DRAFT PRELIMINARY GEOTECHNICAL REPORT
LAKE TO SOUND TRAIL – SEGMENT C
KING COUNTY, WASHINGTON

HWA Project No. 2010-100 T400

November 29, 2016

Prepared for:

Parametrix, Inc.

HWA GEOSCIENCES INC.

November 29, 2016
HWA Project No. 2010-100 T400

Parametrix, Inc.
719 2nd Ave, Suite 200
Seattle, Washington 98104

Attention: Ms. Jenny Bailey

Subject: **DRAFT PRELIMINARY GEOTECHNICAL REPORT**
Lake to Sound Trail – Segment C
King County, Washington

Dear Jenny:

We are pleased to present this draft preliminary geotechnical report prepared in support of Segment C of the Lake to Sound Trail, along a portion of the proposed SR-509 extension in SeaTac, Washington. The purpose of this study was to evaluate the soil and ground water conditions at three proposed concrete boardwalk crossings of wetlands, and provide preliminary recommendations for boardwalk foundations.

We appreciate the opportunity to provide geotechnical engineering services on this project. If you have any questions regarding this preliminary report or require additional information or services, please contact us at your convenience.

Sincerely,

HWA GEOSCIENCES INC.

Brad W. Thurber, L.G., L.E.G.
Senior Engineering Geologist

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DRAFT PRELIMINARY GEOTECHNICAL REPORT
LAKE TO SOUND TRAIL – SEGMENT C
KING COUNTY, WASHINGTON

1.0 INTRODUCTION

1.1 GENERAL

This report presents the results of a preliminary geotechnical study performed by HWA GeoSciences Inc. (HWA) for the proposed Segment C of the Lake to Sound Trail in King County, Washington. The purpose of this study was to evaluate the soil and ground water conditions along three proposed boardwalk crossings of wetlands and provide preliminary geotechnical recommendations for boardwalk foundations.

1.2 PROJECT DESCRIPTION

The project location and general trail alignment in the section with proposed boardwalks are shown on the Vicinity Map, Figure 1. We understand that the boardwalks and paved trail will be constructed on either side of the proposed SR-509 extension, south of the existing terminus at South 188th Street, and west of Des Moines Memorial Parkway South. This section of trail will be through a wooded area with wetlands, and connect to the shoulder of Des Moines Memorial Parkway. Three sections of the trail will be supported on elevated boardwalks, ranging in length from 185 feet for each of the two southern boardwalks and 410 feet for the northern boardwalk.

1.3 SCOPE OF SERVICES AND AUTHORIZATION

Our scope of work was developed in consultation with Parametrix, and our work to date was performed in general accordance with our proposed scope and cost estimate dated June 16, 2016 and the Subconsultant Agreement executed August 23, 2016 by Parametrix. The purpose of this study was to evaluate the soil and ground water conditions at three proposed concrete boardwalk crossings of wetlands, and provide preliminary recommendations for boardwalk foundations. Four boreholes were drilled along the proposed trail alignment in wetland areas. The boreholes were drilled using compact limited-access equipment in order to access the sites and to minimize disturbance. Laboratory testing was conducted on selected soil samples obtained from the explorations to determine relevant engineering properties.

2.0 FIELD AND LABORATORY TESTING

2.1 FIELD INVESTIGATION

The field investigation included review of available geologic and geotechnical data for the project corridor, surface reconnaissance of the alignment, and drilling four boreholes, designated BH-1 through BH-4. The locations of these boreholes are shown on Figure 2, Site and Exploration Plan. Additional information pertaining to the subsurface investigations and summary exploration logs is presented in Appendix A.

2.2 LABORATORY TESTING

Laboratory tests were conducted on selected samples retrieved from the boreholes to determine relevant index and engineering properties of the soils encountered. The tests included natural moisture content, Atterberg limits, and grain size distribution. The tests were conducted in general accordance with appropriate American Society of Testing and Materials (ASTM) standards. The test results and a discussion of the laboratory test methodologies are presented in Appendix B, and/or are displayed on the exploration logs in Appendix A, as appropriate.

3.0 SITE CONDITIONS

3.1 SURFACE CONDITIONS

Des Moines Memorial Drive South runs generally north/south and consists of one lane in each direction with a center-turn lane, with gently rolling topography. The project area is located west of the roadway between its intersection with S 188th Street and S 190th Street. This area consists of wetlands and densely vegetated areas sloping gently to the southeast. The northern half of the project area, located to the west of a Hertz rental car return/maintenance/repair facility, consists of dense deciduous woods and shrubbery. There is also a small creek, located along the west edge of the Hertz property, which flows to the south. The extents of the surface waters widen to the south, and transition into wetlands in the southern half of the project area. Vegetation around BH-1, in the southeast portion of the site, consists of marshy grasses and wetlands with standing water. The standing water was observed to be up to 12 inches deep during our site explorations. Blackberry vines were abundant throughout the project area.

HWA visited the site during periods of interspersed heavy rainfall. During and after the rain, water in the wetlands rose by as much as six inches. Other areas that did not have standing water before the rain were found to have ephemoral braided streams running generally southeast.

3.2 GENERAL GEOLOGIC CONDITIONS

General geologic information for the site was obtained from the publication *Geologic Map of the Des Moines 7.5' Quadrangle, King County, Washington* (Booth and Waldron, 2004). The map indicates that the surficial geology of the site consists of Vashon recessional outwash over glacial till, which were deposited by the Puget Lobe of the Cordilleran Ice Sheet during the Vashon Stade of the Fraser Glaciation. Recessional outwash in the vicinity consists of glacial meltwater deposits of stratified sand with variable gravel and silt content. This material was deposited by the retreating glaciers and has not been glacially overconsolidated, hence its loose to medium dense condition. This material is relatively permeable and may provide suitable foundation support when thoroughly compacted.

In one of our explorations, the outwash was further classified into Recessional Glaciolacustrine, which was deposited in a low-energy hydrologic environment, such as a lake or pond, resulting in more fine-grained stratigraphy.

Glacial till is an unsorted, non-stratified deposit of silt, sand, and gravel with scattered cobbles and boulders, commonly referred to as "hardpan". This material is relatively impermeable and is typically dense to very dense, as a result of being overconsolidated by the advancing glaciers.

Ice-Contact Stratified Drift is a term given to depositional packages consisting of glacial sediments similar to glacial till that were not as thoroughly consolidated. For example, an environment near the edge of a glacier or that experienced multiple smaller-scale advances and retreats during overall glacial recession.

3.3 SUBSURFACE CONDITIONS

3.3.1 Soils

Brief descriptions of the soil units observed in our explorations are presented below in order of deposition, beginning with the most recently deposited. The geotechnical logs in Appendix A (Figures A-2 through A-5) provide more detail of subsurface conditions observed at specific locations and depths.

- **Topsoil** – A 1- to 4-foot thick layer of very loose/very soft, organic-rich, silty sand and/or slightly sandy to sandy silt was encountered at the ground surface at each the drilling sites, which we interpreted to be topsoil.
- **Alluvium** – Below the topsoil, alluvium was observed in each of our borings. In BH-1 and BH-2 the alluvium consisted of loose to medium dense, slightly silty to silty sand and extended up to 7.5 feet below the ground surface. The alluvium consisted of soft to stiff, silt and clay soils in the other two boreholes and was encountered to depths of approximately 5

feet in BH-3 and 7.5 feet in and BH-4. These materials appeared to consist of modern alluvium deposited by ephemeral streams in the wetland area.

- **Recessional Glaciolacustrine Deposits** – This unit was observed below the alluvium in our southeastern-most boring BH-1. This material consisted of medium stiff, silty clay to slightly sandy silt and extended from a depth of 7 feet to a depth of 14 feet.
- **Recessional Outwash** – Recessional outwash was encountered below the alluvium in three of the four borings, BH-2 through BH-4, and below the recessional glaciolacustrine deposits in BH-1. In BH-2 through BH-4, the recessional outwash consisted of stratified deposits of medium dense to dense, clean to very silty sand with varying amounts of gravel. The density of the recessional outwash was likely overstated due to the presence of coarse gravel during sampling at 10 feet in BH-2. The recessional outwash was thickest at BH-3 where it extended from 5 to 18 feet below the ground surface. The thickness of the recessional outwash was similar in BH-2 and BH-4 and extended from 7.5 to 15 feet. In BH-1 this unit was encountered at a depth of 14 feet, was about one-foot thick, and consisted of very dense, slightly silty, gravelly sand.
- **Ice Contact Stratified Drift** – Our southern-most boreholes, BH-1 and BH-2, encountered materials characterized as Ice Contact Stratified Drift (ICSD) below the recessional outwash, at approximately 15 feet. This unit appeared to have similar characteristics as the glacial till observed in the northern boreholes BH-3 and BH-4, but had lower blow counts during sampling. The materials in this area likely experienced erosion or deposition from glacial advance/retreat during the recessional period of glaciation. Boreholes BH-1 and BH-2 were terminated within this deposit at 25.3 and 26.4 feet below the ground surface, respectively.
- **Glacial Till** – Boreholes BH-3 and BH-4 encountered glacial till directly below the recessional outwash at 18 and 15 feet, respectively. The till consisted of an unsorted and unstratified mixture of very dense, fine gravelly, silty sand. Although not observed in our explorations, coarse gravel, cobbles, and boulders are commonly encountered in glacial till deposits. Boreholes BH-3 and BH-4 were terminated within this deposit at 25.3 and 25.4 feet below the ground surface, respectively.

3.3.2 Ground Water

At the times of exploration, ground water was observed downhole only in borehole BH-4, perched above the till at 15 feet. However, samples of the recessional outwash sands were typically wet. Also, standing water was at the ground surface in the southeastern wetland at BH-1, and surface water, overflowing from a small channel due to heavy rains, was present in the vicinity of BH-3 (overflow was not observed the day prior to start of drilling). Variation in ground water conditions should be expected to occur seasonally and with changes in precipitation.

4.0 CONCLUSIONS AND RECOMMENDATIONS

4.1 GENERAL

Based on the findings of the preliminary site investigation, the areas of the proposed boardwalks are underlain by dense, glacially consolidated soils within about 15 feet of the ground surface. These soils are suitable for support of the lateral and vertical loads imposed by the elevated boardwalks.

Some potentially liquefiable soils were encountered above the soils suitable for providing bearing capacity. Given the depth of the bearing soils and the desire to limit the footprint within the existing wetland areas, we recommend that the elevated boardwalks be supported by pipe piles. Based on our understanding of the project at this time, we present the following preliminary geotechnical recommendations for design of the foundations for the boardwalks.

4.1.1 Seismic Design Parameters

We understand the boardwalks are being designed in accordance with the *2012/2015 International Building Code* (IBC), (ICC, 2011, 2014). The IBC requires above-grade structures be designed earthquake loads consisting of the inertial forces induced by a "Maximum Considered Earthquake" (MCE), which corresponds to an earthquake with a 2% probability of exceedance (PE) in 50 years (approximately 2,475 year return period). Accordingly, the relevant probabilistic spectral response parameters were developed using the United States Geological Survey's website.

The IBC accounts for the effects of site-specific subsurface ground conditions on the response of structures in terms of site classes. Site classes are defined by the average density and stiffness of the soil profile underlying the site. The Site Class can be correlated to the average standard penetration resistance (N_{SPT}) in the upper 100 feet of the soil profile. Based on our characterization of the subsurface conditions, the subject site classifies as IBC Site Class C. Table 1 presents the design spectral seismic coefficients obtained for this site based on risk category I/II/III. Based on the S_{DS} and S_{D1} values, the site is considered as Seismic Design Category D.

Table 1. Design Seismic Coefficients for IBC 2012/2015 Code Based Evaluation

Site Class	Spectral Acceleration at 0.2 sec. S_S, g	Spectral Acceleration at 1.0 sec S_1, g	Design Spectral Acceleration at 0.2 sec. S_{DS}, g	Design Spectral Acceleration at 1.0 sec. S_{D1}, g	Site Coefficients		**Peak Horizontal Acceleration PGA, (g)**
					F_a	F_v	
C	1.459	0.546	0.973	0.474	1.0	1.3	0.39

4.1.2 Seismic Considerations

The site will be impacted by the large ground motions that are associated with the design seismic events for the area. These impacts are accounted for in the seismic design parameters provided in the previous section.

Another potential seismic hazard includes ground rupture. As the site is near the Seattle fault zone, we performed a seismic deaggregation analysis to estimate the proximity of the site to the fault using the web tool provided by the United Stated Geologic Survey (USGS) and documented in Frankel et al., 2002, and Peterson et al, 2008. Based on the results of this analysis, the site is located about 4 miles from the nearest Seattle fault trace and therefore, we consider the risk of ground rupture to be low at this site.

Liquefaction, which is a temporary loss of strength due to ground shaking, occurs in loose, saturated granular materials. Some of the materials in the upper 10 to 14 feet are susceptible to liquefaction and may experience settlement due to liquefaction; however, the thickness of non-liquefiable materials above the potentially liquefiable materials are small and therefore; additional vertical loads are expected to be small.

4.2 BOARDWALK FOUNDATIONS

4.2.1 Design Considerations

Based on the subsurface conditions encountered and the need for minimizing short- and long-term impacts to the wetlands, we recommend using steel pipe piles to support the proposed boardwalks. Based on our discussions with the design team, we understand that 8-inch diameter steel pipe piles are the preferred pile section. These piles would be suitable to provide allowable bearing capacities of up to 25 tons each.

We recommend installing closed-ended pipe piles. Closed-ended pipe piles typically require less penetration than open-ended sections. It also allows visual inspection of the inside of the piles after driving to check for damage to the pile that may have occurred during driving. There is one disadvantage of closed-ended sections, which is related to lateral capacity. In some cases, the depth of the bearing materials may be too shallow to provide adequate embedment below the ground surface for limiting deflections from lateral loads imposed on the piles. For these piles, we anticipate that the embedment will be adequate even with closed-ended pipe piles; however, this recommendation should be verified during final design.

4.2.2 Construction Considerations

The foundation piles may be driven to initial refusal with a vibratory hammer. However, all permanent pipe piles should be driven to final set using an impact hammer so that their capacities can be verified. Capacity should be verified based on dynamic pile driving methods, such as the Wave Equation Analysis Program (WEAP). The WEAP evaluation should be performed by the geotechnical engineer after the pile lengths, pile driving hammer, cushion, and pile cap block have been selected by the contractor. WEAP should be performed for each size of pile used for the project and for any modifications in the pile driving equipment or procedures, if they have a bearing on the results. If a wave equation analysis is used to develop the driving criterion, the ultimate load for acceptance of the piles should be taken as the factored maximum design load times a resistance factor (ϕ) of 0.4. This resistance factor is based on the 2005 NHI ("Development of Geotechnical Resistance Factors and Downdrag Load Factors for LRFD for Strength Limit Design", Table 8). In our opinion it is possible to develop the ultimate load of 125 kips (50 kips/0.4) with steel piles driven into glacially overridden soils at the site.

The contractor should be required to drive three test piles, one in each section of proposed boardwalk, with the proposed pile section and the pile-driving equipment to be used for production piles, to at least the penetration resistance calculated with wave equation analyses. The test piles could be used as production piles as long as they meet the requirements. The final pile tip elevation should be accepted on-site by a geotechnical engineer who is monitoring the installation of the piles based on the developed driving criteria.

In any pile driving operation, installation of driven piles could be impacted by the unforeseen presence of cobbles, boulders, buried tree stumps, or other obstructions. Though our explorations do not suggest a high probability of occurrence of such obstructions, to the extent that any of these conditions may exist at this site, provisions should be made in the contract documents to deal with potential obstructions during pile driving, and the contractor should be prepared in advance to deal with them.

5.0 CONDITIONS AND LIMITATIONS

We have prepared this report for use by Parametrix and King County in preliminary design of a portion of this project. Additional geotechnical studies will be necessary for final design. Experience has shown that soil and ground water conditions can vary significantly over small distances. Inconsistent conditions can occur between explorations and may not be detected by a geotechnical study. If, during future site operations, subsurface conditions are encountered which vary appreciably from those described herein, HWA should be notified for review of the recommendations of this report, and revision of such if necessary.

We recommend that HWA be retained to review the plans and specifications and to monitor the geotechnical aspects of construction.

Within the limitations of scope, schedule and budget, HWA attempted to execute these services in accordance with generally accepted professional principles and practices in the fields of geotechnical engineering and engineering geology in the area at the time the report was prepared. No warranty, express or implied, is made.

The scope of our work did not include environmental assessments or evaluations regarding the presence or absence of wetlands or hazardous substances in the soil, surface water, or ground water at this site.

HWA does not practice or consult in the field of safety engineering. We will not direct the contractor's operations, and we cannot be responsible for the safety of personnel other than our own on the site; the safety of others is the responsibility of the contractor. The contractor should notify the owner if he considers any of the recommended actions presented herein unsafe.

We appreciate this opportunity to be of service.

Sincerely,

HWA GEOSCIENCES, INC.

Brad W. Thurber, L.G., L.E.G. Senior Engineering Geologist	JoLyn Gillie, P.E. Geotechnical Engineer, Principal

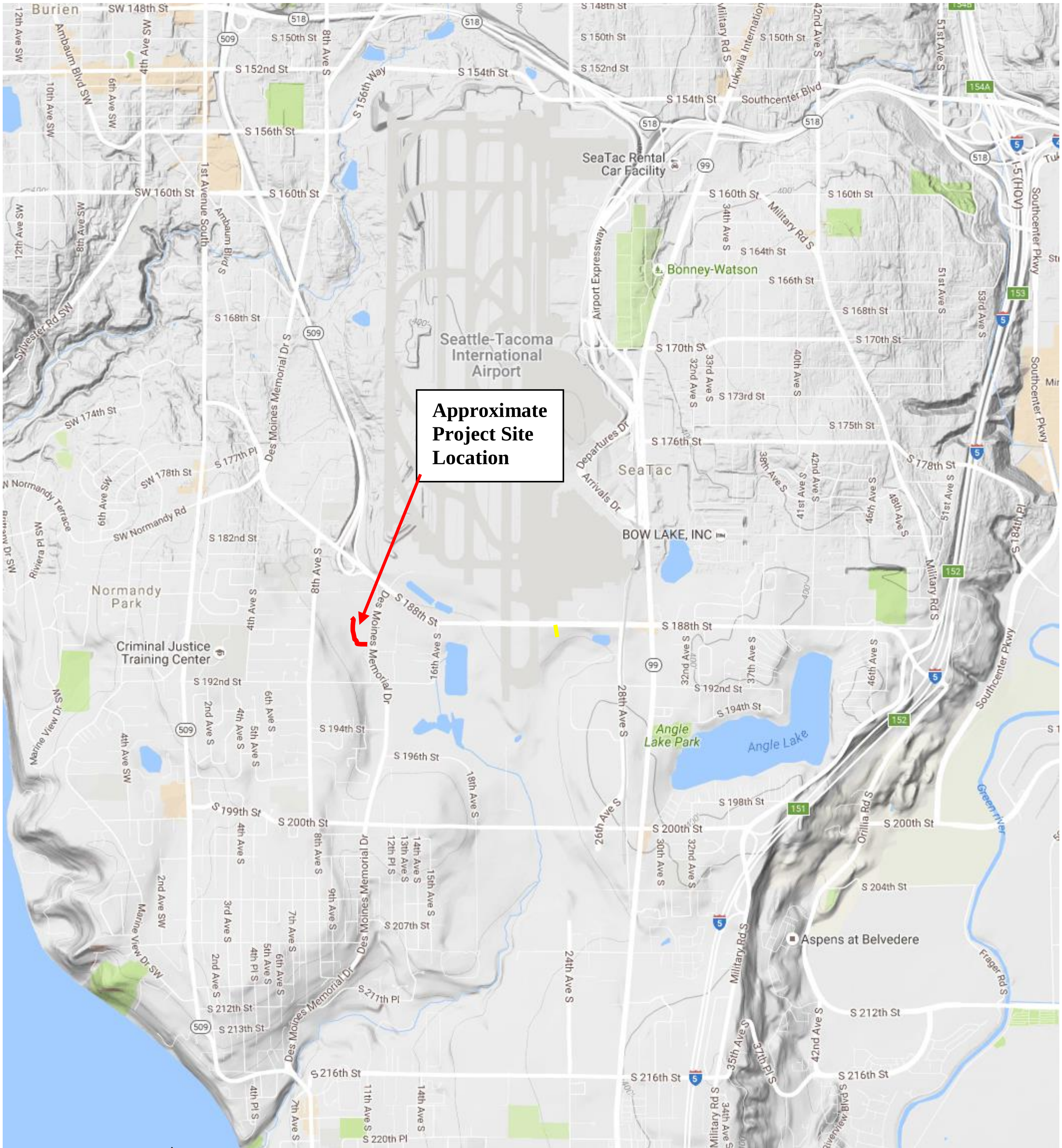
6.0 REFERENCES

Booth, Derek B. and Hank H. Waldron, 2004, *Geologic Map of the Des Moines 7.5' Quadrangle, King County, Washington*. USGS Scientific Investigations Map 2855.

Frankel, et al., 2002, *Documentation for the 2002 Update of the National Seismic Hazard Maps,* USGS Open File Report, 02-420.

International Code Council, 2014, *2015 International Building Code*, Country Club Hills, IL.

Petersen, MD et. al., 2008, *Documentation for the 2008 Update of the United States National Seismic Hazard Maps*, USGS Open File Report, 2008-1128.



BASE MAP FROM HILLS MAPS

NORTH
NOT TO SCALE

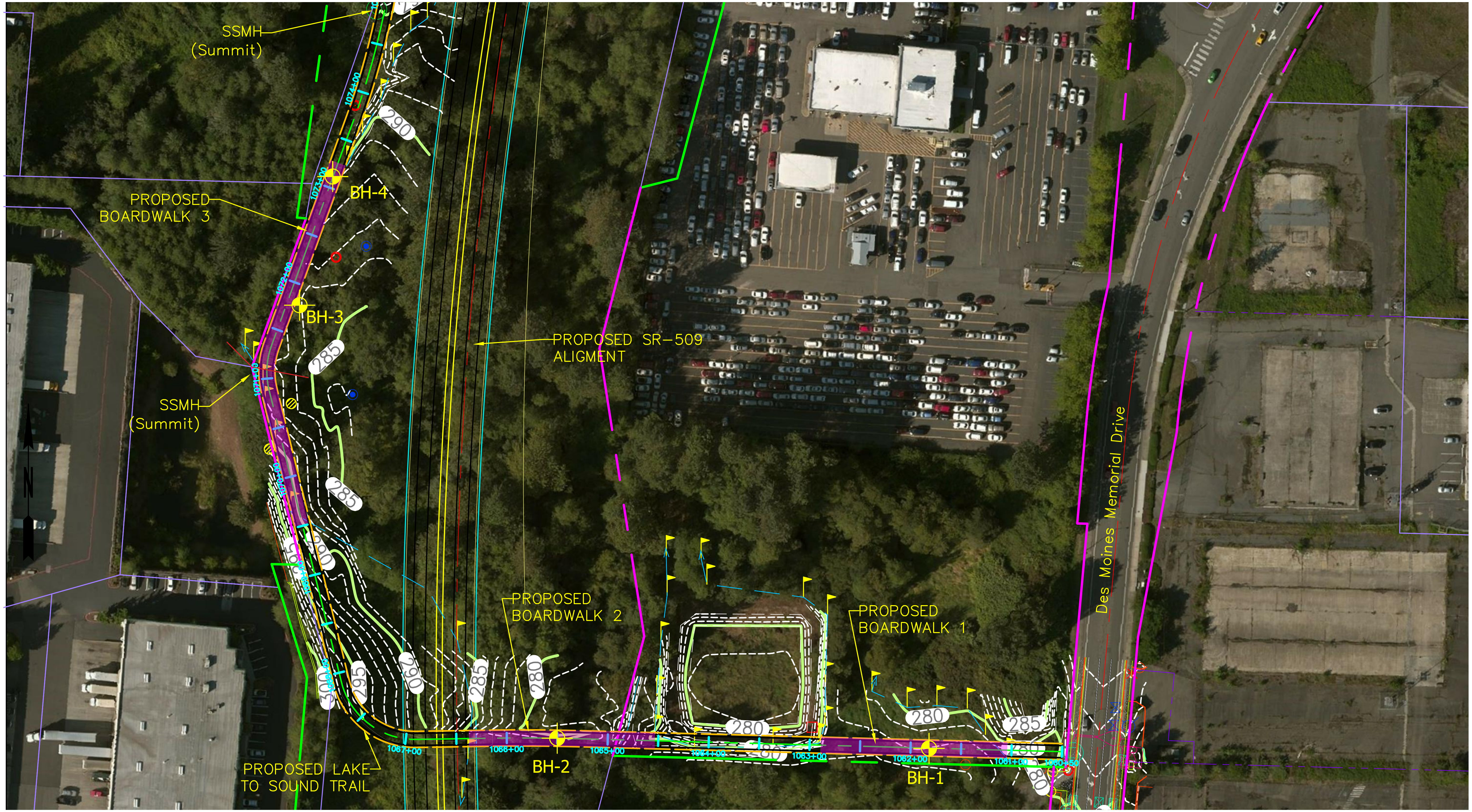
HWA GEOSCIENCES INC.

VICINITY MAP

LAKE TO SOUND TRAIL
SEGMENT "C"
KING COUNTY, WASHINGTON

FIGURE NO.
1

PROJECT NO.
2010-100-T400



BH-4 BORING DESIGNATION AND APPROXIMATE LOCATION

WETLAND BOUNDARY DESIGNATION AND APPROXIMATE LOCATION

PROPOSED BOARDWALK

BASE MAP PROVIDED BY:

0 50 100 150 200

N

HWA GEOSCIENCES INC.

LAKE TO SOUND TRAIL
SEGMENT "C"
KING COUNTY, WASHINGTON

SITE AND
EXPLORATION
PLAN

DRAWN BY EFK	FIGURE # 2
CHECK BY BT	PROJECT # 2010-100-21 T400
DATE: 11/21/2016	

S:\2010 PROJECTS\2010-100-21 LAKE TO SOUND TRAIL\TASK 400 SEGMENT C\CAD 2010-100 T400\HWA 2010-100 T400.DWG <Layout2> Plotted: 11/28/2016 2:27 PM

APPENDIX A

FIELD EXPLORATIONS

APPENDIX A

FIELD EXPLORATIONS

A geotechnical subsurface exploration program was conducted by HWA in November 2016. The field investigation consisted of drilling four boreholes within the proposed locations of three boardwalks. The exploration locations were chosen in consultation with Parametrix based on proposed boardwalk locations. Preliminary locations were determined in the field by Parametrix surveyors, and modified as needed for field conditions by HWA. The borehole locations are shown on the Site and Exploration Plan, Figure 2. The boreholes were drilled on November 26 through 28, 2016 by Geologic Drill Explorations, Inc. of Renton, Washington, under subcontract to HWA. The drilling was conducted in the wetlands using a compact Bobcat MT-55 tracked drill rig weighing approximately 4,000 pounds. The rig advanced 2.25-inch inside diameter (ID), continuous-flight, hollow-stem augers. The boreholes were advanced to depths ranging from about 25 to 26 feet below ground surface.

Soil samples from the boreholes were collected at 2.5- to 5-foot intervals using Standard Penetration Test (SPT) sampling in general accordance with ASTM D 1586. SPT sampling consisted of using a 2-inch outside diameter, split-spoon sampler driven with a 140-pound drop hammer using a rope and cathead. During the test, a sample is obtained by driving the sampler 18 inches into the soil with the hammer free-falling 30 inches per stroke. The number of blows required for each 6 inches of penetration is recorded. The Standard Penetration Resistance ("N-value") of the soil is calculated as the number of blows required for the final 12 inches of penetration. If a total of 50 blows is recorded within a single 6-inch interval, the test is terminated, and the blow count is recorded as 50 blows for the number of inches of actual penetration. This resistance, or N-value, provides an indication of the relative density of granular soils and the relative consistency of cohesive soils. Upon completion of drilling, the boreholes were backfilled using bentonite chips.

The borings were advanced under the full-time observation of an HWA geologist. Soil samples obtained from the explorations were classified in the field and representative portions were placed in plastic bags. These soil samples were then taken to our Bothell, Washington, laboratory for further examination and testing. Pertinent information including soil sample depths, stratigraphy, soil engineering characteristics, and ground water occurrence was recorded and used to develop logs of the explorations. A legend to the terms and symbols used on the exploration logs is presented on Figure A-1; summary logs of the explorations are presented on Figures A-2 through A-5. The stratigraphic contacts shown on the individual logs represent the approximate boundaries between soil types; actual transitions may be more gradual. The soil and ground water conditions depicted are only for the specific dates and locations reported and, therefore, are not necessarily representative of other locations and times.

RELATIVE DENSITY OR CONSISTENCY VERSUS SPT N-VALUE

COHESIONLESS SOILS			COHESIVE SOILS		
Density	N (blows/ft)	Approximate Relative Density(%)	Consistency	N (blows/ft)	Approximate Undrained Shear Strength (psf)
Very Loose	0 to 4	0 - 15	Very Soft	0 to 2	<250
Loose	4 to 10	15 - 35	Soft	2 to 4	250 - 500
Medium Dense	10 to 30	35 - 65	Medium Stiff	4 to 8	500 - 1000
Dense	30 to 50	65 - 85	Stiff	8 to 15	1000 - 2000
Very Dense	over 50	85 - 100	Very Stiff	15 to 30	2000 - 4000
			Hard	over 30	>4000

USCS SOIL CLASSIFICATION SYSTEM

MAJOR DIVISIONS			GROUP DESCRIPTIONS	
Coarse Grained Soils More than 50% Retained on No. 200 Sieve Size	Gravel and Gravelly Soils More than 50% of Coarse Fraction Retained on No. 4 Sieve	Clean Gravel (little or no fines)	GW	Well-graded GRAVEL
			GP	Poorly-graded GRAVEL
		Gravel with Fines (appreciable amount of fines)	GM	Silty GRAVEL
			GC	Clayey GRAVEL
	Sand and Sandy Soils 50% or More of Coarse Fraction Passing No. 4 Sieve	Clean Sand (little or no fines)	SW	Well-graded SAND
			SP	Poorly-graded SAND
		Sand with Fines (appreciable amount of fines)	SM	Silty SAND
			SC	Clayey SAND
Fine Grained Soils 50% or More Passing No. 200 Sieve Size	Silt and Clay	Liquid Limit Less than 50%	ML	SILT
			CL	Lean CLAY
			OL	Organic SILT/Organic CLAY
	Silt and Clay	Liquid Limit 50% or More	MH	Elastic SILT
			CH	Fat CLAY
			OH	Organic SILT/Organic CLAY
Highly Organic Soils			PT	PEAT

TEST SYMBOLS

%F	Percent Fines
AL	Atterberg Limits: PL = Plastic Limit, LL = Liquid Limit
CBR	California Bearing Ratio
CN	Consolidation
DD	Dry Density (pcf)
DS	Direct Shear
GS	Grain Size Distribution
K	Permeability
MD	Moisture/Density Relationship (Proctor)
MR	Resilient Modulus
PID	Photoionization Device Reading
PP	Pocket Penetrometer Approx. Compressive Strength (tsf)
SG	Specific Gravity
TC	Triaxial Compression
TV	Torvane Approx. Shear Strength (tsf)
UC	Unconfined Compression

SAMPLE TYPE SYMBOLS

- 2.0" OD Split Spoon (SPT) (140 lb. hammer with 30 in. drop)
- Shelby Tube
- 3-1/4" OD Split Spoon with Brass Rings
- Small Bag Sample
- Large Bag (Bulk) Sample
- Core Run
- Non-standard Penetration Test (3.0" OD split spoon)

GROUNDWATER SYMBOLS

- Groundwater Level (measured at time of drilling)
- Groundwater Level (measured in well or open hole after water level stabilized)

COMPONENT DEFINITIONS

COMPONENT	SIZE RANGE
Boulders	Larger than 12 in
Cobbles	3 in to 12 in
Gravel	3 in to No 4 (4.5mm)
Coarse gravel	3 in to 3/4 in
Fine gravel	3/4 in to No 4 (4.5mm)
Sand	No. 4 (4.5 mm) to No. 200 (0.074 mm)
Coarse sand	No. 4 (4.5 mm) to No. 10 (2.0 mm)
Medium sand	No. 10 (2.0 mm) to No. 40 (0.42 mm)
Fine sand	No. 40 (0.42 mm) to No. 200 (0.074 mm)
Silt and Clay	Smaller than No. 200 (0.074mm)

COMPONENT PROPORTIONS

PROPORTION RANGE	DESCRIPTIVE TERMS
< 5%	Clean
5 - 12%	Slightly (Clayey, Silty, Sandy)
12 - 30%	Clayey, Silty, Sandy, Gravelly
30 - 50%	Very (Clayey, Silty, Sandy, Gravelly)
Components are arranged in order of increasing quantities.	

NOTES: Soil classifications presented on exploration logs are based on visual and laboratory observation. Soil descriptions are presented in the following general order:

Density/consistency, color, modifier (if any) GROUP NAME, additions to group name (if any), moisture content. Proportion, gradation, and angularity of constituents, additional comments. (GEOLOGIC INTERPRETATION)

Please refer to the discussion in the report text as well as the exploration logs for a more complete description of subsurface conditions.

MOISTURE CONTENT

DRY	Absence of moisture, dusty, dry to the touch.
MOIST	Damp but no visible water.
WET	Visible free water, usually soil is below water table.

HWA GEOSCIENCES INC.

LAKE TO SOUND TRAIL
SEGMENT C
SEATAC, WASHINGTON

LEGEND OF TERMS AND SYMBOLS USED ON EXPLORATION LOGS

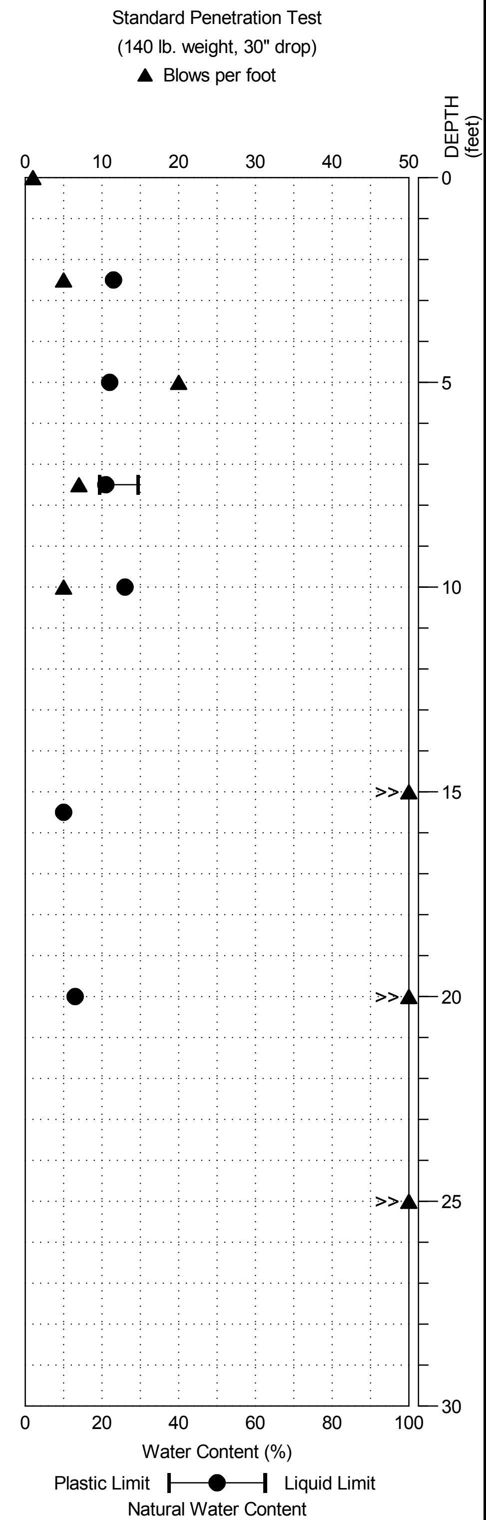
PROJECT NO.: 2010-100 T400 FIGURE: A-1

DRILLING COMPANY: Geologic Drill, Inc.
DRILLING METHOD: Bobcat MT-55 track rig with 4-inch OD HSA
SAMPLING METHOD: SPT w/ cathead
SURFACE ELEVATION: 278.00 ± feet

LOCATION: See Figure 2
DATE STARTED: 10/26/2016
DATE COMPLETED: 10/26/2016
LOGGED BY: B. Salazar

DEPTH (feet)	USCS SOIL CLASS	DESCRIPTION	SAMPLE NUMBER	PEN. RESISTANCE (blows/6 inches)	OTHER TESTS
0		Very soft, dark brown, organic SILT, wet. One fine gravel observed in sample. Roots observed. Standing water on surface. **(TOPSOIL)**	S-1	1-0-1	
	SM	Loose, rust-mottled gray, slightly silty, fine to medium SAND, wet. Grades to silty with depth. Lenses of plastic silt observed at 3.5'. **(ALLUVIUM)**	S-2	5-2-3	
5	SP SM	Medium dense, gray, slightly silty, fine to medium SAND, wet. Trace coarse sand observed to 6.0'. Gravels observed at 5.0'	S-3	9-10-10	GS
	CL	Medium stiff, gray, slightly sandy, silty CLAY, moist. Trace fine gravel (dropstones). **(RECESSIONAL GLACIOLACUSTRINE DEPOSITS)**	S-4	4-3-4	AL
10		Becomes olive brown at 10.8'	S-5	3-2-3	
		Drillers note hard drilling at 13.5'			
15	SM	Very dense, olive gray, slightly silty, gravelly, fine to medium SAND, moist. Gravels are subrounded, up to 3/4" in diameter. **(RECESSIONAL OUTWASH)**	S-6A	15-32-35	
	SM	Very dense, olive gray, very silty, fine to medium SAND, moist. Trace fine gravels. **(ICE CONTACT STRATIFIED DRIFT)** Gravelly drilling below 15.6'	S-6B		
20	SM	Very dense, olive gray, very silty, fine to medium SAND with dropstones (fine gravel), moist. Sand lens observed at 20.8' Rust mottling observed at 20.7'.	S-7	18-24-30	GS
25			S-8	50/4"	

Borehole terminated at 25.3'.
Surface water observed at drilling location (wetlands), perched ground water at 7' bgs.
Borehole abandoned with bentonite chips.



For a proper understanding of the nature of subsurface conditions, this exploration log should be read in conjunction with the text of the geotechnical report.

NOTE: This log of subsurface conditions applies only at the specified location and on the date indicated and therefore may not necessarily be indicative of other times and/or locations.

HWA GEOSCIENCES INC.

LAKE TO SOUND TRAIL
SEGMENT C
SEATAC, WASHINGTON

BORING:
BH-1

PROJECT NO.: 2010-100 T400 FIGURE: A-2

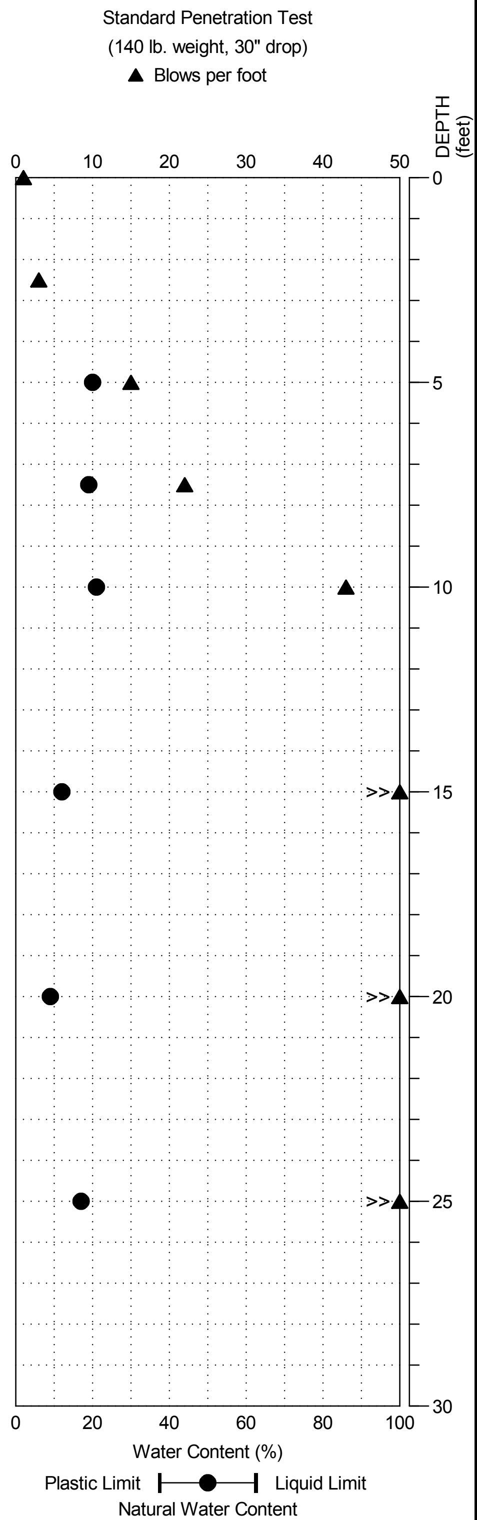
BORING 2010-100-400.GPJ 11/28/16

DRILLING COMPANY: Geologic Drill, Inc.
DRILLING METHOD: Bobcat MT-55 track rig with 4-inch OD HSA
SAMPLING METHOD: SPT w/ cathead
SURFACE ELEVATION: 280.00 ± feet

LOCATION: See Figure 2
DATE STARTED: 10/27/2016
DATE COMPLETED: 10/27/2016
LOGGED BY: B. Salazar

DEPTH (feet)	USCS SOIL CLASS	DESCRIPTION	SAMPLE NUMBER	PEN. RESISTANCE (blows/6 inches)	OTHER TESTS	GROUNDWATER
0		Very soft, dark brown, organic SILT with sand and trace fine gravel, wet. Roots present throughout. **(TOPSOIL)**	S-1	1-0-1		
		Brown sand lens observed from 2.6 to 2.7'. No organics or gravel observed. Gray, silty, fine to medium SAND, wet. Trace fine gravel from 2.8 to 2.9'. No organics.	S-2	0-1-2		
5	SM	Medium dense, gray, silty, fine to medium SAND, moist. Silt lens observed at 5.1'. Rust mottling at 5.5'. **(ALLUVIUM)**	S-3	4-8-7	GS	
	SP	Medium dense, olive gray, clean, fine to coarse SAND, wet. Subrounded gravels. **(RECESSIONAL OUTWASH)**	S-4	9-9-13	GS	▽ (7.5')
10	SP	Dense, olive brown, clean, fine to medium SAND, wet. Some rust mottling throughout. Rust band at 11.3'. Blow counts overstated (Driller believes a gravel was pushed by the sampler for the first 12 inches).	S-5	37-30-13		
	SM	Dense, olive gray, silty fine SAND, wet. Finely bedded. Driller notes possible gravel at 12.5'				
15	SM	Very dense, olive gray, very silty, fine SAND, moist. Trace gravel, subrounded, concentrated at 16.0'. Rust mottling at 15.5'. Silt band at 16.3'. Driller notes very hard drilling beginning at 15.0 feet. **(ICE CONTACT STRATIFIED DRIFT)** Driller notes gravelly drilling at 18.0'	S-6	15-26-30	GS	
20		Sand grades to fine to medium. Some rust mottling around gravels observed in sample from 20 to 21.5'. Driller notes smoother drilling at 21.0'.	S-7	30-50/5"		
25	SP	Very dense, olive gray, clean, fine to coarse SAND, wet. Coarse sand increasing in abundance with depth. Driller notes some heave during sampling.	S-8	31-42-50/5"		

Borehole terminated at 26.4'.
Perched ground water inferred at 7.5'.
Borehole abandoned with bentonite chips.



For a proper understanding of the nature of subsurface conditions, this exploration log should be read in conjunction with the text of the geotechnical report.

NOTE: This log of subsurface conditions applies only at the specified location and on the date indicated and therefore may not necessarily be indicative of other times and/or locations.

HWA GEOSCIENCES INC.

LAKE TO SOUND TRAIL
SEGMENT C
SEATAC, WASHINGTON

BORING:
BH-2

PAGE: 1 of 1

PROJECT NO.: 2010-100 T400 FIGURE: A-3

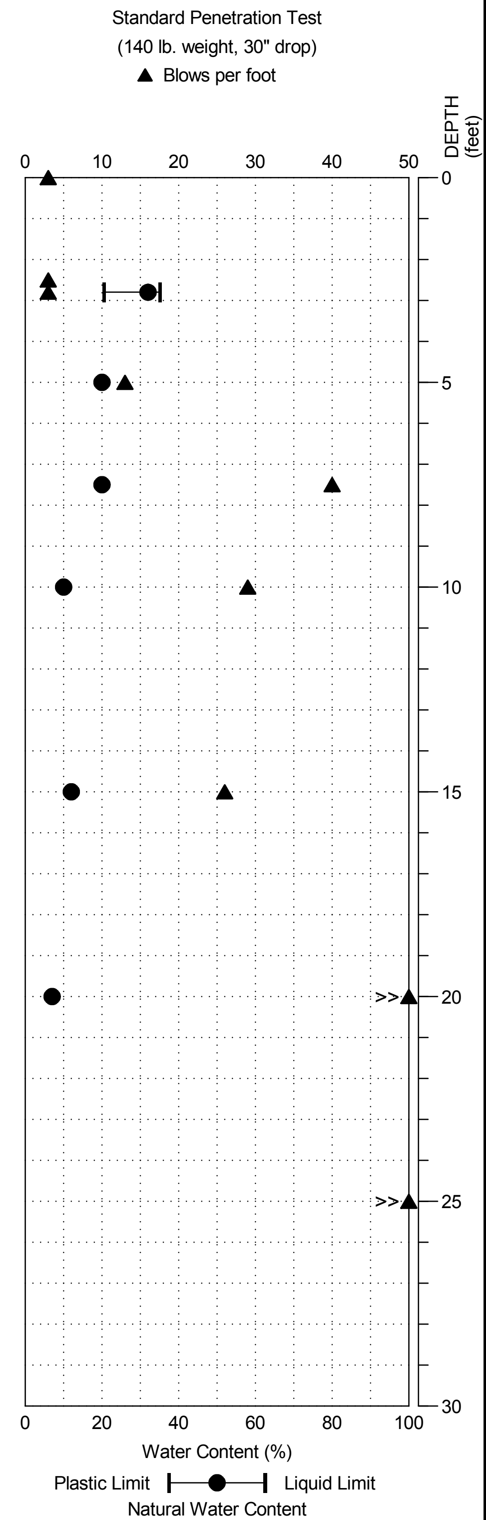
BORING 2010-100-400.GPJ 11/28/16

DRILLING COMPANY: Geologic Drill, Inc.
DRILLING METHOD: Bobcat MT-55 track rig with 4-inch OD HSA
SAMPLING METHOD: SPT w/ cathead
SURFACE ELEVATION: 286.50 ± feet

LOCATION: See Figure 2
DATE STARTED: 10/27/2016
DATE COMPLETED: 10/27/2016
LOGGED BY: B. Salazar

DEPTH (feet)	USCS SOIL CLASS	DESCRIPTION	SAMPLE NUMBER	PEN. RESISTANCE (blows/6 inches)	OTHER TESTS	GROUNDWATER
0		Very loose, brown, silty fine to medium SAND with gravel, moist. Gravel is fine, subrounded. Rootlets observed. **(TOPSOIL)**	S-1	2-2-1		
	CL	Soft, dark brown, sandy SILT, moist. Rootlets, charcoal observed.	S-2A	2-1-2	AL	
		Soft, rust-mottled gray, CLAY, moist. Sand lenses observed at 2.8' and 3.1'. **(ALLUVIUM)**	S-2B	2-1-2		
5	SP SM	Medium dense, gray, slightly silty, fine to medium SAND, wet/saturated. Sand includes coarse grains from 5.5 to 6.0'. Rust mottled from 6.0 to 6.5'. **(RECESSIONAL OUTWASH)**	S-3	6-7-6	GS	∇
	SM	Dense, gray, very silty fine to medium SAND, moist. Rust mottling observed from 7.5 to 8.0'. Becomes less silty, with trace gravels, from 8.5 to 9.0'.	S-4	2-16-24		
10	SM	Medium dense, gray, slightly gravelly, very silty, fine to medium SAND, moist. More abundant gravel observed at 11.1'.	S-5	10-13-16	GS	
15	SM	Medium dense, gray, slightly fine gravelly to gravelly, very silty, fine to medium SAND, moist. With thin, clean sand lenses.	S-6	11-13-13	GS	
20	SM	Very dense, gray, gravelly, silty, fine to medium SAND, moist. Gravel is fine, subrounded. **(GLACIAL TILL)**	S-7	50/6"	GS	
25			S-8	50/4"		

Borehole terminated at 25.3'.
Ground water inferred at 5' bgs.
Borehole abandoned with bentonite chips.



For a proper understanding of the nature of subsurface conditions, this exploration log should be read in conjunction with the text of the geotechnical report.

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LAKE TO SOUND TRAIL
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BORING:
BH-3

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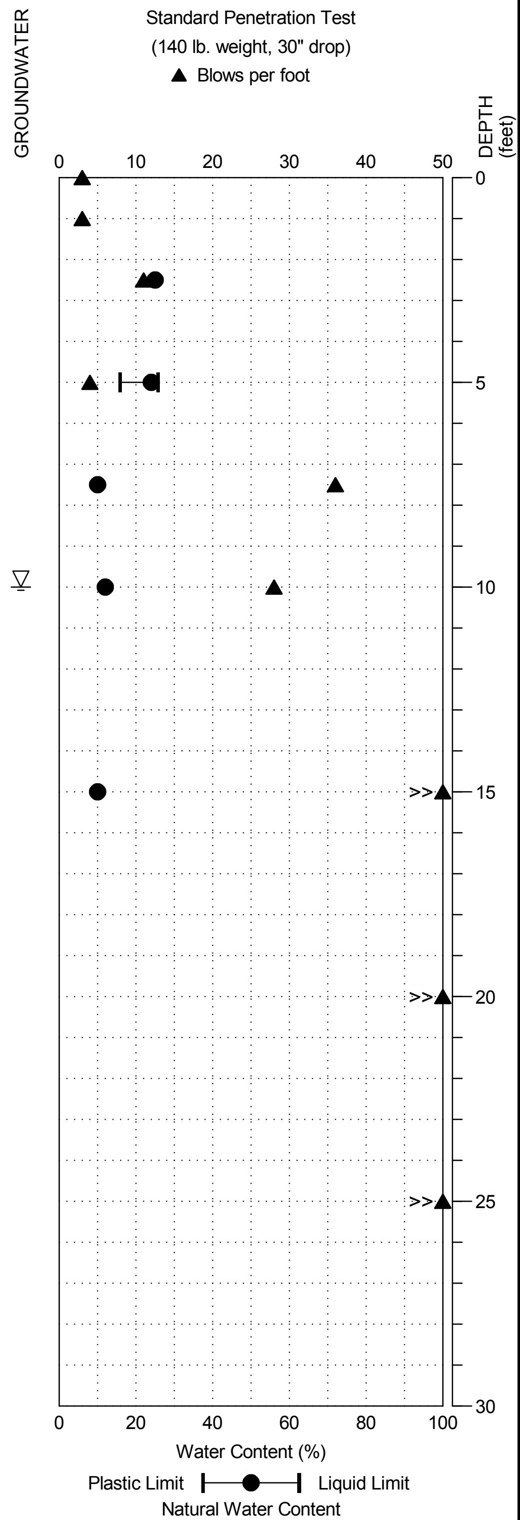
PROJECT NO.: 2010-100 T400 FIGURE: A-4

DRILLING COMPANY: Geologic Drill, Inc.
DRILLING METHOD: Bobcat MT-55 track rig with 4-inch OD HSA
SAMPLING METHOD: SPT w/ cathead
SURFACE ELEVATION: 290.00 ± feet

LOCATION: See Figure 2
DATE STARTED: 10/28/2016
DATE COMPLETED: 10/28/2016
LOGGED BY: B. Salazar

DEPTH (feet)	USCS SOIL CLASS	DESCRIPTION	SAMPLE NUMBER	PEN. RESISTANCE (blows/6 inches)	OTHER TESTS
0		Soft, dark brown sandy organic SILT, wet. Roots, trace fine gravels observed. **(TOPSOIL)**	S-1A	1-1-2	
	ML	Soft, olive gray, fine sandy SILT, moist. Rust mottling observed.	S-1B	1-1-2	
	ML SM	Stiff, gray, sandy SILT, moist. Scattered sand lenses and roots throughout. **(ALLUVIUM)**	S-2	3-4-7	GS
5	CL	Medium stiff, rust-mottled gray, silty CLAY, moist. With scattered fine gravel dropstones.	S-3	3-2-2	AL
	SM	Dense, gray, slightly fine gravelly, very silty, fine to medium SAND, moist. **(RECESSIONAL OUTWASH)**	S-4	13-15-21	GS
10	SM	Medium dense, gray, very silty, fine to medium SAND, with trace fine gravel, wet.	S-5	8-12-16	
15	SP SM	Very dense, gray, gravelly, very silty fine to medium SAND, moist. Water in sampler tube. **(GLACIAL TILL)** Driller notes very gravelly drilling beginning at 16.0'.	S-6	50/5"	GS
20		Increased gravel in sample at 20.0'.	S-7	100/5"	
25		Sample is more dry, friable.	S-8	100/5"	

Borehole terminated at 25.4'.
Surface water in area (wetlands).
Perched ground water observed above 15 feet.
Borehole abandoned with bentonite chips.



For a proper understanding of the nature of subsurface conditions, this exploration log should be read in conjunction with the text of the geotechnical report.

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BORING:
BH-4

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PROJECT NO.: 2010-100 T400 FIGURE: A-5

BORING 2010-100-400.GPJ 11/28/16

APPENDIX B

LABORATORY TESTING

APPENDIX B

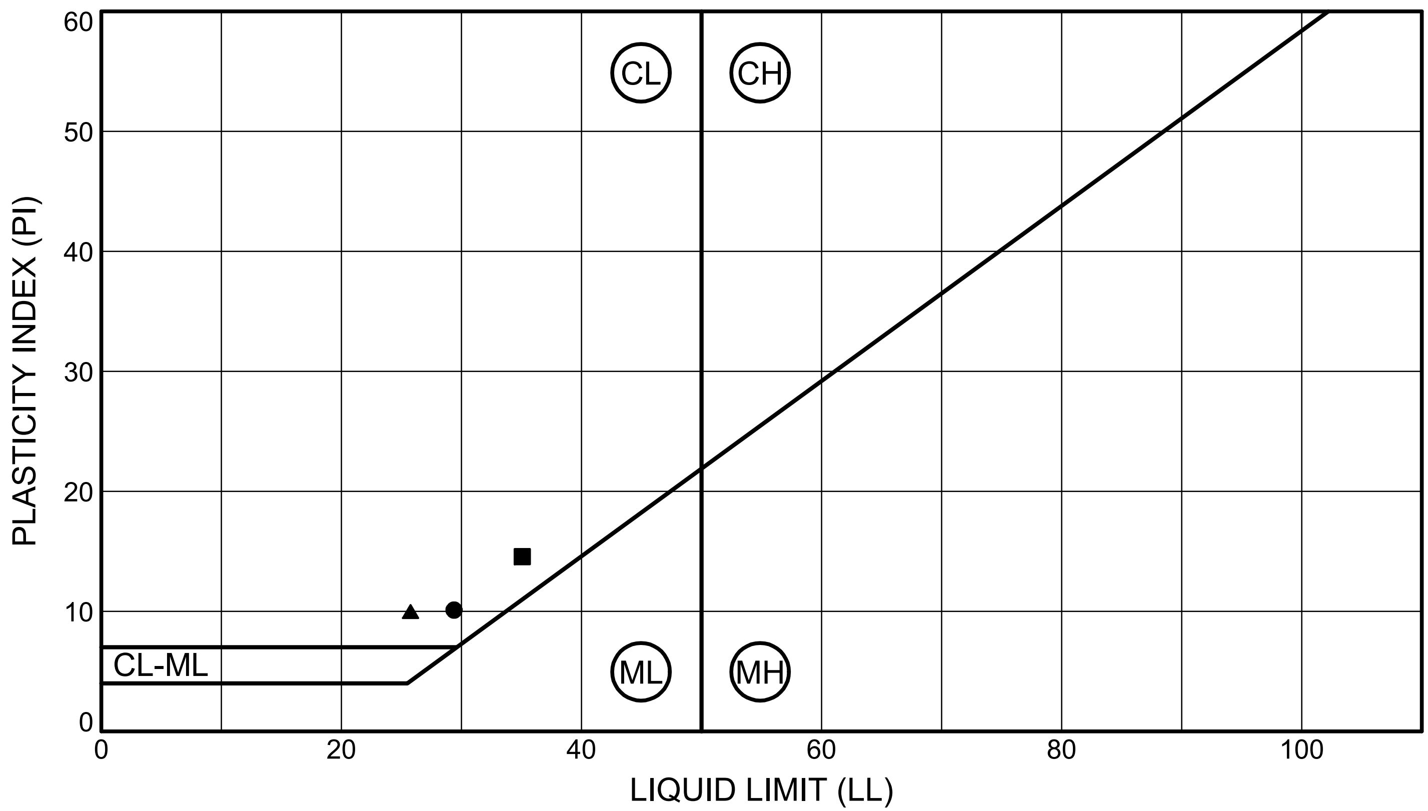
LABORATORY TESTING

HWA personnel performed laboratory tests in general accordance with appropriate ASTM test methods. We tested selected soil samples to determine moisture content, grain-size distribution, and Atterberg Limits. The test procedures and results are briefly discussed below.

MOISTURE CONTENT OF SOIL: Laboratory tests were conducted to determine the natural moisture content of selected soil samples, in general accordance with ASTM D 2216. Test results are indicated at the sampled intervals on the appropriate exploration logs in Appendix A.

LIQUID LIMIT, PLASTIC LIMIT, AND PLASTICITY INDEX OF SOILS (ATTERBERG LIMITS): Selected samples were tested using method ASTM D 4318, multi-point method. The results are reported on the attached Liquid Limit, Plastic Limit, and Plasticity Index report, Figure B-1.

PARTICLE SIZE ANALYSIS OF SOILS: Selected samples were tested to determine the particle size distribution of material in general accordance with ASTM D 422. The results are summarized on the attached Particle-Size Analysis of Soils reports, Figures B-2 through B-5, and provide information regarding the classification of the samples.



SYMBOL	SAMPLE		DEPTH (ft)	CLASSIFICATION	% MC	LL	PL	PI	% Fines
●	BH-1	S-4	7.5 - 9.0	(CL) Gray, lean CLAY with sand	21	29	19	10	
■	BH-3	S-2B	2.8 - 4.0	(CL) Olive brown, lean CLAY with sand	32	35	21	14	
▲	BH-4	S-3	5.0 - 6.5	(CL) Gray, lean CLAY	24	26	16	10	

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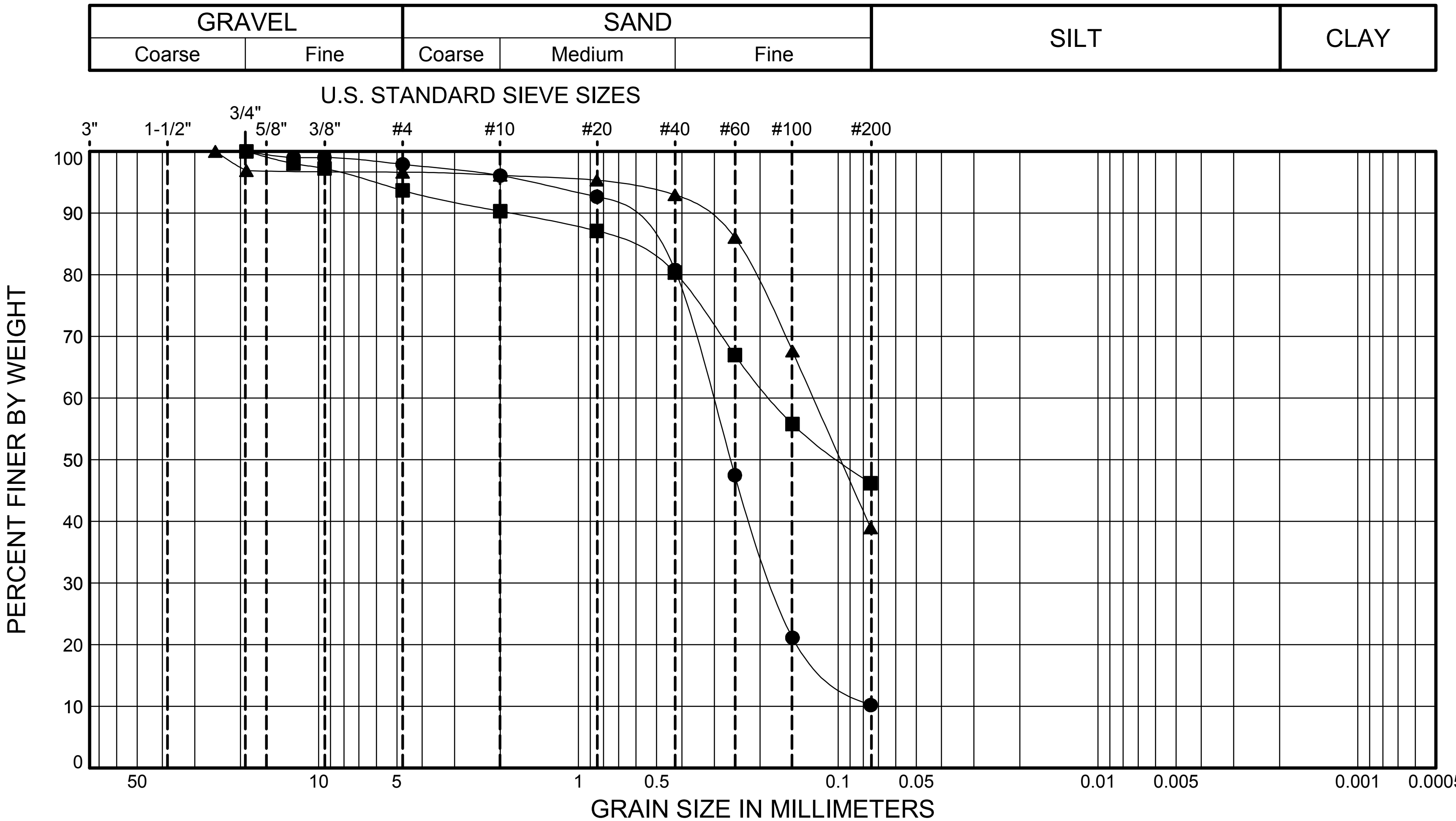
LIQUID LIMIT, PLASTIC LIMIT AND PLASTICITY INDEX OF SOILS
METHOD ASTM D4318

PROJECT NO.: 2010-100 T400 FIGURE: B-1



SYMBOL	SAMPLE		DEPTH (ft)	CLASSIFICATION OF SOIL- ASTM D2487 Group Symbol and Name	% MC	LL	PL	PI	Gravel %	Sand %	Fines %
●	BH-1	S-3	5.0 - 6.5	(SP-SM) Dark gray, poorly graded SAND with silt	22				2.1	87.7	10.2
■	BH-1	S-7	20.0 - 21.5	(SM) Olive brown, silty SAND	13				6.3	47.5	46.2
▲	BH-2	S-3	5.0 - 6.5	(SM) Olive brown, silty SAND	20				3.4	57.7	38.9

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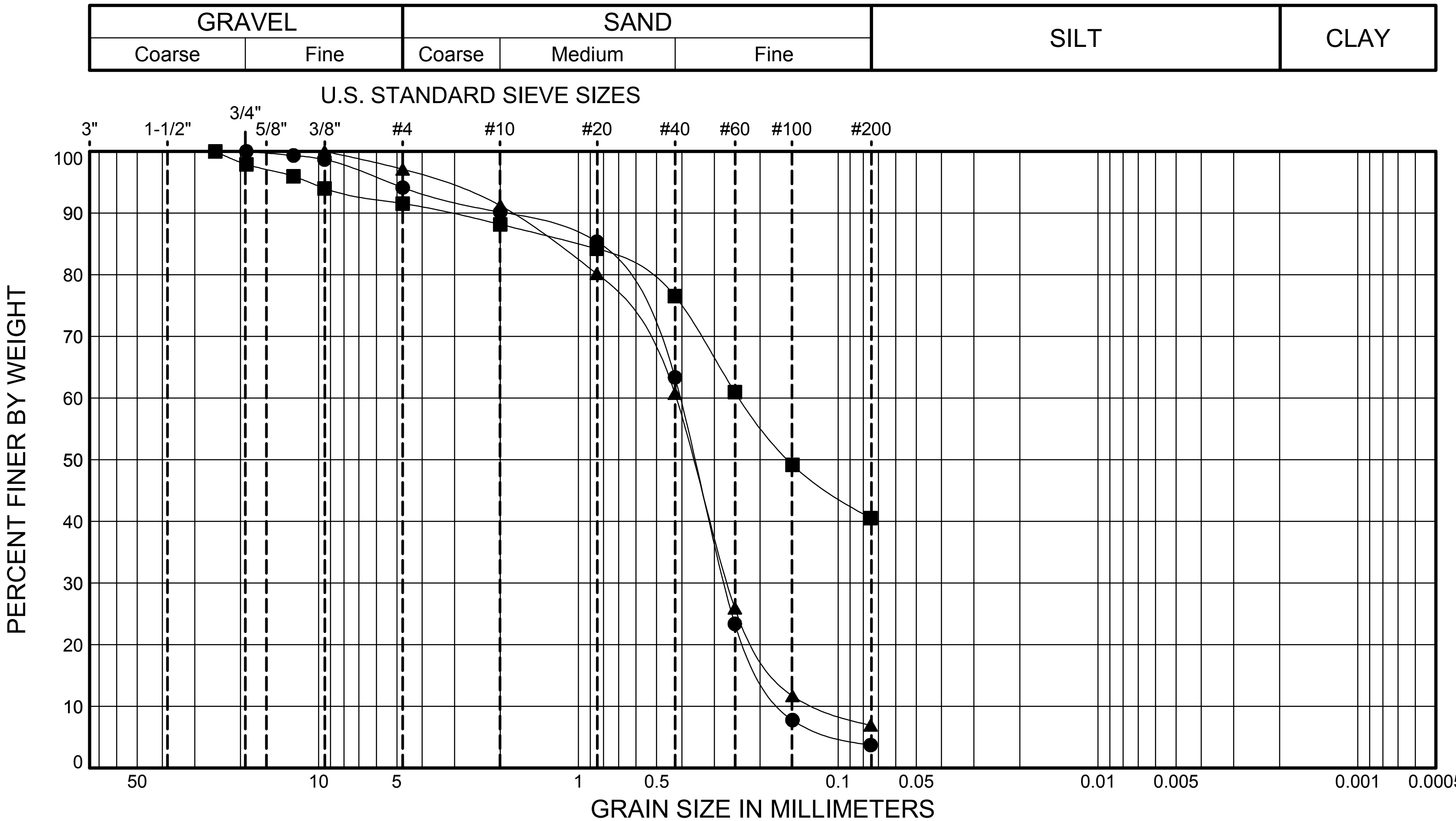
PARTICLE-SIZE ANALYSIS OF SOILS METHOD ASTM D422

PROJECT NO.: 2010-100 T400 FIGURE: B-2



SYMBOL	SAMPLE		DEPTH (ft)	CLASSIFICATION OF SOIL- ASTM D2487 Group Symbol and Name	% MC	LL	PL	PI	Gravel %	Sand %	Fines %
●	BH-2	S-4	7.5 - 9.0	(SP) Olive brown, poorly graded SAND	19				5.9	90.4	3.7
■	BH-2	S-6	15.0 - 16.5	(SM) Olive brown, silty SAND	12				8.5	51.0	40.5
▲	BH-3	S-3	5.0 - 6.5	(SP-SM) Grayish brown, poorly graded SAND with silt	20				2.9	90.2	6.9

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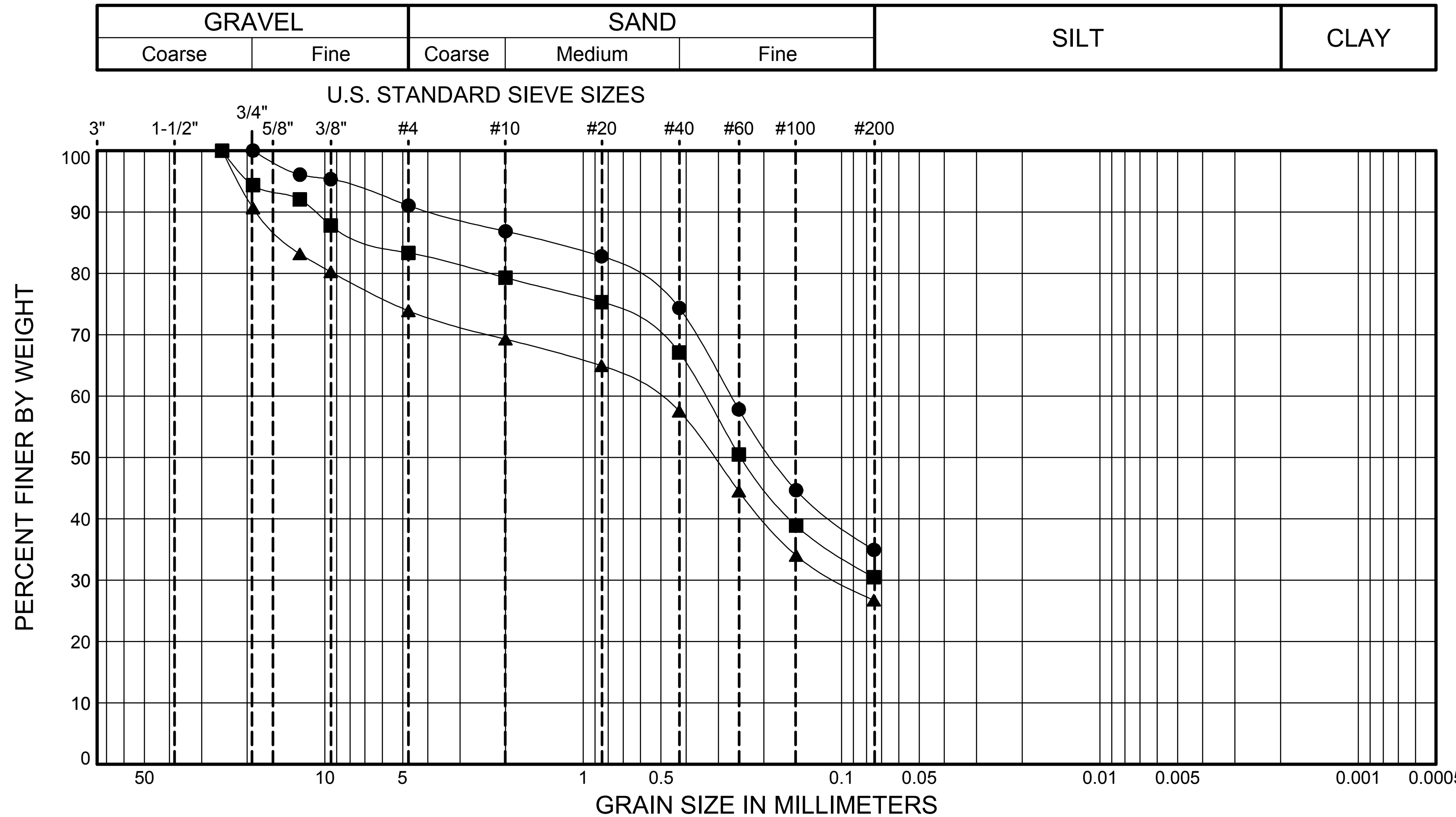
PARTICLE-SIZE ANALYSIS
OF SOILS
METHOD ASTM D422

PROJECT NO.: 2010-100 T400 FIGURE: B-3

HWAGRSZ 2010-100-400.GPJ 11/21/16



SYMBOL	SAMPLE		DEPTH (ft)	CLASSIFICATION OF SOIL- ASTM D2487 Group Symbol and Name	% MC	LL	PL	PI	Gravel %	Sand %	Fines %
●	BH-3	S-5	10.0 - 11.5	(SM) Dark gray, silty SAND	10				9.0	56.1	34.9
■	BH-3	S-6	15.0 - 16.5	(SM) Dark gray, silty SAND with gravel	12				16.7	52.9	30.5
▲	BH-3	S-7	20.0 - 20.5	(SM) Dark gray, silty SAND with gravel	7				26.1	47.2	26.7

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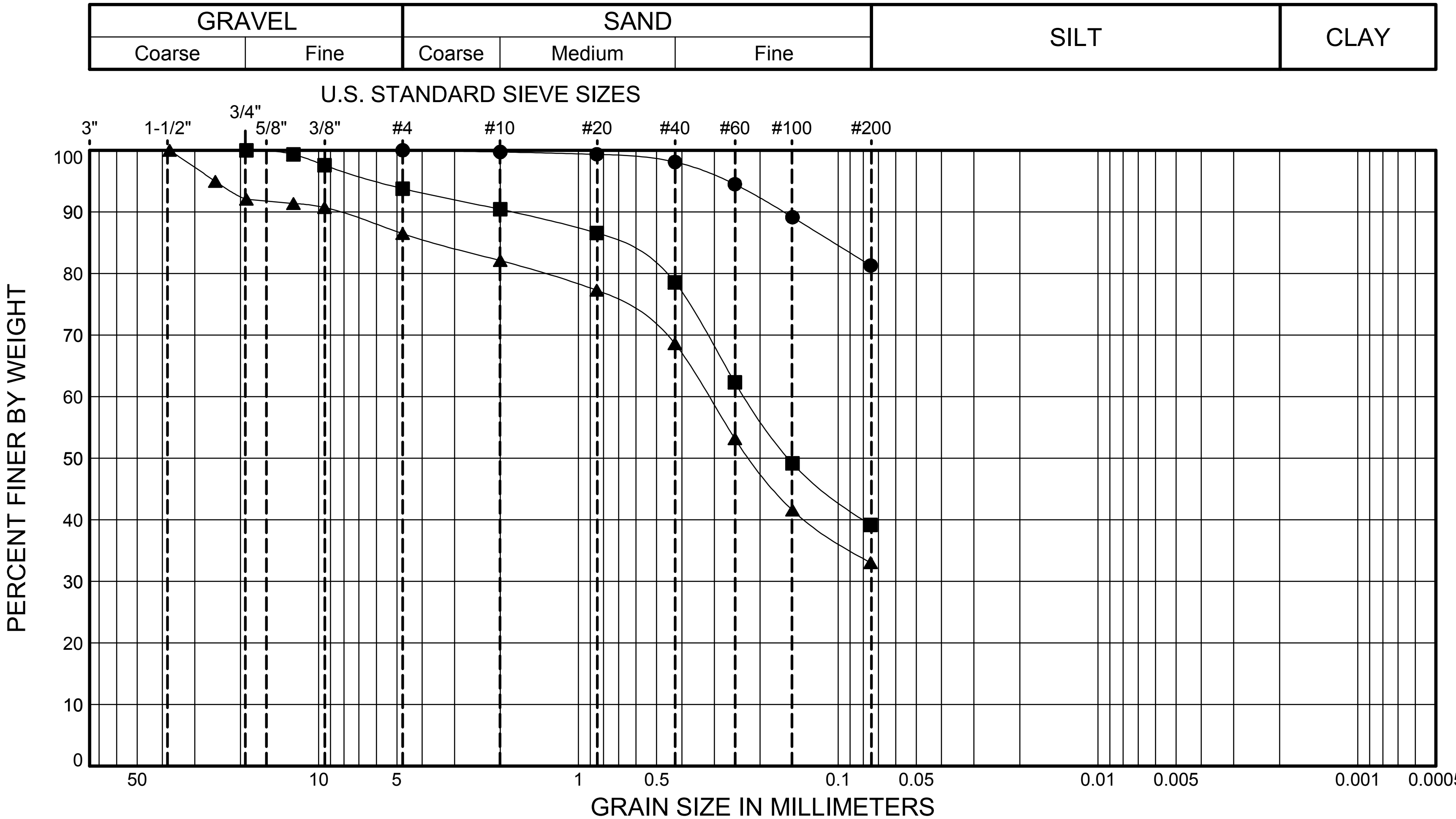
PARTICLE-SIZE ANALYSIS OF SOILS METHOD ASTM D422

PROJECT NO.: 2010-100 T400 FIGURE: B-4



SYMBOL	SAMPLE		DEPTH (ft)	CLASSIFICATION OF SOIL- ASTM D2487 Group Symbol and Name	% MC	LL	PL	PI	Gravel %	Sand %	Fines %
●	BH-4	S-2	2.5 - 4.0	(ML) Grayish brown, SILT with sand	25					18.7	81.3
■	BH-4	S-4	7.5 - 9.0	(SM) Dark gray, silty SAND	10				6.2	54.6	39.2
▲	BH-4	S-6	15.0 - 15.4	(SM) Dark gray, silty SAND	10				13.5	53.4	33.0

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PARTICLE-SIZE ANALYSIS
OF SOILS
METHOD ASTM D422

PROJECT NO.: 2010-100 T400 FIGURE: B-5