.5	Logged By AF2 Checked By SWC	Driller Boretec, Inc.	Drilling Method Hollow-stem Auger
Surface Elevation (ft) Vertical Datum 21.0		Hammer Data 140 (lbs) / 30 (in) Drop	Drilling Equipment EC-55B Tracked Rig	
Easting (X) Northing (Y)		System Datum	Groundwater Date Measured	Depth to Water (ft) 5.5 / Elevation (ft) 15.5
Notes:				

Elevation (feet)	Depth (feet)	Interval Recovered (in)	Blows/foot	Collected Sample	Sample Name Testing	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
	0							TS	Topsoil			
		12	16		1			SP-SM	Light brown fine sand with silt (medium dense, moist) (alluvium)	17		
	5	18	17		2	▽		SP-SM	Light brown fine to coarse sand with silt and gravel (medium dense, wet)	21		SA: %F=14
		18	4		3			CL	Gray-brown clay with fine to coarse sand, occasional gravel and pockets of sand (medium stiff, moist to wet) (glacial drift)	24		
	10	18	2		4			ML/CL	Gray interbedded clayey silt and silty clay with layers of shell fragments (very soft to soft, wet)			
		24	P		5			SM/ML	Gray silty fine sand to sandy silt with shell fragments (loose/soft, wet)			No recovery
	15	18	4		6					23		%F=45
	20	18	4		7			CL	Gray clay with fine sand (soft, wet)			

Notes: See Figure A-1 for explanation of symbols.
The depths on the test pit logs are based on an average of measurements across the test pit and should be considered accurate to 0.5 foot.

Log of Boring GEI-8

GeoEngineers

Project: Post Point WWTP Expansion
Project Location: Bellingham, Washington
Project Number: 356-106-00

Figure A-9
Sheet 1 of 1

Bellingham: Date:9/23/10 Path:P:\0\0356106\GINT\35610600 BORINGS.GPJ DBTemplate/LibTemplate:GEOENGINEERS8.GDT/GEI8_GEOTECH_STANDARD

Drilled Start 4/27/2010 End	Total Depth (ft) 21.5	Logged By AF2 Checked By SWC	Driller Boretec, Inc.	Drilling Method Hollow-stem Auger
Surface Elevation (ft) Vertical Datum 18.5		Hammer Data 140 (lbs) / 30 (in) Drop	Drilling Equipment EC-55B Tracked Rig	
Easting (X) Northing (Y)		System Datum	Groundwater Date Measured	Depth to Water (ft) 5.5 / Elevation (ft) 13.0
Notes:				

Elevation (feet)	Depth (feet)	Interval Recovered (in)	Blows/foot	Collected Sample	Sample Name Testing	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
	0							TS	Sod over dark brown fine sandy silt with organic matter (medium stiff, moist) (topsoil)			
15		18	10		1			SM/ML	Brown-gray silty fine to coarse sand to sandy clayey silt with gravel and occasional organic matter (medium dense/stiff, moist) (fill)	16		
	5	12	4		2	▽		SM	Gray silty fine to coarse sand with gravel and clay (loose, wet) (alluvium)	16		SA; %F=20
10		18	6		3			ML	Light brown fine sandy clayey silt with iron staining (medium stiff, wet)			
								SM	Brown silty fine sand (loose, wet)			
5	10	18	8		4			CL	Brown sandy, silty clay with iron staining (stiff, wet) (glacial drift)			
0	15	18	7		5a				- increasing silt content	24		
					5b			CL	Gray clay with sand lenses (medium stiff, wet)	28		
	20	18	2		6				- decreased sand content, very soft to soft	31		

Notes: See Figure A-1 for explanation of symbols.
The depths on the test pit logs are based on an average of measurements across the test pit and should be considered accurate to 0.5 foot.

Log of Boring GEI-9

GeoEngineers

Project: Post Point WWTP Expansion
Project Location: Bellingham, Washington
Project Number: 356-106-00

Figure A-10
Sheet 1 of 1

Bellingham: Date:9/23/10 Path:P:\0\0356106\GINT\356106\00 BORINGS.GPJ DBTemplate/LibTemplate:GEOENGINEERS8.GDT/GEI8_GEOTECH_STANDARD

Drilled Start 7/15/2010 End	Total Depth (ft) 36.5	Logged By AJH Checked By SWC	Driller Boretec, Inc.	Drilling Method Hollow-stem Auger
Surface Elevation (ft) Vertical Datum 22.0		Hammer Data 140 (lbs) / 30 (in) Drop		Drilling Equipment EC-55B Tracked Rig
Easting (X) Northing (Y)		System Datum		Groundwater: Date Measured / Depth to Water (ft) / Elevation (ft)
Notes:				Undetermined

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Blows/foot	Collected Sample	Sample Name Testing	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
	0								SOD	4 inches of sod			
									SP-SM	Brown fine to medium sand with silt and occasional gravel (dense, moist) (fill)			
20			12	35		1					5		
	5		3	24		2				- medium dense			
15									ML	Gray sandy silt with orange mottling; low plasticity (medium stiff to stiff, moist to wet) (glacial drift)			
	10		18	8		3					25		SA; %F=60
10									CL	Brown to gray silty clay with sand (medium stiff to stiff, moist)			
	15		18	8		4					29		
5													
	20		18	11		5				- with occasional gravel	24		
0													
									SM	Gray silty fine to coarse sand with gravel (medium dense to dense, moist) (glacial till)			
	25												

Notes: See Figure A-1 for explanation of symbols.
The depths on the test pit logs are based on an average of measurements across the test pit and should be considered accurate to 0.5 foot.

Log of Boring GEI-10

GeoEngineers

Project: Post Point WWTP Expansion
Project Location: Bellingham, Washington
Project Number: 356-106-00

Figure A-11
Sheet 1 of 2

Bellingham: Date:9/23/10 Path:P:\0\0356106\GINT\356106\00 BORINGS.GPJ DBTemplate/LibTemplate:GEOENGINEERS8.GDT/GEI8_GEOTECH_STANDARD

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Blows/foot	Collected Sample	Sample Name Testing	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
	25		18	25		6					12		SA; %F=43
-5													
	30		18	55		7				- with sandy clay lenses (dense, wet)	18		
-10													
	35		0	38		8							No recovery

Notes: See Figure A-1 for explanation of symbols.
The depths on the test pit logs are based on an average of measurements across the test pit and should be considered accurate to 0.5 foot.

Log of Boring GEI-10 (continued)

GEOENGINEERS

Project: Post Point WWTP Expansion
Project Location: Bellingham, Washington
Project Number: 356-106-00

Figure A-11
Sheet 2 of 2

Bellingham: Date:9/23/10 Path:P:\0\0356106\GINT\35610600 BORINGS.GPJ DBTemplate/LibTemplate:GEOENGINEERS8.GDT/GEI8_GEOTECH_STANDARD

Drilled Start 7/15/2010 End	Total Depth (ft) 20.5	Logged By AJH Checked By SWC	Driller Boretec, Inc.	Drilling Method Hollow-stem Auger
Surface Elevation (ft) Vertical Datum 27.0		Hammer Data 140 (lbs) / 30 (in) Drop	Drilling Equipment EC-55B Tracked Rig	
Easting (X) Northing (Y)		System Datum	Groundwater Date Measured / Depth to Water (ft) / Elevation (ft)	
Notes:			Undetermined	

Elevation (feet)	Depth (feet)	Interval Recovered (in)	Blows/foot	Collected Sample	Sample Name Testing	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
	0							AC	5 inches of asphalt concrete			
								SP-SM	Brown fine to coarse sand with silt and gravel (medium dense, moist) (fill)			
25								SM	Gray silty fine to coarse sand with gravel (very dense, moist) (glacial till)			
	5	6	50/6"		1					6		
20												
	10	8	83/11"		2				- gray-brown, moist with possible seepage zone	8		
15												
	15	6	84/11"		3					8		
10												
	20	0	50/6"		4							No recovery

Notes: See Figure A-1 for explanation of symbols.
The depths on the test pit logs are based on an average of measurements across the test pit and should be considered accurate to 0.5 foot.

Log of Boring GEI-11

GeoEngineers

Project: Post Point WWTP Expansion
Project Location: Bellingham, Washington
Project Number: 356-106-00

Figure A-12
Sheet 1 of 1

Bellingham: Date:9/23/10 Path:P:\0\0356106\GINT\35610600 BORINGS.GPJ DBTemplate/LibTemplate:GEOENGINEERS8.GDT/GEI8_GEOTECH_STANDARD

Drilled Start 7/15/2010 End	Total Depth (ft) 25.5	Logged By AJH Checked By SWC	Driller Boretec, Inc.	Drilling Method Hollow-stem Auger
Surface Elevation (ft) Vertical Datum 34.0		Hammer Data 140 (lbs) / 30 (in) Drop	Drilling Equipment EC-55B Tracked Rig	
Easting (X) Northing (Y)		System Datum	Groundwater Date Measured	Depth to Water (ft) 1.0 / Elevation (ft) 33.0
Notes:				

Elevation (feet)	Depth (feet)	Interval Recovered (in)	Blows/foot	Collected Sample Sample Name Testing	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
	0						SM	Brown silty sand (medium dense, wet) (fill)			
30							SM	Gray silty fine to coarse sand with gravel; moist with possible seepage zone (medium dense, moist to wet) (glacial drift)			
	5	6	13	1					12		SA; %F=32
		12	15	2					14		
25											
	10	12	58	3			SM	Gray-brown silty fine to coarse sand with gravel (very dense, moist) (glacial till)	9		SA; %f=30
20											
	15	3	50/3"	4					12		
15											
	20	11	50/2"	5							
10											
	25										

Notes: See Figure A-1 for explanation of symbols.
The depths on the test pit logs are based on an average of measurements across the test pit and should be considered accurate to 0.5 foot.

Log of Boring GEI-12

GeoEngineers

Project: Post Point WWTP Expansion
Project Location: Bellingham, Washington
Project Number: 356-106-00

Figure A-13
Sheet 1 of 2

Bellingham: Date:9/23/10 Path:P:\0\0356106\GINT\35610600 BORINGS.GPJ DBTemplate/LibTemplate:GEOENGINEERS8.GDT/GEI8_GEOTECH_STANDARD

Elevation (feet)	Depth (feet)	FIELD DATA: Interval	Recovered (in)	Blows/foot	Collected Sample	Sample Name / Testing	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
	25		6	50/6"		6							

Notes: See Figure A-1 for explanation of symbols.
The depths on the test pit logs are based on an average of measurements across the test pit and should be considered accurate to 0.5 foot.

Log of Boring GEI-12 (continued)

GEOENGINEERS

Project: Post Point WWTP Expansion
Project Location: Bellingham, Washington
Project Number: 356-106-00

Figure A-13
Sheet 2 of 2

Bellingham: Date:9/23/10 Path:P:\0\0356106\GINT\35610600 BORINGS.GPJ DBTemplate/LibTemplate:GEOENGINEERS8.GDT/GEI8_GEOTECH_STANDARD

Drilled Start 7/15/2010 End	Total Depth (ft) 36.5	Logged By AJH Checked By SWC	Driller Boretec, Inc.	Drilling Method Hollow-stem Auger
Surface Elevation (ft) Vertical Datum 24.0		Hammer Data 140 (lbs) / 30 (in) Drop	Drilling Equipment EC-55B Tracked Rig	
Easting (X) Northing (Y)		System Datum	Groundwater Date Measured	Depth to Water (ft) 20.0 / Elevation (ft) 4.0
Notes:				

Elevation (feet)	Depth (feet)	Interval Recovered (in)	Blows/foot	Collected Sample	Sample Name Testing	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
	0							SM	Brown-gray silty fine to coarse sand with occasional gravel (medium dense to dense, moist) (fill)			
20		12	20		1					10		
	5	6	18		2			SC/CL	Gray clayey sand to sandy clay with occasional gravel (medium dense/medium stiff, moist) (glacial drift)	13		SA; %F+35
15												
	10	6	10		3					33		
10								CL	Brown with orange staining clay with sand and occasional gravel (very stiff, moist)			
	15	18	20		4					19		
5												
	20	18	12		5	▽		CL	- sandy clay with occasional gravel (stiff, moist to wet)	17		
0								SM/CL	Gray and gray-brown mixed silty fine to coarse sand with gravel and clay with sand and			
	25											

Notes: See Figure A-1 for explanation of symbols.
The depths on the test pit logs are based on an average of measurements across the test pit and should be considered accurate to 0.5 foot.

Log of Boring GEI-13

GeoEngineers

Project: Post Point WWTP Expansion
Project Location: Bellingham, Washington
Project Number: 356-106-00

Figure A-14
Sheet 1 of 2

Bellingham: Date:9/23/10 Path:P:\0\0356106\GINT\356106\00 BORINGS.GPJ DBTemplate/LibTemplate:GEOENGINEERS8.GDT/GEI8_GEOTECH_STANDARD

Elevation (feet)	Depth (feet)	FIELD DATA: Interval	Recovered (in)	Blows/foot	Collected Sample	Sample Name / Testing	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
	25		18	31		6				occasional gravel (dense/very stiff, wet) (glacial till)			SA
5													
	30		18	50		7					20		
10									SM	Gray silty fine to coarse sand with gravel (very dense, wet)			
	35		6	68		8					13		

Notes: See Figure A-1 for explanation of symbols.
The depths on the test pit logs are based on an average of measurements across the test pit and should be considered accurate to 0.5 foot.

Log of Boring GEI-13 (continued)

GEOENGINEERS

Project: Post Point WWTP Expansion
Project Location: Bellingham, Washington
Project Number: 356-106-00

Figure A-14
Sheet 2 of 2

Bellingham: Date:9/23/10 Path:P:\0\0356106\GINT\35610600 BORINGS.GPJ DBTemplate/LibTemplate:GEOENGINEERS8.GDT/GEI8_GEOTECH_STANDARD

Drilled Start 7/15/2010 End	Total Depth (ft) 26.5	Logged By AJH Checked By SWC	Driller Boretec, Inc.	Drilling Method Hollow-stem Auger
Surface Elevation (ft) Vertical Datum 21.0		Hammer Data 140 (lbs) / 30 (in) Drop	Drilling Equipment EC-55B Tracked Rig	
Easting (X) Northing (Y)		System Datum	Groundwater Date Measured	Depth to Water (ft) 5.0 / Elevation (ft) 16.0
Notes:				

Elevation (feet)	Depth (feet)	Interval Recovered (in)	Blows/foot	Collected Sample	Sample Name Testing	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
	0							SM	Gray silty fine to coarse sand with gravel (medium dense, moist) (fill)			
20		12	20		1					11		
	5	8	3		2	▽		SM	Brown silty fine to medium sand with occasional gravel (loose, wet) (alluvium)	19		SA; %F=29
15								CL	Gray to brown with orange staining clay with sand (stiff, moist) (glacial drift)			
	10	18	15		3					20		
10								SM/ML	Brown silty sand to sandy silt with gravel and clay (dense/very stiff, moist) (glacial till)			
	15	18	36		4					11		
5												
	20	12	52		5			SM	Gray silty fine to coarse sand with gravel (very dense, moist)	11		
0												
	25											

Notes: See Figure A-1 for explanation of symbols.
The depths on the test pit logs are based on an average of measurements across the test pit and should be considered accurate to 0.5 foot.

Log of Boring GEI-14

GEOENGINEERS

Project: Post Point WWTP Expansion
Project Location: Bellingham, Washington
Project Number: 356-106-00

Figure A-15
Sheet 1 of 2

Bellingham: Date:9/23/10 Path:P:\0\0356106\GINT\356106\00 BORINGS.GPJ DBTemplate/LibTemplate:GEOENGINEERS8.GDT/GEI8_GEOTECH_STANDARD

Elevation (feet)	Depth (feet)	FIELD DATA: Interval	Recovered (in)	Blows/foot	Collected Sample	Sample Name / Testing	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
	25		12	51		6				- becomes wet			

Notes: See Figure A-1 for explanation of symbols.
The depths on the test pit logs are based on an average of measurements across the test pit and should be considered accurate to 0.5 foot.

Log of Boring GEI-14 (continued)

GEOENGINEERS

Project: Post Point WWTP Expansion
Project Location: Bellingham, Washington
Project Number: 356-106-00

Figure A-15
Sheet 2 of 2

Bellingham: Date:9/23/10 Path:P:\0\0356106\GINT\35610600 BORINGS.GPJ DBTemplate/LibTemplate:GEOENGINEERS8.GDT/GEI8_GEOTECH_STANDARD

Date Excavated: 5/4/2010 | Logged By: AJH

Equipment: Kubota KX121-3 Mini Excavator | Total Depth (ft) 9.0

Elevation (feet)	Depth (feet)	SAMPLE: Testing Sample	SAMPLE: Sample Name Testing	Graphic Log	Group Classification	Encountered Water	MATERIAL DESCRIPTION	Sheen	Headspace Vapor	Notes
					SOD		6 inches of sod and topsoil			
					SM		Brown silty fine to coarse sand with gravel and occasional cobbles (medium dense to dense, moist) (fill)			
14	1	X	1			▼				
13	2									
12	3				SM		Gray silty fine to coarse sand with gravel and occasional shells and cobbles (medium dense, moist)			
11	4	X	2							
10	5						- grades between brown and gray			
9	6						- 2-foot piece driftwood encountered			
8	7									
7	8					▽	- gray; becomes wet			
6	9	X	3							SA; %F=30

Moderate groundwater seepage observed at 0 to 2 feet (perched) and below 8.2 feet
No caving observed

Notes: See Figure A-1 for explanation of symbols.
The depths on the test pit logs are based on an average of measurements across the test pit and should be considered accurate to 0.5 foot.

Log of Test Pit TP-1

GEOENGINEERS

Project: Post Point WWTP Expansion
Project Location: Bellingham, Washington
Project Number: 356-106-00

Figure A-16
Sheet 1 of 1

Bellingham: Date:9/23/10 Path:P:\0\0356106\GINT\35610600 BORINGS.GPJ DBTemplate/LibTemplate:GEOENGINEERS8.GDT/GEI8_TESTPIT_1P_ENV

Date Excavated: 5/4/2010 | Logged By: AJH

Equipment: Kubota KX121-3 Mini Excavator | Total Depth (ft) 8.0

Elevation (feet)	Depth (feet)	SAMPLE: Testing Sample	SAMPLE: Sample Name Testing	Graphic Log	Group Classification	Encountered Water	MATERIAL DESCRIPTION	Sheen	Headspace Vapor	Notes
					TS		6 inches of sod and topsoil			
					SM		Brown silty fine to coarse sand with gravel (medium dense, moist) (alluvium)			
19	1	X	1							
18	2				SP		Brown fine to coarse sand with gravel and trace silt (medium dense, moist)			
17	3									
16	4	X	2							SA; %F=4
15	5									
14	6					▽	- becomes wet			
13	7	X	3							
12	8									

Rapid groundwater seepage observed from 6.5 to 8 feet
Minor caving observed from 6.5 to 8 feet

Notes: See Figure A-1 for explanation of symbols.
The depths on the test pit logs are based on an average of measurements across the test pit and should be considered accurate to 0.5 foot.

Log of Test Pit TP-2

GEOENGINEERS

Project: Post Point WWTP Expansion
Project Location: Bellingham, Washington
Project Number: 356-106-00

Figure A-17
Sheet 1 of 1

Bellingham: Date:9/23/10 Path:P:\0\0356106\GINT\35610600 BORINGS.GPJ DBTemplate/LibTemplate:GEOENGINEERS8.GDT/GEI8_TESTPIT_1P_ENV

Date Excavated: 5/4/2010 | Logged By: AJH

Equipment: Kubota KX121-3 Mini Excavator | Total Depth (ft) 8.0

Elevation (feet)	Depth (feet)	SAMPLE: Testing Sample	SAMPLE: Sample Name Testing	Graphic Log	Group Classification	Encountered Water	MATERIAL DESCRIPTION	Sheen	Headspace Vapor	Notes
					SOD		6 inches of sod and topsoil			
22	1	X	1		SM		Brown silty fine to coarse sand with gravel and cobbles (medium dense, moist) (fill)			
21	2				SP-SM		Brown fine to medium sand with silt and occasional gravel (medium dense, moist) (alluvium)			
20	3	X	2							SA; %F=10
19	4				SP-SM		Gray-brown fine sand with silt; with iron staining (loose to medium dense, moist)			
18	5	X	3							
17	6									
16	7				SM/ML		Light brown silty fine sand to fine sandy silt with iron staining (medium dense/stiff, moist to wet)			
15	8	X	4							SA; %F=51

No groundwater seepage observed
No caving observed

Notes: See Figure A-1 for explanation of symbols.
The depths on the test pit logs are based on an average of measurements across the test pit and should be considered accurate to 0.5 foot.

Log of Test Pit TP-3

GEOENGINEERS

Project: Post Point WWTP Expansion
Project Location: Bellingham, Washington
Project Number: 356-106-00

Figure A-18
Sheet 1 of 1

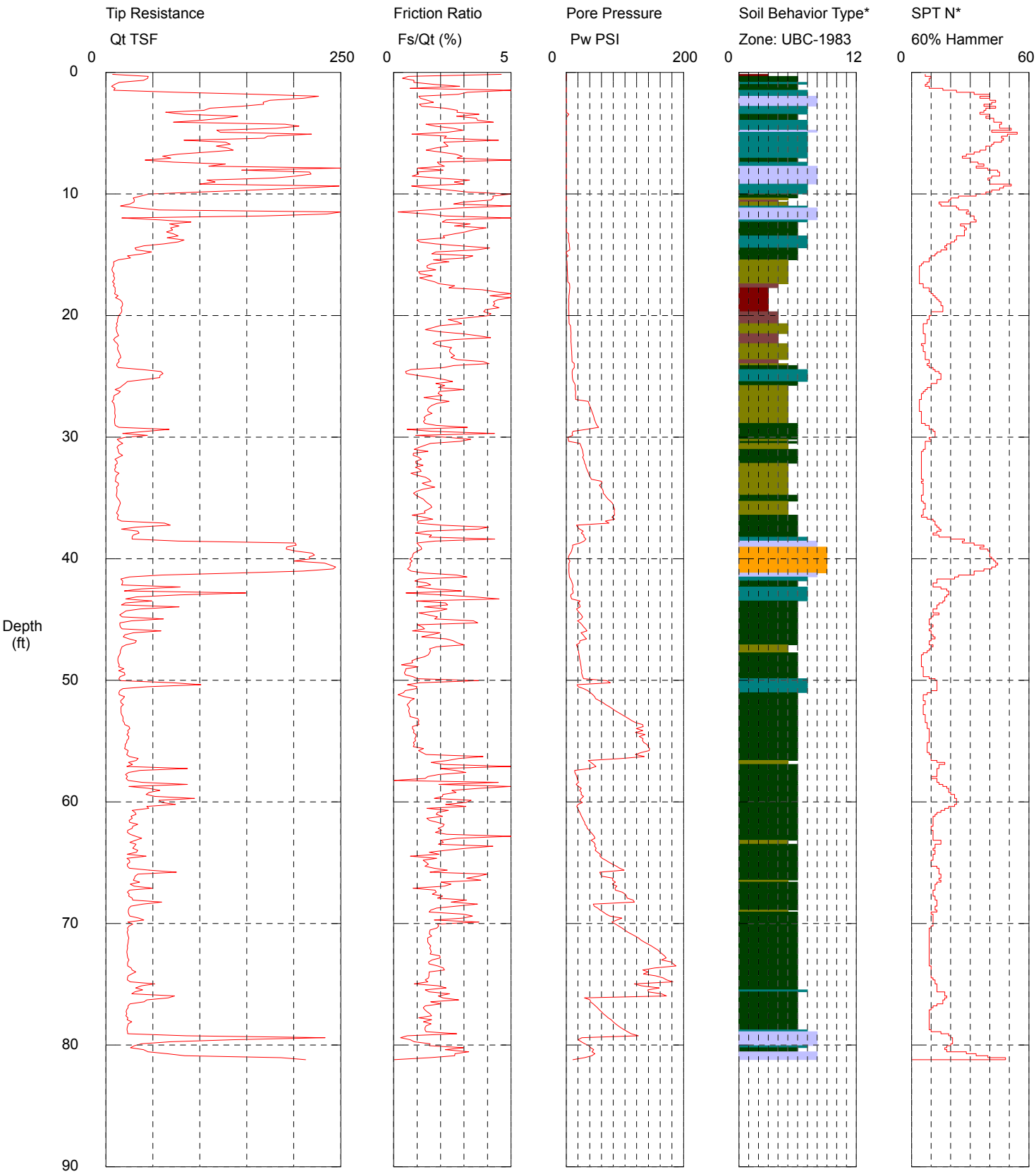
Bellingham: Date:9/23/10 Path:P:\0\0356106\GINT\35610600 BORINGS.GPJ DBTemplate/LibTemplate:GEOENGINEERS8.GDT/GEI8_TESTPIT_1P_ENV

Cone Penetrometer Data CPT-1
Figure A-19

GeoEngineers

Operator: Witthus
Sounding: CPT-01
Cone Used: DSG1015

CPT Date/Time: 4/26/2010 11:04:33 AM
Location: Post Point Wastewater Treatment Plant
Job Number: 0356-106-00



Maximum Depth = 81.20 feet

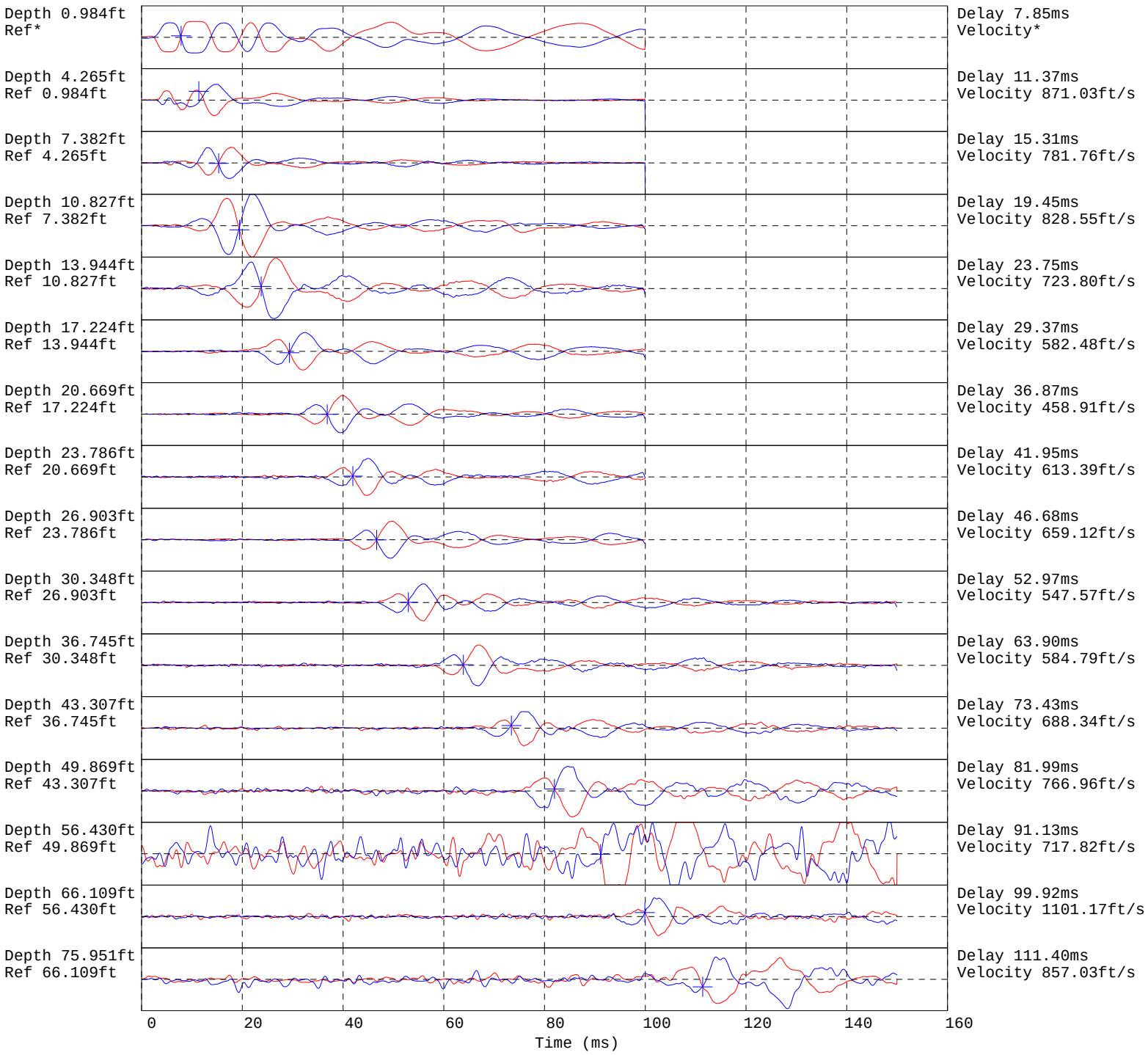
Depth Increment = 0.164 feet

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 (*)

In Situ Engineering

*Soil behavior type and SPT based on data from UBC-1983

Shear Wave Velocity Plots
CPT-01



Hammer to Rod String Distance 0.25 (m)
* = Not Determined

Shear Wave Velocity
Figure A-20

APPENDIX B
Laboratory Testing

APPENDIX B
LABORATORY TESTING

Soil samples obtained from the explorations were transported to our laboratory and examined to confirm or modify field classifications, as well as to evaluate index properties of the soil samples. Representative samples were selected for laboratory testing consisting of the determination of the moisture content, sieve analysis, and Atterberg Limit determinations. The tests were performed in general accordance with test methods of the American Society for Testing and Materials (ASTM) or other applicable procedures. Tests for corrosion potential were subcontracted to ALS Laboratory Group of Everett, Washington.

Moisture Content Testing

The natural moisture contents of selected soil samples obtained from the exploratory borings were determined in general accordance with ASTM D 2216 test procedures. The results from the moisture content determinations are presented in the boring logs.

Sieve Analyses

Sieve analyses were performed on selected samples in general accordance with ASTM D 422 to determine the sample grain size distribution. The wet sieve analysis method was used to determine the percentage of soil greater than the U.S. No. 200 mesh sieve. The results of the sieve analyses were plotted, classified in general accordance with the Unified Soil Classification System (USCS), and are presented in Figures B-1 through B-14.

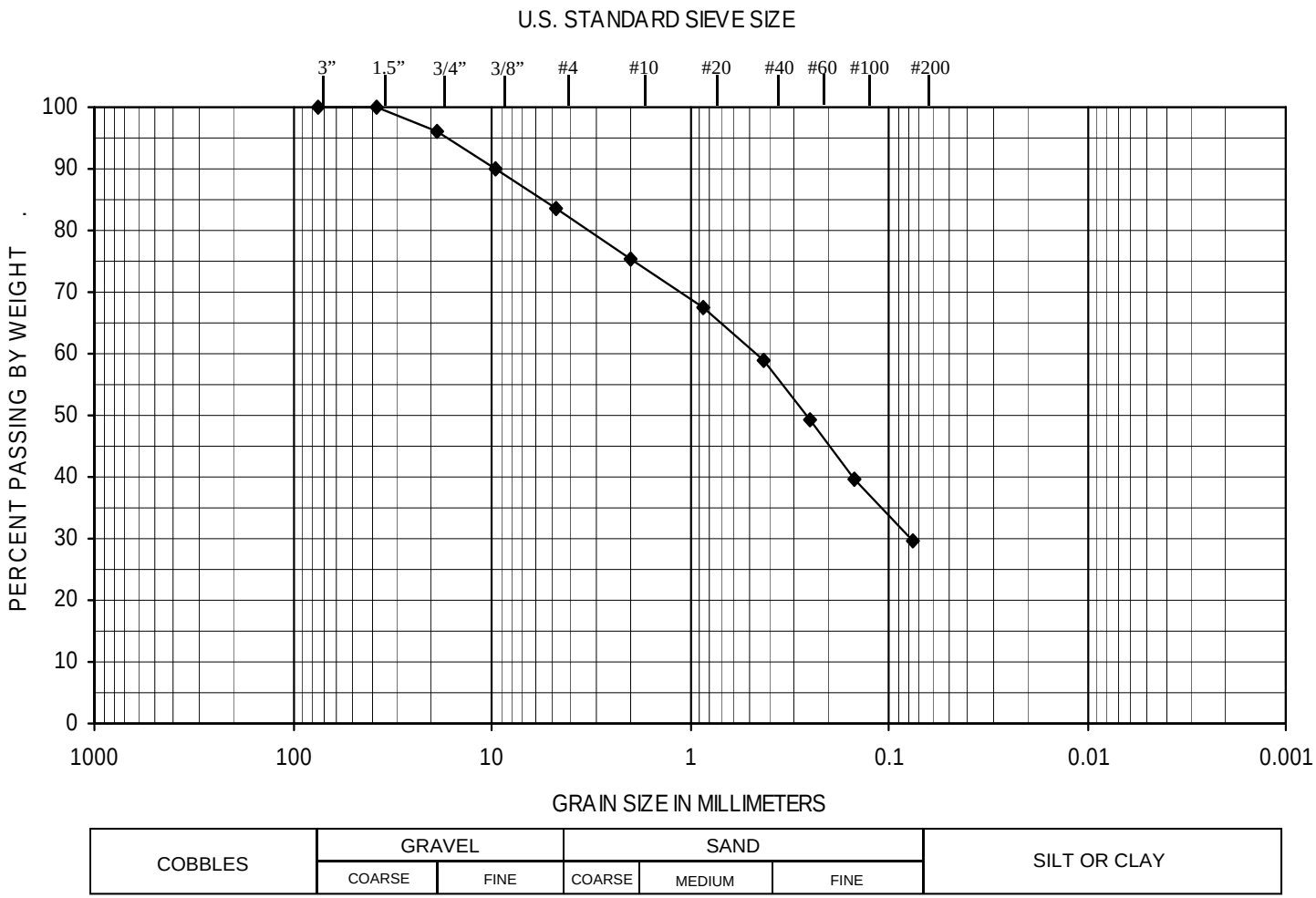
Atterberg Limits

Atterberg limit tests were completed for three soil samples. The tests were used to classify the soil as well as to aid in evaluating index properties and consolidation characteristics of the fine-grained soil deposits. The liquid limit and the plastic limit were obtained in general accordance with ASTM D 4318. The results of the Atterberg limits are summarized in Figures B-15 through B-18.

Chemical Testing

Chemical analytical testing for corrosivity was subcontracted to ALS Laboratory Group in Everett, Washington. Chemical testing was conducted in accordance with our scope and included pH, chloride, sulfate, sulfide, redox potential, and resistivity on selected samples. The results of these tests are presented in Figures B-19 through B-24 in this Appendix.

BELL: P:\03\0356106\00\LAB\[Sieve].ppt AF2:ims 05/11/10



Symbol	Exploration Number	Sample Depth (feet)	Soil Classification
♦	GEI-2	15	Gray silty fine to coarse sand with gravel (SM)

Sieve Analysis Results

Post Point WWTP Expansion
Bellingham, Washington

GEOENGINEERS

Figure B-1

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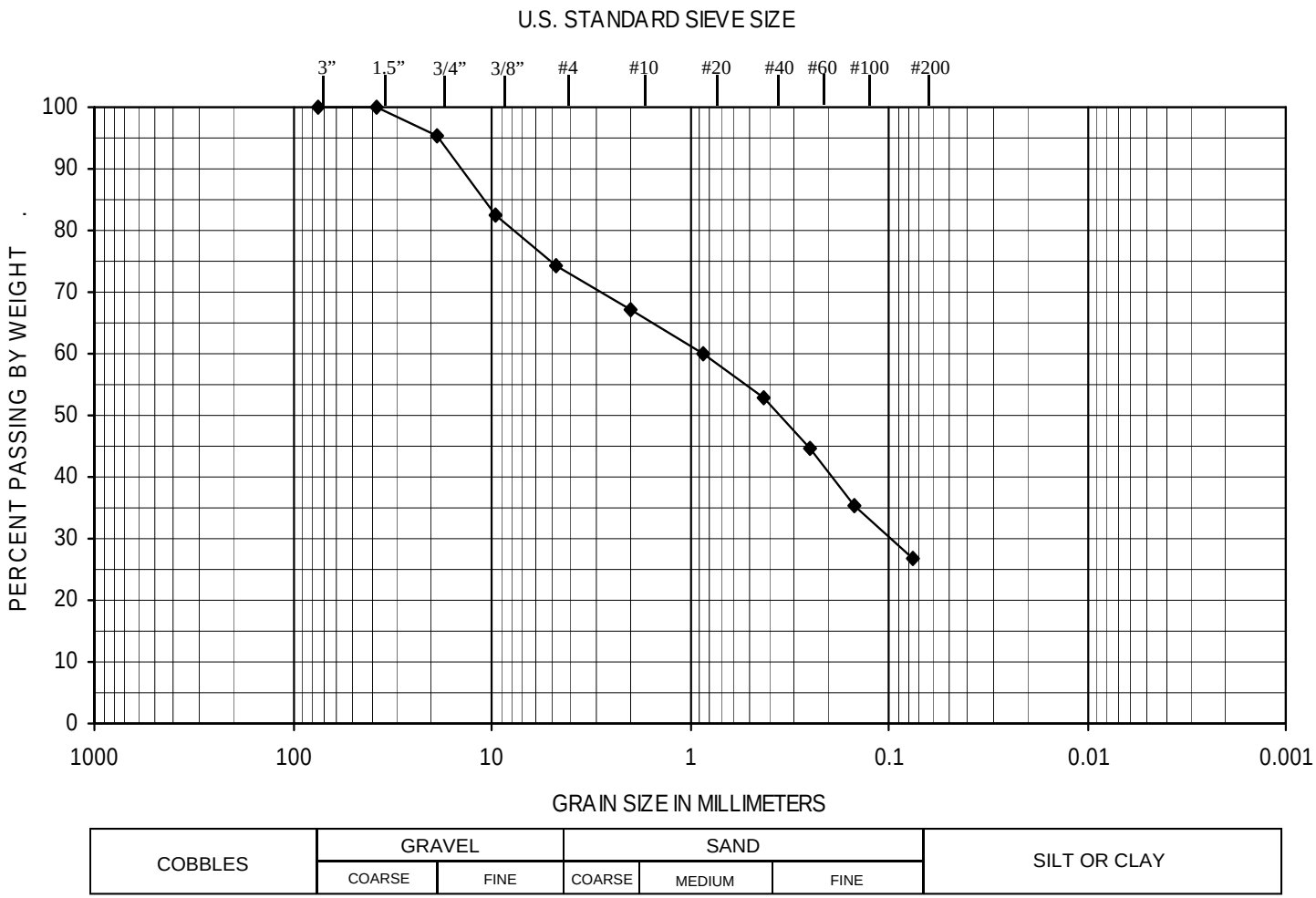

Symbol	Exploration Number	Sample Depth (feet)	Soil Classification
♦	GEI-3	10.8	Gray-brown silty fine to coarse sand with gravel (SM)

Sieve Analysis Results

Post Point WWTP Expansion
Bellingham, Washington

GEOENGINEERS

Figure B-2

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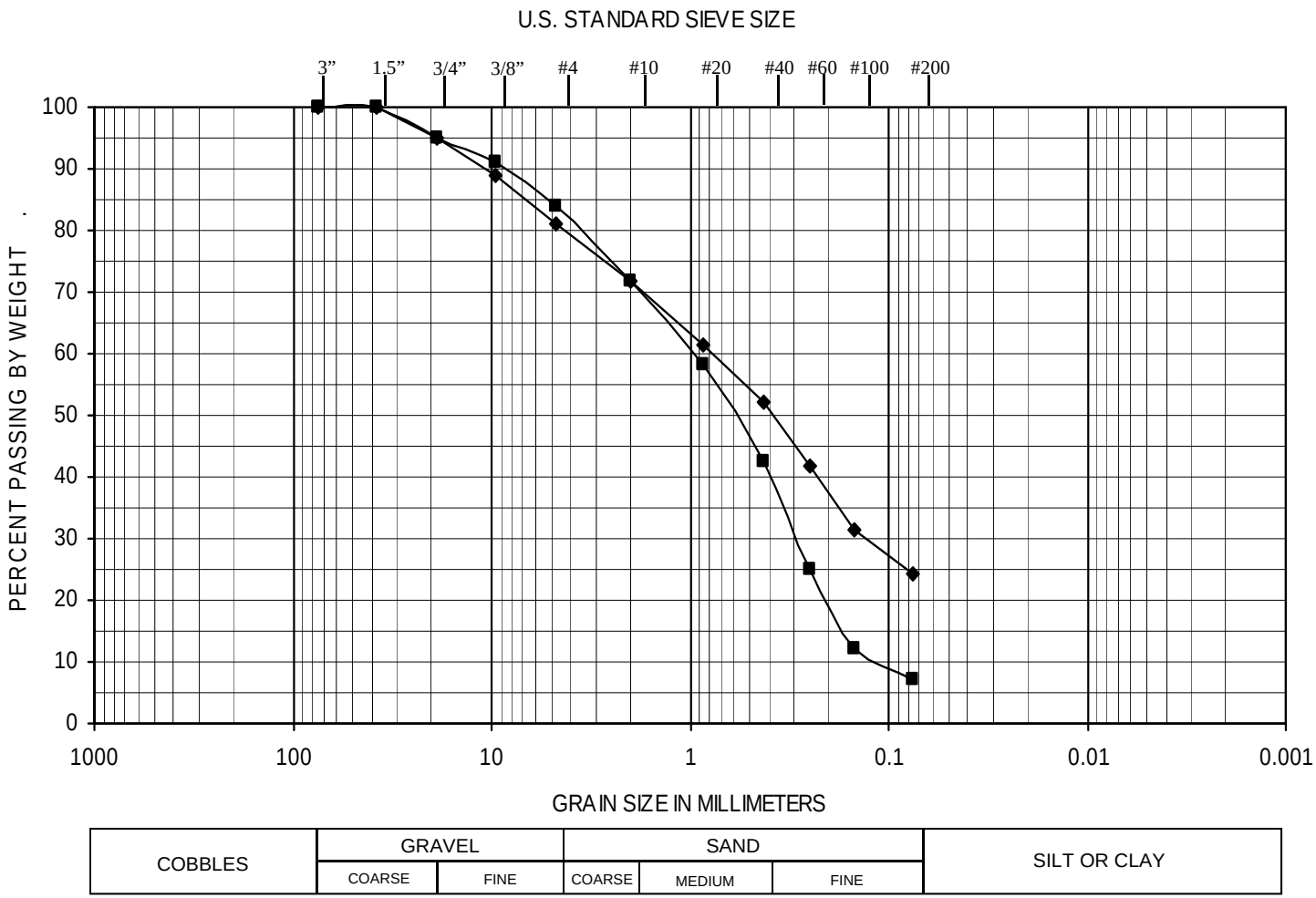
BELL: P:\03\0356106\00\LAB\[Sieve].ppt AF2:ims 05/11/10



Symbol	Exploration Number	Sample Depth (feet)	Soil Classification
♦	GEI-4	10	Brown silty fine to coarse sand with gravel (SM)
■	GEI-4	20½	Brown fine to coarse sand with silt and gravel (SP-SM)

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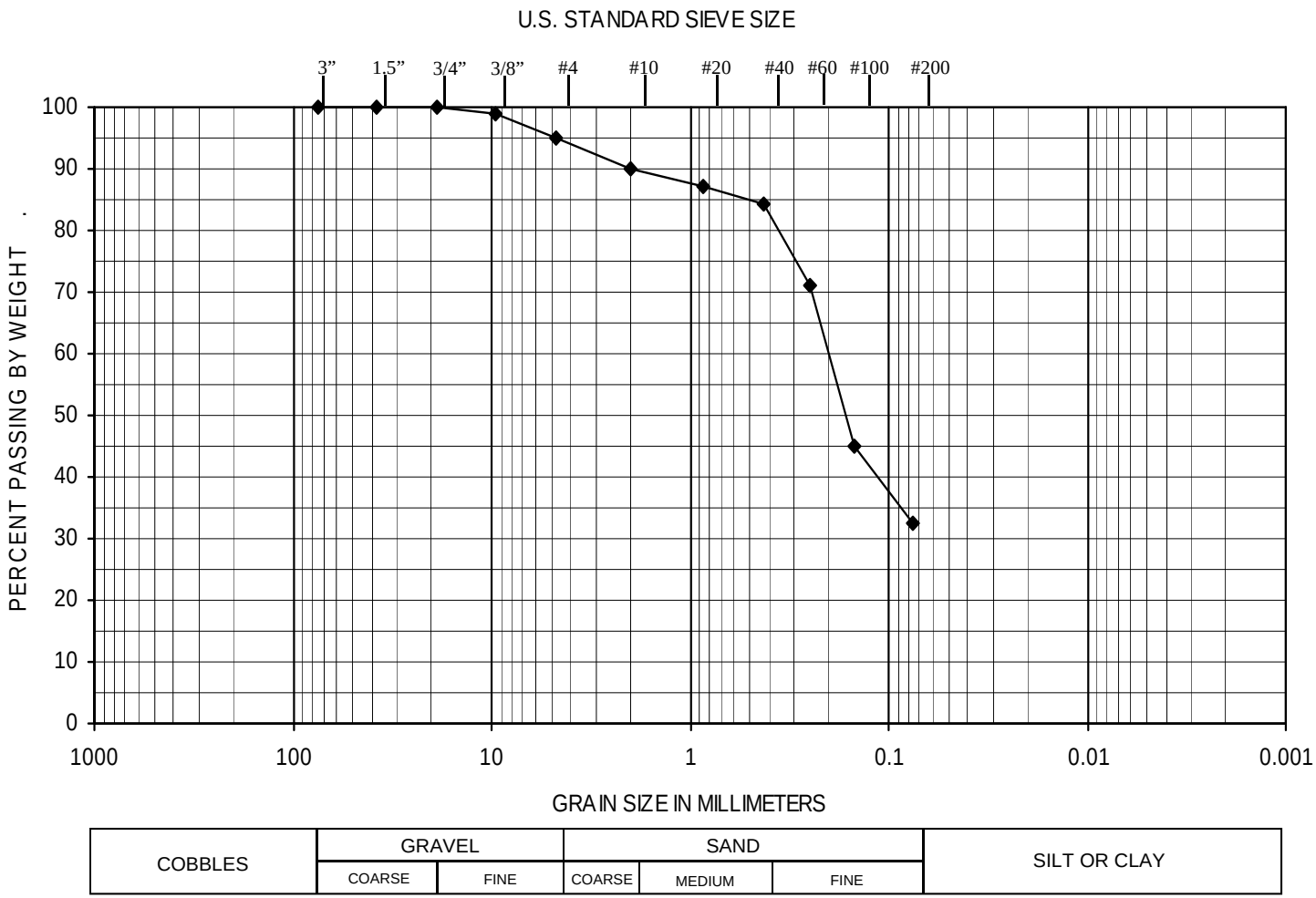
Sieve Analysis Results

Post Point WWTP Expansion
Bellingham, Washington

GEOENGINEERS

Figure B-3

BELL: P:\03\0356106\00\LAB\[Sieve].ppt AF2:ims 05/11/10



Symbol	Exploration Number	Sample Depth (feet)	Soil Classification
♦	GEI-5	17½	Brown-gray clayey fine to medium sand with occasional gravel (SC)

Sieve Analysis Results

Post Point WWTP Expansion
Bellingham, Washington

GEOENGINEERS

Figure B-4

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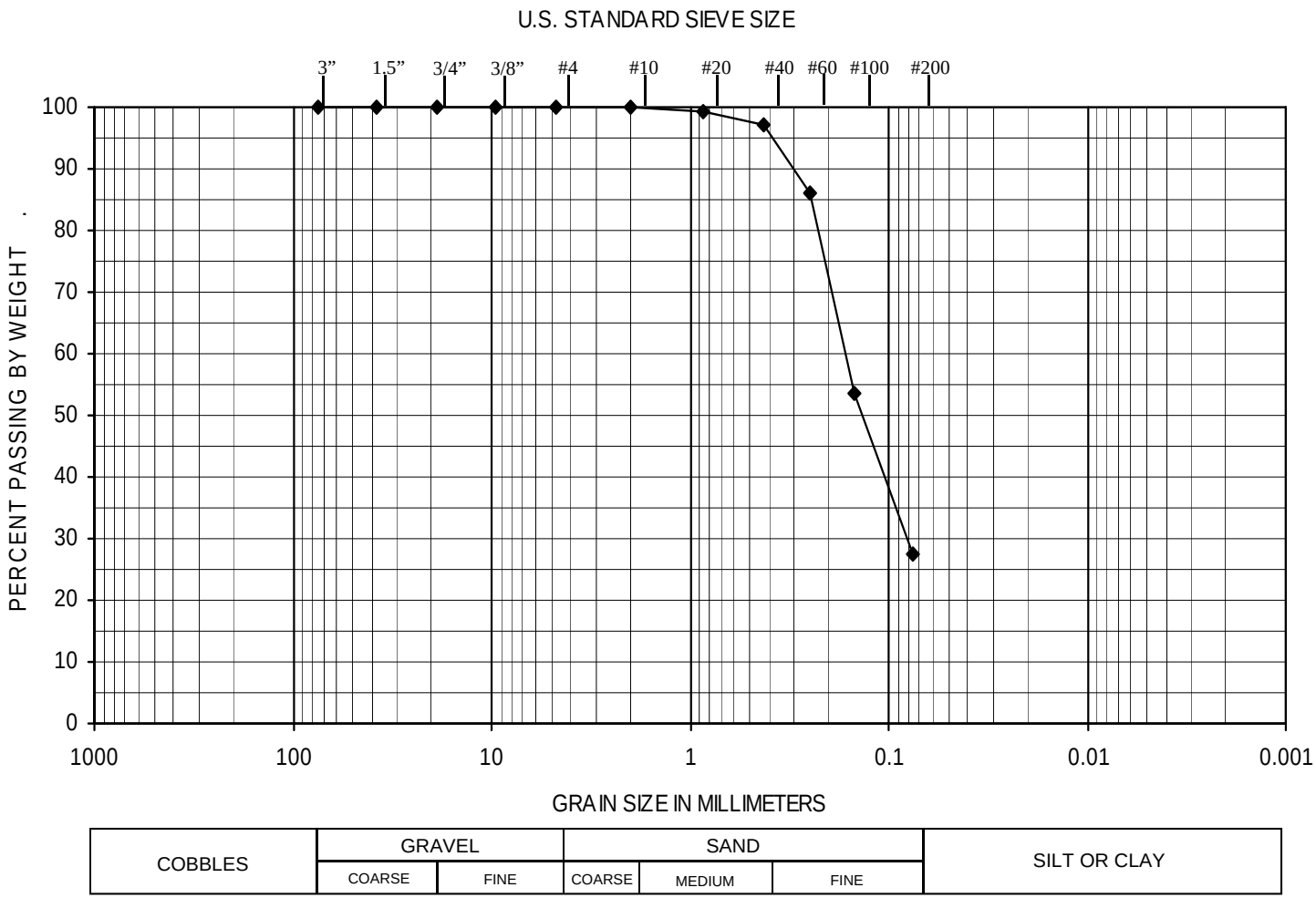
BELL: P:\03\0356106\00\LAB\[Sieve].ppt AF2:ims 05/11/10



Symbol	Exploration Number	Sample Depth (feet)	Soil Classification
♦	GEI-6	7½	Brown silty fine sand (SM)

Sieve Analysis Results

Post Point WWTP Expansion
Bellingham, Washington

GEOENGINEERS

Figure B-5

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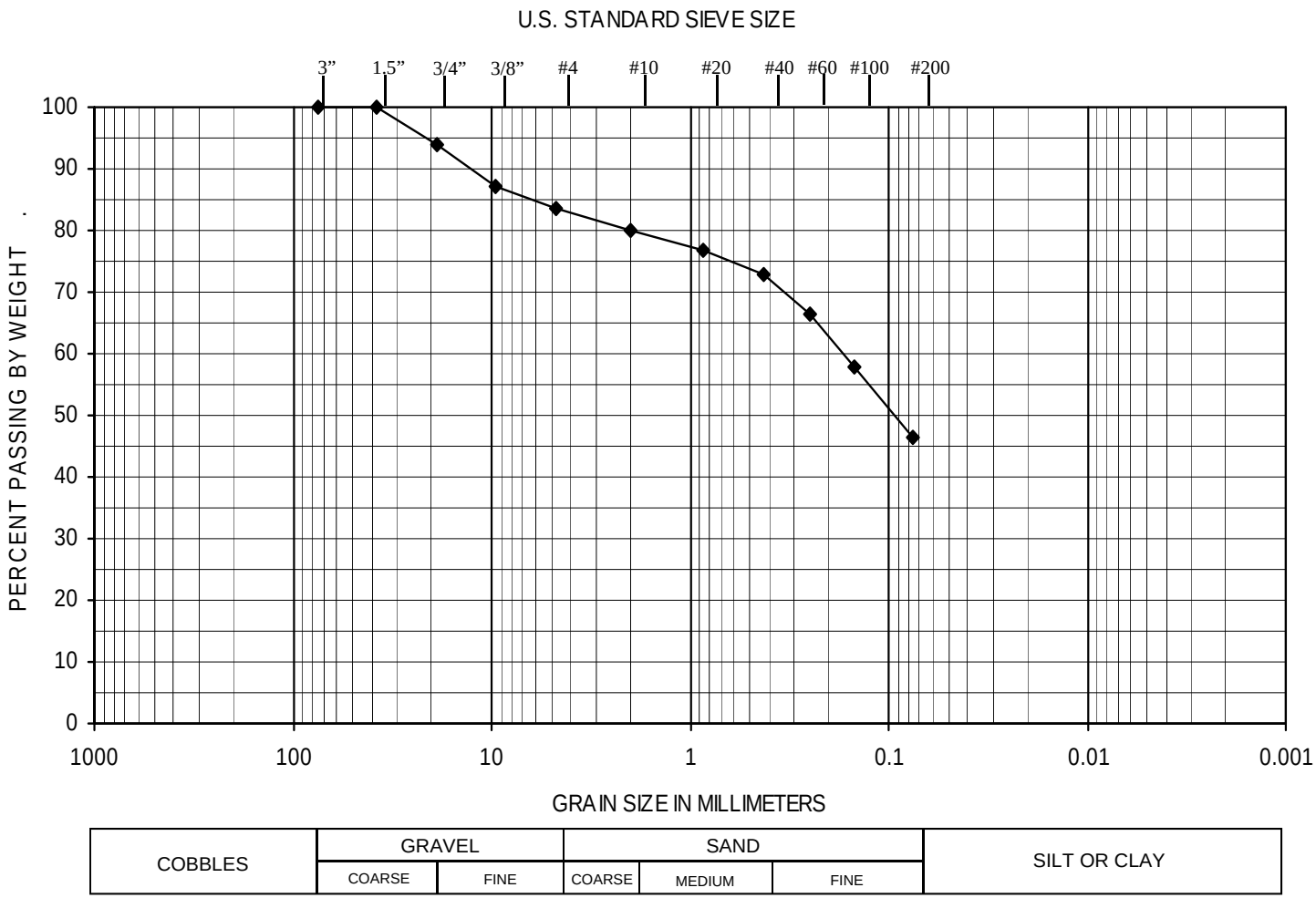
BELL: P:\03\0356106\00\LAB\[Sieve].ppt AF2:ims 05/11/10



Symbol	Exploration Number	Sample Depth (feet)	Soil Classification
♦	GEI-7	15	Gray clayey silty fine to coarse sand with gravel (SC)

Sieve Analysis Results

Post Point WWTP Expansion
Bellingham, Washington

GEOENGINEERS

Figure B-6

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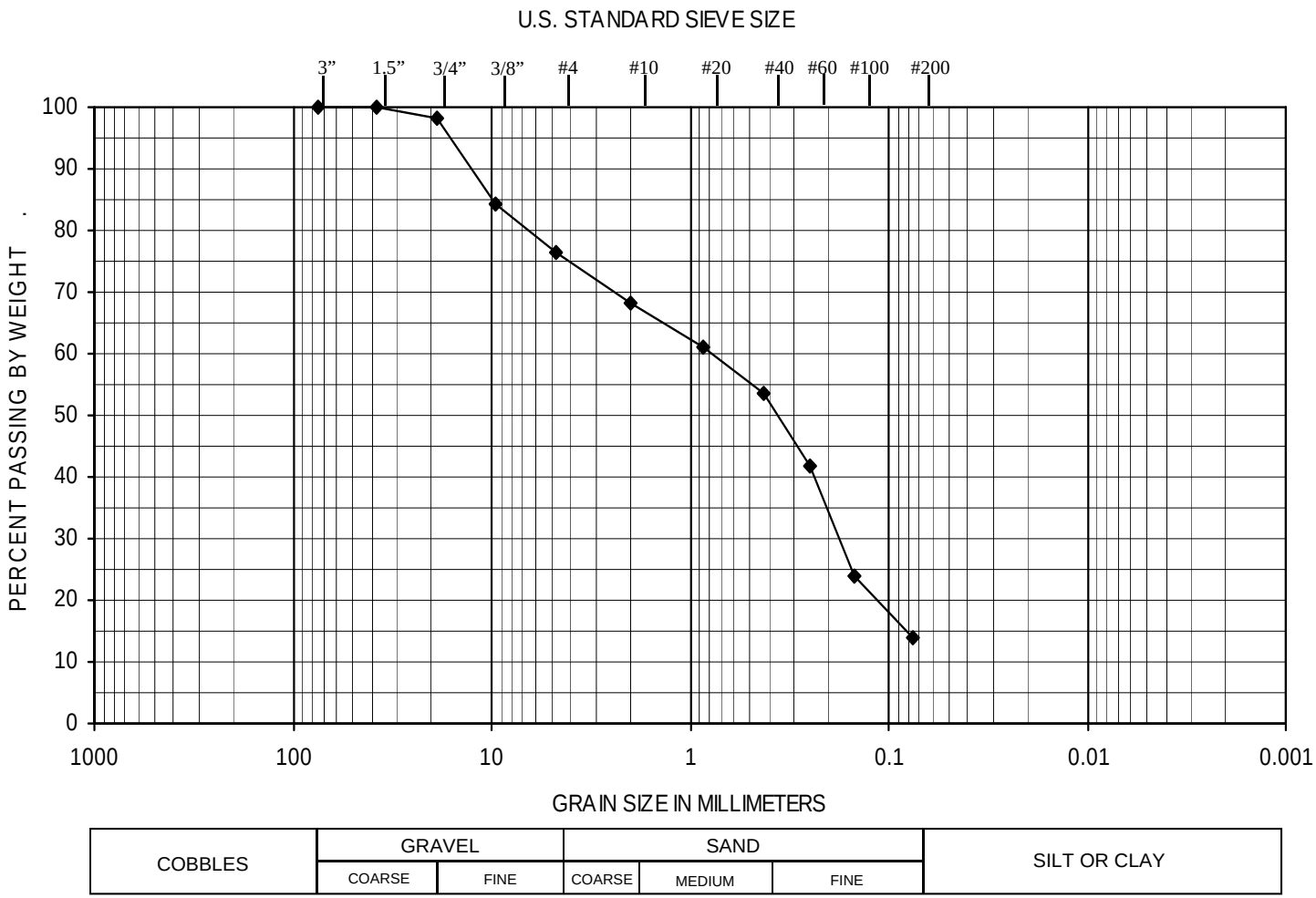
BELL: P:\03\0356106\00\LAB\[Sieve].ppt AF2:ims 05/11/10



Symbol	Exploration Number	Sample Depth (feet)	Soil Classification
♦	GEI-8	5	Brown fine to coarse sand with silt and gravel (SP-SM)

Sieve Analysis Results

Post Point WWTP Expansion
Bellingham, Washington

GEOENGINEERS

Figure B-7

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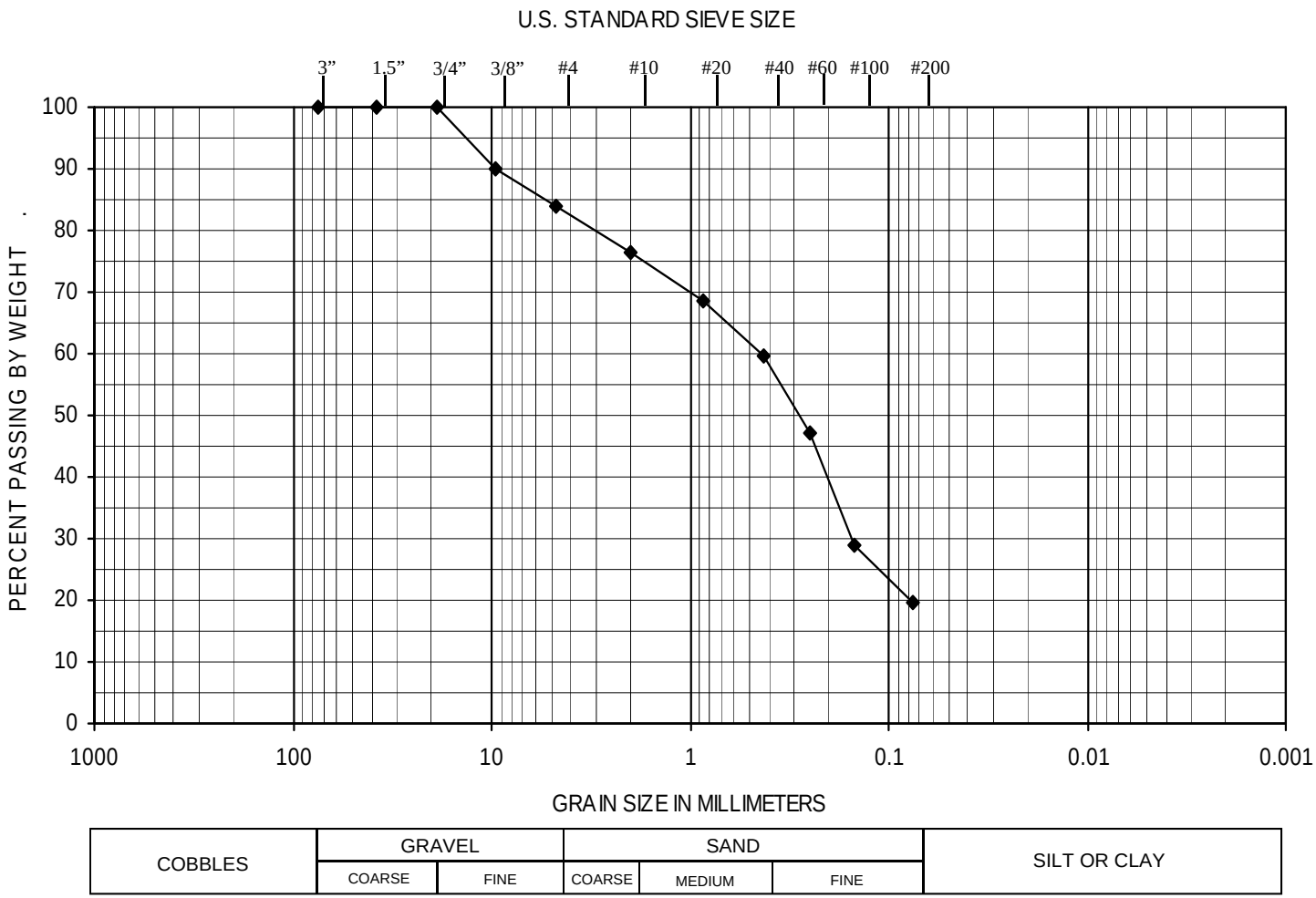
BELL: P:\03\0356106\00\LAB\[Sieve].ppt AF2:ims 05/11/10



Symbol	Exploration Number	Sample Depth (feet)	Soil Classification
♦	GEI-9	5½	Gray-brown silty fine to coarse sand with gravel (SM)

Sieve Analysis Results

Post Point WWTP Expansion
Bellingham, Washington

GEOENGINEERS

Figure B-8

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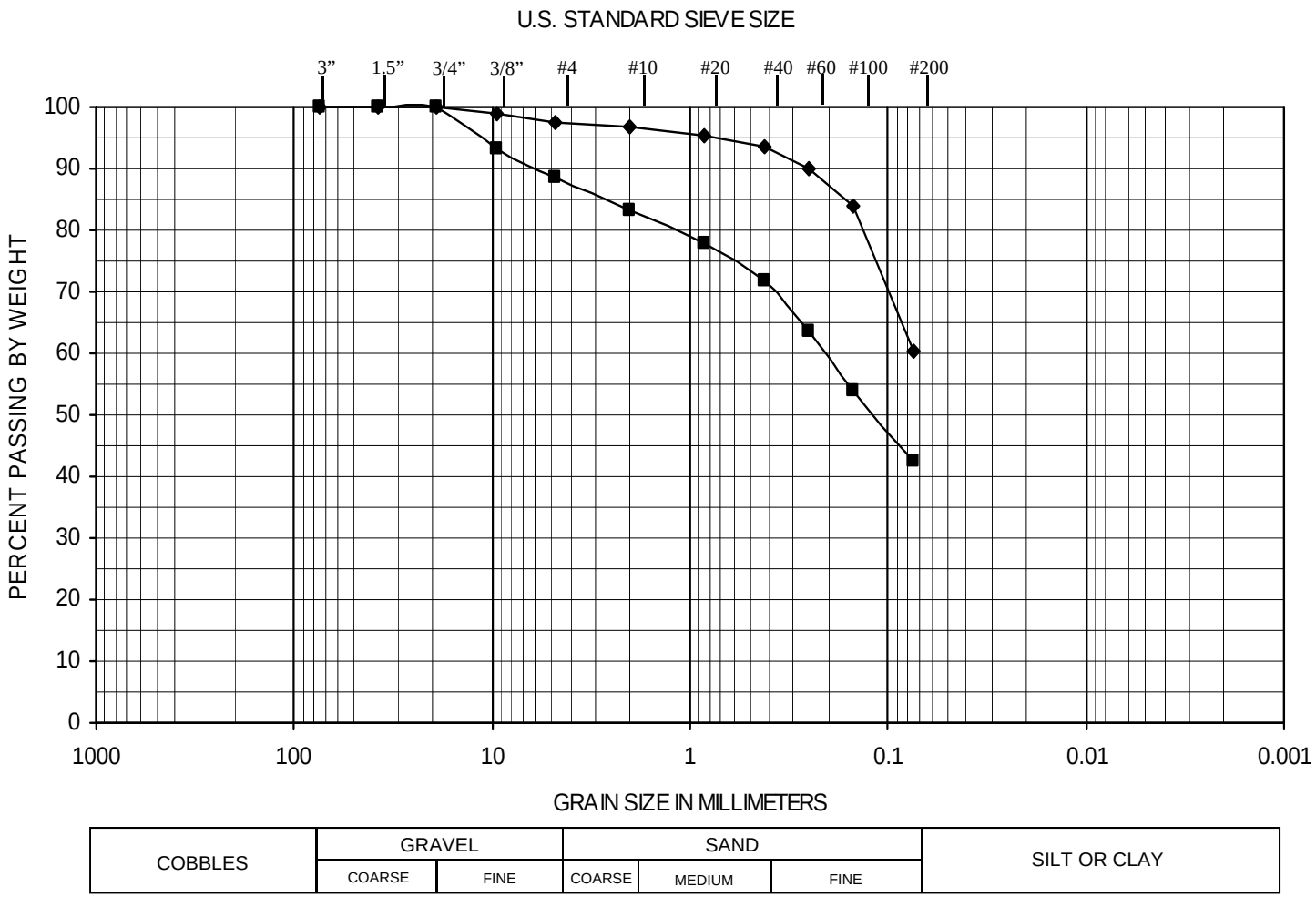
BEL: Sharepoint:\0356-106-00\Laboratory Data\[Post Point Sieve Results July borings.ppt SWC:ajh 7/29/10



Symbol	Exploration Number	Sample Depth (feet)	Soil Classification
♦	GEI-10	10	Gray sandy silt (ML)
■	GEI-10	25	Gray silty fine to coarse sand with gravel (SM)

Sieve Analysis Results

Post Point WWTP Expansion
Bellingham, Washington

GEOENGINEERS

Figure B-9

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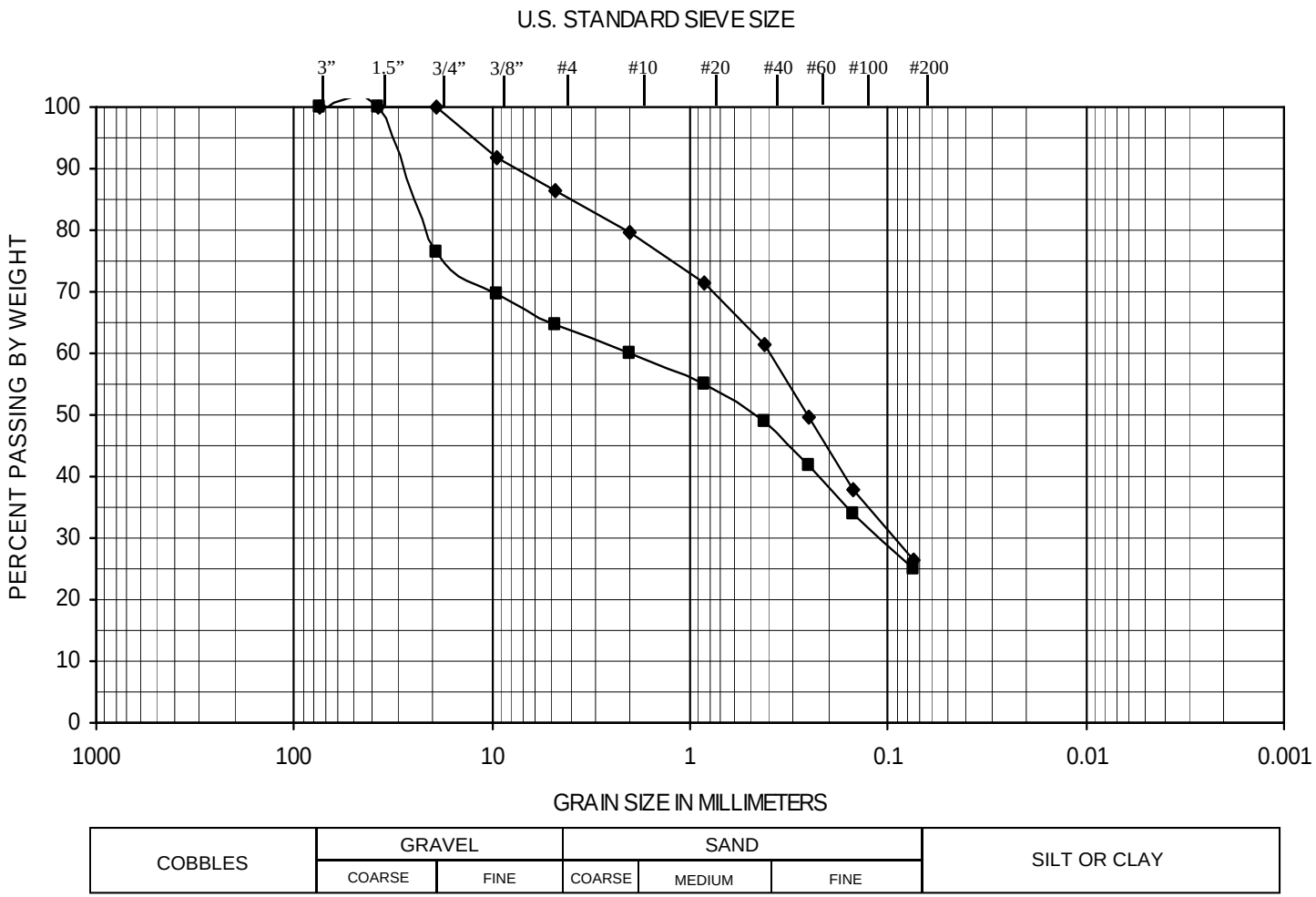
BEL: Sharepoint:\0356-106-00\Laboratory Data\[Post Point Sieve Results July borings.ppt SWC:ajh 7/29/10



Symbol	Exploration Number	Sample Depth (feet)	Soil Classification
♦	GEI-12	5	Gray silty fine to coarse sand with gravel (SM)
■	GEI-12	10	Gray-brown silty fine to coarse sand with gravel (SM)

Sieve Analysis Results

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Bellingham, Washington

GEOENGINEERS

Figure B-10

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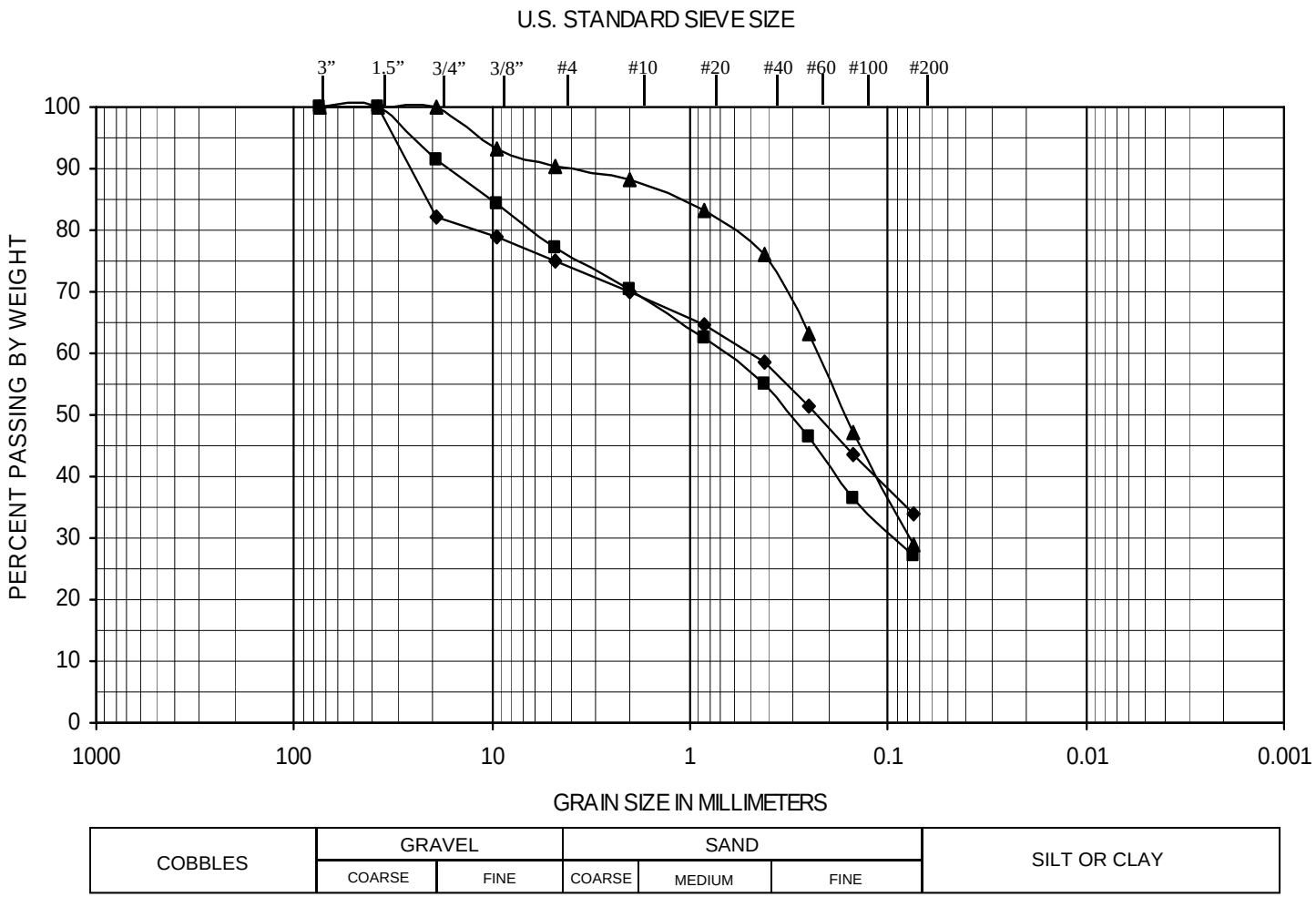
BEL: Sharepoint:\0356-106-00\Laboratory Data\[Post Point Sieve Results July borings.ppt SWC:ajh 7/29/10



Symbol	Exploration Number	Sample Depth (feet)	Soil Classification
♦	GEI-13	5	Gray clayey sand with occasional gravel (SC)
■	GEI-13	25	Gray-brown silty fine to coarse sand with gravel (SM)
▲	GEI-14	5	Brown silty fine to medium sand with occasional gravel (SM)

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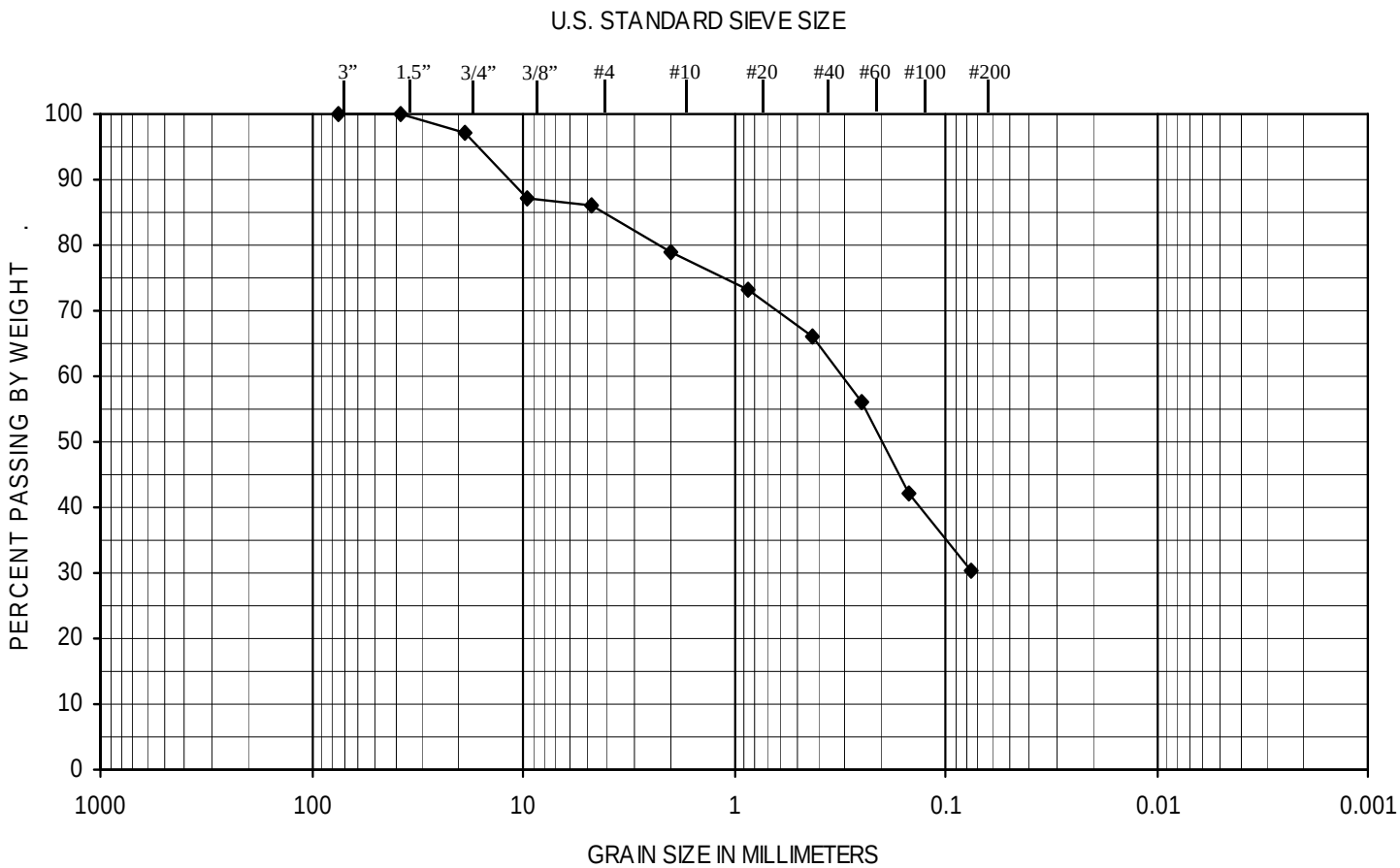
Sieve Analysis Results

Post Point WWTP Expansion
Bellingham, Washington

GEOENGINEERS

Figure B-11



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

Symbol	Exploration Number	Sample Depth (feet)	Soil Classification
♦	TP-1	9	Brown-gray silty fine to coarse sand with gravel (SM)

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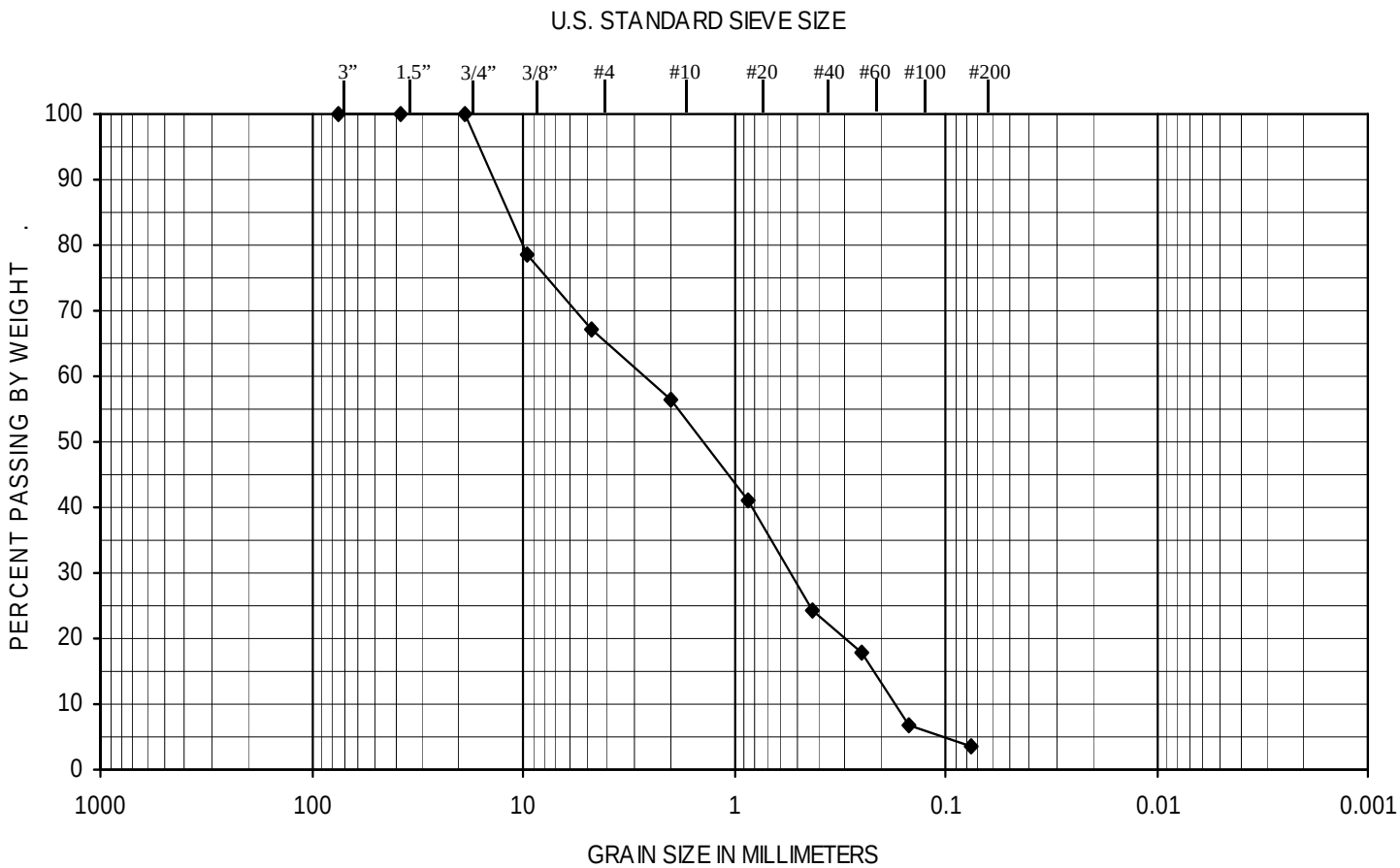
Sieve Analysis Results

Post Point WWTP Expansion
Bellingham, Washington

GEOENGINEERS

Figure B-12



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

Symbol	Exploration Number	Sample Depth (feet)	Soil Classification
♦	TP-2	4	Brown fine to coarse sand with gravel (SP)

Sieve Analysis Results

Post Point WWTP Expansion
Bellingham, Washington

GEOENGINEERS

Figure B-13

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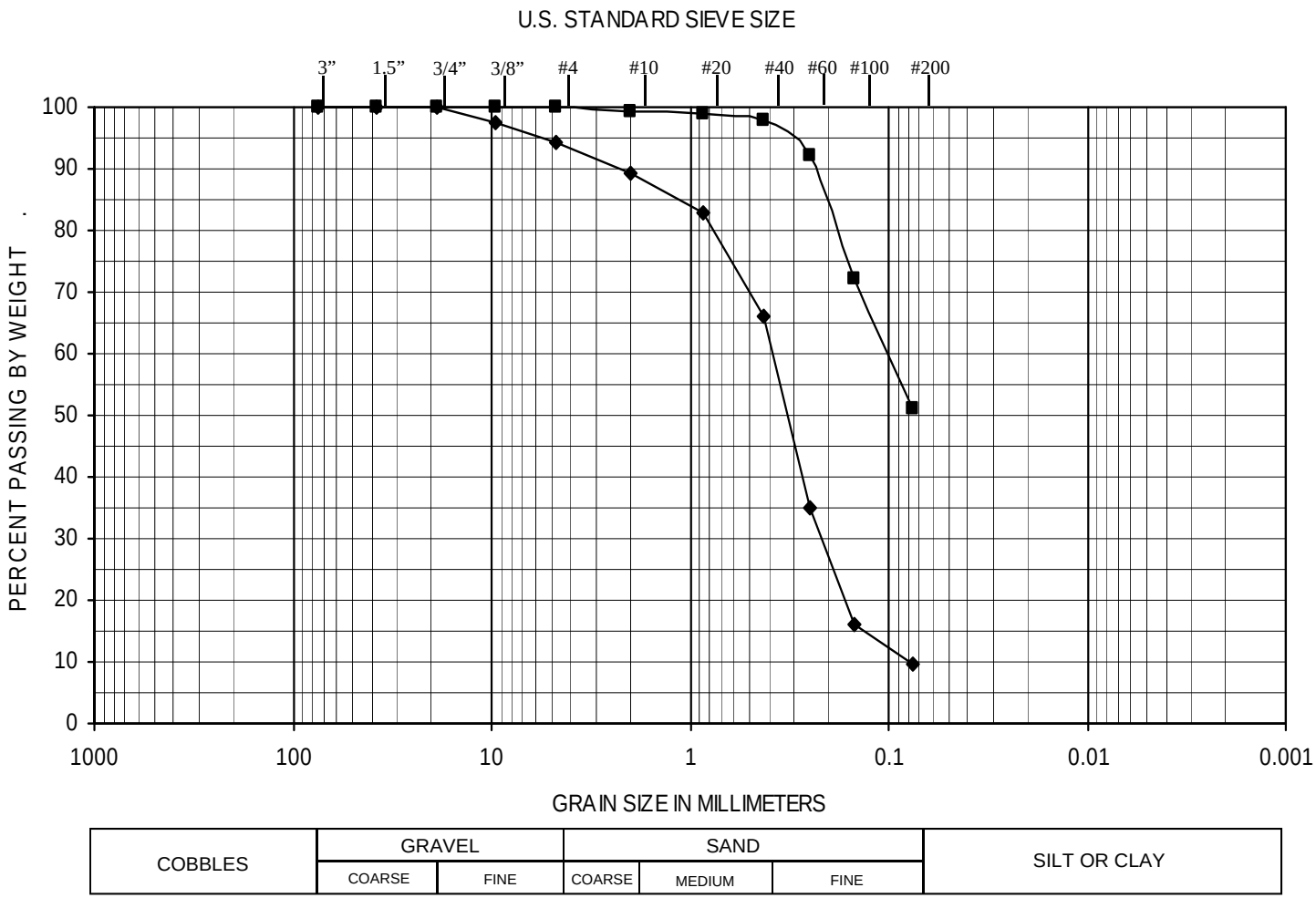
BELL: P:\03\0356106\00\LAB\[Sieve].ppt AF2:ims 05/11/10



Symbol	Exploration Number	Sample Depth (feet)	Soil Classification
♦	TP-3	2 ½	Brown fine to medium sand with silt and occasional gravel (SP-SM)
■	TP-3	7½	Brown fine sandy silt (ML)

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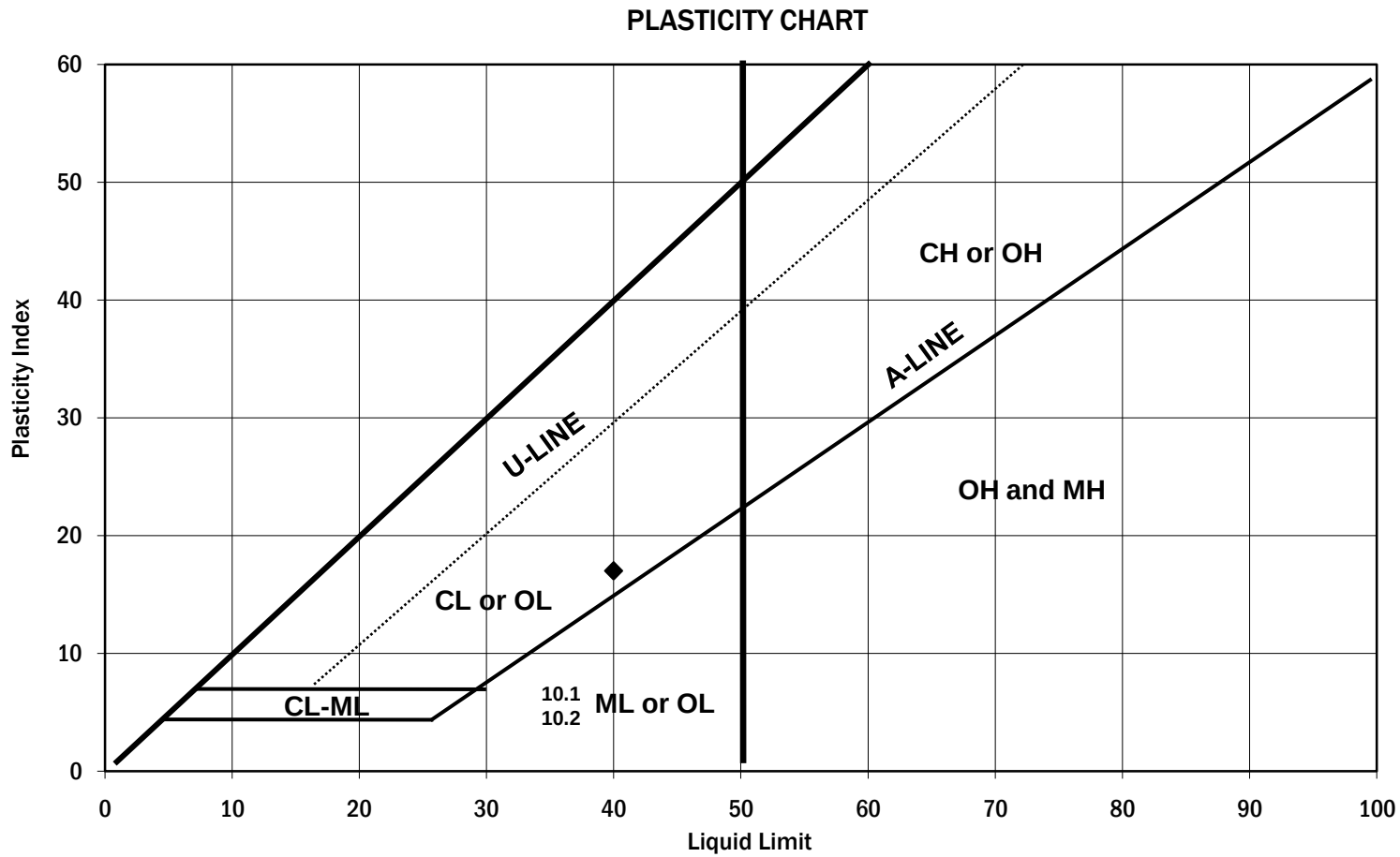
Sieve Analysis Results

Post Point WWTP Expansion
Bellingham, Washington

GEOENGINEERS

Figure B-14



Symbol	Exploration Number	Sample Depth (feet)	Moisture Content (%)	Liquid Limit (%)	Plasticity Index (%)	Soil Description
♦	GEI-1	30	33	40	17	Gray Clay (CL)

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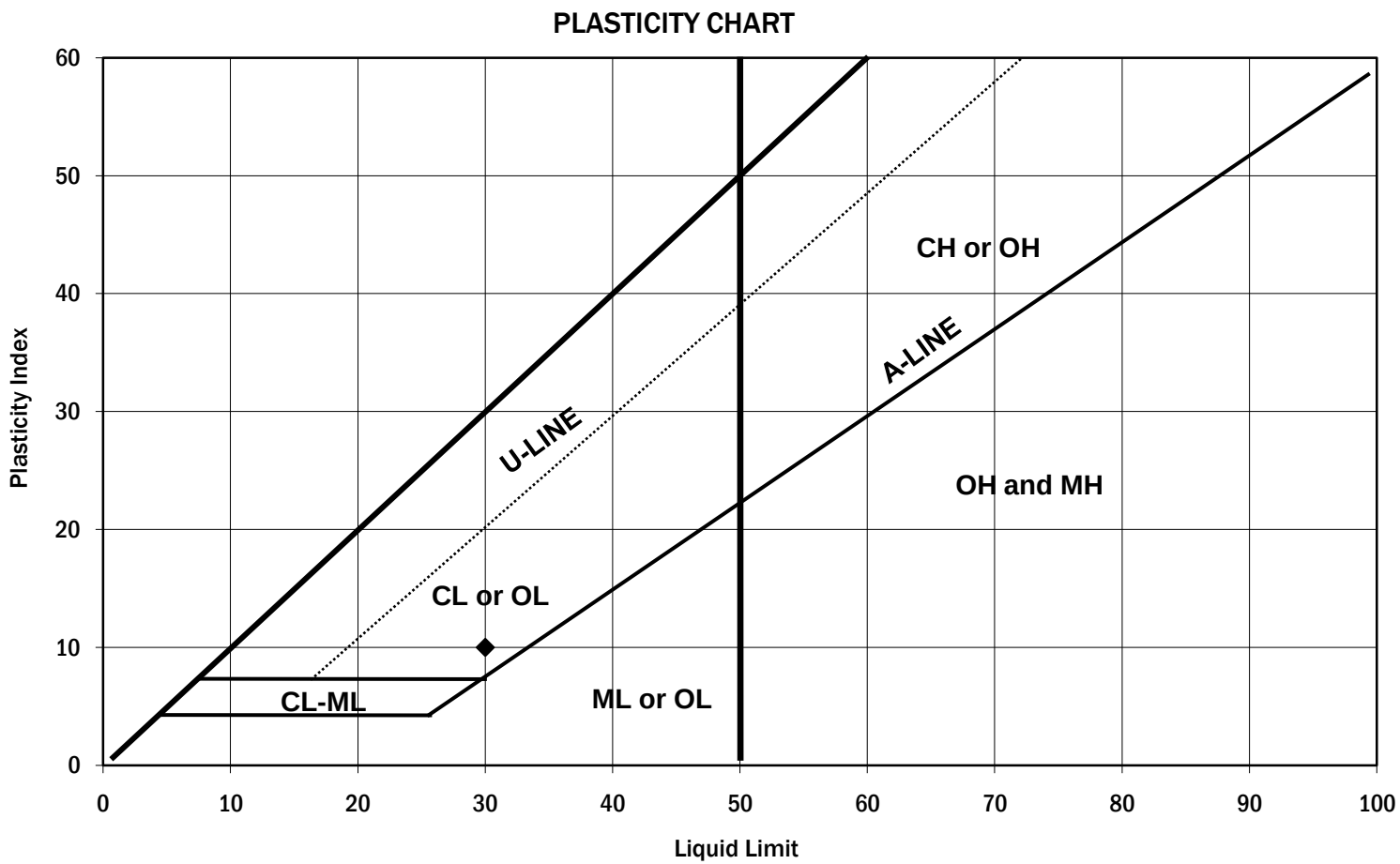
Atterberg Limits Test Results

Post Point WWTP Expansion
Bellingham, Washington

GeoEngineers

Figure B-15



Symbol	Exploration Number	Sample Depth (feet)	Moisture Content (%)	Liquid Limit (%)	Plasticity Index (%)	Soil Description
♦	GEI-3	15	24	30	10	Gray clay (CL)

Atterberg Limits Test Results

Post Point WWTP Expansion
Bellingham, Washington

GeoEngineers

Figure B-16

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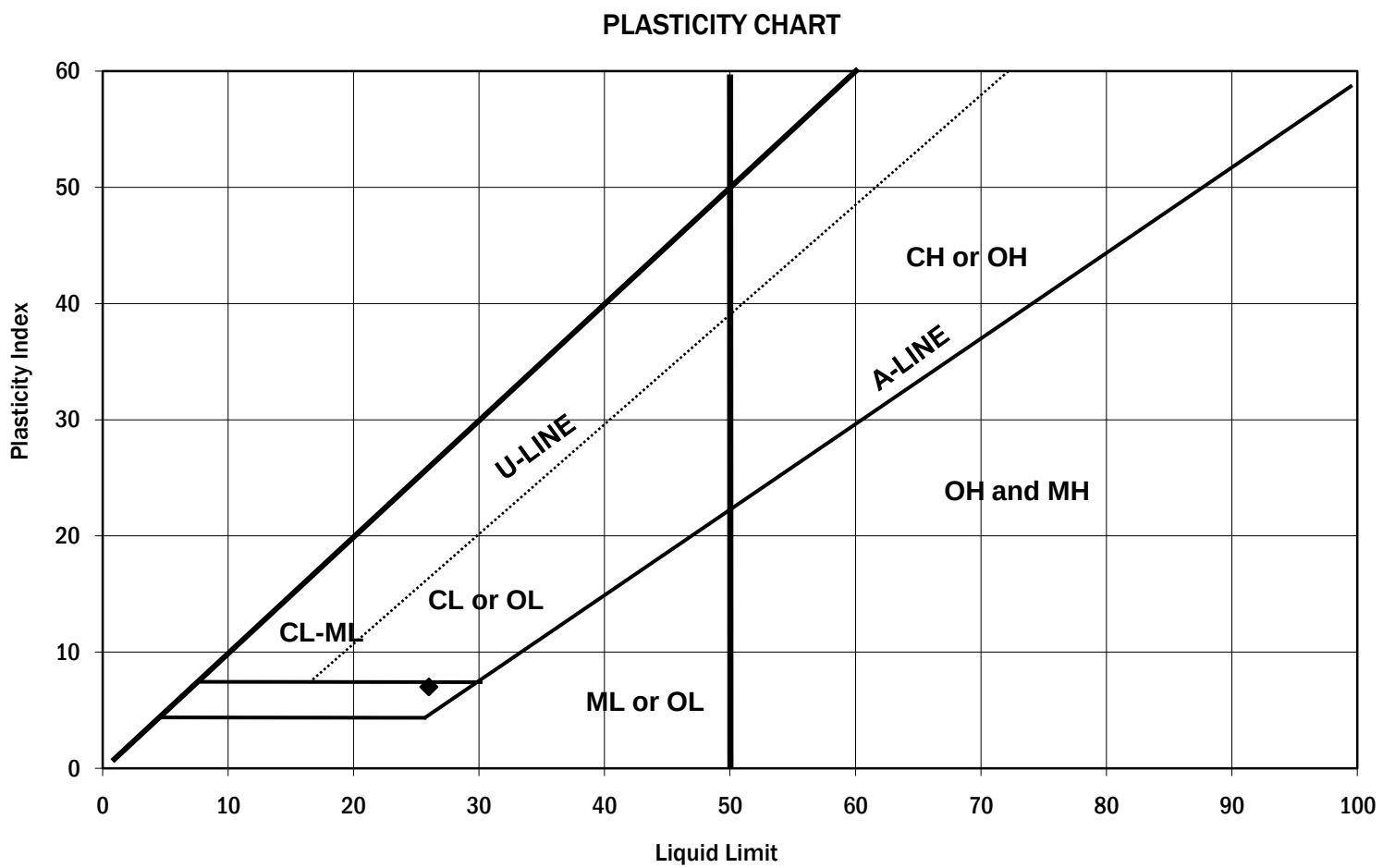

Symbol	Exploration Number	Sample Depth (feet)	Moisture Content (%)	Liquid Limit (%)	Plasticity Index (%)	Soil Description
♦	GEI-4	13.5	22	26	7	Gray silty clay (CL-ML)

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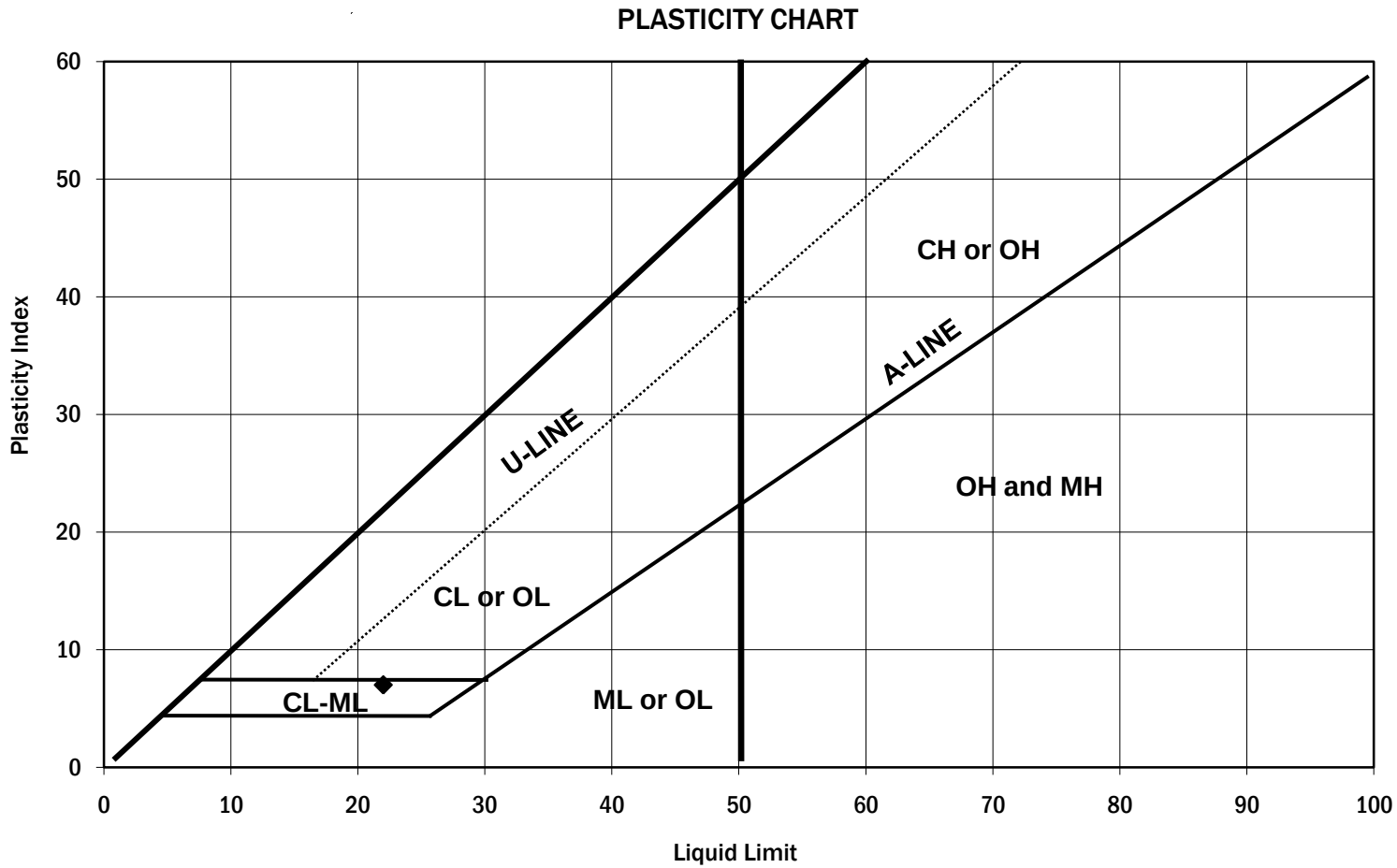
Atterberg Limits Test Results

Post Point WWTP Expansion
Bellingham, Washington

GeoEngineers

Figure B-17



Symbol	Exploration Number	Sample Depth (feet)	Moisture Content (%)	Liquid Limit (%)	Plasticity Index (%)	Soil Description
♦	GEI-7	15	16	22	7	Gray silty clay (CL-ML)

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Atterberg Limits Test Results

Post Point WWTP Expansion
Bellingham, Washington

GeoEngineers

Figure B-18

ALS Laboratory Group
ANALYTICAL CHEMISTRY & TESTING SERVICES

CERTIFICATE OF ANALYSIS

CLIENT: Geoengineers, Inc.
600 DuPont St.
Bellingham, WA 98225

DATE: 6/8/2010
ALS JOB#: 1005039
DATE RECEIVED: 5/12/2010
WDOE ACCREDITATION #: C1336

CLIENT CONTACT: Sean Cool
CLIENT PROJECT ID: 0356-106-00
CLIENT SAMPLE ID: 4/27/2010 GEI-2 S-5 15'
ALS SAMPLE #: -01

DATA RESULTS

pH by EPA-9045

ANALYTE	RESULTS*	REPORTING LIMITS	DETECTION LIMITS	DILUTION FACTOR	UNITS**	ANALYSIS BY
pH	7.2	NA	0	1	PH UNITS	SMR

QC Batch prepared/extracted by EPA-9045 on 5/26/2010.
Sample analyzed by EPA-9045 on 5/26/2010.

Anions by EPA-300.0M

ANALYTE	RESULTS*	REPORTING LIMITS	DETECTION LIMITS	DILUTION FACTOR	UNITS**	ANALYSIS BY
Chloride	180	10	0	10	MG/KG	GAP
Sulfate	340	20	0	10	MG/KG	GAP

QC Batch prepared/extracted by EPA-300.0M on 5/28/2010.
Sample analyzed by EPA-300.0M on 5/28/2010.

Sulfide by EPA-376.1

ANALYTE	RESULTS*	REPORTING LIMITS	DETECTION LIMITS	DILUTION FACTOR	UNITS**	ANALYSIS BY
Sulfide	ND	1.1	0	1	MG/L	ARI2

QC Batch prepared/extracted by EPA-376.1 on 5/27/2010.
Sample analyzed by EPA-376.1 on 5/27/2010.

Redox Potential by SM-2580

ANALYTE	RESULTS*	REPORTING LIMITS	DETECTION LIMITS	DILUTION FACTOR	UNITS**	ANALYSIS BY
Redox Potential	480	0.10	0.1	1	MV	ARI2

QC Batch prepared/extracted by SM2580 on 5/28/2010.
Sample analyzed by SM2580 on 5/28/2010.

Soil Resistivity by ASTM G-57

ANALYTE	RESULTS*	REPORTING LIMITS	DETECTION LIMITS	DILUTION FACTOR	UNITS**	ANALYSIS BY
Resistivity	2500@ 21.5C	NA	0	1	OHM-CM	ARI2

QC Batch prepared/extracted by ASTM G-57 on 5/28/2010.
Sample analyzed by ASTM G-57 on 5/28/2010.

* Note: pH received and analyzed outside of hold time.

* "ND" INDICATES ANALYTE ANALYZED FOR BUT NOT DETECTED AT LEVEL ABOVE REPORTING LIMT.

** UNITS FOR ALL NON-LIQUID SAMPLES ARE REPORTED ON A DRY WEIGHT BASIS.

APPROVED BY:

8620 Holly Drive Suite 100 Everett, WA 98208 425 356-2600 FAX 425 356-2626 Seattle 206 292-9059

ALS Laboratory Group
ANALYTICAL CHEMISTRY & TESTING SERVICES

CERTIFICATE OF ANALYSIS

CLIENT: Geoengineers, Inc.
600 DuPont St.
Bellingham, WA 98225

DATE: 6/8/2010
ALS JOB#: 1005039
DATE RECEIVED: 5/12/2010
WDOE ACCREDITATION #: C1336

CLIENT CONTACT: Sean Cool
CLIENT PROJECT ID: 0356-106-00
CLIENT SAMPLE ID: 4/27/2010 GEI-4 S-3 7.5'
ALS SAMPLE #: -03

DATA RESULTS

pH by EPA-9045

ANALYTE	RESULTS*	REPORTING LIMITS	DETECTION LIMITS	DILUTION FACTOR	UNITS**	ANALYSIS BY
pH	8.3	NA	0	1	PH UNITS	SMR

QC Batch prepared/extracted by EPA-9045 on 5/26/2010.
Sample analyzed by EPA-9045 on 5/26/2010.

Anions by EPA-300.0M

ANALYTE	RESULTS*	REPORTING LIMITS	DETECTION LIMITS	DILUTION FACTOR	UNITS**	ANALYSIS BY
Chloride	32	10	0	10	MG/KG	GAP
Sulfate	410	20	0	10	MG/KG	GAP

QC Batch prepared/extracted by EPA-300.0M on 5/28/2010.
Sample analyzed by EPA-300.0M on 5/28/2010.

Sulfide by EPA-376.1

ANALYTE	RESULTS*	REPORTING LIMITS	DETECTION LIMITS	DILUTION FACTOR	UNITS**	ANALYSIS BY
Sulfide	ND	1.1	0	1	MG/L	ARI2

QC Batch prepared/extracted by EPA-376.1 on 5/27/2010.
Sample analyzed by EPA-376.1 on 5/27/2010.

Redox Potential by SM-2580

ANALYTE	RESULTS*	REPORTING LIMITS	DETECTION LIMITS	DILUTION FACTOR	UNITS**	ANALYSIS BY
Redox Potential	400	0.10	0.1	1	MV	ARI2

QC Batch prepared/extracted by SM2580 on 5/28/2010.
Sample analyzed by SM2580 on 5/28/2010.

Soil Resistivity by ASTM G-57

ANALYTE	RESULTS*	REPORTING LIMITS	DETECTION LIMITS	DILUTION FACTOR	UNITS**	ANALYSIS BY
Resistivity	6500@ 22.0C	NA	0	1	OHM-CM	ARI2

QC Batch prepared/extracted by ASTM G-57 on 5/28/2010.
Sample analyzed by ASTM G-57 on 5/28/2010.

* Note: pH received and analyzed outside of hold time.

* "ND" INDICATES ANALYTE ANALYZED FOR BUT NOT DETECTED AT LEVEL ABOVE REPORTING LIMT.

** UNITS FOR ALL NON-LIQUID SAMPLES ARE REPORTED ON A DRY WEIGHT BASIS.

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Bellingham, WA 98225

DATE: 6/8/2010
ALS JOB#: 1005039
DATE RECEIVED: 5/12/2010
WDOE ACCREDITATION #: C1336

CLIENT CONTACT: Sean Cool
CLIENT PROJECT ID: 0356-106-00
CLIENT SAMPLE ID: 4/28/2010 GEI-6 S-4 10'
ALS SAMPLE #: -05

DATA RESULTS

pH by EPA-9045

ANALYTE	RESULTS*	REPORTING LIMITS	DETECTION LIMITS	DILUTION FACTOR	UNITS**	ANALYSIS BY
pH	7.5	NA	0	1	PH UNITS	SMR

QC Batch prepared/extracted by EPA-9045 on 5/26/2010.
Sample analyzed by EPA-9045 on 5/26/2010.

Anions by EPA-300.0M

ANALYTE	RESULTS*	REPORTING LIMITS	DETECTION LIMITS	DILUTION FACTOR	UNITS**	ANALYSIS BY
Chloride	23	10	0	10	MG/KG	GAP
Sulfate	190	20	0	10	MG/KG	GAP

QC Batch prepared/extracted by EPA-300.0M on 5/28/2010.
Sample analyzed by EPA-300.0M on 5/28/2010.

Sulfide by EPA-376.1

ANALYTE	RESULTS*	REPORTING LIMITS	DETECTION LIMITS	DILUTION FACTOR	UNITS**	ANALYSIS BY
Sulfide	ND	1.2	0	1	MG/L	ARI2

QC Batch prepared/extracted by EPA-376.1 on 5/27/2010.
Sample analyzed by EPA-376.1 on 5/27/2010.

Redox Potential by SM-2580

ANALYTE	RESULTS*	REPORTING LIMITS	DETECTION LIMITS	DILUTION FACTOR	UNITS**	ANALYSIS BY
Redox Potential	380	0.10	0.1	1	MV	ARI2

QC Batch prepared/extracted by SM2580 on 5/28/2010.
Sample analyzed by SM2580 on 5/28/2010.

Soil Resistivity by ASTM G-57

ANALYTE	RESULTS*	REPORTING LIMITS	DETECTION LIMITS	DILUTION FACTOR	UNITS**	ANALYSIS BY
Resistivity	4350@ 21.5C	NA	0	1	OHM-CM	ARI2

QC Batch prepared/extracted by ASTM G-57 on 5/28/2010.
Sample analyzed by ASTM G-57 on 5/28/2010.

* Note: pH received and analyzed outside of hold time.

* "ND" INDICATES ANALYTE ANALYZED FOR BUT NOT DETECTED AT LEVEL ABOVE REPORTING LIMT.

** UNITS FOR ALL NON-LIQUID SAMPLES ARE REPORTED ON A DRY WEIGHT BASIS.

APPROVED BY:

8620 Holly Drive Suite 100 Everett, WA 98208 425 356-2600 FAX 425 356-2626 Seattle 206 292-9059

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600 DuPont St.
Bellingham, WA 98225

DATE: 6/8/2010
ALS JOB#: 1005039
DATE RECEIVED: 5/12/2010
WDOE ACCREDITATION #: C1336

CLIENT CONTACT: Sean Cool
CLIENT PROJECT ID: 0356-106-00
CLIENT SAMPLE ID: 4/27/2010 GEI-9 S-4 10'
ALS SAMPLE #: -06

DATA RESULTS

pH by EPA-9045

ANALYTE	RESULTS*	REPORTING LIMITS	DETECTION LIMITS	DILUTION FACTOR	UNITS**	ANALYSIS BY
pH	7.7	NA	0	1	PH UNITS	SMR

QC Batch prepared/extracted by EPA-9045 on 5/26/2010.
Sample analyzed by EPA-9045 on 5/26/2010.

Anions by EPA-300.0M

ANALYTE	RESULTS*	REPORTING LIMITS	DETECTION LIMITS	DILUTION FACTOR	UNITS**	ANALYSIS BY
Chloride	21	10	0	10	MG/KG	GAP
Sulfate	190	20	0	10	MG/KG	GAP

QC Batch prepared/extracted by EPA-300.0M on 5/28/2010.
Sample analyzed by EPA-300.0M on 5/28/2010.

Sulfide by EPA-376.1

ANALYTE	RESULTS*	REPORTING LIMITS	DETECTION LIMITS	DILUTION FACTOR	UNITS**	ANALYSIS BY
Sulfide	ND	1.1	0	1	MG/L	ARI2

QC Batch prepared/extracted by EPA-376.1 on 5/27/2010.
Sample analyzed by EPA-376.1 on 5/27/2010.

Redox Potential by SM-2580

ANALYTE	RESULTS*	REPORTING LIMITS	DETECTION LIMITS	DILUTION FACTOR	UNITS**	ANALYSIS BY
Redox Potential	380	0.10	0.1	1	MV	ARI2

QC Batch prepared/extracted by SM2580 on 5/28/2010.
Sample analyzed by SM2580 on 5/28/2010.

Soil Resistivity by ASTM G-57

ANALYTE	RESULTS*	REPORTING LIMITS	DETECTION LIMITS	DILUTION FACTOR	UNITS**	ANALYSIS BY
Resistivity	4350@ 21.5C	NA	0	1	OHM-CM	ARI2

QC Batch prepared/extracted by ASTM G-57 on 5/28/2010.
Sample analyzed by ASTM G-57 on 5/28/2010.

* Note: pH received and analyzed outside of hold time.

* "ND" INDICATES ANALYTE ANALYZED FOR BUT NOT DETECTED AT LEVEL ABOVE REPORTING LIMT.

** UNITS FOR ALL NON-LIQUID SAMPLES ARE REPORTED ON A DRY WEIGHT BASIS.

APPROVED BY:

8620 Holly Drive Suite 100 Everett, WA 98208 425 356-2600 FAX 425 356-2626 Seattle 206 292-9059

ALS Laboratory Group
ANALYTICAL CHEMISTRY & TESTING SERVICES

CERTIFICATE OF ANALYSIS

CLIENT:	Geoengineers, Inc. 600 DuPont St. Bellingham, WA 98225	DATE: ALS JOB#: DATE RECEIVED: WDOE ACCREDITATION #:	6/8/2010 1005039 5/12/2010 C1336

CLIENT CONTACT: Sean Cool
CLIENT PROJECT ID: 0356-106-00

QUALITY CONTROL RESULTS

BLANK RESULTS

QC SAMPLE ID	MATRIX	METHOD	ANALYTE	RESULT	UNITS
MBLK-5282010	Soil	EPA-300.0M	Chloride	ND(<1.0)	MG/KG
MBLK-5282010	Soil	EPA-300.0M	Sulfate	ND(<2.0)	MG/KG
MBLK-5272010	Water	EPA-376.1	Sulfide	ND(<0.050)	MG/L

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WDOE ACCREDITATION #: C1336

CLIENT CONTACT: Sean Cool
CLIENT PROJECT ID: 0356-106-00

QUALITY CONTROL RESULTS

BLANK SPIKE/BLANK SPIKE DUPLICATE RESULTS

QC BATCH ID	MATRIX	METHOD	ANALYTE	SPIKE AMOUNT	BLANK SPIKE RECOVERY	BLANK SPIKE DUPLICATE RECOVERY	RPD
R69086	Soil	EPA-300.0M	Chloride	100	101%	101%	0
R69086	Soil	EPA-300.0M	Sulfate	100	109%	106%	3
R69188	Soil	SM2580	Redox Potential	100	100%	**NA**	NA

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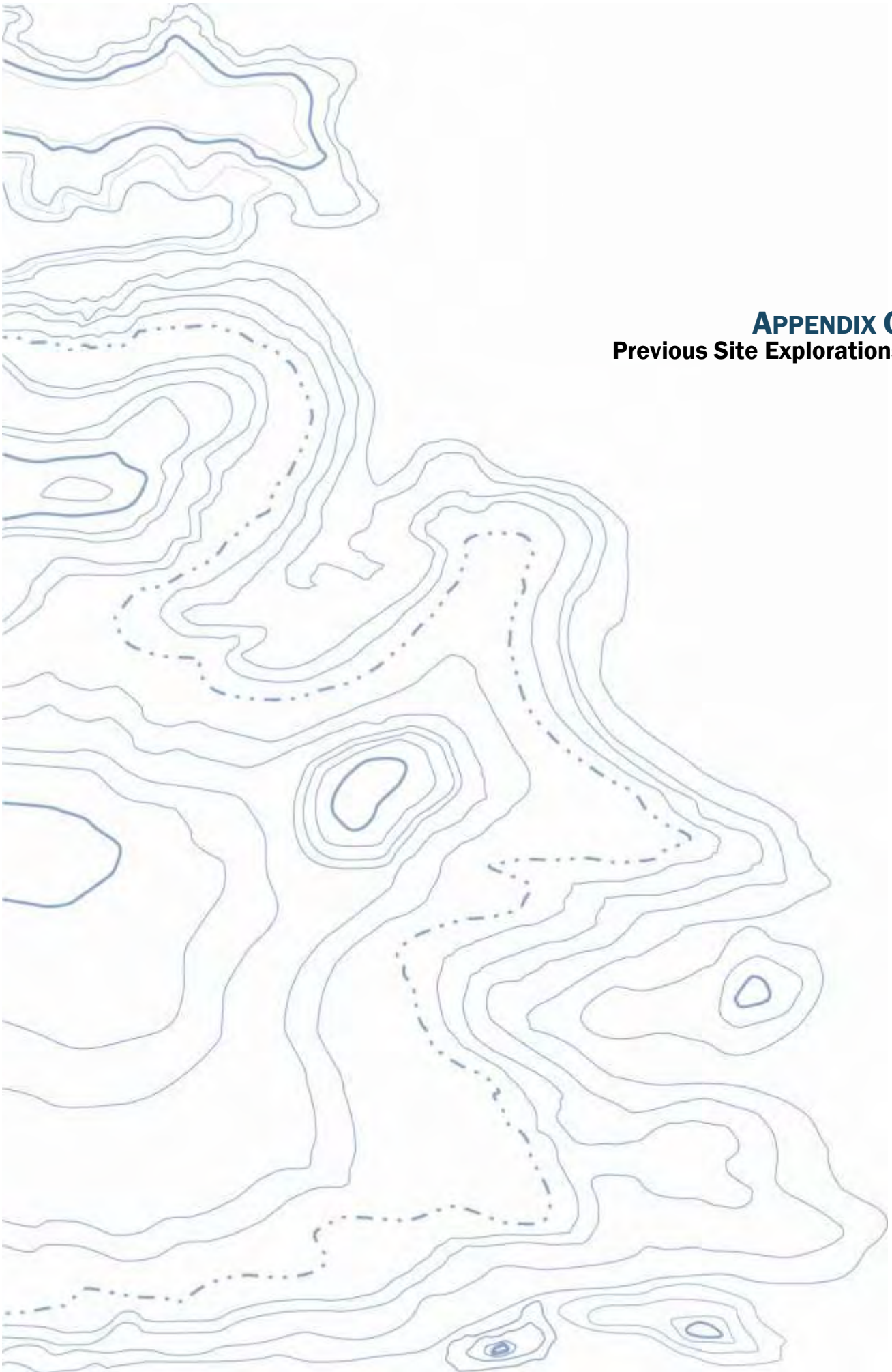


APPENDIX C
Previous Site Explorations

CH2M HILL

PROJECT NUMBER: SEA22462.B5.20 | BORING NUMBER: B-4 | SHEET: 1 | OF: 1

SOIL BORING LOG

PROJECT: POST POINT WWTP
LOCATION: B-4
ELEVATION: 32.6'
DRILLING CONTRACTOR: KENNER DRILLING
DRILLING METHOD AND EQUIPMENT: MUD ROTARY/CME 75
WATER LEVEL AND DATE: NONE ENCOUNTERED
START: 06/15/89 FINISH: 06/15/89 LOGGER: B.M. WITEK

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL (FT)	TYPE AND NUMBER	REC (FT)	STD. PEN. TEST 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL	SYMBOL	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TEST AND INSTRUMENTATION
0							
	2.5						
		S1	0.1	3-2-2 (4)	SILTY SAND with GRAVEL, brown, wet, loose (SM).		Sample recovered looks like slough.
	4.0						
5	5.0						
		S2	1.0	3-9-20 (29)	SILTY SAND with GRAVEL, brown, wet, medium dense, with about 25-30% rounded and broken gravel, and about 20% fines (SM).		
	6.5						
	7.5						
		S3	0.8	10-17-16 (33)	SILTY SAND with GRAVEL, brown, moist, hard, with about 40% fines and about 25% fine gravel (SM).		
	9.0						
10	10.0						
		S4	0.5	15-21-29 (50)	Same as above (SM).		
	11.5						
	15.0						
15							
		S5	0.3	19-26-39 (65)	Same as above (SM).		Larger cobbles at 16'.
	16.5						Observation well installation.
	20.0						Hole plug to 15'. Gravel pack 7-15'. Tip - 10-12'. Hole plug to 2'. Cement grout and monument cover at surface.
20							
		S6	1.1	20-29-50 (79)	POORLY GRADED SAND, brown, moist, very dense, sand very fine grained, may contain some coarse silt (SP).		
	21.5						
	25.0						
25							
		S7	0.3	40-60/5"	SILTY SAND with GRAVEL, gray-brown, moist, very dense, fine-grained sand with about 10-20% rounded gravel (SM).		
	25.9						
	30.0						
30							
		S8		21-60/6"	Same as above (SM).		
	31.0				END OF HOLE AT 31.0 FEET.		

CH2M HILL

PROJECT NUMBER: SEA22462.B5.20 | BORING NUMBER: B-6 | SHEET: 1 | OF: 3

SOIL BORING LOG

PROJECT: POST POINT WWTP
LOCATION: B-6
ELEVATION: 23.6'
DRILLING CONTRACTOR: KENNER DRILLING
DRILLING METHOD AND EQUIPMENT: MUD ROTARY/CME 75
WATER LEVEL AND DATE: 5.8' 07/21/89
START: 06/22/89
FINISH: 06/23/89
LOGGER: B.M. WITEK

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL (FT)	TYPE AND NUMBER	REC (FT)	STD. PEN. TEST 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL	SYMBOL	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TEST AND INSTRUMENTATION
0							Start of drilling - 3:15 P.M.
							Cuttings - loose gravel, sand and silt.
	5.0						
5		S1	0.0	4-4-4 (8)	No recovery.		
	6.5						
	10.0						
10		S2	1.8	1-2-2 (4)	SANDY SILT to a SANDY LEAN CLAY, brown, wet, soft, with occasional gravel and sand seams, moderately plastic (ML to CL).		
	11.5						
	15.0						
15		ST3	1.8		Bottom of tube: SANDY LEAN CLAY.		
	17.0						
		S4	1.8	3-3-3 (6)	SANDY LEAN CLAY, gray, wet, soft to medium firm, moderately plastic (CL).		
	18.5						
	20.0						
20		S5	0.7	6-3-3 (6)	Same as above (CL), with interbeds of POORLY GRADED SILTY SAND, gray, wet, loose, medium grained (SP-SM).		
	21.5						
	25.0						
25		S6	1.5	4-6-5 (11)	Same as above,(CL) except with occasional gravel and no sand seams.		
	26.5						
							Harder at 29'.
30							

SOIL BORING LOG

PROJECT: POST POINT WWTP
LOCATION: B-6
ELEVATION: 23.6'
DRILLING CONTRACTOR: KENNER DRILLING
DRILLING METHOD AND EQUIPMENT: MUD ROTARY/CME 75
WATER LEVEL AND DATE: 5.8' 07/21/89
START: 06/22/89
FINISH: 06/23/89
LOGGER: B.M. WITEK

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL (FT)	SAMPLE TYPE AND NUMBER	SAMPLE REC (FT)	STD. PEN. TEST 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL	SYMBOL	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TEST AND INSTRUMENTATION
30		S7	1.5	13-50-60/5"	INTERBEDDED, SILTY SAND and SILTY POORLY GRADED SAND, both gray, wet, very dense, silty sand is fine grained with occasional gravel, poorly graded sand is medium to coarse grained (SM to SM-SP).		
	31.4						
	35.0						
35		S8	0.5	11-9-9 (18)	FAT CLAY to SANDY LEAN CLAY with GRAVEL, gray, wet, very stiff (CH to CL).		
	36.5						
	40.0						
40		S9	1.0	13-21-17 (38)	SANDY LEAN CLAY interbedded with SILT, both gray, clay is wet, silt is moist, hard, with occasional gravel (CL to ML).		
	41.5						
	45.0						
45		S10	0.0	9-12-17 (29)	SANDY LEAN CLAY, gray, wet, with occasional gravel, very stiff (CL).		From 45' down, drilling in and out of gravel layers.
	46.5						
	50.0						
50		S11	1.0	9-13-18 (31)	SANDY SILT to SANDY LEAN CLAY, gray, wet, hard, with occasional gravel (ML to CL).		
	51.5						
	55.0						
55		S12	0.8	14-44-60/4"	SANDY SILT, same as above (ML).		
	56.3						
60							

CH2M HILL

PROJECT NUMBER: SEA22462.B5.20 | BORING NUMBER: B-6 | SHEET: 3 OF: 3

SOIL BORING LOG

PROJECT: POST POINT WWTP
LOCATION: B-6
ELEVATION: 23.6'
DRILLING CONTRACTOR: KENNER DRILLING
DRILLING METHOD AND EQUIPMENT: MUD ROTARY/CME 75
WATER LEVEL AND DATE: 5.8' 07/21/89
START: 06/22/89
FINISH: 06/23/89
LOGGER: B.M. WITEK

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL (FT)	SAMPLE TYPE AND NUMBER	SAMPLE REC (FT)	STD. PEN. TEST 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL	SYMBOL	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TEST AND INSTRUMENTATION
60	60.2	S13	0.0	60/2"	No recovery.		Observation well installation.
							Drilled hole 7' north of original location to 17' depth.
	65.0						Gravel pack from 11-17'. Tip from 13-15'. Cement grout to surface with protective monument casing.
65	65.4	S14	0.3	60/4.5"	SILTY SAND with GRAVEL, gray with brown pods, wet, very dense, with 25% gravel (SM).		
					END OF HOLE AT 65' 4.5".		
70							
75							
80							
85							
90							

CH2M HILL

PROJECT NUMBER: SEA22462.B5.20 | BORING NUMBER: B-7 | SHEET: 1 OF: 2

SOIL BORING LOG

PROJECT: POST POINT WWTP
LOCATION: B-7
ELEVATION: 22.4'
DRILLING CONTRACTOR: KENNER DRILLING
DRILLING METHOD AND EQUIPMENT: MUD ROTARY/CME 75
WATER LEVEL AND DATE: 5.8' 07/21/89
START: 06/20/89
FINISH: 06/21/89
LOGGER: B.M. WITEK

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL (FT)	SAMPLE TYPE AND NUMBER	SAMPLE REC (FT)	STD. PEN. TEST 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL	SYMBOL	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TEST AND INSTRUMENTATION
0							
	5.0						
5		S1	0.7	7-8-6 (14)	SILTY GRAVEL with SAND, brown, wet, medium dense, with about 10-15% fines (SM).		
	6.5						
	10.0						
10		S2	1.0	5-10-16 (26)	Upper 6": SILT with SAND and occasional GRAVEL, gray, wet, stiff (ML).		
	11.5				Lower 6": SILTY, WELL GRADED SAND, gray, wet, medium dense, with occasional gravel (SM-SW).		
	15.0						
15		S3	1.8	2-1-2 (3)	LEAN CLAY with SAND, gray, wet, soft, with occasional shells (CL).		
	16.5						
	20.0						
20		ST4	2.0		LEAN CLAY, gray, wet, soft (CL).		
	22.0	S5	0.3	2-2-2 (4)	BROKEN GRAVEL in a SILT MATRIX.		Sample appears to be slough.
	23.5						
	25.0						
25		S6	2.0	1-3-3 (6)	Same as in S3 above, except medium firm (CL).		
	26.5						
30							

CH2M HILL

PROJECT NUMBER: SEA22462.B5.20 | BORING NUMBER: B-7 | SHEET: 2 OF: 2

SOIL BORING LOG

PROJECT: POST POINT WWTP
LOCATION B-7
ELEVATION: 22.4'
DRILLING CONTRACTOR: KENNER DRILLING
DRILLING METHOD AND EQUIPMENT: MUD ROTARY/CME 75
WATER LEVEL AND DATE: 5.8' 07/21/89
START: 06/20/89
FINISH: 06/21/89
LOGGER: B.M. WITEK

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL (FT)	SAMPLE TYPE AND NUMBER	SAMPLE REC (FT)	STD. PEN. TEST 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL	SYMBOL	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TEST AND INSTRUMENTATION
30		ST7	2.0		Bottom of tube looks like: SILT with SAND and GRAVEL, gray, wet, medium firm to stiff (ML).		Bottom of tube bent by gravel.
	32.0	S8	2.0	5-6-7 (13)	SILT, gray, wet, moderately plastic, stiff (ML).		Scrape from rock along 3/4 of tube.
	33.5 35.0						
35		S9	0.5	5-6-7 (13)	SILT, same as above, possibly a lean clay (ML-CL?).		
	36.5						
	40.0						
40		S10	2.0	2-4-6 (10)	LEAN to FAT CLAY, gray, wet, stiff, with fine to medium sand partings (CL to CH).		
	41.5						
							Drilling got harder at 43' - more sand and gravel.
	45.0						
45		S11	1.0	10-18-30 (48)	SILT with SAND and OCCASIONAL GRAVEL, gray, wet, very dense (ML).		
	46.5						Hit real hard material at 47.5'.
	50.0						
50	50.4	S12	0.1	60/5" (31)	SILTY SAND with GRAVEL, gray, wet, very dense (SM).		
							Got sandier at 52' - a little easier to drill.
	55.0						
55		S13	0.3	22-60/6"	SANDY SILT, gray, wet, very hard, with about 5-10% gravel (ML).		Observation well installation.
	56.0						Drilled hole 7.5' north of original location to 17' depth. Gravel pack from 11-17'. Tip from 13-15'. Cement grout to surface with protective monument casing.
					END OF HOLE AT 56.5 FEET.		
60							

CH2M HILL

PROJECT NUMBER: SEA22462.B5.20 | BORING NUMBER: B-8 | SHEET: 1 OF: 4

SOIL BORING LOG

PROJECT: POST POINT WWTP
LOCATION: B-8
ELEVATION: 19.2'
DRILLING CONTRACTOR: KENNER DRILLING
DRILLING METHOD AND EQUIPMENT: MUD ROTARY/CME 75
WATER LEVEL AND DATE: NOT RECORDED
START: 06/15/89 FINISH: 06/17/89 LOGGER: B.M. WITEK

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL (FT)	SAMPLE TYPE AND NUMBER	SAMPLE REC (FT)	STD. PEN. TEST 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL	SYMBOL	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TEST AND INSTRUMENTATION
0							
	5.0						
5		S1	0.8	4-7-5 (12)	ORGANIC SILT, dark brown, moist, stiff, with about 10-15% medium sand, and about 5% rounded gravel (OL).		
	6.5						
	10.0						
10		S2	0.9	1-3-4 (7)	LEAN CLAY, brown with gray mottling, wet, medium firm (CL).		
	11.5						
	15.0						
15		ST3	2.0		Same as above, except gray and hard (CL).		
	17.0						
	20.0						
20		S4	1.2	3-6-9 (15)	Same as above, except gray in lower 8" of sampler and brown above, with thin (1/16" or less) zones of sand (CL).		
	21.5						
	25.0						
25		S5	2.0	0-2-1 (3)	LEAN CLAY, gray, wet, soft, with up to 5% medium sand and occasional shells and fine gravel (CL).		
	26.5	ST6					
	28.5						
		S8	2.0	2-2-3 (5)	Same as S5, gray, wet, medium firm (CL).		
30	30.0						

SOIL BORING LOG

PROJECT: POST POINT WWTP
LOCATION: B-8
ELEVATION: 19.2'
DRILLING CONTRACTOR: KENNER DRILLING
DRILLING METHOD AND EQUIPMENT: MUD ROTARY/CME 75
WATER LEVEL AND DATE: NOT RECORDED
START: 06/15/89 FINISH: 06/17/89 LOGGER: B.M. WITEK

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL (FT)	SAMPLE TYPE AND NUMBER	SAMPLE REC (FT)	STD. PEN. TEST 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL	SYMBOL	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TEST AND INSTRUMENTATION
30							
							Harder drilling at 34'.
	35.0						
35		S9	0.3	20-10-9 (19)	POORLY GRADED SAND, gray, wet, medium dense, medium grained (slough?).		
	36.5						
	40.0						
40		S10	2.0	1-3-2 (5)	INTERBEDDED ELASTIC SILT, LEAN CLAY and POORLY GRADED FINE TO MEDIUM SAND, gray, wet, soft to loose (MH, CL & SP).		
	41.5						
	45.0						
45		S11	0.2	3-2-3 (5)	LEAN CLAY, gray, wet, medium firm (CL).		Sample may be slough.
	46.5						Driller says material becoming sandy at 47'.
	50.0						At 49', drilling gets softer; cuttings are silt or clay with fine gravel.
50		S12	0.4	8-8-8 (16)	SILT, gray, wet, with about 10% fine sand, occasional fine gravel, very stiff (ML).		
	51.5						
							Harder at 53'.
	55.0						
55		S13	0.2	11-14-18 (32)	SILTY GRAVEL with SAND, gray, wet, dense (GM?).		S13 small sample - difficult to classify.
	56.5						Hard drilling at 57'.
60							

SOIL BORING LOG

PROJECT: POST POINT WWTP
LOCATION: B-8
ELEVATION: 19.2'
DRILLING CONTRACTOR: KENNER DRILLING
DRILLING METHOD AND EQIPMENT: MUD ROTARY/CME 75
WATER LEVEL AND DATE: NOT RECORDED
START: 06/15/89
FINISH: 06/17/89
LOGGER: B.M. WITEK

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL (FT)	SAMPLE TYPE AND NUMBER	SAMPLE REC (FT)	STD. PEN. TEST 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL	SYMBOL	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TEST AND INSTRUMENTATION
60		S14	0.8	25-29-60/4.5"	SILTY SAND, gray, wet, very dense, with about 10% gravel (SM).		
	61.4						Rock in tip of sampler.
	65.0						Few rocks present at 64'.
65		S15	1.5	11-23-47 (70)	LEAN CLAY with SAND, gray, wet, hard, with occasional gravel (CL).		Becoming gravelly at 66'.
	66.5						
	70.0						
70		S16	0.6	18-22-45 (67)	SILTY SAND, gray, wet, very dense, with occasional gravel (SM).		
	71.5						
	75.0						
75		S17	0.7	44-60/5"	Same as above, except less silt, 10-15% fines (SM).		
	75.9						
	80.0						
80		S18	0.1	22-12-12 (24)	Broken gravel in drilling mud.		S18 - Sample recovered broken gravel in drilling mud.
	81.5						Drilling got a little softer at 81'.
							A little firmer at 83.5'.
	85.0						
85		S19	1.1	19-45-60/5.5"	SILTY SAND, gray, moist to wet, with occasional fine gravel, sand, fine grained, very dense (SM).		
	86.5						
90							

CH2M HILL

PROJECT NUMBER: SEA22462.B5.20 | BORING NUMBER: B-8 | SHEET: 4 | OF: 4

SOIL BORING LOG

PROJECT: POST POINT WWTP
LOCATION: B-8
ELEVATION: 19.2'
DRILLING CONTRACTOR: KENNER DRILLING
DRILLING METHOD AND EQUIPMENT: MUD ROTARY/CME 75
WATER LEVEL AND DATE: NOT RECORDED
START: 06/15/89
FINISH: 06/17/89
LOGGER: B.M. WITEK

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL (FT)	SAMPLE TYPE AND NUMBER	SAMPLE REC (FT)	STD. PEN. TEST 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL	SYMBOL	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TEST AND INSTRUMENTATION
90	90.4	S20		60/5"	POORLY GRADED SAND, gray, wet, dense, fine to medium grained (SP).		End of day - 06/16/89.
	95.0						
95	95.3	S21	0.3	120/4"	SANDY SILT, gray, wet, hard, with occasional gravel, 20-30% fine to medium grained sand, interbedded with layers of sand (ML).		Used D&M sampler with 140# hammer.
	100.0						
100	100.5	S22	0.4	120/5.5"	POORLY GRADED SAND, gray, wet, very dense, fine to medium grained (SP).		
					END OF HOLE AT 100.5 FEET.		No observation well installed.
105							
110							
115							
120							

CH2M HILL

PROJECT NUMBER: SEA22462.B5.20 | BORING NUMBER: B-9 | SHEET: 1 | OF: 2

SOIL BORING LOG

PROJECT: POST POINT WWTP
LOCATION: B-9
ELEVATION: 18.6'
DRILLING CONTRACTOR: KENNER DRILLING
DRILLING METHOD AND EQUIPMENT: MUD ROTARY/CME 75
WATER LEVEL AND DAte: 4.0' 07/21/89
START: 06/22/89
FINISH: 06/22/89
LOGGER: B.M. WITEK

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL (FT)	SAMPLE TYPE AND NUMBER	SAMPLE REC (FT)	STD. PEN. TEST 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL	SYMBOL	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TEST AND INSTRUMENTATION
0							Cuttings. 6" topsoil, below topsoil gravel to 3' and from 3-5', gravelly silt with wood.
	5.0						
5		S1	0.5	3-2-2 (4)	ORGANIC SILT/PEAT, dark brown, wet, soft, with wood fibers and gravel (OL/PT).		
	6.5						
							At 8', got into a brown, gravelly silt with wood fibers.
	10.0						
10		ST2	1.8		Bottom of tube: SILT with SAND, gray with brown mottling, wet, stiff (ML).		
	12.0						
		S3	0.7	4-4-5 (9)	INTERBEDDED SILT, same as above, with LEAN CLAY, brown with gray mottling, wet, stiff, with occasional gravel (ML/CL).		
	13.5						
	15.0						
15		S4	1.8	4-4-9 (13)	INTERBEDDED SILTY SAND, SANDY CLAY and LEAN CLAY, brown, wet, clay is stiff, sand is loose to medium dense (CL to SM).		
	16.5						
							At about 18', change to a gray clay/silt.
	20.0						
20		ST5					
	22.0						
		S6		3-1-2 (3)	LEAN CLAY with SAND, gray, wet, soft, with occasional gravel and thin sand interbeds (CL).		
	23.5						
	25.0						
25		S7		1-1-10 (11)	Same as above, except stiff, may be a fat clay (CH), in tip, material is sandier, unit also has occasional shells.		
	26.5						
							At 28', got firmer.
30							

CH2M HILL

PROJECT NUMBER: SEA22462.B5.20 | BORING NUMBER: B-9 | SHEET: 2 | OF: 2

SOIL BORING LOG

PROJECT: POST POINT WWTP | LOCATION: B-9
ELEVATION: 18.6' | DRILLING CONTRACTOR: KENNER DRILLING
DRILLING METHOD AND EQUIPMENT: MUD ROTARY/CME 75
WATER LEVEL AND DAte: 4.0' 07/21/89 | START: 06/22/89 | FINISH: 06/22/89 | LOGGER: B.M. WITEK

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL (FT)	SAMPLE TYPE AND NUMBER	SAMPLE REC (FT)	STD. PEN. TEST 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL	SYMBOL	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TEST AND INSTRUMENTATION
30							Drilling got hard at 30'.
	31.0	S8	0.1	18-60/6"	Sample recovered is slough - LEAN CLAY with GRAVEL, gray, wet (CL).		Got into soft material at 32'.
	35.0						
35		ST9	2.0		Same as in S7.		
	37.0	S10	2.0	2-2-2 (4)	SANDY LEAN CLAY with GRAVEL, gray, wet, soft (CL).		
	38.5 40.0						At 39', got into a firmer silt.
40		S11	0.0	7-8-11 (19)	No recovery.		
	41.5						
	45.0						
45		S12	2.0	5-4-60 (64)	Same as in S10 above, except sandier (CL).		
	46.5						Harder from 47-48'.
	50.0						
50		S13	1.0	11-47-60/4.5"	SILTY SAND, gray, wet, very dense, with occasional gravel, appears layered with sandy silt (SM).		
	51.4						
							Observation well installation.
	55.0						
55	55.4	S14	0.4	60/5"	SILTY SAND, same as above, except with a small (6") zone of sandy silt (SM).		Drilled hole 8.5' north of original location to 17' depth. Gravel pack from 11-17'. Tip from 13-15'. Cement grout to surface with protective monument casing.
	60.0						
60		S15		60/2"	No recovery.		
	60.2				END OF HOLE AT 60.2 FEET.		

CH2M HILL

PROJECT NUMBER: SEA22462.B5.20 | BORING NUMBER: B-10 | SHEET: 1 | OF: 3

SOIL BORING LOG

PROJECT: POST POINT WWTP
LOCATION: B-10
ELEVATION: 15.8'
DRILLING CONTRACTOR: KENNER DRILLING
DRILLING METHOD AND EQUIPMENT: MUD ROTARY/CME 75
WATER LEVEL AND DAte: 2.5' 07/21/89
START: 06/23/89
FINISH: 06/27/89
LOGGER: B.M. WITEK

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL (FT)	SAMPLE TYPE AND NUMBER	SAMPLE REC (FT)	STD. PEN. TEST 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL	SYMBOL	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TEST AND INSTRUMENTATION
0							
	5.0						Gravelly drilling until about 5'.
5		S1	0.8	3-4-4 (8)	SILT, to ORGANIC SILT, dark brown, moist to wet, medium firm, with occasionl gravel and wood/organic pieces (ML/OL).		
	6.5						
	10.0						
10		ST2	2.0		Top of tube: same as above. Bottom of tube: LEAN CLAY, gray, wet, medium firm (CL).		
	12.0	S3	0.5	2-2-3 (5)	SANDY LEAN CLAY to LEAN CLAY, gray, wet, medium firm (CL).		
	13.5						
	15.0						
15		S4	1.2	5-12-9 (21)	CLAYEY to SILTY SAND with GRAVEL, gray, wet, medium dense, with 15% gravel (SC to SM).		
	16.5						
	20.0						
20		S5	NR	0 (0)	FAT CLAY, gray, wet, soft, with occasional fine sand or coarse silt (CH).		Classified sample from material on sides of sampler.
	21.5						
	22.0	ST6	0.0				Sample too soft; slipped out of tube. Bagged sample remaining, about 1-2" of disturbed material.
	24.0						
25	25.0	ST7	2.3		LEAN CLAY to SILT, gray, wet, soft (CL-ML).		
	27.0	S8	0.3	1-1-2 (3)	LEAN CLAY to FAT CLAY, gray, wet, soft, with medium sand lenses (CL to CH).		
	28.5						
30							

CH2M HILL

PROJECT NUMBER: SEA22462.B5.20 | BORING NUMBER: B-10 | SHEET: 2 OF: 3

SOIL BORING LOG

PROJECT: POST POINT WWTP
LOCATION: B-10
ELEVATION: 15.8'
DRILLING CONTRACTOR: KENNER DRILLING
DRILLING METHOD AND EQUIPMENT: MUD ROTARY/CME 75
WATER LEVEL AND DAte: 2.5' 07/21/89
06/23/89
FINISH: 06/27/89
LOGGER: B.M. WITEK

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL (FT)	SAMPLE TYPE AND NUMBER	SAMPLE REC (FT)	STD. PEN. TEST 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL	SYMBOL	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TEST AND INSTRUMENTATION
30		S9	1.2	1-2-2 (4)	LEAN CLAY, gray, wet, soft, with occasional gravel and fine to medium sand interbeds (CL).		
	31.5						
	35.0						
35		ST10	2.0				
	37.0						
		S11	1.5	3-4-11 (15)	SILT with SAND, INTERBEDDED with LEAN CLAY and SILTY SAND, gray, wet, sand, medium dense, silt and clay, stiff (ML, CL and SM).		
	38.5						
	40.0						
40		S12	1.5	1-2-1 (3)	Same as in S9 - LEAN CLAY (CL).		
	41.5						
	45.0						
45		ST13	1.2				ST13 - Bottom of tube wrinkled, sample moved within tube; bottom 8" of sample fell out of tube - likely sandy.
	47.0						
		S14	1.0	7-7-6 (13)	SANDY LEAN CLAY, gray, wet, stiff (CL).		
	48.5						
	50.0						
50		S15	1.5	4-2-7 (9)	Same as above (CL).		
	51.5						
							Little harder drilling at 53'.
	55.0						
55		S16	1.2	6-8-11 (19)	SANDY LEAN CLAY, interbedded with CLAYEY SAND, same as above, gray, wet, fine to medium grained, medium dense, with occasional gravel (CL to SC).		
	56.5						
60							

CH2M HILL

PROJECT NUMBER: SEA22462.B5.20 | BORING NUMBER: B-10 | SHEET: 3 | OF: 3

SOIL BORING LOG

PROJECT: POST POINT WWTP
LOCATION: B-10
ELEVATION: 15.8'
DRILLING CONTRACTOR: KENNER DRILLING
DRILLING METHOD AND EQUIPMENT: MUD ROTARY/CME 75
WATER LEVEL AND DATE: 2.5' 07/21/89
START: 06/23/89
FINISH: 06/27/89
LOGGER: B.M. WITEK

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL (FT)	SAMPLE TYPE AND NUMBER	SAMPLE REC (FT)	STD. PEN. TEST 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL	SYMBOL	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TEST AND INSTRUMENTATION
60		S17	2.0	3-3-5 (8)	INTERBEDDED SANDY LEAN CLAY, LEAN CLAY and CLAYEY SAND, all gray, wet, clay medium firm, sand loose, with zones of fine gravel within the units (CL to SC).		
	61.5						
	65.0						
65		S18	1.2	12-8-8 (16)	Same as above, except also with lenses of poorly graded sand, fine to medium grained, gray, wet (CL, SC and SP).		
	66.5						Hit hard drilling at 68'.
	70.0						Got softer at 69'.
70		S19	2.0	3-5-7 (12)	LEAN CLAY, gray, wet, stiff, with erratic lenses of poorly graded sand in sample (CL).		
	71.5						Hardened at 72'.
	75.0						
75	75.3	S20	0.3	60/4"	LEAN CLAY, gray, wet, hard, with up to 20% broken angular gravel (CL).		Sample S20 may be slough.
	80.0						
80	80.5	S21	0.4	60/5.5"	SILTY SAND and GRAVEL, gray, wet, very dense, sand, medium to course grained, with broken angular gravel (SM to GM).		Observation well installation.
					END OF HOLE AT 80' 5.5".		Drilled hole 10' north of original location to 17' depth. Gravel pack from 11-17'. Tip from 13-15'. Hole plug from 1-11'. Monument casing at surface in cement grout.
85							
90							

CH2M HILL

PROJECT NUMBER: SEA22462.B5.20 | BORING NUMBER: B-11 | SHEET: 1 | OF: 2

SOIL BORING LOG

PROJECT: POST POINT WWTP
LOCATION: B-11
ELEVATION: 16.3'
DRILLING CONTRACTOR: KENNER DRILLING
DRILLING METHOD AND EQUIPMENT: MUD ROTARY/CME 75
WATER LEVEL AND DATE: NOT RECORDED
START: 06/27/89
FINISH: 06/27/89
LOGGER: B.M. WITEK

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL (FT)	SAMPLE TYPE AND NUMBER	SAMPLE REC (FT)	STD. PEN. TEST 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL	SYMBOL	LOG	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TEST AND INSTRUMENTATION
0								1' of gravelly topsoil, then hit wood from about 1 to 2 feet then back in gravelly soils.
	5.0							
5		S1	0.3	5-3-3 (6)	SILTY SAND, gray, wet, loose, with about 20-30% fines, 10% gravel (SM).			
	6.5							
	10.0							Drilling got siltier at 9', but still has gravel in it. Drilling seems to be in more cobbles and boulders at about 10'.
10		S2	0.5	10-12-13 (25)	Same as above, except medium dense (SM).			
	11.5							
	15.0							
15		S3	1.0	3-3-3 (6)	SANDY LEAN CLAY to CLAYEY SAND, brown, wet, medium firm to loose, with occasional gravel (CL to SC).			
	16.5							
	20.0							Drills as if there was more gravel in it.
20		S4	1.2	3-4-7 (11)	Same as above, except with some gray mottling.			
	21.5							
	25.0							
25		S5	1.7	4-3-4 (7)	SANDY LEAN CLAY, same as above (CL), except grading into a fat clay, gray, wet, soft in tip of sampler (CH).			
	26.5							
								Hit gravel at 29'.
30								

CH2M HILL

PROJECT NUMBER: SEA22462.B5.20 | BORING NUMBER: B-11 | SHEET: 2 | OF: 2

SOIL BORING LOG

PROJECT: POST POINT WWTP
LOCATION: B-11
ELEVATION: 16.3'
DRILLING CONTRACTOR: KENNER DRILLING
DRILLING METHOD AND EQUIPMENT: MUD ROTARY/CME 75
WATER LEVEL AND DATE: NOT RECORDED
START: 06/17/89 FINISH: 06/27/89 LOGGER: B.M. WITEK

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL (FT)	SAMPLE TYPE AND NUMBER	SAMPLE REC (FT)	STD. PEN. TEST 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL	SYMBOL	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TEST AND INSTRUMENTATION
30		S6	1.5	30-34-37 (71)	POORLY GRADED SAND with SILT and GRAVEL, gray, wet, very dense, with about 35-40% broken gravel and about 10% fines (SP-SM).		
	31.5						
	35.0						
35		S7	1.0	33-38-44 (82)	Same as above, some large (1") gravel in sample (SP-SM).		
	36.5						
	40.0						
40	40.5	S8	0.5	60/6"	Same as above (SP-SM).		
	45.0						
45	45.5	S9	0.4	60/6"	Same as above (SP-SM).		
	50.0						
50		S10	0.8	38-60/4"	SILT with SAND and GRAVEL, gray, wet, hard (ML), with fine gravel and fine to medium sand, with zones of sandy lean clay with gravel (CL).		No observation well installed.
	50.8				END OF HOLE AT 50'. 8".		
55							
60							

CH2M HILL

PROJECT NUMBER: SEA22462.B5.20 | BORING NUMBER: B-12 | SHEET: 1 | OF: 2

SOIL BORING LOG

PROJECT: POST POINT WWTP
LOCATION: B-12
ELEVATION: 16.4'
DRILLING CONTRACTOR: KENNER DRILLING
DRILLING METHOD AND EQUIPMENT: MUD ROTARY/CME 75
WATER LEVEL AND DATE: NOT RECORDED
START: 06/20/89 FINISH: 06/20/89 LOGGER: B.M. WITEK

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL (FT)	SAMPLE TYPE AND NUMBER	SAMPLE REC (FT)	STD. PEN. TEST 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL	SYMBOL	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TEST AND INSTRUMENTATION
0							Hit log and debris in upper 2.5'. Hit gravel at 2.5'.
	5.0						
5		S1	1.0	11-8-13 (21)	Upper 6": ROUNDED to BROKEN GRAVEL in drilling mud. Lower 6": SILTY SAND, blue-gray with brown-orange mottling, medium dense, with occasional gravel (SM).		
	6.5						
	10.0						
10		S2	1.1	6-5-4 (9)	SANDY SILT, gray-brown, mottled, wet, medium firm (ML).		Gravel slough at top of sampler.
	11.5						
	15.0						
15		S3	0.7	1-1-2 (3)	LEAN CLAY with SAND, gray, wet, soft, with occasional gravel (CL).		
	16.5						
	20.0						
20		ST4	2.0		Same as above (CL).		Bottom 6" of tube dented by gravel or rock.
	22.0						
		S5	0.9	2-3-7 (10)	FAT CLAY to ELASTIC SILT, INTERBEDDED, clay is gray, wet, stiff; silt is brown, wet, stiff; both with occasional sand (CH to MH).		
	23.5						Hit a hard gravel layer at 24'.
25							Appears to have large cobbles in a silt layer.
30							

CH2M HILL

PROJECT NUMBER: SEA22462.B5.20 | BORING NUMBER: B-12 | SHEET: 2 | OF: 2

SOIL BORING LOG

PROJECT: POST POINT WWTP
LOCATION: B-12
ELEVATION: 16.4'
DRILLING CONTRACTOR: KENNER DRILLING
DRILLING METHOD AND EQUIPMENT: MUD ROTARY/CME 75
WATER LEVEL AND DATE: NOT RECORDED
START: 06/20/89 FINISH: 06/20/89 LOGGER: B.M. WITEK

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL (FT)	SAMPLE TYPE AND NUMBER	SAMPLE REC (FT)	STD. PEN. TEST 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL	SYMBOL	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TEST AND INSTRUMENTATION
30		S6	0.9	6-4-28 (32)	LEAN CLAY with SAND, brown, wet, hard, with occasional gravel (CL).		Drills solid from about 29'.
	31.5						Drills very hard at 32'.
	35.0						
35	35.5	S7	0.5	60/5.75"	SILTY SAND, gray-brown, wet, very dense, with about 15-20% fines, up to 10% gravel (SM).		
	40.0						
40		S8	0.7	45-60/4"	POORLY GRADED SAND, gray, wet, medium to coarse grained, very dense (SP).		Driller says gravels present within unit.
	40.8						
	45.0						
45	45.5	S9	0.4	60/5.5"	SILTY SAND, as in S7 above (SM).		
	50.0						No observation well installed.
50	50.4	S10	0.4	60/5"	Same as above (SM).		
					END OF HOLE AT 50' 5".		
55							
60							

CH2M HILL

PROJECT NUMBER: SEA22462.B5.20 | BORING NUMBER: B-13 | SHEET: 1 OF: 4

SOIL BORING LOG

PROJECT: POST POINT WWTP
LOCATION: B-13
ELEVATION: 12.9'
DRILLING CONTRACTOR: KENNER DRILLING
DRILLING METHOD AND EQUIPMENT: MUD ROTARY/CME 75
WATER LEVEL AND DAte: 3.5' 07/21/89
START: 06/19/89
FINISH: 06/20/89
LOGGER: B.M. WITEK

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL (FT)	SAMPLE TYPE AND NUMBER	SAMPLE REC (FT)	STD. PEN. TEST 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL	SYMBOL	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TEST AND INSTRUMENTATION
0							
	5.0						Cuttings indicate a loose gravel.
5		S1	0.0	3-1-4 (5)	No recovery.		
	6.5						Peat with gravel at 6.5'.
	10.0						Interbedded peat and granular material.
10		S2	0.7	1-1-1 (2)	ORGANIC SILT/PEAT, brown, moist to wet, soft, with poorly graded gray sand in tip (OH/PT).		Sample smells like rotten eggs (sulfer smell).
	11.5						
	15.0						
15		ST3	2.0		SILT, blue-gray, wet, with occasional gravel, medium stiff (ML).		Will try Osterberg sampler at 15'.
	17.0						
		S4	0.9	2-3-3 (6)	LEAN CLAY to SANDY CLAY, gray-blue with black mottling, wet, medium firm (CL).		
	18.5						
	20.0						
20		S5	1.2	1-2-3 (5)	LEAN CLAY, same as above, with brown mottling (CL).		
	21.5						
	25.0						
25		ST6	2.0		In bottom of tube: SANDY SILT, blue-gray with brown mottling, wet.		Color change to brown at 25'.
	27.0						
		S7	1.0	2-2-1 (3)	SILT with SAND to CLAY with SAND, blue-gray to gray with brown mottling, wet, soft (ML to CL).		
	28.5						
30							

CH2M HILL

PROJECT NUMBER: SEA22462.B5.20 | BORING NUMBER: B-13 | SHEET: 2 | OF: 4

SOIL BORING LOG

PROJECT: POST POINT WWTP | LOCATION: B-13
ELEVATION: 12.9' | DRILLING CONTRACTOR: KENNER DRILLING
DRILLING METHOD AND EQUIPMENT: MUD ROTARY/CME 75
WATER LEVEL AND DAte: 3.5' 07/21/89 | START: 06/19/89 | FINISH: 06/20/89 | LOGGER: B.M. WITEK

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL (FT)	SAMPLE TYPE AND NUMBER	SAMPLE REC (FT)	STD. PEN. TEST 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL	SYMBOL	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TEST AND INSTRUMENTATION
30		S8	0.3	0-2-1 (3)	LEAN CLAY, gray-brown, wet, soft, with silt and fine sand (CL).		
	31.5						
	35.0						Driller says it drills like there is gravel in unit.
35		S9	1.2	13-19-25 (44)	SILTY SAND, gray, wet, dense, fine to medium grained (SM).		
	36.5						
	40.0						
40		S10	2.0	0-3-6 (9)	LEAN CLAY, as in S8, except stiff, with interbeds of sandy clay to silty clay with sand (CL).		
	41.5						Got hard at 42.5' - gravel.
	45.0						Got softer at 43.5', still firm - more silt and sand with unit.
45		S11	2.0	2-2-2 (4)	LEAN CLAY to FAT CLAY, gray, wet, soft, with occasional zones of less plastic (fine sandy clay) material (CL to CH).		
	46.5						
	50.0						
50		ST12					
	52.0						
		S13	2.0	4-4-6 (10)	INTERBEDDED SILT, SILTY SAND and ELASTIC SILT, gray, wet, loose to stiff (ML, SM, MH?).		
	53.5						
55							
60							

CH2M HILL

PROJECT NUMBER: SEA22462.B5.20 | BORING NUMBER: B-13 | SHEET: 3 | OF: 4

SOIL BORING LOG

PROJECT: POST POINT WWTP
LOCATION: B-13
ELEVATION: 12.9'
DRILLING CONTRACTOR: KENNER DRILLING
DRILLING METHOD AND EQUIPMENT: MUD ROTARY/CME 75
WATER LEVEL AND DAte: 3.5' 07/21/89
START: 06/19/89
FINISH: 06/20/89
LOGGER: B.M. WITEK

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL (FT)	SAMPLE TYPE AND NUMBER	SAMPLE REC (FT)	STD. PEN. TEST 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL	SYMBOL	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TEST AND INSTRUMENTATION
60		S14	2.0	3-4-6 (10)	SANDY LEAN CLAY, gray, wet, medium firm to stiff, with thin interbeds of silty sand and lean clay (CL).		
	61.5						
	65.0						
65		S15	2.0	3-4-4 (8)	LEAN CLAY, gray, wet, medium firm, with interbeds of sandy clay to elastic silt with sand (CL).		
	66.5						
	70.0						
70		ST16	0.0		Same as above (CL).		Tried to take shelby tube. Sample did not work. Drilled out 2' and took Osterberg.
	72.0	ST17	2.0		Same as above (CL).		
	74.0	S18	1.7	3-9-31 (40)	Upper 14": Same as above, gray, moist, hard, hit hard unit at 75', silt with sand and occasional gravel (ML).		
75	75.5						
	80.0						
80	80.5	S19	0.3	60/6"	SILTY SAND with GRAVEL, gray, wet, very dense, with up to 20% broken gravel (SM).		
	85.0						
85		S20	0.3	42-60/6"	Same as above, except in tip poorly graded sand, gray, wet, very dense (SP).		
	86.0						
90							

CH2M HILL

PROJECT NUMBER: SEA22462.B5.20 | BORING NUMBER: B-13 | SHEET: 4 | OF: 4

SOIL BORING LOG

PROJECT: POST POINT WWTP
LOCATION: B-13
ELEVATION: 12.9'
DRILLING CONTRACTOR: KENNER DRILLING
DRILLING METHOD AND EQUIPMENT: MUD ROTARY/CME 75
WATER LEVEL AND DAte: 3.5' 07/21/89
START: 06/19/89
FINISH: 06/20/89
LOGGER: B.M. WITEK

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL (FT)	SAMPLE TYPE AND NUMBER	SAMPLE REC (FT)	STD. PEN. TEST 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL	SYMBOL	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TEST AND INSTRUMENTATION
90							Observation well installation. Drilled hole 15' west of original location to 20' depth. Gravel pack from 13-20'. Tip from 15-17'. Hole plug from 1-13'. Monument casing at surface in cement grout.
	95.0						
95		S21	0.8	6-18-32 (50)	SANDY LEAN CLAY, gray, wet, hard, with up to 10% gravel (CL).		
	96.5				END OF HOLE AT 96.5 FEET.		
100							
105							
110							
115							
120							

CH2M HILL

PROJECT NUMBER: SEA22462.B5 | BORING NUMBER: B-14 | SHEET: 1 OF: 5

SOIL BORING LOG

PROJECT: POST POINT WWTP
LOCATION: B-14
ELEVATION: 14.7'
DRILLING CONTRACTOR: KENNER DRILLING
DRILLING METHOD AND EQUIPMENT: MUD ROTARY, CME-75
WATER LEVEL AND DATE: 10.7' - 08/04/89
START: 08/01/89
FINISH: 08/02/89
LOGGER: B.K. WITEK

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL (FT)	SAMPLE TYPE AND NUMBER	SAMPLE REC (FT)	STD. PEN. TEST 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL	SYMBOL	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TEST AND INSTRUMENTATION
0							
	5.0						
5		S1	0.6	8-31-43 (74)	SILTY SAND with GRAVEL, brown, slightly moist, very dense, with up to 20% subrounded gravel (SM).		
	6.5						
	10.0						
10		S2	0.3	5-5-8 (13)	SILTY SAND with GRAVEL, moist to wet, medium dense, with up to 15% subounded gravel and localized lenses of dark brown ORGANIC SILT (SM with lenses of OL).		From 12-14 feet softer drilling, at 14 feet got into gravelly material.
	11.5						
	15.0						
15		S3	0.5	9-11-7 (18)	WELL GRADED SAND, gray, wet, medium dense, with occasional fine gravel and broken shells (SW).		Got into clay at about 17 1/2 feet.
	16.5						
	20.0						
20		S4	0.0	1-2-2 (4)	FAT CLAY, gray to blue gray, wet, soft, with occasional gravel and fine interbeds of peat and woody inclusions (CH).		
	21.5						
	25.0						
25		ST5	2.0				Hard clay in base of tube.
	27.0						
		S6	.04	3-4-5 (9)	FAT CLAY, gray, wet, with up to 10% subounded gravel (CH).		Sample S6 may be slough.
	28.5						
30							

CH2M HILL

PROJECT NUMBER: SEA22462.B5 | BORING NUMBER: B-14 | SHEET: 2 | OF: 5

SOIL BORING LOG

PROJECT: POST POINT WWTP
LOCATION: B-14
ELEVATION: 14.7'
DRILLING CONTRACTOR: KENNER DRILLING
DRILLING METHOD AND EQUIPMENT: MUD ROTARY, CME-75
WATER LEVEL AND DATE: 10.7' - 08/04/89
START: 08/01/89
FINISH: 08/02/89
LOGGER: B.M. WITEK

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL (FT)	SAMPLE TYPE AND NUMBER	SAMPLE REC (FT)	STD. PEN. TEST 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL	SYMBOL	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TEST AND INSTRUMENTATION
30		S7	1.5	3-4-10 (14)	FAT CLAY, gray brown with brown mottling, wet, very stiff (CH) BROWN SILT (ML) present in tip of sampler.		
	31.5						
	35.0						
35		S8	0.2	3-1-2 (3)	FAT CLAY, as above, except soft, with occasional gravel (CH).		
	36.5						
	40.0						Becoming gravelly at 38 feet.
40		S9	1.3	17-23-26 (49)	POORLY GRADED SAND, gray, wet, dense, fine to medium grained (SP).		
	41.5						
	45.0						Drilling a little softer at 44 feet, driller thinks S10 pushed on a rock.
45		S10	0.0	2-15-7 (22)	No recovery.		
	46.5						
	50.0						
50		S11	1.5	2-1-2 (3)	FAT CLAY, gray, wet, soft(CH).		
	51.5						
	55.0						
55		ST12	1.0		As above.		Bottom 12 inches of sample ST-12 lost.
	57.0						
		S13	2.0	2-4-5 (9)	FAT to LEAN CLAY, as above except stiff with occasional fine to medium sand (CL to CH).		
	58.5						
60							

CH2M HILL	PROJECT NUMBER: SEA22462.B5	BORING NUMBER: B-14	SHEET: 3	OF: 5

SOIL BORING LOG

PROJECT: POST POINT WWTP
LOCATION: B-14
ELEVATION: 14.7'
DRILLING CONTRACTOR: KENNER DRILLING
DRILLING METHOD AND EQUIPMENT: MUD ROTARY, CME-75
WATER LEVEL AND DATE: 10.7' - 08/04/89
START: 08/01/89 FINISH: 08/02/89 LOGGER: B.M. WITEK

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL (FT)	SAMPLE TYPE AND NUMBER	SAMPLE REC (FT)	STD. PEN. TEST 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL	SYMBOL	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TEST AND INSTRUMENTATION
60							
	65.0						
65		S14	1.5	3-4-6 (10)	FAT to LEAN CLAY, as in S-13 except with thin zones of sand, (CH) with zones of (SP-SM).		
	66.5						
							Hit a little gravel from 68 to 68 1/2 feet.
	70.0						
70		S15	0.3	4-6-7 (13)	As above.		S15 appears to be slough.
	71.5						
	75.0						
75		S16	2.0	3-3-5 (8)	LEAN CLAY, gray, wet, medium firm, with zones of fine sand/coarse silt and occasional fine gravel (CL).		
	76.5						
80							
	85.0						A little firmer drilling at 84 feet.
85		S17	1.5	3-2-5 (7)	As above, may possibly be a fat clay (CL-CH?).		
	86.5						
90							

CH2M HILL

PROJECT NUMBER: SEA22462.B5 | BORING NUMBER: B-14 | SHEET: 4 | OF: 5

SOIL BORING LOG

PROJECT: POST POINT WWTP
ELEVATION: 14.7'
DRILLING METHOD AND EQUIPMENT: MUD ROTARY, CME-75
WATER LEVEL AND DATE: 10.7' - 08/04/89

LOCATION: B-14
DRILLING CONTRACTOR: KENNER DRILLING
START: 08/01/89 FINISH: 08/02/89 LOGGER: B.M. WITEK

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL (FT)	SAMPLE TYPE AND NUMBER	SAMPLE REC (FT)	STD. PEN. TEST 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL	SYMBOL	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TEST AND INSTRUMENTATION
90							
	95.0						
95		S18	1.5	2-6-7 (13)	AS in S-17, except stiff, some 1/2 inch diameter angular gravel fragments.		
	96.5						
100							
							Gravel layer from 102 to 103 feet, then firmer sand? below that.
	105.0						
105		S19	0.9	2-5-8 (13)	As above (CL).		
	106.5						
							A few scattered large rocks.
110							
	115.0						Stiffer drilling.
115		S20	NR	6-10-13 (23)	As above, very stiff (CL).		
	116.5						
120							

CH2M HILL

PROJECT NUMBER: SEA22462.B5 | BORING NUMBER: B-14 | SHEET: 5 | OF: 5

SOIL BORING LOG

PROJECT: POST POINT WWTP
ELEVATION: 14.7'
DRILLING METHOD AND EQUIPMENT: MUD ROTARY, CME-75
WATER LEVEL AND DATE: 10.7- 08/04/89

LOCATION: B-14
DRILLING CONTRACTOR: KENNER DRILLING
START: 08/01/89 FINISH: 08/02/89 LOGGER: D.E. MYERS

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL (FT)	SAMPLE TYPE AND NUMBER	SAMPLE REC (FT)	STD. PEN. TEST 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL	SYMBOL	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TEST AND INSTRUMENTATION
120							
							At 123 feet, hard gravel layer.
125							
	130.0						Observation well installation.
130		S21	0.3	60/3"	WELL GRADED SAND with GRAVEL, gray, wet, very dense, medium grained (SW).		Drilled hole 15 feet south of original location to depth of 20 feet.
	130.3				End of boring at 130.3 feet.		Monument casing at surface set in cement grout.
							Hole plug from 1 to 13 feet.
135							Gravel pack from 13 to 20 feet.
							2 inch diameter slotted PVC tip from 16 to 18 feet.
140							
145							
150							

CH2M HILL

PROJECT NUMBER: SEA22462.B5 | BORING NUMBER: B-15 | SHEET: 3 | OF: 3

SOIL BORING LOG

PROJECT: POST POINT WWTP
ELEVATION: 17.2'
DRILLING METHOD AND EQUIPMENT: MUD ROTARY, CME-75
WATER LEVEL AND DATE: 12.8' - 08/04/89

LOCATION: B-15
DRILLING CONTRACTOR: KENNER DRILLING
START: 08/02/89 FINISH: 08/03/89 LOGGER: D.E. MYERS

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL (FT)	SAMPLE TYPE AND NUMBER	SAMPLE REC (FT)	STD. PEN. TEST 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL	SYMBOL	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TEST AND INSTRUMENTATION
60		S12	1.5	5-6-6 (12)	SILTY SAND, gray, moist, medium dense, sand, medium grained (SM).		
	61.5						
	65.0						At 63-1/2 feet, back into softer material, silt?
65		S13	1.7	2-3-5 (8)	SILTY FINE SAND, gray, moist, loose, poorly graded, with interbeds of fat gray clay and well graded, medium grained, gray silty sand (SM)(CH).		
	66.5						
	70.0						Into Gravels at 68 feet.
70		S14	1	16-27-42 (69)	SILTY FINE SAND and SANDY GRAVEL INTERBEDDED, gray, moist, very dense, sand, well graded, gravel, 1/2 inch minus (SP).		
	71.5						
	75.0						
75		S15	.4	29-22-16 (38)	POORLY GRADED SAND, gray, moist, dense, fine grained (SP).		
	76.5						
	80.0						
80		S16	1.3	3-35 (60/4")	As in S-14.		Slow drilling 81 to 85 feet.
	81.3						Bottom 5 inches of sample appears to be dense sandy gravel.
	85.0						Observation well installation.
85		S17	.7	29-26-44 (70)	WELL GRADED GRAVEL with SAND, gray, moist, very dense (GW).		Drilled hole 15 feet S.E. of original location to 20 foot depth.
	86.5				End of Boring at 86.5 feet.		Monument casing at surface set in cement grout.
90							Hole plug from 1 to 12 feet. Gravel pack from 12 to 20 feet. 2 inch diameter slotted PVC tip from 16 to 18 feet.

CH2M HILL

PROJECT NUMBER: SEA22462.B5 | BORING NUMBER: B-16 | SHEET: 1 | OF: 5

SOIL BORING LOG

PROJECT: POST POINT WWTP
ELEVATION:
DRILLING METHOD AND EQUIPMENT: MUD ROTARY, CME-75
WATER LEVEL AND DATE:

LOCATION: B-16
DRILLING CONTRACTOR: KENNER DRILLING
START: 08/03/89 FINISH: 08/03/89 LOGGER: D.E. MYERS

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL (FT)	TYPE AND NUMBER	REC (FT)	STD. PEN. TEST 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL	SYMBOL	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TEST AND INSTRUMENTATION
0							
	5.0						
5		S1	0.6	17-19-12 (31)	WELL GRADED GRAVEL with SAND, gray, moist, dense, (GW).		3/4 inch diameter rock fragments.
	6.5						
	10.0						
10		S2	0.0	5-3-7 (10)	No recovery.		1-1/2 inch rock in sampler.
	11.5						
	15.0						Drilled through fill at 14 feet.
15		S3	0.0	2-1-2 (3)	No recovery.		
	16.5						
	20.0						
20		S4	1.3	1-1-3 (4)	SILT, gray, moist, soft, with organics (ML).		Roots present through bottom 5 inches of sample.
	21.5						Gravel layer, from 23 1/2 to 24 1/2 feet.
	25.0						
25		S5	1.0	2-3-2 (5)	SILTY CLAY, gray with some brown staining, wet, firm (CL-ML).		
	26.5						
30							

CH2M HILL

PROJECT NUMBER: SEA22462.B5 | BORING NUMBER: B-16 | SHEET: 2 | OF: 5

SOIL BORING LOG

PROJECT: POST POINT WWTP
LOCATION: B-16
ELEVATION:
DRILLING CONTRACTOR: KENNER DRILLING
DRILLING METHOD AND EQUIPMENT: MUD ROTARY, CME-75
WATER LEVEL AND DATE:
START: 08/03/89 FINISH: 08/03/89 LOGGER: D.E. MYERS

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL (FT)	TYPE AND NUMBER	REC (FT)	STD. PEN. TEST 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL	SYMBOL	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TEST AND INSTRUMENTATION
30	32.0	ST6	2.0	PUSH			ST6, easy push.
		S7	1.5	1-2-1 (3)	FAT CLAY, gray, wet, soft, highly plastic (CH).		
	33.5 35.0						
35		S8	2.0	1-1-1 (2)	SANDY LEAN CLAY, gray, wet, soft, slightly plastic (CL).		
	36.5						Sand at 37 1/2 feet.
	40.0						
40		S9	0.2	8-5-9 (14)	CLAYEY SAND, gray & tan, wet, stiff, clay is highly plastic (SC).		
	41.5						
	45.0						Back into silt at 43.5 feet.
45		S10	0.8	4-5-10 (23)	SANDY LEAN CLAY, interbedded with SILTY FINE SAND, CLAY: gray, wet, very stiff, moderately plastic (CL). SAND: gray, moist, medium dense, poorly graded (SM).		
	46.5						
	50.0						
50		S11	1.2	2-2-6 (8)	FAT CLAY with COARSE SAND, gray, wet, firm, highly plastic (CH).		
	51.5						
	55.0						
55		S12	1.1	3-3-2 (5)	SILT with SAND, gray, wet, firm, slightly to moderately plastic, sand, fine grained (ML).		
	56.5						
60							

CH2M HILL

PROJECT NUMBER: SEA22462.B5 | BORING NUMBER: B-16 | SHEET: 3 | OF: 5

SOIL BORING LOG

PROJECT: POST POINT WWTP
ELEVATION:
DRILLING METHOD AND EQUIPMENT: MUD ROTARY, CME-75
WATER LEVEL AND DATE:

LOCATION: B-16
DRILLING CONTRACTOR: KENNER DRILLING
START: 08/03/89 FINISH: 08/03/89 LOGGER: D.E. MYERS

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL (FT)	TYPE AND NUMBER	REC (FT)	STD. PEN. TEST 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL	SYMBOL	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TEST AND INSTRUMENTATION
60		S13	1.3	5-5-7 (12)	SILT with SAND and GRAVEL, gray, wet, stiff, (ML)		
	61.5						
	65.0						
65		S14	1.7	3-3-6 (9)	SILT, gray, wet, stiff, slightly plastic (ML) interbedded with SILTY SAND, wet, loose, sand, medium grained and well graded (SM).		
	66.5						
	70.0						
70		S15	1.2	17-11-3 (14)	SILT, gray, wet, stiff, slightly to moderately plastic (ML).		
	71.5						
	75.0						
75		S16	0.7	4-2-7 (9)	SANDY SILT with SILTY SAND INTERBEDS, SAND: fine, well graded, loose (SM), SILT: gray, wet, stiff, moderately plastic (ML).		
	76.5						
	80.0						
80		S17	1.3	3-2-5 (7)	As in S16.		
	81.5						
	85.0						
85		S18	1.5	7-5-5 (10)	As above, except primarily silty sand.		Went to 10 foot sample interval at 85 feet.
	86.5						
90							

SOIL BORING LOG

PROJECT: POST POINT WWTP
ELEVATION:
DRILLING METHOD AND EQUIPMENT: MUD ROTARY, CME-75
WATER LEVEL AND DATE:

LOCATION: B-16
DRILLING CONTRACTOR: KENNER DRILLING
START: 08/03/89 FINISH: 08/03/89 LOGGER: D.E. MYERS

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL (FT)	SAMPLE TYPE AND NUMBER	SAMPLE REC (FT)	STD. PEN. TEST 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL	SYMBOL	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TEST AND INSTRUMENTATION
90							
	95.0						
95		S19	1.2	5-3-5 (8)	SANDY SILT to SILTY SAND, gray, wet, firm, silt, slightly plastic (ML-SM).		
	96.5						
100							
	105.0						
105		S20	0.4	5-6-8 (14)	SANDY SILT, gray, wet, stiff, moderately plastic (ML).		
	106.5						
110							
							Hard drilling at 114 feet.
115							
120							

CH2M HILL

PROJECT NUMBER: SEA22462.B5 | BORING NUMBER: B-16 | SHEET: 5 | OF: 5

SOIL BORING LOG

PROJECT: POST POINT WWTP
ELEVATION:
DRILLING METHOD AND EQUIPMENT: MUD ROTARY,
WATER LEVEL AND DATE:

LOCATION: B-16
DRILLING CONTRACTOR: KENNER DRILLING CME-75
START: 08/03/89 FINISH: 08/03/89 LOGGER: D.E. MYERS

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL (FT)	SAMPLE TYPE AND NUMBER	SAMPLE REC (FT)	STD. PEN. TEST 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL	SYMBOL	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TEST AND INSTRUMENTATION
120		S21	0.3	60/3"	WELL GRADED GRAVEL with SAND, gray, moist, very dense (GW).		
	120.3				End of Boring at 120.3 feet.		
125							
130							
135							
140							
145							
150							

CH2M HILL

PROJECT NUMBER: SEA22462.B5 | BORING NUMBER: B-15 | SHEET: 1 | OF: 3

SOIL BORING LOG

PROJECT: POST POINT WWTP
LOCATION: B-17
ELEVATION:
DRILLING CONTRACTOR: KENNER DRILLING
DRILLING METHOD AND EQUIPMENT: MUD ROTARY, CME-75
WATER LEVEL AND DATE: 12.8' - 08/04/89
START: 08/02/89 FINISH: 08/03/89 LOGGER: D.E. MYERS

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL (FT)	SAMPLE TYPE AND NUMBER	SAMPLE REC (FT)	STD. PEN. TEST 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL	SYMBOL	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TEST AND INSTRUMENTATION
0							
	5.0						
5		S1	0.6	15-10-10 (20)	SILTY SAND, brown, moist, medium dense, with occasional gravel (SM).		2 to 1-1/2 inch gravel fragments.
	6.5						
	10.0						
10		S2	0.5	10-11-7 (18)	WELL GRADED SAND with GRAVEL, gray, moist?, medium dense (SW).		
	11.5						
							Softened at 14 feet.
	15.0						
15		S3	0.0	1-1-2 (3)	No Recovery.		
	16.5						Back into loose gravel at 17 feet.
	20.0						
20		S4	0.2	10-5-3 (8)	POORLY GRADED GRAVEL, gray, moist, loose, angular to subangular 1 1/4 inch minus gravel (GP).		
	21.5						Softer drilling at 23 feet.
	25.0						
25		S5	0.4	4-3-3 (6)	SILT, gray, wet, medium firm (ML)		
	26.5						
30							

CH2M HILL

PROJECT NUMBER: SEA22462.B5 | BORING NUMBER: B-15 | SHEET: 2 | OF: 3

SOIL BORING LOG

PROJECT: POST POINT WWTP
LOCATION: B-17
ELEVATION:
DRILLING CONTRACTOR: KENNER DRILLING
DRILLING METHOD AND EQUIPMENT: MUD ROTARY, CME-75
WATER LEVEL AND DATE: 12.8' - 08/04/89
START: 08/02/89 FINISH: 08/03/89 LOGGER: D.E. MYERS

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL (FT)	SAMPLE TYPE AND NUMBER	SAMPLE REC (FT)	STD. PEN. TEST 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL	SYMBOL	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TEST AND INSTRUMENTATION
30		S6	1.5	1-6" 1-12"	FAT CLAY, gray, wet, very soft, highly plastic (CH).		
	31.5						
	35.0						
35		S7	1.2	7-9-23 (32)	SILTY FINE SAND, gray, moist?, medium dense (SM)		
	36.5						
							Into softer material.
	40.0						
40							Back into sand.
		S8	0.8	7-15-12 (27)	As above in S7.		
	41.5						
							Back into silt?
	45.0						
45		S9	1.3	1-5-3 (8)	FAT CLAY, as in S6, interbeded with silty fine sand.		
	46.5						
							Scattered rocks.
							Back into silt.
	50.0						
50		S10	1.7	2-3-4 (7)	FAT CLAY with GRAVEL, gray, wet, firm, gravel, mainly 3/4 inch minus.		
	51.5						
	55.0						
55		S11	1.7	4-3-4 (7)	FAT CLAY, gray, wet, firm, moderately plastic (CH) INTERBEDDED with SILTY FINE SAND to FINE SAND with SILT, gray, moist, loose (SM).		
	56.5						
							Back into sand.
60							

APPENDIX D
Site Specific Seismic Response Analysis

APPENDIX D
SITE-SPECIFIC SEISMIC RESPONSE ANALYSIS

General

A site-specific seismic site response analysis was completed for this project to evaluate the site effects and to develop the ground surface design response spectra for use in the design and analysis of the Bellingham Waste Water Treatment Plant improvements. The analysis was completed and the design response spectra were developed in general accordance with the procedures outlined in the 2009 International Building Code (IBC) in conjunction with Chapter 21 of the American Society of Civil Engineers (ASCE) 7-05 code. The following presents the general approach in completing the analysis and development of the ground surface design spectra:

- Developing a target rock outcrop response spectrum using the probabilistic ground motion parameters determined from the 2002 United States Geological Survey (USGS) Probabilistic Seismic Hazard Model.
- Selecting representative earthquake time histories with source zones, magnitudes and site to source distance that are consistent with the site regional tectonic setting and seismicity.
- Scaling the selected time histories such that the average of their response spectra is a good match to the target rock outcrop response spectrum.
- Developing a soil models using subsurface soil information obtained from the explorations completed at the project site, published shear wave velocity data in close proximity to the project site, and geologic maps.
- Propagating the scaled time histories through the soil models developed to assess the amplification and damping effect of the site soils and developing response spectra at the ground surface (top of the soil profile).
- Establishing site specific design spectra using the results of the seismic response analysis per ASCE 7-05 code.

DEVELOPMENT OF TARGET ROCK OUTCROP RESPONSE SPECTRUM

The USGS 2002 probabilistic seismic hazard deaggregation was completed for a 2 percent probability of exceedance (PE) in 50 years and used to evaluate the seismic hazard at the project area (122.514 W, 48.717 N). Using the spectral acceleration values estimated by the USGS for periods between 0 and 2 seconds, a maximum considered earthquake (MCE) response spectrum for the rock site condition was constructed and was used as the target spectrum in scaling our selected input motions used in our site response analysis, as described below.

SITE-RESPONSE ANALYSIS

Selection of Input Ground Motions

In order to provide representative earthquake acceleration time histories for the site-response analysis, we reviewed the percent contribution of the regional source zones to the estimated seismic hazard at the project area using the USGS 2002 probabilistic seismic hazard

deaggregation for ground motions with a 2 percent PE in 50 years. From the USGS deaggregation, we observed that 54 percent was attributed to shallow gridded earthquakes, 30 percent was attributed to deep gridded earthquakes, 15 percent was attributed to a magnitude 9 cascadia subduction zone earthquake and 1 percent to the Devil's Mountain Fault. Based on this evaluation, we selected three intraplate subduction zone [IP] events, three shallow crustal events [C], and one interface subduction zone [IF] event to be used as input ground motions for the site response analysis. The ground motions selected using the criteria described above are presented in Table D-1.

Scaling of Input Ground Motions

The selected input motion time histories were scaled prior to completing site response analysis. Each selected time history was scaled so that its response spectrum is, on average, approximately at the level of the target rock site response spectrum as defined above over the period range of 0 to 2 seconds. The scaling factors applied to each earthquake are shown in Table D-2. Figure D-1 shows the response spectra for the average of each orthogonal pair of scaled input motion time histories, their average, and the target response spectrum used as a guide for scaling the input motions.

TABLE D-1. GROUND MOTIONS

Earthquake, Year	Recording Station	Fault Mechanism	Magnitude	Distance (km)	Scale Factor for 2475-YR Event	Unscaled PGA (orientation of orthogonal component)
Loma Prieta, 1989	Los Gatos	Crustal	6.9	6	0.61	0.97 (NS)
						0.59 (EW)
Nisqually, 2001	Maple Valley	Subduction Zone, Intraplate	6.8	75.2	4.80	0.08 (000)
						0.10 (090)
Morgan Hill, 1984	USGS 1652 Anderson Dam (downstream)	Crustal	6.2	3.3	1.30	0.423 (250)
						0.289 (340)
El Salvador, 2001	Santiago de Maria	Subduction Zone, Intraplate	7.6	52.2	0.53	0.72 (090)
						0.88 (360)
North Palm Springs, 1986	CDMG 12204 San Jacinto - Soboba	Crustal	6.1	22.9	2.00	0.250 (000)
						0.239 (090)
Nisqually, 2001	Tacoma UPS	Subduction Zone, Intraplate	6.8	56.8	7.30	0.06 (000)
						0.06 (090)
Synthetic	N/A	Subduction Zone, Interface	9.2	N/A	1.52	0.09 (FP)
						0.44 (FN)

Soil Profile

A site-response model based on low-strain shear wave velocities was developed for this project. The explorations completed at the project area extend to an approximate maximum depth of 125 feet and were terminated in very dense sand. A review of the regional geology at the site shows that the site is located in an alluvial valley ranging from approximately 20 to 100 feet deep, which is underlain by undifferentiated glacial drift deposits from the Vashon stage of the Frasier glaciation. The glacial deposits are underlain by the Chuckanut Formation consisting of sandstone and siltstone. The Chuckanut Formation generally dips towards Bellingham Bay at the northwest portion of the site creating a bedrock bowl formation beneath the project area. The depth to bedrock was assumed to range from 80 to 120 feet below the ground surface (bgs).

Based on the field data from the subsurface explorations the project area was split into two areas: the west profile and the east profile. A preliminary sensitivity analysis was completed to compare the site response using the west and east profiles. Because the west profile was determined to show a higher site response, it was selected to be used in the more in-depth site-specific seismic response analysis presented below. The results of the seismic analysis for the west profile were then adjusted to determine the response spectrum for the east profile. A detailed description of the soil profile used in the analysis is presented below.

The shear wave velocities of the soil for the site were determined using a seismic cone penetrometer test (CPT) and standard penetration tests (SPT). The shear wave velocities of the bedrock for the site were chosen based on published sonic wave velocity data specific to the Chuckanut Formation (bedrock) near the project site reported in a USGS Technical Report (Brocher and Ruebel, 1998)

In general, a mantle of fill soils, approximately 5 feet thick, overlies the project area and is underlain by alluvial deposits. The thickness of the alluvial deposits were approximately 85 feet at the west half of the project area. The alluvial deposits were assumed to consist of a 35-foot thick younger alluvial deposit overlying a 40-foot thick layer of older alluvial deposit, of greater consistency. Below the alluvial deposits undifferentiated glacial deposits were assumed to extend to a depth of 120 feet below ground surface to the Chuckanut Formation (bedrock). The design shear wave velocity profile used in D-MOD2000 for the seismic analysis are shown in Figure D-5. Table D-2 summarizes the soil type, unit weights (γ), shear wave velocity (Vs) and shear modulus reduction and damping curves used in the D-MOD2000 model for the soil profile used in our analysis.

TABLE D-2. SOIL PROFILE MODEL

Depth (ft)		Material Type	γ (pcf)	Vs (ft/s)	Shear Modulus Reduction and Damping Curves
Start	End				
0	5	Sandy Silt to Silty Sand (Fill)	125	850	EPRI: Deep, Cohesionless: 0 – 20 ft
5	20	Sand, Silt and Clay (Younger Alluvium)	115	600	EPRI: Deep, Cohesionless: 0 – 20 ft
20	40	Sand, Silt and Clay (Younger Alluvium)	115	600	EPRI: Deep, Cohesionless: 21 – 50 ft
40	60	Silt and Clay with Sand (Older Alluvium)	115	700	Soil with PI=15 (Vucetic et al, 1991)
60	80	Silt and Clay with Sand (Older Alluvium)	115	850	Soil with PI=15 (Vucetic et al, 1991)
80	100	Glacial Deposits	130	1200	EPRI: Deep, Cohesionless: 251 – 500 ft
100	120	Glacial Deposits	130	1500	EPRI: Deep, Cohesionless: 251 – 500 ft
120+		Chuckanut Formation (bedrock)	150	2500	N/A

Site-Response Analysis and Computed Results

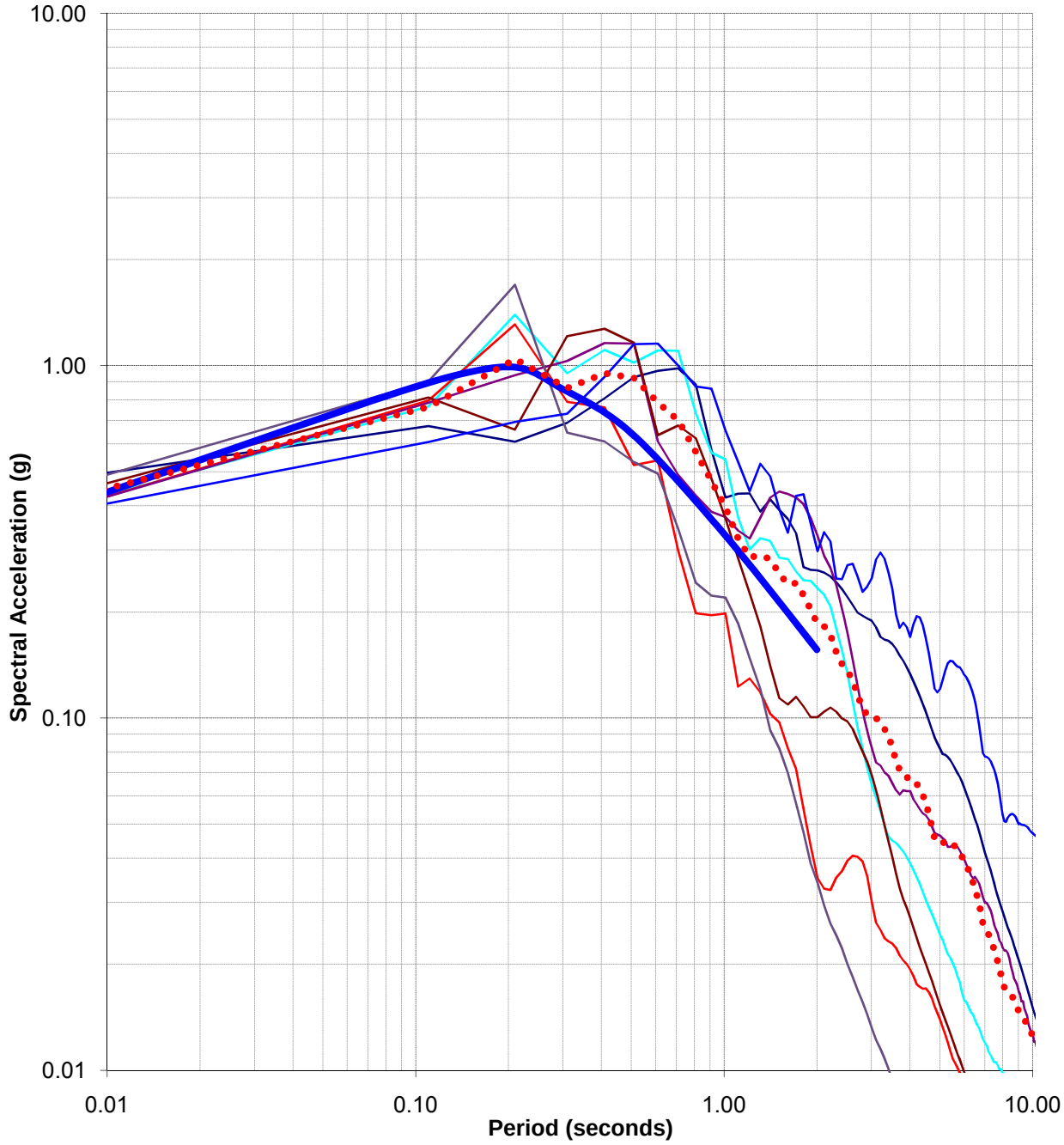
The site-response analysis was completed using the computer program D-MOD2000 (GeoMotions, LLC. 2007). D-MOD2000 is a computer program for nonlinear, one-dimensional seismic-response analysis.

Response spectra for 5 percent structural damping were developed for the site by propagating the scaled input motions through the soil profile using D-MOD2000. We analyzed one soil profile under a Maximum Considered Earthquake (MCE) event. For each profile 14 response spectra at the ground surface were computed, one for each component of the seven input acceleration time histories. Figure D-3 shows the MCE response spectra for each motion and their respective computed average. The amplification factor (AF), which is the ratio of the surface spectral acceleration to the scaled input rock spectral acceleration, was then calculated. Figure D-4 shows the amplification factor for each motion and their respective computed average. The average AF at the ground surface was then used to construct the site-specific design spectra for the project, as described below.

Site-Specific Design Spectrum

The site-specific design spectrum for the project area was determined by applying the average AF for the profile to the target rock spectrum in accordance with the procedures outlined in the ASCE 7-05 code, Sections 21.1.3 and 21.4. Figure D-5 shows the average AF computed by D-MOD2000 multiplied by the target rock spectrum determined from the USGS probabilistic seismic hazard

deaggregation. The average soil shear wave velocity in the top 100 feet of the profile ($\overline{V}_s$) was determined for the soil profile. This soil property was then used to determine the site class per the 2009 IBC. Site class E was identified for the project site. For comparison purposes, the site class E generalized design response spectrum and 80 percent of the site class E generalized response spectrum per the ASCE 7-05 are shown on Figure D-5. The recommended design response spectrum was developed based on the 80 percent site class E and site specific AF and is shown in red on Figure D-5.



Legend

- Loma Prieta 1989 - Los Gatos AVG [C]
- Nisqually 2001 Maple Valley AVG [IP]
- El Salvador Santiago de Maria AVG [IP]
- Nisqually 2001 - Tacoma UPS AVE [IP]
- Morgan Hill 1984 - Anderson Dam AVG [C]
- N. Palm Springs 1986 - San Jacinto AVG [C]
- Synthetic Cascadia AVE [IF]
- USGS Rock Outcrop 2475-year event

[C] Crustal Event
[IF] Interface Subduction Zone Event
[IP] Intraplate Subduction Zone Event

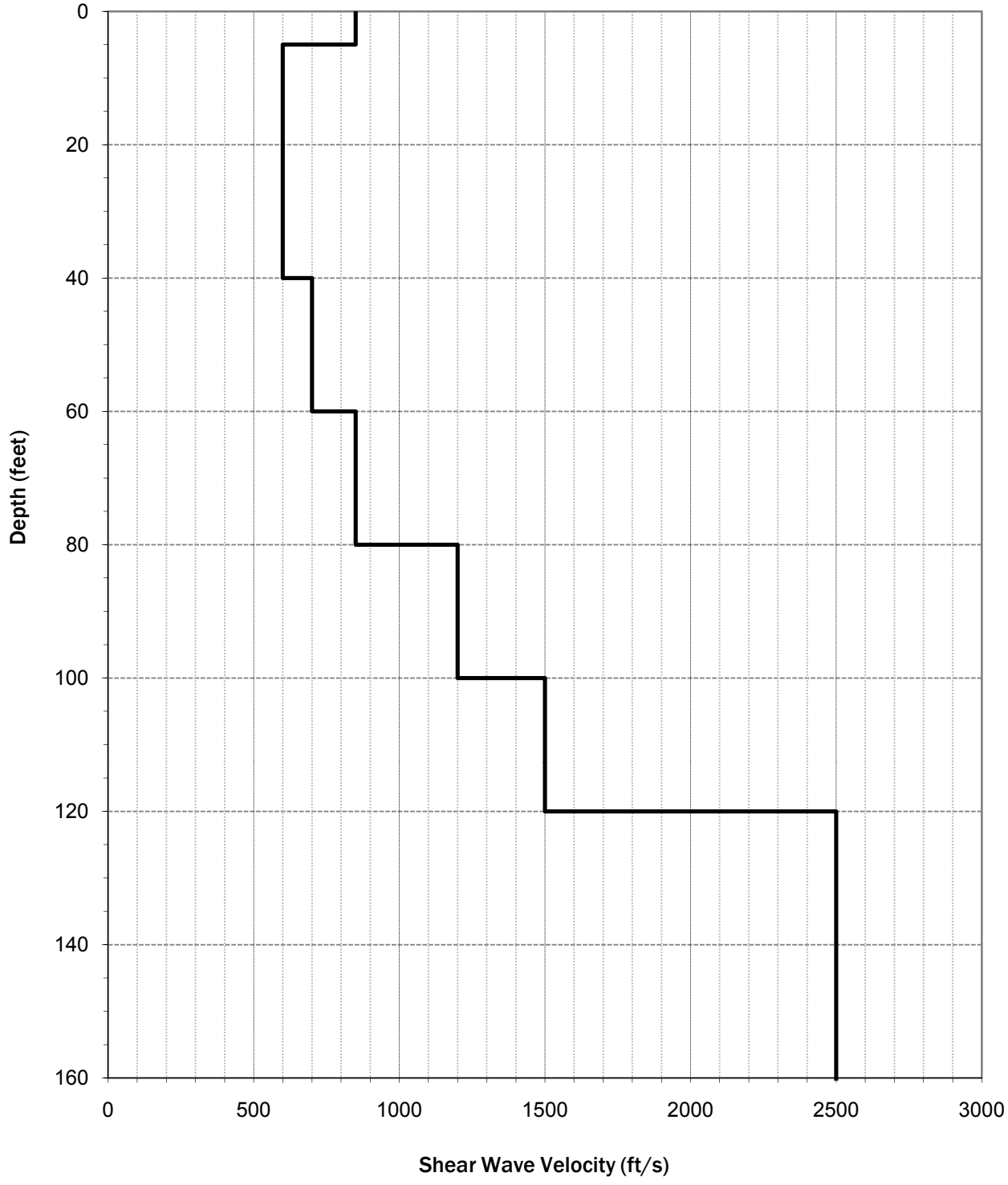
5% Damped Response Spectra of Scaled Input Ground Motions, 2475 YR EQ Event

Post Point WWTP Expansion
Bellingham, Washington

GeoEngineers

Figure D-1

SharePoint: 035610600\Technical Analysis\Seismic Site Response Analysis\Bham_WWTP_Rock Outcrop Target Spectra Match_2475.xlsx NCS:khc



Best Estimate Vs

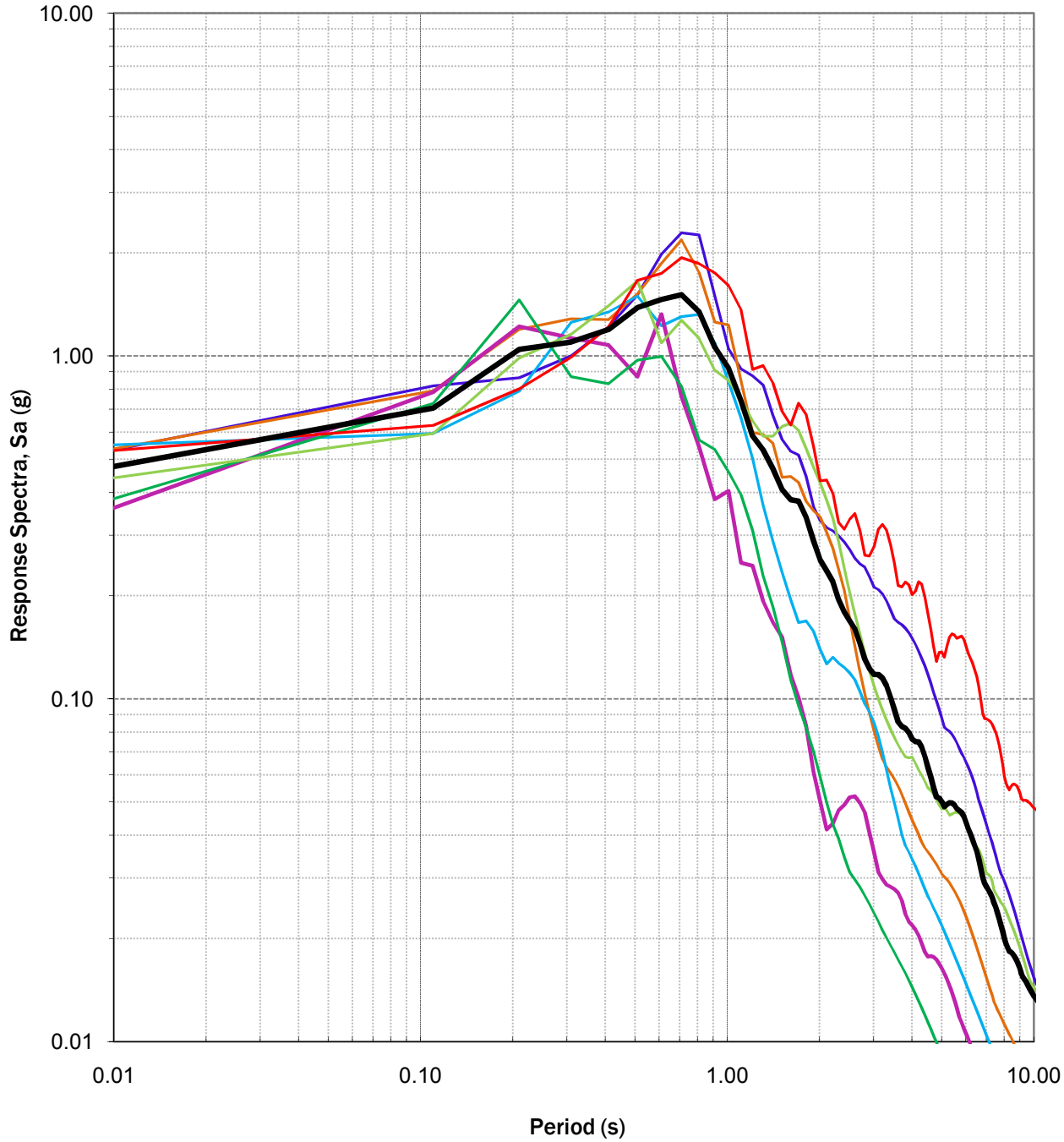
Design Shear Wave Velocity Profile

Post Point WWTP Expansion
Bellingham, Washington

GeoEngineers

Figure D-2

SharePoint: 035610600\Technical Analysis\Seismic Site Response Analysis\Bham_WWTP - Vs Profile_A.xlsx NCS:khc



SharePoint: 035610600\Technical Analysis\Seismic Site Response Analysis\Bham_WWTP-Response Spectra.xlsx NCS:khc

- Loma Prieta 1989 - Los Gatos AVG [C]
- Nisqually 2001 Maple Valley AVG [IP]
- Morgan Hill 1984 - Anderson Dam AVE [C]
- El Salvador Santiago de Maria AVG [IP]
- North Palm Springs 1986 - San Jacinto AVE [C]
- Nisqually 2001 - Tacoma UPS AVE [IP]
- Synthetic Cascadia AVE [IF]
- Average

Legend

[C] Crustal Event

[IF] Interface Subduction Zone Event

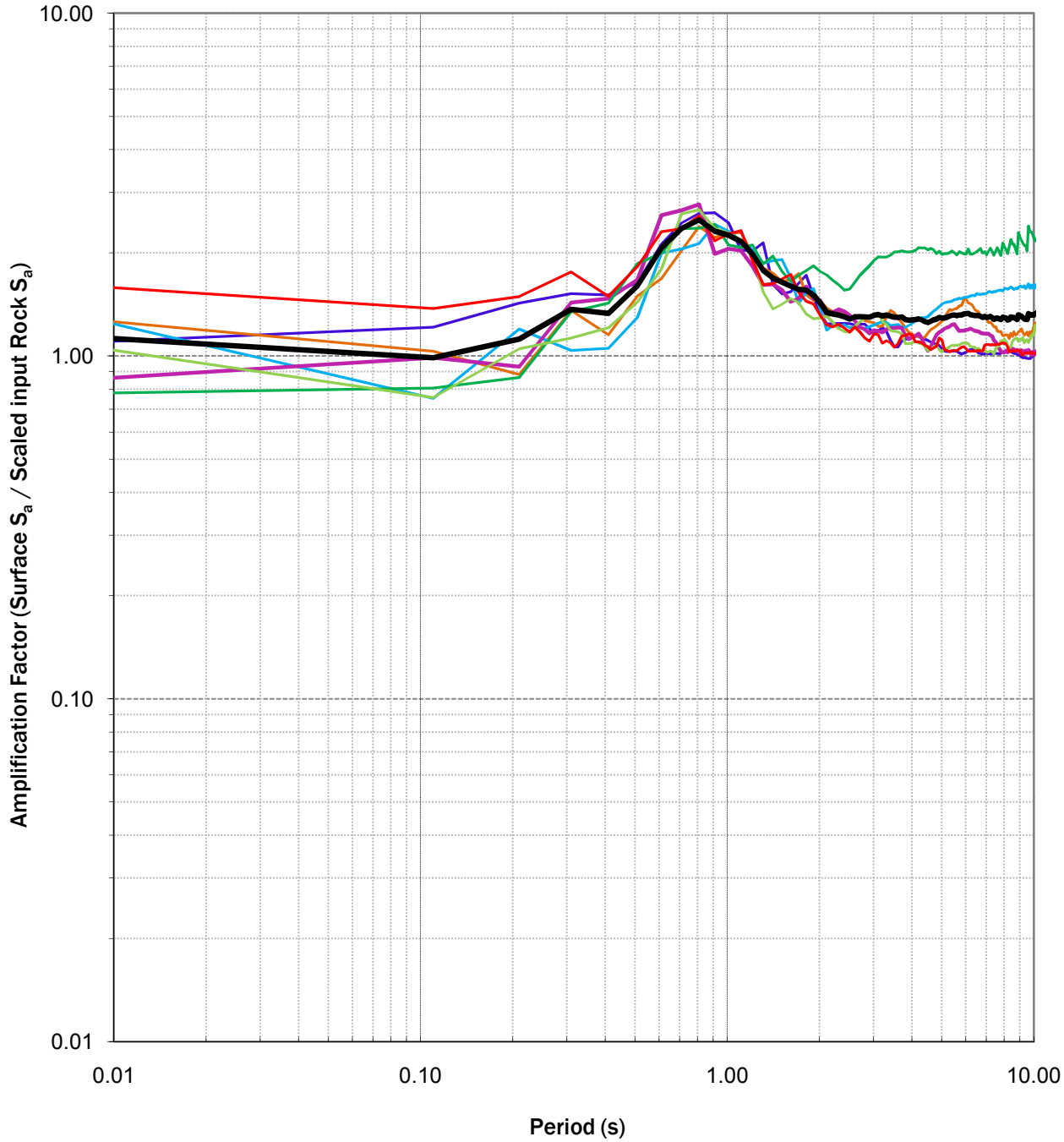
[IP] Intraplate Subduction Zone Event

5% Damped MCE Response Spectra at Surface, 2475 YR EQ Event

Post Point WWTP Expansion
Bellingham, Washington

GeoEngineers

Figure D-3



Legend

- Loma Prieta 1989 - Los Gatos AVG [C]
- Nisqually 2001 Maple Valley AVG [IP]
- Morgan Hill 1984 - Anderson Dam AVE [C]
- El Salvador Santiago de Maria AVG [IP]
- North Palm Springs 1986 - San Jacinto AVE [C]
- Nisqually 2001 - Tacoma UPS AVE [IP]
- Synthetic Cascadia AVE [IF]
- Average

[C] Crustal Event
[IF] Interface Subduction Zone Event
[IP] Intraplate Subduction Zone Event

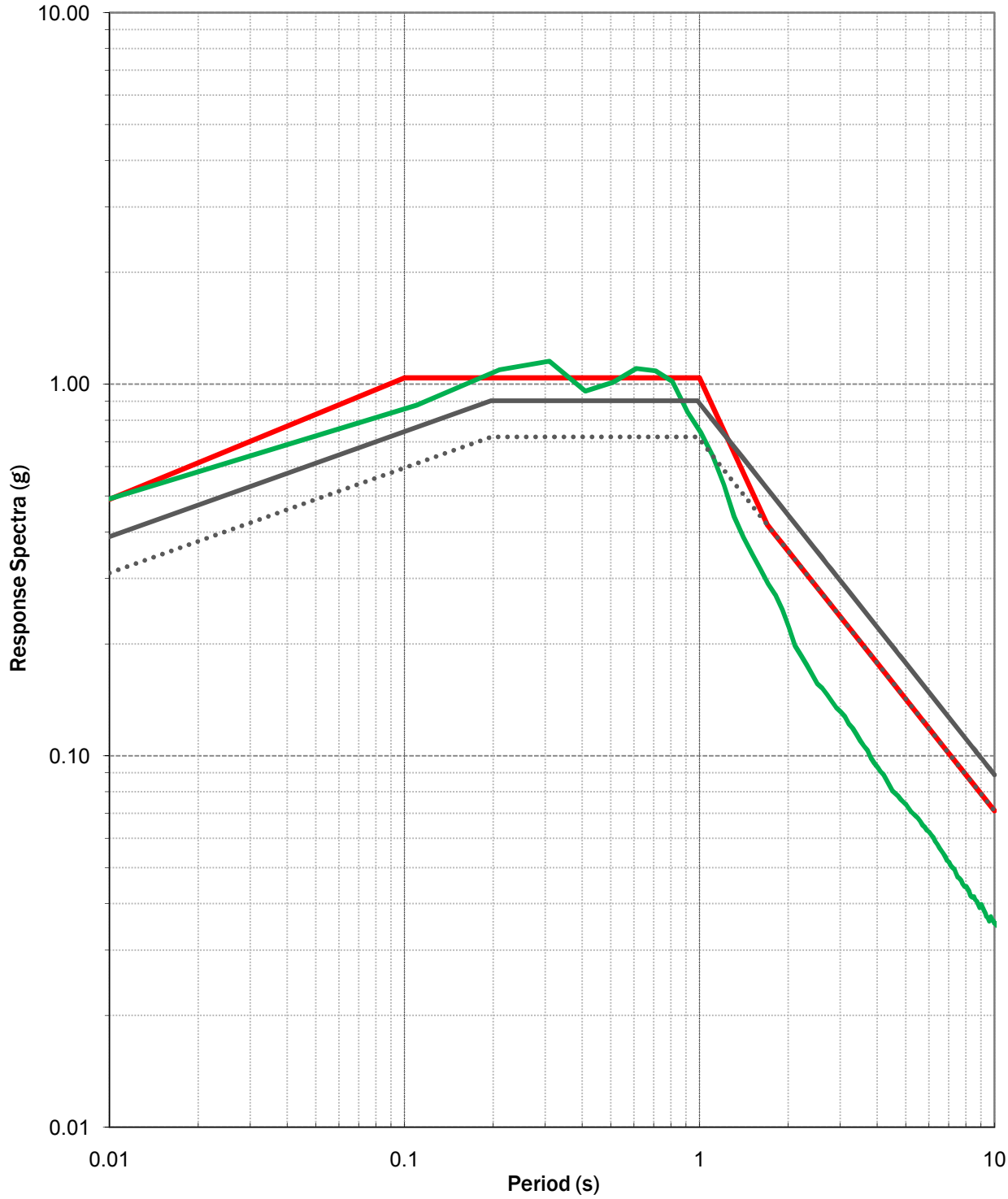
5% Damped MCE Amplification Factor at Surface, 2475 YR EQ Event

Post Point WWTP Expansion
Bellingham, Washington

GeoEngineers

Figure D-4

SharePoint: 0356 10600\Technical Analysis\Seismic Site Response Analysis\Bham_WWTP-Response Spectra.xlsx NCS:khc



MCE Response Spectrum for 2475 year Event

Average Best Estimate AF X Rock Outcrop (ASCE 7 Approach)

Site Class E General Response Spectrum (ASCE 7 Approach)

0.8 x Site Class E General Response Spectrum (ASCE 7 Approach)

5% Damped Site Specific MCE Response Spectra, 2475 YR EQ Event

Post Point WWTP Expansion
Bellingham, Washington

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Figure D-5

SharePoint: 03561060\Technical Analysis\Seismic Site Response Analysis\Bham_WWTP- Design Response Spectra.xlsx NCS:khc

APPENDIX E
Report Limitations and Guidelines for Use

REPORT LIMITATIONS AND GUIDELINES FOR USE[1]

This appendix provides information to help you manage your risks with respect to the use of this report.

Geotechnical Services are Performed for Specific Purposes, Persons and Projects

This report has been prepared for the exclusive use of the City of Bellingham, Carollo Engineers, and their authorized agents. This report may be made available to other members of the design team. This report is not intended for use by others, and the information contained herein is not applicable to other sites.

GeoEngineers structures our services to meet the specific needs of our clients. For example, a geotechnical or geologic study conducted for a civil engineer or architect may not fulfill the needs of a construction contractor or even another civil engineer or architect that are involved in the same project. Because each geotechnical or geologic study is unique, each geotechnical engineering or geologic report is unique, prepared solely for the specific client and project site. Our report is prepared for the exclusive use of our Client. No other party may rely on the product of our services unless we agree in advance to such reliance in writing. This is to provide our firm with reasonable protection against open-ended liability claims by third parties with whom there would otherwise be no contractual limits to their actions. Within the limitations of scope, schedule and budget, our services have been executed in accordance with our Agreement with the Client and generally accepted geotechnical practices in this area at the time this report was prepared. This report should not be applied for any purpose or project except the one originally contemplated.

A Geotechnical Engineering or Geologic Report is Based on a Unique Set of Project-specific Factors

This report has been prepared for the proposed Post Point Wastewater Treatment Plant Expansion project to be located in Bellingham, Washington. GeoEngineers considered a number of unique, project-specific factors when establishing the scope of services for this project and report. Unless GeoEngineers specifically indicates otherwise, do not rely on this report if it was:

- not prepared for you,
- not prepared for your project,
- not prepared for the specific site explored, or
- completed before important project changes were made.

For example, changes that can affect the applicability of this report include those that affect:

- the function of the proposed structure;
- elevation, configuration, location, orientation or weight of the proposed structure;

[1] Developed based on material provided by ASFE, Professional Firms Practicing in the Geosciences; www.asfe.org .

- composition of the design team; or
- project ownership.

If important changes are made after the date of this report, GeoEngineers should be given the opportunity to review our interpretations and recommendations and provide written modifications or confirmation, as appropriate.

Subsurface Conditions Can Change

This geotechnical or geologic report is based on conditions that existed at the time the study was performed. The findings and conclusions of this report may be affected by the passage of time, by manmade events such as construction on or adjacent to the site, or by natural events such as floods, earthquakes, slope instability or groundwater fluctuations. Always contact GeoEngineers before applying a report to determine if it remains applicable.

Most Geotechnical and Geologic Findings are Professional Opinions

Our interpretations of subsurface conditions are based on field observations from widely spaced sampling locations at the site. Site exploration identifies subsurface conditions only at those points where subsurface tests are conducted or samples are taken. GeoEngineers reviewed field and laboratory data and then applied our professional judgment to render an opinion about subsurface conditions throughout the site. Actual subsurface conditions may differ, sometimes significantly, from those indicated in this report. Our report, conclusions and interpretations should not be construed as a warranty of the subsurface conditions.

Geotechnical Engineering Report Recommendations are Not Final

Do not over-rely on the preliminary construction recommendations included in this report. These recommendations are not final, because they were developed principally from GeoEngineers' professional judgment and opinion. GeoEngineers' recommendations can be finalized only by observing actual subsurface conditions revealed during construction. GeoEngineers cannot assume responsibility or liability for this report's recommendations if we do not perform construction observation.

Sufficient monitoring, testing and consultation by GeoEngineers should be provided during construction to confirm that the conditions encountered are consistent with those indicated by the explorations, to provide recommendations for design changes should the conditions revealed during the work differ from those anticipated, and to evaluate whether or not earthwork activities are completed in accordance with our recommendations. Retaining GeoEngineers for construction observation for this project is the most effective method of managing the risks associated with unanticipated conditions.

A Geotechnical Engineering or Geologic Report Could be Subject to Misinterpretation

Misinterpretation of this report by other design team members can result in costly problems. You could lower that risk by having GeoEngineers confer with appropriate members of the design team after submitting the report. Also retain GeoEngineers to review pertinent elements of the design team's plans and specifications. Contractors can also misinterpret a geotechnical engineering or

geologic report. Reduce that risk by having GeoEngineers participate in pre-bid and preconstruction conferences, and by providing construction observation.

Do Not Redraw the Exploration Logs

Geotechnical engineers and geologists prepare final boring and testing logs based upon their interpretation of field logs and laboratory data. To prevent errors or omissions, the logs included in a geotechnical engineering or geologic report should never be redrawn for inclusion in architectural or other design drawings. Only photographic or electronic reproduction is acceptable, but recognize that separating logs from the report can elevate risk.

Give Contractors a Complete Report and Guidance

Some owners and design professionals believe they can make contractors liable for unanticipated subsurface conditions by limiting what they provide for bid preparation. To help prevent costly problems, give contractors the complete geotechnical engineering or geologic report, but preface it with a clearly written letter of transmittal. In that letter, advise contractors that the report was not prepared for purposes of bid development and that the report's accuracy is limited; encourage them to confer with GeoEngineers and/or to conduct additional study to obtain the specific types of information they need or prefer. A pre-bid conference can also be valuable. Be sure contractors have sufficient time to perform additional study. Only then might an owner be in a position to give contractors the best information available, while requiring them to at least share the financial responsibilities stemming from unanticipated conditions. Further, a contingency for unanticipated conditions should be included in your project budget and schedule.

Contractors are Responsible for Site Safety on Their Own Construction Projects

Our geotechnical recommendations are not intended to direct the contractor's procedures, methods, schedule or management of the work site. The contractor is solely responsible for job site safety and for managing construction operations to minimize risks to on-site personnel and to adjacent properties.

Read These Provisions Closely

Some clients, design professionals and contractors may not recognize that the geoscience practices (geotechnical engineering or geology) are far less exact than other engineering and natural science disciplines. This lack of understanding can create unrealistic expectations that could lead to disappointments, claims and disputes. GeoEngineers includes these explanatory "limitations" provisions in our reports to help reduce such risks. Please confer with GeoEngineers if you are unclear how these "Report Limitations and Guidelines for Use" apply to your project or site.

Geotechnical, Geologic and Environmental Reports Should Not be Interchanged

The equipment, techniques and personnel used to perform an environmental study differ significantly from those used to perform a geotechnical or geologic study and vice versa. For that reason, a geotechnical engineering or geologic report does not usually relate any environmental findings, conclusions or recommendations; e.g., about the likelihood of encountering underground

storage tanks or regulated contaminants. Similarly, environmental reports are not used to address geotechnical or geologic concerns regarding a specific project.

Biological Pollutants

GeoEngineers' Scope of Work specifically excludes the investigation, detection, prevention or assessment of the presence of biological pollutants. Accordingly, this report does not include any interpretations, recommendations, findings, or conclusions regarding the detecting, assessing, preventing or abating of biological pollutants and no conclusions or inferences should be drawn regarding biological pollutants, as they may relate to this project. The term "biological pollutants" includes, but is not limited to, molds, fungi, spores, bacteria, and viruses, and/or any of their byproducts.

If Client desires these specialized services, they should be obtained from a consultant who offers services in this specialized field.