GEOTECHNICAL REPORT
Hidden Lake Dam Removal and Stream Restoration Project
Shoreline, Washington

HWA Project No. 2017-096-21

Prepared for
Herrera Environmental Consultants, Inc.
& City of Shoreline

November 26, 2019 (Updated January 22, 2020)

HWA GEOSCIENCES INC.
DBE/MWBE

Geotechnical Engineering
Pavement Engineering
Geoenvironmental
Hydrogeology
Inspection & Testing

November 26, 2019 (Updated January 22, 2020)
HWA Project No. 2017-096-21

Herrera Environmental Consultants
2200 Sixth Avenue, Suite 1100
Seattle, Washington 98121

Attention: Mark Ewbank, P.E.

Subject: **GEOTECHNICAL REPORT**
Hidden Lake Dam Removal and Stream Restoration Project
Shoreline, Washington

Dear Mr. Ewbank:

As requested, HWA GeoSciences Inc. (HWA) has performed geotechnical engineering evaluations for the proposed Hidden Lake Dam Removal and Stream Restoration Project in Shoreline, Washington. The objective of this work is to evaluate subsurface conditions at the site and provide recommendations for design and construction of the proposed dam removal and replacement of the existing culvert below Innis Arden Way. This geotechnical report summarizes the results of our study and presents our conclusions and recommendations. We will finalize this report upon receipt of review comments.

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

Sincerely,

HWA GEOSCIENCES INC.

JoLyn Gillie, P.E.
Geotechnical Engineer, Principal

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES (FOLLOWING TEXT)

APPENDICES

GEOTECHNICAL REPORT
HIDDEN LAKE DAM REMOVAL AND STREAM RESTORATION PROJECT
SHORELINE, WASHINGTON

1 INTRODUCTION

1.1 GENERAL

This report summarizes the results of geotechnical engineering studies performed to date by HWA GeoSciences Inc. (HWA) for the proposed Hidden Lake Dam Removal and Stream Restoration project in Shoreline, Washington. The purpose of this study this is to evaluate subsurface conditions at the site and provide recommendations for design and construction of the proposed dam removal, replacement of the existing culvert below NW Innis Arden Way, stream restoration that will occur once the lake is drained, and trail restoration within Shoreview Park east of Hidden Lake.

The approximate location of the project site is shown on the Site and Vicinity Map, Figure 1, and on the Site and Exploration Plan, Figures 2A and 2B.

1.2 PROJECT UNDERSTANDING

The City of Shoreline is planning to remove the existing dam that has created Hidden Lake. Along with dam removal, the project is also considering the feasibility of replacing the existing twin 48-inch diameter reinforced concrete culverts below NW Innis Arden Way with a larger, fish passable culvert. As part of the improvements, the City would like to lower the culvert to prevent a barrier to fish passage, if improvements are constructed downstream are made to allow fish passage.

The site is located within the Boeing Creek valley at the southern end of Hidden Lake, west of Shoreline Community College and Shoreview Park. We understand the lake was initially created as an amenity to the Boeing estate by damming Boeing Creek. During the 1950s to 1970s development upstream of the lake resulted in greater storm water flows leading to persistent erosion issues. By the 1970's Tthe original earthen dam had failed, and the lake had filled with sediment by the 1970s. In 1996, King County rebuilt the dam and recreated the lake. In 1997, a sinkhole formed due to ruptured sewer lines near 175th Street and the lake filled in with sediment again requiring that the lake be re-excavated. The lake has been maintained since then; however, sediment deposition into the lake is estimated to be of the order of a thousand cubic yards per year. The City has elected to stop dredging to maintain the lake. Without periodic removal of sediment, the lake will fill with sediment and could impact other utilities and the infrastructure in the road. To mitigate these risks, the City is exploring options for removing the dam and replacing the existing twin culverts with a fish passable culvert that will flow under NW Innis Arden Way.

The full dam removal and culvert replacement project will be constructed in two separate phases. The first phase will include removing the existing dam, draining the lake, and constructing a new stream channel. The second phase will include replacement of the existing twin 48-inch diameter culverts under NW Innis Arden Way and installation of permanent walls upstream and downstream of the culvert to allow for excavation of a new, lower stream bed.

For the first phase, the project will begin by diverting Boeing Creek such that it flows within a pipe from the inlet of Hidden Lake to the existing culvert, allowing the lake to drain. Once the lake is drained, work will begin to remove the dam and recreate the stream channel. Restoration will include constructing a berm along the west side of the new channel from STA 5+00 to 9+00. The berm is needed to keep the stream from flowing into the basin to the west. A revetment structure to resist erosion is proposed at the base of the adjacent steep slope near the upstream end (STA 8+65 to 9+45) and a series of anchored log installations are planned along the entire alignment to create habitat structures as shown on Figures 2A and 2B, the Site and Exploration Plan, and on the Proposed Site Plan, Sheet C-1.0 of the 60 percent design plans prepared by Herrera Environmental Consultants (Herrera), and provided in their draft Critical Areas Report and Mitigation Plan provided for our review in January 2020. Where the dam is removed, the slope will be regraded with 2H:1V slopes. An interim block wall about 10 to 12 feet high will be required along the west side of the stream north of the culverts to reduce the extents of the excavation needed in this area and retain several of the existing trees. The first phase will also include restoration of the trail within Shoreview Park. Improvements will include adding turnpike and boardwalk supported trail sections at the base of the slope at the north end of the project.

The second phase of the project will replace the existing culverts and lower the stream channel about 8 feet to allow for future fish passage. The proposed culvert will be about 24 feet wide with an internal height of about 12 to 15 feet. The top of the lid will be about 16 feet below the final design ground surface. As a result, the installation of the proposed culvert will require excavations within NW Innis Arden Way of up to 35 feet deep. Due to the lowering of the culvert, retaining walls are needed to reduce the extents of the cut slopes upstream and downstream of the culvert. These walls are expected to extend 75 feet upstream and 27 feet downstream of the new culvert.

2 FIELD INVESTIGATION AND LABORATORY TESTING

2.1 SITE RECONNAISSANCE

HWA performed a reconnaissance of the site to assess the stability of slopes and evaluate surficial soil conditions in the vicinity of the dam and culverts in 2017 and for the proposed trail improvements in Shoreview Park in 2019. The depths of weathered soil on slopes were determined at selected locations using a ½-inch diameter steel T-handled probe. Observations were made of soil exposures, seepage zones and other features indicating relative slope stability. Details of our observations made during the site reconnaissance are provided in Section 4: Geologic Hazard Assessment.

2.2 Geotechnical Subsurface Explorations

HWA GeoSciences Inc. (HWA) conducted seven (7) geotechnical borings in support of the design of the dam removal and culvert replacement. The locations of the boreholes are shown on the Site and Exploration Plan, Figures 2A and 2B. The borings, designed BH-1 through BH-7, were drilled to depths ranging from 3 feet to 49 feet below existing ground surface. The borings were completed in phases consisting of two borings north of NW Innis Arden Way, designated BH-1 and BH-2, two borings in the roadway of NW Innis Arden Way, designated BH-3 and BH-4, and three borings south of the road, designated BH-5 through BH-7. Field exploration methods are described in more detail in Appendix A which also contains summary of the logs for each exploration.

Four (4) hand borings, designated HH-1 through HH-4, were also performed to obtain samples of site soils to evaluate their potential corrosivity. These hand borings were excavated using hand augers, post hole diggers, and digging bars to depths ranging from near surface to 8 feet below ground surface. Their locations are shown on the Site and Exploration Plan, Figures 2A and 2B.

2.3 Laboratory Testing

Laboratory tests were conducted at HWA's Bothell, Washington laboratory, on selected samples retrieved from the borings to determine relevant index and engineering properties of the soils encountered at the site. The tests included visual classifications, natural moisture content determinations, grain size distribution analyses using wet sieve and fines content hydrometer analysis, and soil pH and resistivity determination. A discussion of laboratory test methodology is presented below, and test results are provided in Appendix B, displayed on the exploration logs in Appendix A, and/or presented in a table below, as appropriate. The laboratory testing program was performed in general accordance with appropriate American Society of Testing and Materials (ASTM) Standards, as outlined below.

Moisture Content of Soil: The moisture content of selected soil samples (percent by dry mass) was determined in general accordance with ASTM D 2216. The results are shown at the sampled intervals on the appropriate summary 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 reports (Figures B-1 and B-2, Appendix B).

PARTICLE SIZE ANALYSIS OF SOILS: Selected granular samples were tested to determine the particle size distribution of material in accordance with ASTM D 422 (wash sieve or wash sieve and hydrometer methods). The results are summarized on the attached Particle-Size Distribution reports (Figures B-3 through B-5, Appendix B), which also provide information regarding the classification of the samples and the moisture content at the time of testing.

PH AND RESISTIVITY TEST RESULTS: Testing was carried out on selected samples using ASTM G187. The indicated pH and minimum resistivity of the samples are as follows:

Table 1: pH and Resistivity

Sample	Depth	Soil Type	pH	Minimum Resistivity
HH-1, S-1	Surface	Lean Clay	7.3	6,000 ohm-cm
HH-2, S-4	7.75-7.9 feet	Silty Sand	6.5	9,000 ohm-cm
HH-3, S-5	8.55-8.8 feet	Silty Sand	5.8	22,000 ohm-cm
HH-4, S-1	3.0-3.5 feet	Lean Clay	8.7	3,200 ohm-cm

2.4 EXPLORATIONS BY OTHERS

HWA reviewed existing geotechnical data available at the site. The following documents were used to provide information regarding the subsurface conditions at the site.

- **Perrone Consulting Inc**., October 2015, *Hidden Lake Dam Removal*: Project No. 15126 for Herrera Consultants. This report was prepared as part of the Alternatives Selection for the Hidden Lake Dam Removal Project. The explorations performed for the evaluation consisted of two borings, designated B-1 and B-2, that ranged in depth from approximately 19 feet in B-1 to 31½feet at B-2. The site plan, geologic cross-section and boring data from this report is provided in Appendix D.
- **Shannon & Wilson Inc.,** September 1995, *Geotechnical Engineering Report, Hidden Lake Restoration Project*, King County, Washington: Project No. W-7022-03 for R.W. Beck. The report was prepared for the dam replacement project completed in 1996. The report includes seven borings, designed B-1 through B-7, that ranged in depth from approximately 10½ feet to 18½ feet, including three borings completed about 60 feet north of the existing dam alignment, and four conducted at various location around the lake. Nine hand borings, designated HA-1 through HA-9, were also conducted ranging in depth from approximately 1 to 11½ feet. Four of the handholes were conducted near the existing dam and the rest at various locations around the lake. The site plan, geologic cross-section and boring data from this report is provided in Appendix E. Note that the elevations provided for this report are based on the NGVD datum, whereas the current

study is based on the NAVD88 datum. To convert NGVD elevations to NAVD88, 3.6 feet should be added to the NGVD elevations.

The approximate location of the relevant available soil information along the project alignment is presented on the Site and Exploration Plans, Figures 2A and 2B.

3 SITE CONDITIONS

3.1 SITE TOPOGRAPHY

Hidden Lake is a man-made lake situated in a bowl-like depression with steep slopes surrounding the site. At the north end of the site, Boeing Creek flows into Hidden Lake. Steep slopes outside the project site are present within the properties to the north and west of the lake. Steep slopes are also present along the east side of the lake, the area that is part of Shoreview Park where trail restoration is proposed. The site for the dam removal and culvert replacement is located within a ravine at the south end of the lake. In this location, fill has been placed to create the roadway embankment for Innis Arden Way as well as the earthen dam that was installed to create Hidden Lake. Elevations of the existing ground and improvements are shown on Figure 2A and 2B and range from about Elev. 160 feet (NAVD88) at the downstream end of the stream to about Elev. 280 feet at the top of the bluff along eastern edge of the site. At the location of Innis Arden Way, the upstream end of the twin culverts is approximately Elev. 184 feet, the roadway is approximately Elev. 205 feet, and the top of the dam is about Elev. 195 feet.

3.2 GENERAL GEOLOGIC CONDITIONS

The project is located within the Puget Lowland. The Puget Lowland has repeatedly been occupied by a portion of the continental glaciers that developed during the ice ages of the Quaternary period. During at least four periods, portions of the ice sheet advanced south from British Columbia into the lowlands of Western Washington. The southern extent of these glacial advances was near Olympia, Washington. Each major advance included numerous local advances and retreats, and each advance and retreat resulted in its own sequence of erosion and deposition of glacial lacustrine, outwash, till, and drift deposits. Between and following these glacial advances, sediments from the Olympic and Cascade Mountains accumulated in the Puget Lowland in lakes and valleys.

Geologic information for the project area was obtained from the *Geologic Map of the Edmonds East and part of the Edmonds West Quadrangles, Washington* (Minard, 1983). Per these maps, near-surface deposits in the vicinity of the project area consist of soils associated with the Vashon Stade of the most recent continental glaciation (Fraser Glaciation). The geologic map indicates that the project area is underlain by Transitional Beds deposits, which consist of a combination of glaciolacustrine deposits and non-glacial lake deposits. Geomorphology of the Boeing Creek valley indicates it was cut through these deposits (and advance outwash and glacial till on higher slopes) by glacial outwash channels and subsequent non-glacial alluvial processes.

3.3 Subsurface Soil Conditions

The soils at the site consist of a series of fill, colluvium, alluvium, glaciolacustrine, and Pre-Fraser deposits. There is also a unit that appears to be old slide debris along the west side of the ravine, which was identified in the 1995 Shannon and Wilson report (see cross-section in Appendix E) and was observed in the HWA boring BH-5. Brief descriptions of the major soil units observed in explorations performed at the site are presented below in order of deposition, beginning with the most recently deposited.

- **Colluvium:** Colluvium was observed in the HWA borings, BH-1, BH-2, and BH-6, ranging in depth from about 7½ to 12 feet below the ground surface. Colluvium was found at the ground surface in BH-1 and BH-2 and was observed below the fill in BH-6. This recent deposit consists of soils that have moved downslope due to processes of weathering (chemical, mechanical, and biological), gravity, and water.
- **Fill/Buried Topsoil:** Fill was observed in each of our borings and hand-holes, except BH-2, HH-1 and HH-4. Fill ranged from about 3 feet thick in BH-1 to about 22½ feet thick in BH-4. Fill placed for the roadway and the culvert embankment generally consisted of loose to medium dense, slightly silty to silty, sand with no to little gravel. Below the fill in BH-4, a buried topsoil layer was observed. The explorations BH-5A and BH-7 were terminated on quarry spalls at depths of about 7 feet and 2½ feet respectively, indicating the presence of rock materials that have been placed on the downstream side of the culvert embankment.

  Previous borings at the dam by Perrone Consulting (2015; borings B-1 and B-2) encountered dam fill (placed in 1996) consisting of sandy lean clay and silty sand with gravel.

- **Alluvium:** Boreholes BH-3, and BH-4 encountered alluvium beneath the roadway fill and BH-6 encountered alluvium below the colluvium. The alluvium ranged in thickness from about 3½ to 11 feet. Alluvium consisted of loose, sandy gravel and silty sand, as well as medium stiff, silt and stiff, lean clay. Alluvial soils were generally saturated, indicating a perched ground water table.

  Previous explorations also encountered alluvium, specifically at B-2 by Perrone Consulting, where soft to medium stiff lean clay and very loose to loose, silty sand was shown to depths of about 30 feet near the west end of the existing dam.

- **Slide Debris:** Material interpreted as Slide Debris was previously identified at the site by Shannon & Wilson (1995) in their boring B-1. Similar materials were also recorded in HWA's boring BH-5, drilled west of the existing riprap slope on the south side of NW Innis Arden Way. This deposit consisted of soft to stiff, sandy silt, fat clay and lean clay with slickensides and blocky/crumbly texture. Each of these borings encountered wood at the base of the slide debris unit.

- **Glaciolacustine**: Glaciolacustine was encountered in each of HWA's borings, except for those terminated in riprap fill. This unit consists of very stiff to hard, gray, silt, silty clay, lean clay, and fat clay. The glaciolacustrine deposits ranged from massive, to finely laminated, to disturbed with blocky texture. Within the fat clay observed between 31 to 47 feet in BH-3 and 37 to 47 feet in BH-4, slickensides were observed and are likely due to compression forces experienced during the Fraser Glaciation. Glaciolacustrine deposits typically have high shear strength and low permeability, with ground water often perched within more permeable materials on top of the glaciolacustrine deposits or within sandier lenses of soil within the unit.

  The hard/silt clay glaciolacustrine unit is exposed on the east side of the ravine in a 15-foot high bluff just above the colluvial slope explored by HWA's boreholes BH-1 and BH-2. Based on this exposure, we conclude that the elevations of the glaciolacustrine layer can vary significantly over short distances at this site.

- **Pre-Frasier Deposits**: Below the glaciolacustrine in boring BH-5, at a depth of 35 feet, dense, sandy silt with organics was observed. The organics indicate this material was likely deposited during an interglacial period prior to the most recent (Frasier) glaciation. This material is more permeable than the overlying glaciolacustrine and ground water seepage and caving soils are anticipated where drilling penetrates into these soils.

3.4 GROUND WATER CONDITIONS

Ground water, or saturated soil conditions, were observed during drilling of BH-3, BH-4, BH-5, BH-6, HH-2 and HH-3. Ground water was noted in BH-3, BH-5 and BH-6 at about 3 to 5 feet above to top of the glaciolacustrine, with depths ranging from about 10 to 25 feet below the ground surface (bgs). The highest ground water level was observed in BH-4 at a depth of 6 feet bgs during drilling, which was later observed at a similar depth in both HH-2 and HH-3 along the roadway during August 2019. This shallower water level likely represents perched ground water encountered within the silty fill. Ground water was encountered in most of the previous borings, completed by others, within 10 feet of the ground surface. We expect ground water levels will vary depending on location, season, and the relative abundance of precipitation.

4 GEOLOGIC HAZARD ASSESSMENT

4.1 General

The purpose of this section is to identify the potential geologic hazards and describe how their presence may impact site development. Geotechnical recommendations that relate to mitigating the potential hazards are addressed in our conclusions and recommendations section. Areas with potential geologic hazard are defined in the Shoreline Municipal Code (SMC) Section 20.80, which regulates development within the geologic hazard areas and their buffers. The specific areas regulated as potential geologic hazards include:

a) Landslide hazards areas

b) Seismic hazard areas

c) Erosion hazard areas

Upon review of these sections we have identified the presence of each of these three potential geologic hazards at the site. Descriptions of these areas are provided in the following sections.

4.2 Landslide Hazard Areas

4.2.1 General

Hidden Lake lies in a basin surrounded by moderate to very steep slopes, as shown on Figures 2A and 2B. To identify the presence of Landslide Hazard Areas at the site, we reviewed the definition of a Landslide Hazard Area presented in the SMC 20.80.220.A&B. Within this definition, landslide hazard areas are classified into two classes and include "Moderate to High Risk" and "Very High Risk". These classifications are defined as:

- Moderate to High Risk:
  - Areas with slopes between 15 percent and 40 percent and that are underlain by soils that consist largely of sand, gravel or glacial till (that do not classify as "Very High Risk" slopes);
  - Areas with slopes between 15 percent and 40 percent that are underlain by soils consisting largely of silt and clay (that do not classify as "Very High Risk" slopes); and
  - All slopes of 10 to 20 feet in height that are 40 percent slope or steeper.
- Very High Risk:
  - Areas with slopes steeper than 15 percent with zones of emergent water (e.g., springs or ground water seepage);

- Areas of landslide activity (scarps, movement, or accumulated debris) regardless of slope; or
- All slopes that are 40 percent or steeper and more than 20 feet in height when slope is averaged over 10 vertical feet of relief.

HWA reviewed the City of Shoreline's Critical Areas Maps available using the ArcGIS application on their web site (City of Shoreline, 2019). HWA also reviewed the site survey provided as part of the design of the project and redefined the Landslide Hazard Areas provided by the City based on the site survey data. The delineations for each slope classification are provided on Figure 3, Landslide Hazard Area Delineation.

We have divided these Landslide Hazard Areas into three zones for the purposes of discussion and to provide specific conclusions and recommendations for each zone. The zones are:

- Zone #1: Slopes at the existing dam and culverts
- Zone #2: Slopes east of Hidden Lake in Shoreview Park, and
- Zone #3: Slopes west of Hidden Lake.

Descriptions of the slopes and the alternations proposed in each of the zones are provided in the following sections.

4.2.2 Zone #1: Slopes at the Existing Dam and Culverts

A site reconnaissance was performed in 2017 to evaluate the stability of the slopes adjacent to the existing dam and at the north and south ends of the culverts that flow under Innis Arden Way. It was observed that slopes of 1H:1V or steeper are present with total vertical relief of 40 to 90 feet along the eastern side of the ravine upstream and downstream of Innis Arden Way. These slopes classify as "Very High Risk" slopes. The slopes generally consist of exposed deposits of hard clay/silt, characteristic of the glaciolacustrine observed the borings. The topography includes an approximately 15-foot tall vertical bluff north of Innis Arden Way and east of the dam. The glaciolacustrine has high strength and can stand vertical or near-vertical for decades to centuries without failure. The surficial layers of glaciolacustrine have experienced weathering, as indicated by the presence of approximately 7½ feet of soft silt and clay (characterized as colluvium), which was observed in borings BH-1 and BH-2. Further weathering of the slope above will add to the thickness of colluvium; however, this is not likely to impact the overall stability of the slope.

The slopes on the west side of the ravine and the slope along the south side of Innis Arden Way are generally less steep, of the order of about 1.5H:1V. These slopes were constructed as fill slopes to support Innis Arden Way. Most of these slopes classify as "Moderate to High Risk" since they range in height from 10 to 20 feet; however, there are also areas where the slopes are greater than 20 feet tall, such that they classify as "Very High Risk" slopes. The fill used to construct the slopes generally consists of silty sand, except for the southern slope near the culverts' outfall, which has been constructed using riprap. Based on information gathered regarding construction of the culverts, the initial culverts needed to be extended and materials placed to reduce the potential for slope instability along the west side of the culvert alignment. During our evaluation it does not appear that slope movement has occurred since the placement of these materials.

Removal of the dam and construction to replace the existing culverts will result in alternations to the slopes in this landslide hazard area in both phases of the project. Alternations for Phase 1 will include excavating the existing dam fill to create 2H:1V slopes on both sides of the channel. Construction of these slopes will require some over-excavation to place materials which will be resistant to erosion along the channel. Recommendations for scour protection are provided in Section 6.3. There will be a section from approximate STA 2+35 to 2+70 that will require installation of a block wall on the west bank to limit the extent of excavation required to form the channel. Recommendations for wall design and installation are provided in Sections 6.8 and 6.9. A section of north of the proposed wall, from STA 2+40 to 4+00, has some potential for instability following a seismic event due to flow sliding/lateral spreading. Options for mitigation are provided in Section 6.7.

Alternations for Phase 2 will include additional excavation of soils within the proposed stream channel, which will extend up to 8 feet below the elevations proposed in Phase 1. To create this proposed deeper stream channel, we recommend installing soldier pile walls to maintain slope stability in accordance with the requirements for “Very High Risk” landslide hazard areas as provided in SMC Section 20.80.224. Our recommendations for wall design are provided in Section 7.4 of this report. The recommendations provided in this report are intended to meet the requirements for development within a "Very High Risk" landslide hazard area, and we conclude the proposed alterations to this landslide hazard area and its buffers are acceptable from a geo-hazard/stability standpoint.

4.2.3 Zone #2: Slopes East of Hidden Lake in Shoreview Park

A second site reconnaissance was performed in 2019 to evaluate the slopes along the existing trail within Shoreview Park to evaluate the feasibility of trail restoration. The slope along the east side of Hidden Lake has a total vertical relief of about 80 feet. The average slope inclination is about 38 degrees, e.g. 1.3H:1V, with localized areas having slopes up to 48 degrees, e.g. 0.9H:1V, such that Zone #2 classifies as a "Very High Risk" landslide hazard area.

The surficial soils in this area consist of well drained, slightly silty to silty sand, apparently derived from weathering of the underlying advance outwash. There was no evidence of clay at the toe of the slope or resulting groundwater seepage. Evidence of soil creep was observed; however, rodents appear to be the main driver of downslope surficial creep, due to sidecasting of their burrow spoils. Where the trail has been cut into the side of the hill, raveling of the cut slope has resulted in narrowing of the trail. Although surficial weathering, raveling, and creep were observed, the existing advance outwash slopes exhibit adequate long-term stability to support the proposed trail restoration. Bluff retreat in this area will be minimal. Some surficial sliding of soils within the upper two to three feet of the site soils is anticipated during a seismic event. The primary long-term stability issue for this slope is to mitigate for potential erosion of the soils, particularly at the base of the slope. Methods to protect against erosion are addressed in Section 6.3. The recommendations provided in this report are intended to meet the requirements for development within a "Very High Risk" landslide hazard area, and we conclude the proposed alterations to this landslide hazard area and its buffers are acceptable from a geo-hazard/stability standpoint.

4.2.4 Zone #3: Slopes West of Hidden Lake

Steep slopes are present on the properties adjacent to the project site on the west side of the lake. The total vertical relief of the slope on this side of the lake is about 70 feet. The average slope, as estimated from contours provided by lidar, is about 1.5H:1V with localized areas as steep as 1.1H:1V. Based on the 60 percent design plans provided by Herrera, the improvements will include placing fill at the base of the slope on east end of the parcel at 17040 10th Ave NW to create a berm that will form the new channel for the proposed stream restoration. No excavation is anticipated within 50 feet of the base of the slope, such that no reduction of stability will occur within the Very High Risk slope area or its buffers. The existing channel does appear to be eroding material away from the base of the slope within the parcel at 17052 10th Ave NW. To mitigate the erosion, the project includes installation of a revetment structure, as shown in the 60 percent plans prepared by Herrera. Installing this structure will increase the stability of the existing slope, such that the proposed improvements will increase the overall slope stability within Zone #3, such that the proposed alterations to this landslide hazard area and its buffers are acceptable from a geo-hazard/stability standpoint.

4.2.5 Buffers for Landslide Hazard Areas

Standard buffers were reviewed for each of the landslide hazard areas. For "Moderate to High Risk" landslide hazard areas, SMC Section 20.80.230, indicates that the critical area hazard assessment can determine if buffers are needed. Based on our assessment, we conclude that buffers are not necessary for "Moderate to High Risk;" however, most of these areas are adjacent to "Very High Risk" landslide hazard areas and will likely be within the buffer required for those areas.

For "Very High Risk" landslide hazard areas, the SMC Section 20.80.230, requires standard buffers of 50 feet. Whereas the standard buffer can be reduced to 15 feet, we recommend that the buffers be maintained for the final condition. This buffer could be reduced to 15 feet for the temporary construction condition, such as the along the proposed open channel for the temporary bypass, as shown on Plan Sheet C-2.0. Where possible improvements such as drainage improvements and other site grading should be performed outside of the buffers; however, as noted in the previous sections, the project does require construction within the landslide hazard areas and the buffers themselves. All the recommendations presented in this report should be applied to the improvements within these areas to mitigate the impacts of the construction.

4.3 SEISMIC HAZARD AREAS

Seismic Hazard Areas, as defined in SMC 20.80.220 C, are those areas that are subject "to risk of ground shaking, lateral spreading, subsidence or liquefaction of soils during earthquakes." Seismic hazards are present at the site, as summarized in Table 2 and discussed in more detail in the referenced report sections. The recommendations provided in this report are intended to meet the requirements for development within a seismic hazard area, and we conclude the proposed alterations to this landslide hazard area and its buffers are acceptable from a geo-hazard/stability standpoint.

Seismic Hazard Area Buffers: For Seismic Hazard areas, no standard buffer is required in SMC 20.80 and in our opinion, the seismic hazard areas do not require a buffer, provided they adhere to the recommendations of this report.

Table 2: Qualitative Seismic Hazard Site Assessments

Liquefaction	High	Saturated, loose alluvial sands and non-cohesive silts are present within the lake and at the culvert crossing under Innis Arden Way, and the site susceptibility to liquefaction is high. Liquefaction susceptibility and its anticipated impacts are discussed in Section 5.
Slope Stability	Low to Moderate	The steep slopes at the site are typically located in areas underlain by glacial soils that are not anticipated to experience slope instability except for some near surface sloughing.
Lateral Spread/Flow Sliding	Low to Moderate	Liquefiable soils are generally located in the base of the basin with no non-liquefiable crust over liquefiable materials, such that the risk of lateral spreading/flow sliding is low, except for the western slope of the stream channel at STA 2+40 to 4+00. Liquefaction of saturated soils in this zone could result in flow sliding and/or lateral spreading within this zone. Mitigation measures for this hazard are discussed in Section 6.7.
Surface Rupture	Low	Based on our review of the USGS Fault map Database (USGS, 2019), no faults were observed to underly the site.

4.4 EROSION HAZARD AREAS

Erosion hazard areas, defined by SMC 20.80.220 D, are those areas that are underlain by soils that are identified by the U.S. Department of Agriculture Natural Resources Conservation

Service (formerly the Soil Conservation Service) as having "severe" or "very severe" erosion hazards, this includes the following groups of soils when they occur on slopes of 15 percent or greater: Alderwood gravelly sandy loam, Kitsap silt loam, Everett, and Indianola. The soils mapped at the site include the groups of Alderwood, Alderwood-Everett, and Alderwood-Kitsap, indicating that erosion hazard areas are present wherever the site slopes are greater than 15 percent.

Potential erosion is made up of two components, (1) short-term erosion during construction, and (2) long-term erosion due stormwater runoff and the presence of a stream channel at the base of the slopes. Potential erosion during construction can be mitigated by minimizing disturbance and managing runoff generated by the proposed construction activities provided the development standards and BMP's set forth in SMC 20.80.250 are followed. If grading is to occur between September 30 and May 1, the recommendations provided in Section 7.9.4 Wet Weather Earthwork of this report should be implemented in addition to the requirements of the SMC. Long-term erosion due to channel flow and potential for rapid drawdown conditions will be mitigated by installation of armoring the stream channels with riprap, as described in Section 6.3, and with placement of large woody debris and the revetment structure as shown on Figures 2A and 2B. The recommendations provided in this report are intended to meet the requirements for development within an erosion hazard area, and we conclude the proposed alterations to this landslide hazard area and its buffers are acceptable from a geo-hazard/stability standpoint.

Erosion Hazard Area Buffers: For Erosion Hazard areas, no standard buffer is required in SMC 20.80 and in our opinion, erosion hazard areas do not require a buffer, except where they are within a Landslide Hazard Area. Refer to Section 4.2.5, for the required buffers for Landslide Hazard areas.

5 SEISMIC AND SLOPE STABILITY ANALYSES

5.1 SEISMIC DESIGN CONSIDERATIONS

5.1.1 Seismic Design Parameters for Culvert and Walls

Earthquake loading for design of walls and the proposed culvert structure was developed in accordance with Section 3.4 of the *AASHTO Guide Specifications for LRFD Seismic Bridge Design*, 2nd Edition, 2011 and the Washington State Department of Transportation (WSDOT) amendments to the AASHTO *Guide Specifications* provided in the *Bridge Design Manual* (WSDOT, 2019). For seismic analysis, the Site Class is required to be established and is determined based on the average soil properties in the upper 100 feet below the ground surface. Based on our explorations and understanding of site geology, it is our opinion that the proposed structures are to be underlain by soils consistent with Site Class C, without regard to liquefaction. Accounting for the presence of potentially liquefiable materials, the site classifies as Site Class F, and would require a site-specific analysis to be performed to determine the seismic coefficients. However, based on our experience with similar sites, the presence of the liquefied soils will likely deamplify short period response, which includes peak ground acceleration (PGA). Seismic design for assessment of walls and culverts is based on the site PGA; therefore, use of Site Class C will be conservative.

The design peak ground acceleration for the design level event (equal to a return period of 1,033 years) was obtained using BridgeLink, a program developed by WSDOT to incorporate the probabilistic seismic hazard parameters developed by the United States Geologic Survey (USGS) and presented in the *2014 Updates to the National Hazard Maps* (Peterson, et al., 2014) as well as adopt the peak ground acceleration site coefficient (F_{pga}) provided in Table 11.8-1 of the ASCE 7-16. From BridgeLink, we obtained a mapped PGA of 0.395 g for the site. The corresponding site application factor for PGA (F_{pga}) for Site Class C is 1.2. Based on these values and using the General Procedure provided by AASHTO, we recommend using a design peak ground acceleration, designated the Acceleration Coefficient (A_s) by AASHTO, of 0.474 g for wall and culvert design.

5.1.2 Seismic Parameters for Geologic Hazard Assessment

For evaluation of geologic hazards including liquefaction susceptibility and slope stability, seismic parameters were developed in accordance with the 2015 *International Building Code* (IBC) (ICC, 2015), as required by Shoreline Municipal Code (SMC) Section 20.80.224. The selection of seismic design parameters for geologic hazard assessment conforms to Section 1613 of the 2015 *IBC*, which also references the *ASCE 7-10* code. Per the 2015 *IBC* and *ASCE 7-10*, the selection of seismic design parameters is based on the maximum considered earthquake (MCE), which corresponds to an event with a 2% probability of exceedance in 50 years, (i.e. an event with a return period of 2,475 years). As with AASHTO, the Site Class is required to be established and is determined based on the average soil properties in the upper 100 feet below the ground surface and this site is consistent with Site Class C, without regard to liquefaction. With liquefaction the site classifies as Site Class F and would require site-specific site response analyses; however, based on the half second period exception stated in section 20.3.1 of *ASCE 7-10*, the site class may be determined in accordance with section 20.3 and the corresponding F_a and F_v values may be determined based on Tables 11.4-1 and 11.4-2, respectively, assuming a Site Class C soil profile provided the structure has a fundamental period of less than 0.5 seconds. The analyses for geologic hazard for liquefaction and slope stability utilize PGA, which is defined as period of zero seconds; therefore, site-specific response analyses are not required, and developments can be designed assuming the site class assigned to the site without regard to liquefaction. For this site, we recommend using site parameters associated with Site Class C.

The mapped seismic design parameters for this site were obtained using the Applied Technology Council Seismic Hazard webtool, which incorporates the probabilistic seismic hazard maps developed by the USGS. The 2015 IBC and ASCE 7-10 utilize the site parameters based on the

2008 Updates to the National Hazard Maps (Peterson, et al., 2008), which we have utilized to be consist with the current code adopted by the City. The mapped site parameters were then multiplied by the site coefficients to determine the spectral response parameters for the MCE. The design spectral parameters are taken as two-thirds of the values of the spectral response parameters. Table 3 presents the design parameters computed for this site.

Table 3. Seismic Coefficients for IBC 2015 Code Based Evaluation

Period (sec)	Mapped MCE Spectral Response Acceleration (g)		Site Coefficients		Adjusted MCE Spectral Response Acceleration (g)		Design Spectral Response Acceleration (g)	
0.2	S_S	1.257	F_a	1.000	S_{MS}	1.257	S_{DS}	0.838
1.0	S_1	0.490	F_v	1.308	S_{M1}	0.644	S_{D1}	0.429

Notes: **2% Probability of Exceedance in 50 years for Latitude 47.715° and Longitude -122.371°*

S_S = Short period (0.2 second) Mapped Spectral Acceleration

S_1 = 1.0 second period Mapped Spectral Acceleration

S_{MS} = Spectral Response adjusted for site class effects for short period = $F_a \cdot S_S$

S_{M1} = Spectral Response adjusted for site class effects for 1-second period = $F_v \cdot S_1$

S_{DS} = Design Spectral Response Acceleration for short period =2/3 • S_{MS}

S_{D1} = Design Spectral Response Acceleration for 1-second period =2/3 • S_{M1}

$S_{a\ @\ T=0\ sec}$ = Design Spectral Acceleration at a period (T) of 0 secs taken to be equal to the design Spectral Response for Peak Ground Acceleration (PGA)

F_a = Short Period Site Coefficients

F_v = Long Period Site Coefficients

Seismic Parameters for Pseudo-Static Analyses using 2015 IBC

For checking slope stability and design of walls, a pseudo-static coefficient based on the design spectrum was evaluated. To represent the peak ground acceleration that is consistent with the design spectrum developed from the Code, the spectral acceleration at a period of zero seconds, (T=0.0 secs) was computed using Equation 11.4-5 of ASCE 7-10, which simplifies $0.4*S_{DS}$, and equals 0.335 g for this site. This value is lower than the design value for evaluation using AASHTO parameters; therefore, where slope stability and wall design meet the requirements of AASHTO design, the requirements for the IBC will also be met.

Seismic Parameters for Evaluation of Liquefaction using 2015 IBC

Since S_{DS} is greater than 0.5 g, and S_{D1} is greater than 0.2 g, the 2015 IBC refers to ASCE 7-10 Section 11.8.3 Note 2 for developing the design PGA to be used in assessing the susceptibility of soils at the site to experience liquefaction. In ASCE 7-10 the potential for liquefaction must be evaluated using the site peak ground acceleration defined as the maximum considered earthquake geometric mean (MCE_G) PGA and factored by the site coefficient F_{PGA}. For this site the MCE_G PGA is 0.507 g and the site coefficient (F_{PGA}) is 1.0. The resulting PGA for evaluation of susceptibility to liquefaction is 0.507 g. We have used this value to assess the potential susceptibility of the site soils to experience liquefaction for consistency with the requirements of SMC 20.80.224 as this value is greater than the design PGA obtained for design in accordance with AASHTO.

5.1.3 Liquefaction Susceptibility

Liquefaction is a temporary loss of soil shear strength due to earthquake shaking. Loose, saturated cohesionless soils are highly susceptible to earthquake-induced liquefaction. Research has shown that certain silts and low-plasticity clays are also susceptible. Primary factors controlling the development of liquefaction include the intensity and duration of strong ground motions, the characteristics of subsurface soils, in-situ stress conditions and the depth to ground water. To evaluate the liquefaction susceptibility of the soils along the project alignment, the simplified procedure originally developed by Seed and Idriss (1971), updated by Youd et. al., (2001), and by Idriss and Boulanger (2004, 2006) was used.

The analyses indicate that where loose to medium dense, fill and alluvial sands and gravels are encountered below the ground water table, they are likely to liquefy during a moderate to large earthquake. This includes alluvium deposited by Boeing Creek within and around the margins of Hidden Lake. At the south end of the Lake, where dam removal, site grading, wall construction and culvert replacement is proposed, the site is underlain by loose to medium dense fill and alluvium that is present below the ground water table. Liquefiable materials are generally confined to the west side of the embankment, where fill and alluvium are thicker due to a steeply declining contact between the alluvium and the underlying glaciolacustrine.

The depth of potentially liquefiable soils will vary depending on the elevation of the ground water at the time of a seismic event. The existing borings currently show the ground water table to be near Elev. 190 feet; however, this is likely due to the presence of the lake that maintains the water level at that elevation. Once the lake is drained, the water table is likely to decrease, which will reduce the thickness of potentially liquefiable soils. If current water levels are used, we estimate about 7 feet of the alluvial soils will liquefy near the location of the existing dam, and up to 9 feet of soils could liquefy near the existing culvert crossing below Innis Arden Way. This assumption was used for evaluation of liquefaction in wall design. For that case, we estimate that liquefiable soils will range from Elev. 181 to 188 feet at the existing dam and from Elev. 181 to 190 at the culvert crossing. For slope stability, we assumed the depth of the saturated soils would decrease to about 3 to 4 feet thick at the face of the slope.

5.1.4 Post-Liquefaction Residual Strength

Residual shear strengths for the liquefiable soils at the above described locations were developed using a weighted average of the results of the Idriss (as described in Kramer 2008), Olson and Stark (2002), Idriss and Boulanger (2007) and Kramer (2008) relationships. The residual shear strengths assigned are a function of the equivalent clean sand SPT value, $(N_1)_{60cs}$, the potential for void redistribution, and the initial effective overburden stress. At locations where $(N_1)_{60cs}$ is less than 10, we assumed void redistribution effects could be significant, which gives an appropriate conservative estimate of residual shear strength. Our analyses indicate that residual shear strength of the potentially liquefiable soil layers at the project site result in post-liquefaction residual friction angles that vary from 5 to 16 degrees. Evaluation of lateral earth pressures for culvert and retaining wall design, as well as slope stability at the west end of the dam used post-liquefaction residual strengths. Values of residual friction angle selected for these analyses are discussed in their respective sections.

5.1.5 Liquefaction Settlement

There is likely to be settlement of soils within the lake as well as below the roadway embankment at the west side of the proposed culvert. Explorations to identify the depth and extents of liquefiable soils within the lake were not performed; however, the depths are likely to be less at the toe of the steep slopes where the creek has eroded into the very dense glacial material and greater in the middle of the lake where loose/soft sediments from the stream and the lake have been deposited. Impacts to the project are that the constructed channel could experience some differential settlement and overall heights of the channel embankments are likely to decrease. This could result in the formation of depressions within the channel resulting in water ponding within these areas. If the channel berms settle significantly, overtopping could occur following high flows; however, overtopping of flows is not anticipated to be a significant geologic hazard as water from the stream will fill in the low areas that currently make up the lake and can subsequently drain once the high flows decrease.

At the culvert location; we evaluated the potential for liquefaction settlement around the culvert where fill and alluvium are saturated. The potential for liquefaction-induced settlement was evaluated in accordance with Yi and Andrus (2010) and Tokimatsu and Seed (1987) and are generally based on the relationship between cyclic stress ratio, corrected SPT blow counts, and volumetric strain. Using these methods, liquefaction-induced settlements along the culvert alignment were estimated to vary from 3 to 10 inches. We expect that the liquefaction-induced settlement will be highly variable due to the presence of localized saturated zones and varying thickness of non-liquefiable crust over the liquefiable zones within the subgrade deposits. These settlements are not anticipated to negatively impact the integrity of the structure; however, due to the high variability in the onsite materials differential settlement could result in settlement of the roadway and impact where it is passable following an earthquake even for a relatively moderate event. It should be noted that this condition is also the current condition of the road at this time and the proposed improvements are likely to decrease the potential for liquefaction settlement.

5.1.6 Slope Instability Due to Liquefaction

Where liquefiable materials are encountered in and around sloping areas, there is potential for slope instability to occur as the soils lose their shear strength. Liquefaction-induced slope failures can either occur as a lateral spreading event or as a flow failure. Liquefaction-induced lateral spreading occurs as the shear strength of liquefiable soils decrease during seismic shaking but do not decrease to the point that a complete flow failure would occur. Lateral spreading occurs cyclically when the horizontal ground accelerations combine with gravity to create driving forces which temporarily exceed the available strength of the soil mass. The result of a lateral spreading failure is horizontal movement of the liquefied soils and any overlying crust of non-liquefied soils. Displacements associated with lateral spreading are generally difficult to quantify, but may be on the order of several feet. The actual magnitude of displacement depends on the site geometry, soil characteristics and earthquake loading.

In contrast to lateral spreading, liquefaction-induced flow failures result when the residual strength of the liquefied mass is not sufficient to withstand the static stresses that existed before the earthquake. Upon initiation of liquefaction-induced flow failure, the liquefied soil behaves like a debris flow, characterized by very large displacements. Flow failures involve horizontal and vertical movements of the liquefied soils and any overlying crust of non-liquefied soils. The chaotic nature of flow failures is such that estimation of the magnitude of displacement is not reasonable.

Between STA 2+40 and STA 4+00, potentially liquefiable materials are present within the slope that will be graded as part of the Phase 1 improvements and where the retaining walls will be installed for Phase 2. To determine if liquefaction could result in slope instability, we evaluated the post-liquefaction slope stability in this area, as described in Section 5.2. This evaluation indicates that the slope stability following a seismic event could result in localized slope instability for this section of the streambank. Recommendations for mitigation methods for the post-liquefaction slope stability and necessary additional analyses are provided in Section 6.7.

5.2 Slope Stability Analyses

Due to slope regrading within the Very High Risk landslide hazard areas, we have evaluated the slope stability for the surrounding slopes. Detailed analyses of the steep slopes within Shoreview Park and at the north end of the lake were not performed as limited grading is proposed in these areas and improvements are anticipated to improve slope stability, as described in Section 6.10. Grading will be significant where the dam will be removed, and we have performed preliminary slope stability evaluations of the proposed improvements in this area to provide proof of concept for the proposed slopes.

The preliminary analyses were performed between STA 2+35 and 4+00 and consisted of evaluating generalized slope configurations that represent the site conditions for the proposed embankment slopes and interim block wall for Phase 1 of the project. Slope stability was performed using limit-equilibrium methods utilizing the computer program SLIDE 5.0 (Rocscience, 2010). Limit equilibrium methods consider force (or moment) equilibrium along potential failure surfaces. Results are provided in terms of a factor of safety, which is computed as the ratio of the summation of the resisting forces to the summation of the driving forces. Where the factor of safety is less than 1.0, instability is predicted.

Results of the analyses indicate that where slopes are cut into the existing glaciolacustrine, the slopes will meet the requirements for slope stability for the static, seismic, and post-liquefaction cases. We anticipate that this zone will extend along the east side of the channel from the existing culvert headwall (STA 2+35) to near the crest of the dam (STA 3+00), and for a short distance along the west side of the channel north of the headwall (including a portion the proposed interim wall).

Where slopes are cut into existing alluvium, as is the case for most of the western bank and the portion of the eastern bank north of approximate STA 3+00 (near the crest of the dam), we anticipate that slopes will meet the requirements for static slope stability, but could experience some slumping for both the pseudo-static case and the post-liquefaction case. Along the east side, this is not anticipated to extend beyond the graded slope given the dense soils that compose the adjacent steep slope area; however, there is potential for the slumping to extend beyond the slope into the adjacent property and Innis Arden Way along the west side of the channel. Recommendations for anticipated mitigation measures and additional analyses to design for these impacts are discussed in further detail in Section 6.7.

6 CONCLUSIONS AND RECOMMENDATIONS FOR DAM REMOVAL AND CHANNEL RESTORATION

6.1 GENERAL

The soil conditions and site topography are such that design and construction of the proposed dam removal and channel restoration improvements are feasible. However, several geotechnical constraints will need to be addressed during design.

The proposed slopes along the channel can be graded at 2H:1V and should be protected from scour with riprap armoring and bioengineered slopes. Additional scour protection can be provided with log revetment structures. The berm to be constructed along the west side of the channel is likely to experience seepage of water toward the basin to the west and should be constructed with a core of impermeable material and a keyway at the base. Details regarding berm construction and methods to provide resistance to seepage will be provided in future reports.

Logs used for habitat structures and log revetments will need to be embedded in the stream channel. Excavations of up to 8 feet deep will be needed. The Contractor should be responsible to select means and methods of excavation and backfill for log burial; however, the amount of dewatering and the quantity of soils suitable for reuse will vary depending on the selected means and methods. Existing alluvium soils may be suitable for reuse where they are placed in dry excavations with moisture contents near the optimum needed for compaction. Dewatering could require deep wells to limit caving and heave for excavations that are a significant depth below the static ground water levels.

There is potential for liquefaction to induce some lateral spread or flow liquefaction failures along the western slope of the project from STA 2+40 to 4+00. To minimize this potential, the installation of crushed rock liquefaction cutoff trench could be installed along the west side of the stream channel. HWA can provide details regarding the design and installation for this element as design progresses.

The interim wall north of the culverts can be constructed as an Ultra-Block wall, although this will require removal of some additional trees. Temporary excavations for wall installation may require shoring, depending on the soil and ground water conditions encountered during excavation.

For trail restoration, the soils encountered on the slopes are suitable to reconstruct 6-foot trails and overlapping timber stairs. Turnpike construction will be suitable for trails on level ground at the base of the slope and boardwalks supported on Diamond Pier® pile foundations. Details regarding pile capacities for the pile foundations will be provided in future reports.

6.2 Dam Removal and Channel Grading

Dam removal will require excavation of the existing materials and structures that form the dam including the riprap/quarry spall material, gabion baskets, the concrete control structure and the existing pipes. Once the dam is removed, the side slopes on both the east and west sides will need to be regraded. We recommend grading permanent slopes no steeper than 2H:1V (horizontal:vertical). Along the east side of the channel, we recommend that the top of the regraded slope tie into existing grade near the break in slope where the soils transition from colluvial materials to more steeply sloped advance outwash and glaciolacustrine soils. Stream bank stabilization measures should be implemented to reduce scour and undermining of the side slopes, as described below.

6.3 Scour and Erosion Protection

For the portions of the channel slopes that will be below the design ordinary high water level for the stream, we recommend armoring the slopes by installing a layer of riprap to limit the potential for sloughing and erosion of the streambank. The layer of riprap should have a minimum thickness of 3 feet and be sized to resist scour for the anticipated stream velocities. A minimum 1-foot thick layer of Permeable Ballast, meeting the requirements of Section 9-03.9(2) of the 2018 WSDOT *Standard Specifications* should be placed behind the riprap. To reduce erosion and potential for piping of fine soils through the riprap and permeable ballast, we recommend placing a geotextile at the interface between the permeable ballast and the native materials.

Additionally, consideration should be given to prevent concentrated flows of surface water from flowing directly down permanent side slopes. Diversion berms or cutoff trenches, at the top of slopes, should be considered where this potential exists. If down slope surface water conveyance is required, it should be completed within tight lines from the top of the slope to an appropriate armored discharge point away from the toe of the slope. Where this is not possible, slope armoring/vegetation, as described in this section, should be considered to prevent future slope erosion.

6.4 Channel Revetment

From STA 8+70 to 9+50, the existing channel flows along the toe of the existing slope and is within both the Very High Risk landslide hazard area and its buffer located at the north end of the site. The project proposes to use the existing Boeing Creek channel north of STA 9+00 and begin channel grading to restore the stream south of this point. At this location the stream currently backwaters into the lake. Once the stream is restored, the backwater effect will no longer occur, and the velocity of the stream is anticipated to increase. To protect the bank from erosion, the design team proposes to install a log revetment integrated with riprap armoring along the west bank of the channel. The log revetment will help slow the velocity of the stream along the outside edge of the bank, allowing additional sediment to collect and for vegetation to develop. Considerations for log revetment construction are provided in Section 6.5. Riprap armoring, as described in the previous section (Section 6.3), should also be installed below the log revetment so that scour does not undermine and compromise the revetment.

6.5 Installation of Log Revetment and Habitat Structures

Habitat structures and the log revetment will be constructed using large woody debris. Large woody debris consists of tree trunks ranging in diameter from about 12 to 24 inches with overall lengths of about 10 to 35 feet. Large woody debris should be anchored in place, which can be accomplished by excavating the site soils, placing the logs in the excavation, and backfilling around the logs. The proposed excavations will be of the order of 8 feet below the ground surface.

Although Boeing Creek will be diverted, it is anticipated that excavations for large woody debris will extend below the local ground water table during construction and some level of additional water management will be required. The Contractor's methods for installation of the logs will impact the amount of dewatering needed as well as the types of soils that will be suitable to place as backfill. The logs could be installed in wet excavations; however, this will require the use of imported sand and gravel materials for backfill of the excavations, and on-site soils would not be suitable for reuse. If dewatering to lower the ground water table is done, it is likely that more of the on-site materials would be suitable for reuse, provided the soils are adequately dried to allow compaction.

The Contractor should be aware that dewatering using sumps and pumps is likely to be difficult and could create flowing soil conditions in the base of the excavations, due to the seepage forces in the soils. The Contractor should be responsible for designing and installing deeper dewatering wells in these circumstances if they choose more intensive water management methods.

6.6 CHANNEL BERM DESIGN

South of the channel revetment from STA 5+00 to STA 9+00, the proposed stream channel will require construction of a berm to contain the stream within the proposed alignment. The berm will need to be designed to limit seepage through and/or under the embankment toward the lower lying area to the west. The stream side of the berm will be constructed using the riprap scour protection provided in Section 6.3. Outside of the scour protection, the berm should be constructed with a low permeability core to limit seepage of water through the berm. The embankment should also include a keyway at the base of the slope that extends an adequate depth below the berm to limit seepage under the berm. Details for design and installation of the berm and options for providing seepage cutoff will need to be considered for final design. This design will also need to address methods for mitigating piping that could occur within the berm.

On the outside of the berm, it is anticipated that the slope could be inundated with water at some point in the future. The materials for the outside slope should be designed to maintain the 2H:1V slope even when saturated. We therefore recommend providing either riprap armoring similar to the stream side of the berm or constructing a bioengineered slope. A bioengineered slope would consist of a geogrid reinforced and geosynthetic wrapped face slope. Live cuttings would then be installed between the layers or installed into the soil through the geosynthetic facing.

6.7 MITIGATION FOR LIQUEFACTION INDUCED SLOPE INSTABILITY

Regrading of the stream channel between STA 2+40 to 4+00, will cut into material that is expected to liquefy during a moderate to large earthquake and our slope stability evaluations indicate that liquefaction could result in slumping of the slope that could impact Innis Arden Way and the adjacent property west of the existing dam. The design will need to consider methods to enhance the stability of the proposed cut slope. One possible method that has been used in similar situations is to construct a liquefaction cutoff trench. This would consist of installing an 8- to 10-foot trench filled with crushed rock manufactured from 100 percent crushed ledge rock that would extend through the liquefiable soils and key into non-liquefiable soils below. The trench would provide a zone of material with higher strength to help support the slope while the liquefiable soils are at their post-liquefaction residual strength. Design for the trench would need to be undertaken to perform more detailed slope stability analyses to determine the optimal location of the trench, the depths and widths required and to provide recommendations for construction. HWA can provide details regarding the design and installation for this element as design progresses.

6.8 INTERIM BLOCK WALL RECOMMENDATIONS

From the culvert inlet near STA 2+35 to approximate STA 3+75, the channel that will be constructed for the dam removal phase (Phase 1) will be shifted towards the west side of the ravine to limit the required cut into the eastern slope. To meet the grade requirements, this will require a wall along the west side of the restored stream channel from STA 2+35 to 2+70. This wall can be constructed as a gravity block wall consisting of Ultra-Blocks™. The block wall should be embedded at least two feet into the native materials. We recommend that the embankment slopes behind the wall be no greater than 1.5H:1V, which may require some fill placement behind the wall to reduce the angle of the existing slope. Based on our evaluation, we anticipate that the walls will be up to about 12½feet tall with blocks as the base of the wall extending approximately 7½feet behind the wall face. Once the wall is constructed, the slope should be reconstructed by backfilling with properly compacted Crushed Surfacing Base Course (CSBC) per Section 9-03.9(3) of the 2018 WSDOT *Standard Specifications*.

To provide room to construct the proposed wall, the trees within 15 feet of the base of the slope would need to be removed. Alternatively, a soldier pile and lagging wall could be installed to provide support of the soil without extensive excavations that undermine the trees. If this option is selected, HWA can provide details regarding wall design in final design.

6.9 TEMPORARY EXCAVATIONS FOR BLOCK WALL INSTALLATION

The proposed block wall will require temporary excavations for installation of the blocks, which will be made into a combination of fill, alluvium, and glaciolacustrine soils. The area available behind the walls for sloped excavations is limited and we expect that excavation work will be greatest near the headwall of the existing culverts, where it ties into the existing slope. Even with removal of the adjacent trees, steeply sloped temporary cuts into the slope are expected in this area. We recommend that a geotechnical engineer be on site full time during excavation and construction of the wall to evaluate the cut stability and make in the field recommendations to protect worker safety. In addition, excavation and wall construction should be performed during the dry season and should be accomplished in short sections, with no more than about 20 feet of unsupported excavation open at one time.

If shoring is needed, we anticipate that shoring would consist of soldier piles installed in drilled shaft excavations with wood or steel sheets for lagging. Piles should not be driven, as vibrations from pile driving could initiate sloughing of the adjacent slopes. The contractor should be responsible for the design, installation, maintenance, and removal of temporary shoring.

6.10 TRAIL RESTORATION

The proposed trail improvements will restore a short section of the trail on the slope within Shoreview Park and construct a new trail within the level area at the base of the slope.

6.10.1 Trail Restoration on the Slope

Trail restoration will be limited to an approximately 120-foot long section within the Landslide Hazard Area #2 (see Section 4.2.3). Restoration will generally consist of minor regrading to remove soils that have been loosened and/or sloughed into the trail prism and backfilling the tread with suitable material to provide an even trail surface about 5 feet wide with 6-inch shoulders on each side. Restoration of the trail on the slope should follow recommendations from the United States Department Agriculture (USDA) Forest Service provided in detail Drawing No. STD_911-30-01 of the *Standard Trail Plans,* available on the US Forest Service website (accessed November 14, 2019). A portion of this section will also include installation of overlapping timber steps that are anchored to the ground using steel rebar provided in detail Drawing No. STD_936-20-02, as shown on Sheet C-7.4 of the 60-percent Plans (see the Herrera Critical Areas and Mitigation Report). We conclude that the weathered outwash underlying the site in this area is suitable to support the construction of the proposed improvements. Regarding slope stability, the proposed trail improvements on the slope are surficial and do not significantly impact the slope, and in the case of the timber step provide added stability to the slope at that location.

6.10.2 Trail Construction for Boardwalk Supported Section

In the flat area at the base of the slope, the proposed trail will be supported on turnpikes and on a pile supported boardwalk where it crosses through the wetland. Where the boardwalk is installed, it will be supported using the Diamond Pier® foundation system. Diamond Pier® consists of a concrete pier supported on pin-piles that are installed through holes cast in each concrete pier. Four piles are installed for each pier. The piles are driven at a 45-degree batter and are splayed out from the center at 90 degrees to each other.

The Diamond Pier® manufacturer guidelines provide site conditions for which presumptive bearing capacity values can be assumed; however, these values are provided for soils that are not saturated. Given that the boardwalk will traverse a wetland, we assume that the soils will be saturated, which will reduce the bearing capacities that can be achieved for each pile. At this time, we do not have soil type and density data that would indicate the anticipated bearing capacity that could be reached for pile support. Review of design loads and conducting additional handhole explorations to determine the density of the soils at this location are recommended for final design.

7 CONCLUSIONS AND RECOMMENDATIONS FOR CULVERT REPLACEMENT

7.1 GENERAL

For culvert replacement, two culvert construction alternatives have been considered. One option would consist of installation of temporary shoring that would subsequently be incorporated into the final structure. The second option would utilize temporary shoring, but the culvert would be a pre-fabricated structure that would not rely on the temporary shoring for structural support. The soil conditions and site topography are such that both options are feasible, though several geotechnical constraints will need to be addressed during design.

The temporary excavation will extend 30 to 35 feet below the current roadway surface on Innis Arden Way. The excavation can be accomplished using a combination of sloping and shoring. To maintain stability of the slope to the west and limit the extents of the excavation, temporary shoring should be installed below Elev. 190 feet. The Contractor should be prepared to remove large riprap on the slope south of Innis Arden Way within the proposed culvert location. Shoring will likely consist of drilled soldier piles and lagging. Design of the temporary shoring will vary depending on the final structure type. If the culvert will be constructed by using the temporary shoring to install cast-in-place walls, the shoring should be designed to accommodate the permanent lateral and vertical loads that will be imposed on the structure. If the temporary shoring will not be integrated into the final structure, it can be design for the lateral pressures anticipated to occur during construction.

Permanent loads on the culvert will consist of lateral loads due to lateral earth pressures as well as the weight of the fill placed over the lid of the culvert. The depth of cover over the culvert will be of the order of 16 feet thick and vertical loads on the foundations will be significant. Vertical loads on soldier piles for the permanent structure will be close to loads associated with drilled shafts for bridge structure and the depths required to achieve adequate bearing capacity are likely significant. If a prefabricated structure is used, the foundation can consist of spread footings supported on the hard glaciolacustrine soils observed in our borings. The vertical loads could be decreased by placing lightweight fill over the culvert. If this option is selected, we recommend using lightweight cellular concrete as lightweight fill.

Excavation to facilitate the proposed depth of the channel, following culvert replacement, will require the use of retaining walls upstream and downstream of the new culvert. These walls will consist of soldier pile and lagging walls to limit the extents of cuts required for wall installation.

During construction, the Contractor will need to protect the existing 8-inch diameter sewer line within NW Innis Arden Way. Control of seepage will be required and will likely consist of intercepting the ground water outside the shoring, and/or using sumps and pumps to collect and pump ground water that collects in the base of the excavation. To protect the subgrade at the base of the excavation, a 12-inch thick layer of CSBC should be placed. Granular soils excavated for the culvert can be reused provided they are near their optimum moisture during placement.

7.2 CULVERT WITH PERMANENT SOLDIER PILES

7.2.1 Design using Soldier Piles to Form Permanent Culvert Walls

This option would integrate the soldier piles used for temporary shoring into the final culvert structure. Design of the soldier piles for this option requires that the piles be designed to resist both temporary and permanent lateral earth pressures, as well as the vertical loads imposed on the structure by the weight of the soil that will be placed over the culvert. For this design, the top of the culvert would consist of a reinforced cast-in-place concrete lid that spans over the soldier piles. Recommendations for lateral and vertical loading on culvert walls are provided below.

7.2.2 Lateral Earth Pressures for Culvert Walls

Permanent wall design will need to consider the lateral loads imposed on the sides of the culvert by the surrounding soils for static, seismic and post-liquefaction conditions. For static design, the walls will be braced at the top by the concrete lid, such that at-rest earth pressures will develop on the outside of the piles. For pseudo-static seismic design, we assume that there will be sufficient yielding between the soil and the culvert walls to allow an active condition to develop. Due to the potential for liquefaction of loose fill and alluvium below the top of the culvert, we anticipate that increased lateral loads will be placed on the sides of the culvert by liquefied soils once shaking has stopped. Although we have assumed that adequate drainage will be provided behind the walls and that hydrostatic pressures will not develop behind the walls for static and pseudo-static design, saturated soils around the culvert could still experience liquefaction such that increased lateral pressures do occur.

The earth pressures acting on the culvert walls will be resisted by concrete lid at the top of the culvert and passive earth pressures of the soils below the final ground surface on the inside of the culvert. For long-term design, the soils that could experience scour should not be included in the calculations to provide resistance to the lateral loads. Based on discussions with the design team, we assume that the depth of scour will be approximately 3 feet below the final design ground surface inside the culvert. Assumptions for ground water depths, surcharge loads from traffic loads, and widths of application of lateral loads, and appropriate resistance factors are summarized in our lateral earth pressure diagrams, which are provided on Figures 4 through 6. The loading provided is consisted with Load and Resistance Factor Design (LRFD) methods and includes static loading for Strength and Service Limit States. There are two separate Extreme Limit States including one for the pseudo-static case when seismic loads are applied to the structure during shaking and one for the post-liquefaction case, which occurs after shaking has stopped and liquefied materials have reached their residual strengths.

7.2.3 Vertical Loads on Culvert Soldier Piles

Considerable vertical loads will be imposed on the culvert due to the 24-foot wide span and 16 feet of soil cover. For the culvert design that integrates the soldier piles into the structure, these vertical loads will be transferred from the concrete lid to the soldier piles. Given the magnitude of the loading, the soldier piles will need to be designed for vertical loads that are typical of small bridge piers. Recommended vertical capacity curves for use with LRFD methods are provided on Figure 7. These curves indicate that the shafts will likely need to extend beyond the base of the existing glaciolacustrine into granular Pre-Frasier soils below. Construction of the piles will likely require the use of temporary casing and/or drilling fluid to maintain stability of granular materials within the shafts. Details for soldier pile construction are provided in Section 7.2.6.

7.2.4 Reduction of Load on Culvert with Lightweight Fill

Vertical loads acting on the culvert and the supporting piles could be reduced by substituting lightweight cellular concrete in place of conventional soil backfill. Lightweight cellular concrete is a proprietary product that can be manufactured onsite with unit weights from ranging from 30 to 120 pounds per cubic foot (pcf). It is relatively strong, low-density, and can have a bearing capacity higher than compacted fill. Cellular concrete is produced by adding a pre-formed foam to a slurry of Portland cement, fly ash, water, and occasionally aggregates. The resulting mixture is highly flowable and pumpable as well as self-leveling and will harden between 2 to 6 hours after production depending on the mix design and admixture. Cellular concrete is also known by other names including foam cement, foamed concrete, or lightweight flowable fill. The cost of cellular concrete is dependent on-site access conditions, volume of placement and desired unit weight. Based on our previous experience, for high volume lightweight applications, cellular concrete have previously ranged from $50 to $80 per cubic yard. If the use of cellular concrete is determined to be desirable, HWA can assist with defining the extents of the fill, as well as considerations related to buoyancy, and recommendations to provide drainage around the materials.

7.2.5 Considerations for Permanent Soldier Piles as Temporary Shoring

Soldier piles used for both temporary shoring and the permanent structure should also be designed to resist lateral soil loads during excavation and support of construction loading. This will include supporting the excavation while soils are excavated to 3 feet below the final stream channel elevation. The project design should allow the Contractor to select how they will utilize the soldier piles as shoring.

Two main options were considered, one where the soldier piles support the excavation as cantilever walls, and another where internal bracing is incorporated into the shoring design. Temporary shoring diagrams for use in shoring design are presented in Appendix F.

Cantilever option: no bracing would be installed, and the wall height for the temporary shoring will be limited by the capacity of the steel sections installed, which would be of the order of 12 to 15 feet above the bottom of the stream channel excavation. This option requires excavating temporary slopes within the existing roadway embankment to limit the height of the shoring. The advantage of using cantilever shoring is that there would be no bracing to interfere with access within the excavation; however, the greater extents of the excavation slopes would reduce the work area outside the excavation limits and complicate utility protection.

Internally braced option: may be preferred to limit the sizes of the steel sections needed for the culvert soldier piles, or if the Contractor would prefer to reduce the extents of the temporary slopes needed for construction.

7.2.6 Soldier Pile Construction Considerations

Soldier piles for culvert replacement will be drilled through loose to medium dense fill, loose colluvium and alluvium, very stiff to hard glaciolacustrine, and will likely terminate in dense to very dense Pre-Frasier coarse-grained deposits. Where loose soils are encountered, temporary casing will likely be necessary to limit the caving and reduce ground water seepage into the shafts. Moreover, the contractor should be prepared to flood the casing with water or suitable drilling fluid, should it become apparent that water infiltration into the casing will result in potential disturbance to the soils that can impact their ability to provide lateral resistance.

Portions of the excavations will be advanced through hard glaciolacustrine soils and hard drilling conditions should be anticipated. Although not encountered in our borings, large cobbles and boulders are known to exist in these glacial deposits. The shaft contractor should be prepared to handle cobbles and boulders if they are encountered.

Soldier pile shaft bottoms should be cleaned to the extent practical using appropriate methods. If more than 12 inches of water are present in the shaft, concrete should be placed by the tremie method into the shafts. Temporary casing should be withdrawn such that the level of concrete is always maintained above the bottom of the casing and at elevations sufficient to counteract any potential hydrostatic effects associated with ground water conditions that may be present at the location of the work. Once below the water table, the drilling spoils excavated from the shafts will be saturated. These soils will need to be transported to a nearby facility for decanting or be loaded into special sealed dump trucks for transport off site.

7.3 PRE-FABRICATED OPTION

7.3.1 Pre-Fabricated Culvert Assembled and Installed in Shored Excavation

The culvert replacement could also be constructed using a prefabricated culvert, such as pre-cast concrete culvert, or a steel arch culvert. These culvert types would not incorporate the temporary shoring as a part of the structure. These culverts would be designed to resist the same lateral loads as those provided for the permanent soldier piles, as provided on Figures 4 through 6; however, the large vertical loads from the thick soil cover would be transferred to the underlying soils using spread or mat foundations.

7.3.2 Bearing Capacity and Embedment Depth

The footings for the proposed culvert would bear on the underlying glaciolacustrine, which is glacially consolidated. The culvert footings could be designed for an allowable bearing capacity of 7,000 pounds per square foot. The proposed culvert footings should be embedded a minimum of two feet below the anticipated depth of scour.

7.3.3 Corrosivity Considerations for Steel Arch Culverts

The design team is evaluating the suitability of using a steel arch culvert in place of a pre-cast concrete culvert for a potential cost savings. As part of the evaluation, the corrosivity of the site soils was evaluated using a series of hand borings, designated HH-1 through HH-4, excavated to obtain soils samples for testing of both resistivity and pH of the fill, alluvial, and glaciolacustrine soils. The corrosivity testing indicates the soils at the site range in resistivity from 3,200 to 22,000 ohm-cm and range in pH from 6.5 to 8.7.

The design data provided to us for Contech steel culverts indicates that resistivity should range from 2,000 to 8,000 ohm-cm, while pH should range from 6 to 10. It is not clear the reason to set a maximum resistivity for consideration of corrosion for the culvert. Generally, the higher the resistivity the less corrosive the material is expected to be. Thus, given that the soils tested all have a resistivity of greater than 2,000 ohm-cm, while, in our opinion, indicates the soils at the site would suitable for use of the proposed steel arch culvert. Based on this, it would be worthwhile to discuss with the manufacturer the intent of providing a maximum resistivity for their design if a steel arch culvert is still being considered.

7.4 RETAINING WALLS FOR CULVERT REPLACEMENT

For the culvert replacement phase of the project, the proposed channel will be cut about 6 to 8 feet below the depth of the existing culvert and the channel will be widened to about 24 feet. To meet these grading requirements and maintain stability of the existing slopes at the site, soldier pile wing walls are recommended upstream and downstream of the culvert.

7.4.1 Lateral Earth Pressures for Upstream and Downstream Walls

Design for the walls considers the presence of very loose, silty sand and soft to medium stiff clay to depths of 30 feet, which were observed in boring B-2 (Perrone, 2015) at the west end of the existing dam. The Shannon and Wilson report from 1995 also indicates that the depths to glacially consolidated materials can change significantly over short distances at the site, as illustrated in the S&W geologic profile A-A' along the crest of the dam (provided in Appendix E). To account for this variability, the walls were designed for lower strength materials. Lateral design parameters are provided on Figures 8 through 11 and are consistent with Load and Resistance Factor Design (LRFD) methods. This includes static loading for Strength and Service Limit States, as well as pseudo-static and post-liquefaction loading for the Extreme Limit State.

7.4.2 Drainage for Soldier Pile Walls

Design parameters provided for the wing walls and culvert walls assume that hydrostatic pressure will not buildup behind the walls. Drainage should be incorporated into the design of the cast-in-place fascia and construction methods should be appropriate so that ground water levels remain equal on both the back and front of the walls installed for the project.

7.5 TEMPORARY EXCAVATIONS AND SHORING FOR CULVERT REPLACEMENT

The proposed excavations will extend about 30 feet below the existing ground surface. To limit the extent of the excavation and provide stability for the slide debris observed in our borings, we recommend that shoring be used to support the excavation for the lower 15 feet, at a minimum. The Contractor may choose to extend the shoring higher depending on their preference for constructing the culvert. Depending on the height selected for the top of shoring, the upper portion of the excavation may employ temporary sloping within the roadway embankment soils. Temporary shoring is the responsibility of the contractor and where implemented, should follow the requirements of Part N of Washington Administrative Code (WAC) 296-155, latest revisions, all temporary cuts in excess of 4 feet in height must be either sloped or shored prior to entry by personnel. The fill, colluvium, alluvium, and slide debris soil would classify as Type C soils, per WAC 296-155. Where shoring is not used, temporary cuts in Type C soils should be sloped no steeper than 1.5H:1V. Where seepage is presence flatter slopes may be required.

We provide the following recommendations for temporary shoring for culvert installation that should be incorporated into the project specifications or be provided for the basis of Contractor bidding for the project:

- Maintenance of safe working conditions, including temporary excavation stability, is the responsibility of the contractor. The contractor should be responsible for the design, installation, maintenance, and removal of temporary shoring.

- Prior to commencing construction, the Contractor should provide a submittal detailing a proposed temporary shoring plan to be implemented. We anticipate that shoring would consist of soldier piles installed in drilled shaft excavations with wood or steel sheets for lagging. Piles should not be driven, as vibrations from pile driving are likely to cause slope instability.

- Lagging should be installed promptly after excavation, especially in areas where groundwater is present or where clean sand and gravel soils are present and caving soils conditions are likely. The workmanship associated with lagging installation is important for maintaining the integrity of the excavation.

- The space behind the lagging should be filled with soil as soon as practicable. The voids behind the lagging should be backfilled immediately or within a single shift, depending on the selected method of backfill. Filter and drainage materials will be required to prevent fines migration through the gaps between laggings. Placement of backfill will help reduce the risk of voids developing behind the wall and damage to existing improvements located behind the wall.

7.6 DEWATERING FOR CULVERT CONSTRUCTION

Ground water was generally observed to be perched on top of the glaciolacustrine soils and within the fill soils. This seepage was observed during our explorations in the dry season (July 2017) and thus we anticipate seepage will occur year-round. In addition, we anticipate that ground water levels will likely be higher at wetter times of year. As a result, the seepage within this layer should be accounted for during construction. Methods for controlling seepage will likely differ depending Contractor's selected height for shoring. For open excavations within the saturated alluvium, control of seepage during construction could consist of installing trench drains to cut off the seepage upslope prior to advancing the excavation. If shoring is constructed through the saturated zone, seepage would likely drain through the wood lagging. Sumps and pumps in the bottom of the excavation could then be used to collect seepage that enters the excavation. Seeps within the glaciolacustrine are also anticipated and sumps and pumps may be needed even with other dewatering methods implemented to capture seepage upslope of the excavation.

7.7 Riprap on South Abutment Slope

Construction activities on the southern slope will be impacted by the presence of several feet of riprap, quarry spalls, and large rocks that were placed to form a headwall around the downstream end of the existing culvert. These materials were placed to buttress the existing slope following completion of the original culverts. No record of the depth of the materials has been obtained at this time; however, the Contractor should be prepared to remove the rock materials prior to excavation of the slope and installation of the proposed soldier piles.

7.8 Utility Relocation and Protection

Several utilities are present within the NW Innis Arden Way embankment including water, gas, sewer, and communications. We understand the communications, gas, and water utilities will be rerouted for the duration of the project. However, the sewer line needs to remain in service during the project. At this time, the sewer is anticipated to be converted to a 6-inch PVC force main that will function as a temporary bypass during construction. The Contractor will be responsible for determining the alignment and the method for supporting the pipe across the temporary excavation required for installing the culvert. Once the culvert is installed and backfilled, the temporary PVC sewer line will be replaced with an 8-inch high density polyethene (HDPE) pipe and connected at the new manhole locations.

7.9 Earthwork for Culvert Replacement

7.9.1 Subgrade Preparation and Protection

At the base of all excavations, the final excavation should be made with a smooth-edge (toothless) bucket or a bucket with a plate welded over the teeth to minimize disturbance to the subgrade. The exposed subgrade should be inspected by the Geotechnical Engineer, or their representative, and any loose or unsuitable soils should be over-excavated and replaced with properly compacted structural fill. Where excavation below the foundation elevation is required, the width of the excavation should extend beyond the edge of the footing a distance equal to the depth of the over-excavation required to reach the bearing soils.

Once excavation is completed, the exposed subgrade soils should be protected from softening due to the presence of seepage and tracking of equipment. We recommend placing a minimum 12-inch thick layer of crushed rock at the base of the excavation as a working pad.

7.9.2 Structural Fill and Compaction Below Footings and Behind Walls

Structural fill below footings and behind walls should consist of Crushed Surfacing Base Course (CSBC) meeting the requirements of Section 9-03.9(3) of the WDOT *Standard Specifications* (WSDOT, 2016).

CSBC should be compacted to at least 95 percent maximum dry density, as determined by ASTM D 1557 (Modified Proctor). Achievement of proper density of a compacted fill depends on the size and type of compaction equipment, the number of passes, thickness of the layer being compacted, and soil moisture-density properties. In areas where limited space restricts the use of heavy equipment, smaller equipment can be used, but the fill must be placed in thin enough layers to achieve the required relative compaction.

7.9.3 Roadway Embankment Fill and Compaction

The granular portions of the existing fill and alluvium observed in our borings may be reused as roadway embankment fill; however, these materials contain a significant amount of silt and will be moisture sensitive. Reuse will likely be suitable only if the construction is performed during the dry summer months and the contractor selectively excavates and stores the granular excavation spoils. The hard glaciolacustrine and clayey and silty colluvium and slide deposits are not suitable for reuse.

Where import materials used as fill to backfill the culvert excavation and reestablish the roadway, they should consist of Gravel Borrow, as described in Section 9-03.14(1) or Gravel Backfill for Walls, as described in Section 9-03.12(2) of the *Standard Specifications,* (WSDOT. 2018).

In order to minimize subsequent settlement of the excavation backfill and new pavements, we recommended that backfill soils be placed in loose, lifts no thicker than 8 inches and each lift should be compacted to at least 95 percent of its Modified Proctor maximum density (ASTM D-1557). The procedure to achieve proper density of compacted fill depends on the size and type of compaction equipment, the number of passes, thickness of the layer being compacted, and soil moisture-density properties.

7.9.4 Wet Weather Earthwork

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 in small areas to minimize exposure to wet weather. Excavation of unsuitable and/or softened soil should be followed promptly by placement and compaction of clean structural fill. The size and type of construction equipment used may need to be limited to prevent soil disturbance. Under some circumstances, it may be necessary to excavate soils with a backhoe to minimize subgrade disturbance caused by equipment traffic.

- For wet weather conditions, the allowable fines content of the structural fill should be reduced to no more than 5 percent by weight of the portion of the fill material passing the ¾-inch sieve. The fines should be non-plastic. It should be noted this is an additional restriction on the structural fill materials specified.
- The ground surface within the construction area should be graded to promote surface water run-off and to prevent ponding.
- Within the construction area, the ground surface should be sealed on completion of each shift by a smooth drum vibratory roller, or equivalent, and under no circumstances should soil be left uncompacted and exposed to moisture infiltration.
- Straw wattles and/or geotextile silt fences should be strategically located to control erosion and the movement of soil.

8 CONDITIONS AND LIMITATIONS

We have prepared this report for Herrera Environmental Consultants, Inc. and the City of Shoreline for use in design of portions of this project. This report should be provided in its entirety to prospective contractors for bidding and estimating purposes; however, the conclusions and interpretations presented in this report should not be construed as our warranty of the subsurface conditions. 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 HWA be retained to review the plans and specifications to verify that our recommendations have been interpreted and implemented as intended. Sufficient geotechnical monitoring, testing, and consultation should be provided during construction to confirm the conditions encountered are consistent with those indicated by the explorations, to provide recommendations for design changes should conditions revealed during construction differ from those anticipated, and to verify that the geotechnical aspects of construction comply with the contract plans and specifications.

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 do not direct the contractor's operations, and cannot be responsible for the safety of personnel other than our own on the site. As such, the safety of others is the responsibility of the contractor(s). The contractor(s) should notify the owner if it is considered that any of the recommended actions presented herein are unsafe.

We appreciate the opportunity to provide geotechnical services on this project. Should you have any questions or comments, or if we may be of further service, please do not hesitate to call.

Sincerely,

HWA GEOSCIENCES INC.

JoLyn Gillie, P.E.
Geotechnical Engineer, Principal

Michael Place, P.E.
Senior Geotechnical Engineer

9 LIST OF REFERENCES

American Association of State Highway and Transportation Officials (AASHTO), 2011, *Guide Specifications for LRFD Seismic Bridge Design*, 2nd Edition, Washington D.C.

American Associate of State Highway and Transportation Officials (AASHTO), 2017, *LRFD Bridge Design Specifications*, Eight Edition, Washington D.C.

American Society of Civil Engineers (ASCE), 2010, *Minimum Design Loads for Buildings and Other Structures*, ASCE/SEI Standard 7-10

BridgeLink, 2019, URL: http://www.wsdot.wa.gov/eesc/bridge/software

City of Shoreline, 2019, Property Information, [webtool], URL: https://shoreline.maps.arcgis.com/apps/webappviewer/index.html?id=0d3bff120e054f8b81e0ca8681351d08

Idriss, I.M., and Boulanger, R.W., 2004, *Semi-Empirical Procedures for Evaluating Liquefaction Potential During Earthquakes*, presented at the Joint 11th ISCDEE & 3rd ICEGE, January, 2004.

Idriss, I.M., and Boulanger, R.W., 2006, "Semi-empirical procedures for evaluating liquefaction potential during earthquakes", *Soil Dynamics and Earthquake Engineering*, 11th International Conference on Soil Dynamics and Earthquake Engineering (ICSDEE): Part II, Volume 26, Issues 2–4, February–April 2006, Pages 115–130.

Idriss, I.M. and Boulanger, R.W., 2007, *SPT- and CPT-Based Relationships for the Residual Shear Strength of Liquefied Soils*, Earthquake Geotechnical Engineering, 4th International Conference on Earthquake Geotechnical Engineering, K. D. Pitilakis, ed., Springer, The Netherlands, 1-22.

International Code Council, Inc. (ICC), 2015, *2015 International Building Code (IBC)*, Country Club Hills, IL.

Kramer, S. L., 2008. *Evaluation of Liquefaction Hazards in Washington State, Final Research Report, Agreement T2695, Task 66 Liquefaction Phase III*, Washington State Department of Transportation, Report WA-RD 668.1, 312 pp.

Minard, J.P., 1983, *Geologic Map of the Edmonds East and part of the Edmonds West Quadrangles, Washington:* USGS Miscellaneous Field Studies Map MF-1541.

Olson, S.M. and Stark, T.D., 2002. *Liquefied Strength Ratio from Liquefied Flow Failure Case Histories*, Canadian Geotechnical Journal, Vol. 39, June, PP629-647.3

Perrone Consulting Inc., October 2015, *Hidden Lake Dam Removal*: Project No. 15126 for Herrera Consultants.

Petersen, MD et. al., 2008, Documentation for the 2008 update of the United States national seismic hazard maps, *USGS Open File Report 2008-1128.*

Petersen, M.D., et al., 2014, Documentation for the 2014 update of the United States national seismic hazard maps: *USGS Open-File Report 2014–1091*.

Rocscience Inc., 2018, Slide, Version 8.020, Computer Software.

Seed, H.B. and Idriss, I.M. 1971, "Simplified procedure for evaluating soil liquefaction potential, *Journal of Soil Mechanics and Foundation Division*, ASCE Vol. 97(SM9), 1240-273.

Shannon & Wilson Inc., September 1995, Geotechnical Engineering Report, Hidden Lake Restoration Project, King County, Washington: Project No. W-7022-03 for R.W. Beck

Tokimatsu, K. and Seed, H.B., 1987. "Evaluation of Settlement in Sands Due to Earthquake Shaking." ASCE Journal of Geotechnical Engineering, Vol. 113, No. 8, August 1987Washington State Department of Transportation (WSDOT), 2018, *Standard Specifications for Road, Bridge, and Municipal Construction*, M 41-10.

USGS Earthquake Hazards Program, 2019, Faults - Quaternary Fault and Fold Database of the United States, [webtool], URL: https://earthquake.usgs.gov/hazards/qfaults/

Washington State Department of Transportation (WSDOT), 2019, *Bridge Design Manual,* M 23-50.

Yi, F., and Andrus, D.A., 2010, *Procedure to evaluate liquefaction-induced settlement based on shear wave velocity*, presented at the 9th US National and 10th Canadian Conference on Earthquake Engineering.

Youd, TL, et al., 2001, Liquefaction Resistance of Soils: Summary Report from the 1996 NCEER and NCEER/NSF Workshop on Evaluations of Liquefaction Resistance of Soils. *Journal of Geotechnical and Geoenvironmental Engineering*, ASCE, Vol. 127, No. 10, pp. 817-833.

SITE MAP

0 200' 400' 600' 800'

SCALE: 1" = 400'

N

VICINITY MAP

0 1000' 2000' 3000' 4000'

SCALE: 1" = 2000'

N

HWA GEOSCIENCES INC.	SITE AND VICINITY MAP	FIGURE NO.: 1
	HIDDEN LAKE DAM REMOVAL AND STREAM RESTORATION PROJECT SHORELINE, WASHINGTON	DRAWN BY: BFM CHECK BY: JG
		PROJECT # 2017-096-21

S:\2017 PROJECTS\2017-096-21 HIDDEN LAKE DAM REMOVAL PROJECT\CAD\2017-096-21 HIDDEN LAKE DAM 10.14.2019.DWG <1> Plotted: 11/22/2019 5:18 PM

MATCHLINE 2B

MATCHLINE 2B

HIDDEN LAKE DAM

Scale: 1" = 50'-0"

EXPLORATION LEGEND

- BH-1 — BOREHOLE DESIGNATION AND APPROX. LOCATION FOR CURRENT STUDY
- B-1 — BOREHOLE DESIGNATION AND APPROX. LOCATION (SHANNON & WILSON, INC., 1995)
- HA-1 — HANDHOLE DESIGNATION AND APPROX. LOCATION (SHANNON & WILSON, INC., 1995)
- B-1 — BOREHOLE DESIGNATION AND APPROX. LOCATION (PERRONE, 2015)
- HH-1 — HANDHOLE DESIGNATION AND APPROXIMATE LOCATION FOR CURRENT STUDY

N

0 25 50 75 100

SCALE: 1" = 50'

BASE MAP PROVIDED BY: BING AND SURVEYOR

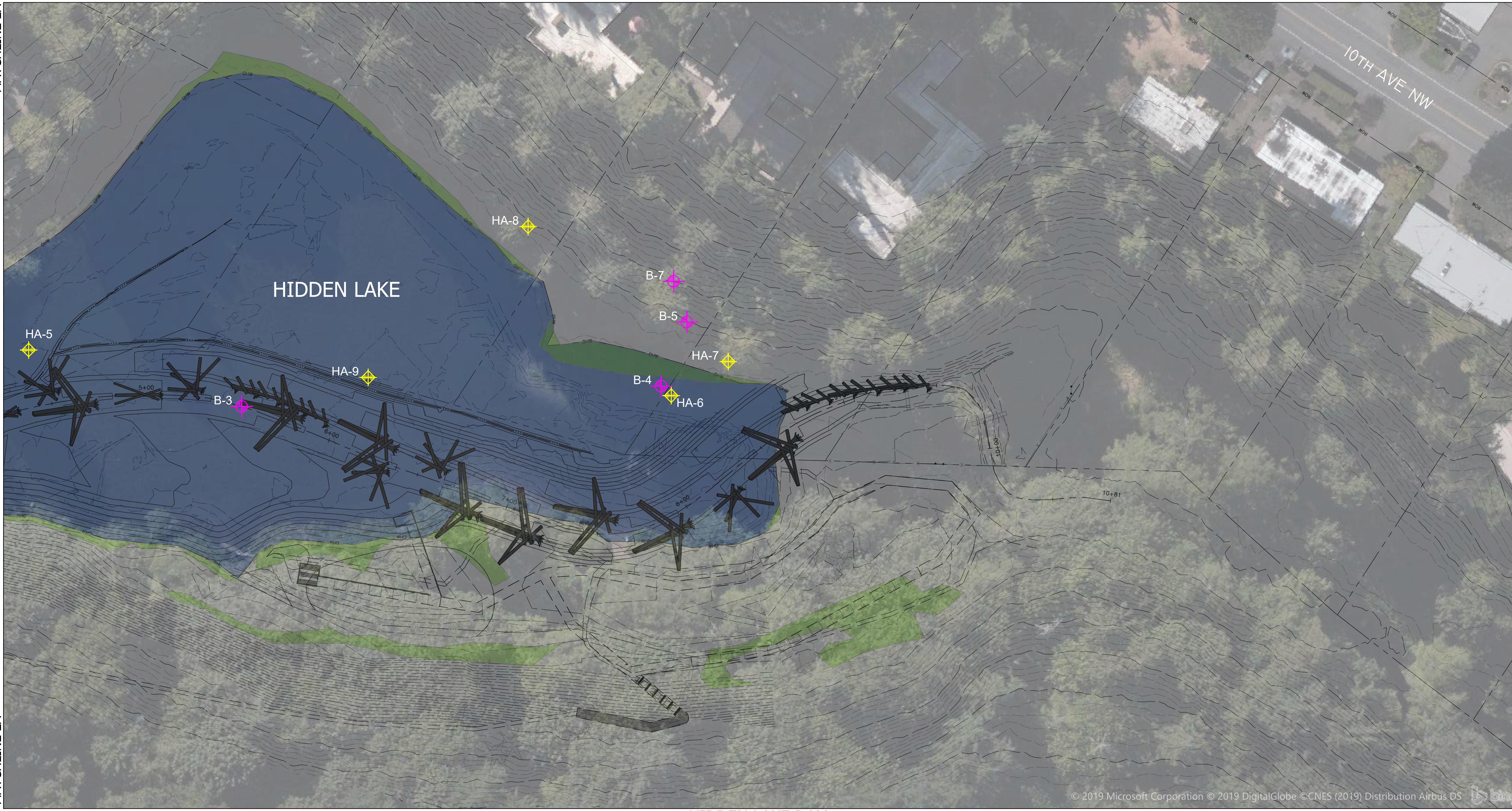
HWA GEOSCIENCES INC.
DBE/MWBE

HIDDEN LAKE DAM REMOVAL AND
STREAM RESTORATION PROJECT
SHORELINE, WASHINGTON

SITE &
EXPLORATION PLAN

DRAWN BY:	FIGURE NO.:
BFM	2A
CHECK BY:	PROJECT NO.:
JG	2017-096-21

S:\2017 PROJECTS\2017-096-21 HIDDEN LAKE DAM REMOVAL PROJECT\CAD\2017-096-21 HIDDEN LAKE DAM 10.14.2019.DWG <2A> Plotted: 11/22/2019 4:39 PM



HIDDEN LAKE DAM
Scale: 1" = 50'-0"

EXPLORATION LEGEND

B-1 BOREHOLE DESIGNATION AND APPROX. LOCATION (SHANNON & WILSON, INC., 1995)

HA-1 HANDHOLE DESIGNATION AND APPROX. LOCATION (SHANNON & WILSON, INC., 1995)

N

0 25 50 75 100
SCALE: 1" = 50'

HWA GEOSCIENCES INC.
DBE/MWBE

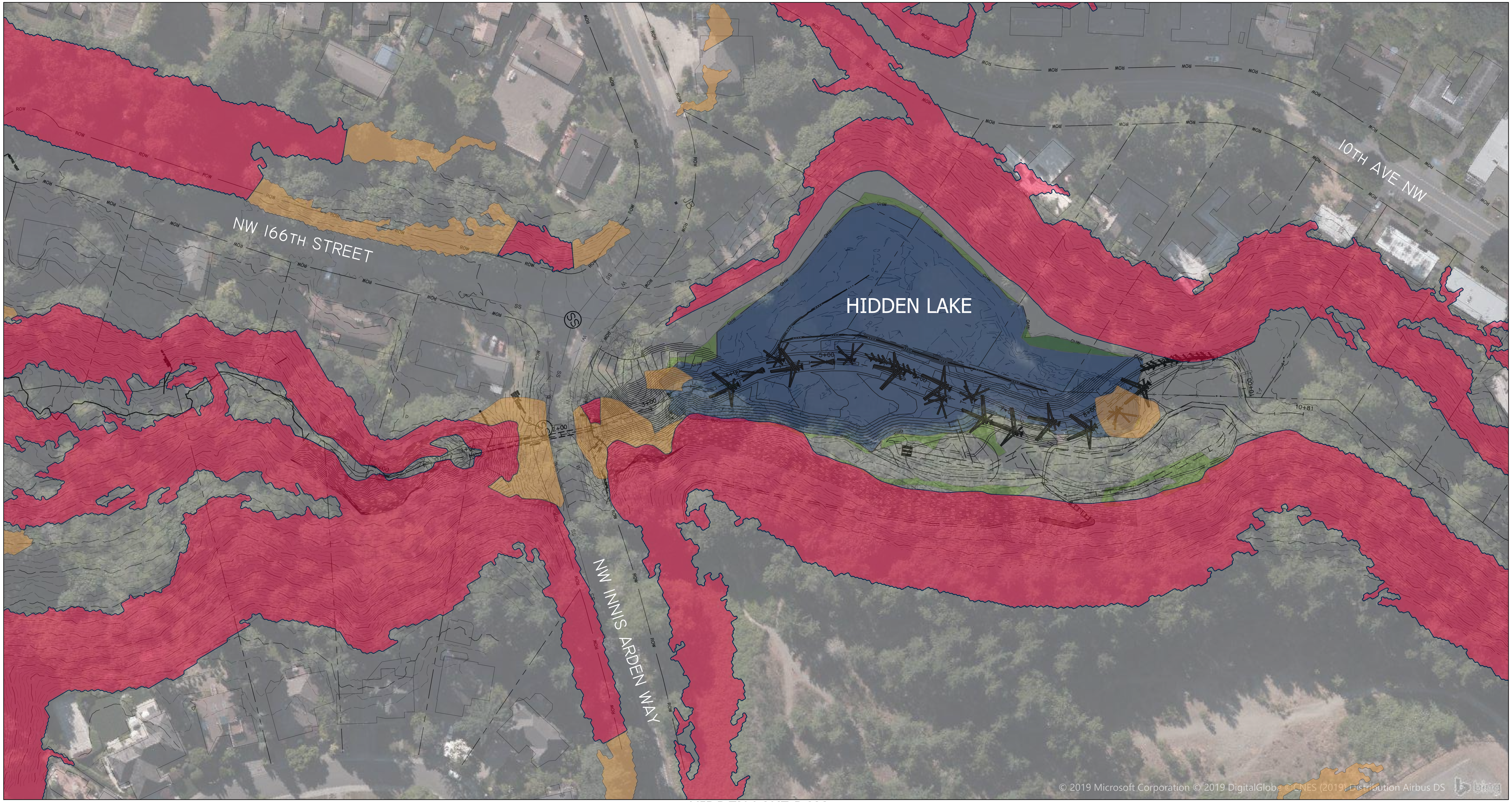
HIDDEN LAKE DAM REMOVAL AND
STREAM RESTORATION PROJECT
SHORELINE, WASHINGTON

SITE &
EXPLORATION PLAN

DRAWN BY:	FIGURE NO.:
BFM	2B
CHECK BY:	PROJECT NO.:
JG	2017-096-21

BASE MAP PROVIDED BY: BING AND SURVEYOR

S:\2017 PROJECTS\2017-096-21 HIDDEN LAKE DAM REMOVAL PROJECT\CAD\2017-096-21 HIDDEN LAKE DAM 10.14.2019.DWG <2B> Plotted: 11/22/2019 4:41 PM



HIDDEN LAKE DAM
Scale: 1" = 100'-0"

LANDSLIDE HAZARD LEGEND

- VERY HIGH RISK AREAS
- MODERATE - HIGH RISK AREAS
- WETLANDS AREAS
- LAKE AREA

0 50 100 150 200
SCALE: 1" = 100'

BASE MAP PROVIDED BY: BING AND SURVEYOR

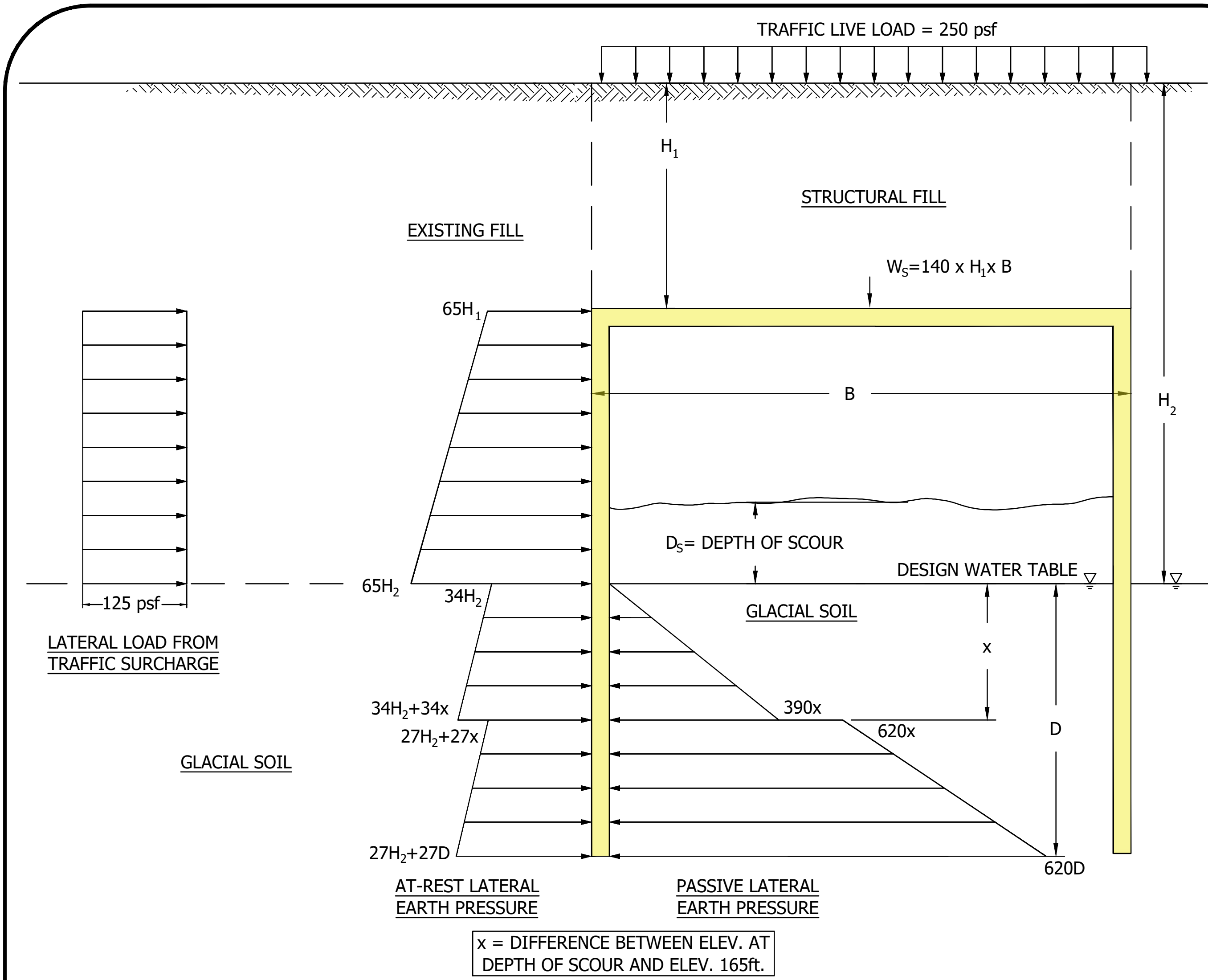
HWA GEOSCIENCES INC.
DBE/MWBE

HIDDEN LAKE DAM REMOVAL AND STREAM RESTORATION PROJECT SHORELINE, WASHINGTON

LANDSLIDE HAZARD AREA DELINEATION

DRAWN BY:	FIGURE NO.:
BFM	3
CHECK BY:	PROJECT NO.:
JG	2017-096-21

S:\2017 PROJECTS\2017-096-21 HIDDEN LAKE DAM REMOVAL PROJECT\CAD\2017-096-21 HIDDEN LAKE DAM 10.14.2019.DWG <3> Plotted: 11/22/2019 4:44 PM

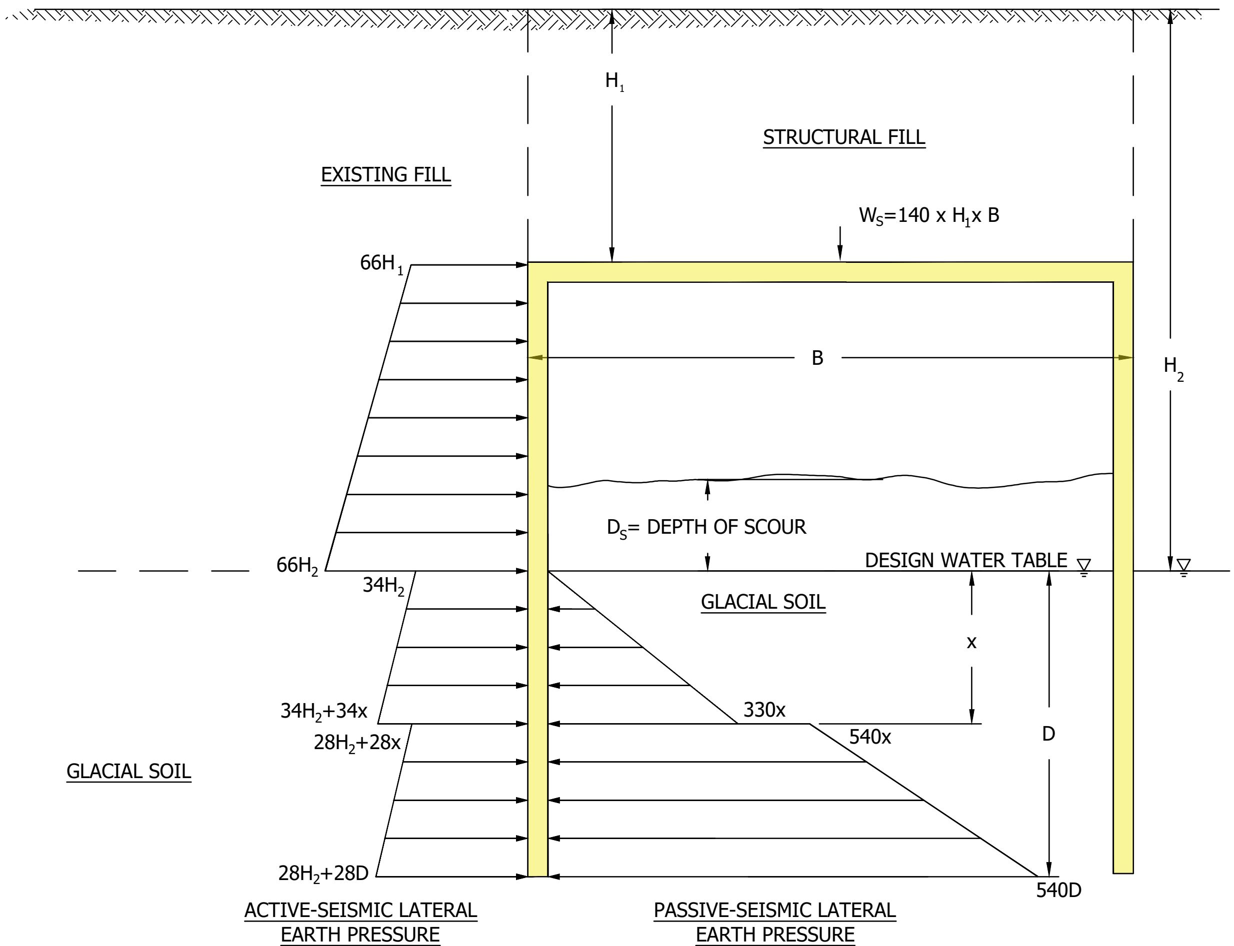


STRENGTH & SERVICE LIMIT STATE (STATIC)

GENERAL NOTES:

1. H IS MEASURED IN FEET, PRESSURES SHOWN ARE IN POUNDS PER SQUARE FOOT (PSF).
2. STATIC CASE ASSUMES AT-REST PRESSURES ACT ON CULVERT.
3. DESIGN ASSUMES THAT GROUND WATER LEVELS WILL BE THE SAME ON THE INSIDE AND THE OUTSIDE OF THE CULVERT.
4. ALL AT-REST EARTH PRESSURES ACTING ABOVE THE BASE OF THE LAGGING SHOULD BE APPLIED ACROSS THE PILE SPACING.
5. ALL AT-REST EARTH PRESSURES ACTING BELOW THE BASE OF THE LAGGING SHOULD BE APPLIED OVER ONE PILE SHAFT DIAMETER.
6. PASSIVE PRESSURES SHOWN ACT OVER 2 TIMES THE PILE DIAMETER AND ASSUME THAT THE MATERIAL ABOVE THE DEPTH OF SCOUR WILL NOT CONTRIBUTE TO PASSIVE RESISTANCE.
7. ALL EARTH PRESSURES PROVIDED ARE ULTIMATE (UNFACTORED), THE APPROPRIATE LOAD AND RESISTANCE FACTORS SHOULD BE APPLIED FOR EACH LIMIT STATE.
8. FOR STRENGTH LIMIT STATE DESIGN, A RESISTANCE FACTOR (Φ) OF 0.75 SHOULD BE APPLIED TO THE PASSIVE EARTH PRESSURES SHOWN.
9. FOR SERVICE LIMIT STATE DESIGN, A RESISTANCE FACTOR (Φ) OF 1.0 SHOULD BE APPLIED TO THE PASSIVE EARTH PRESSURES SHOWN.

	STATIC EARTH PRESSURES FOR PERMANENT CULVERT STRUCTURE	DRAWN BY BFM CHECK BY JG
HWA GEOSCIENCES INC.	HIDDEN LAKE DAM REMOVAL AND STREAM RESTORATION PROJECT SHORELINE, WASHINGTON	FIGURE # 4 PROJECT # 2017-096-21



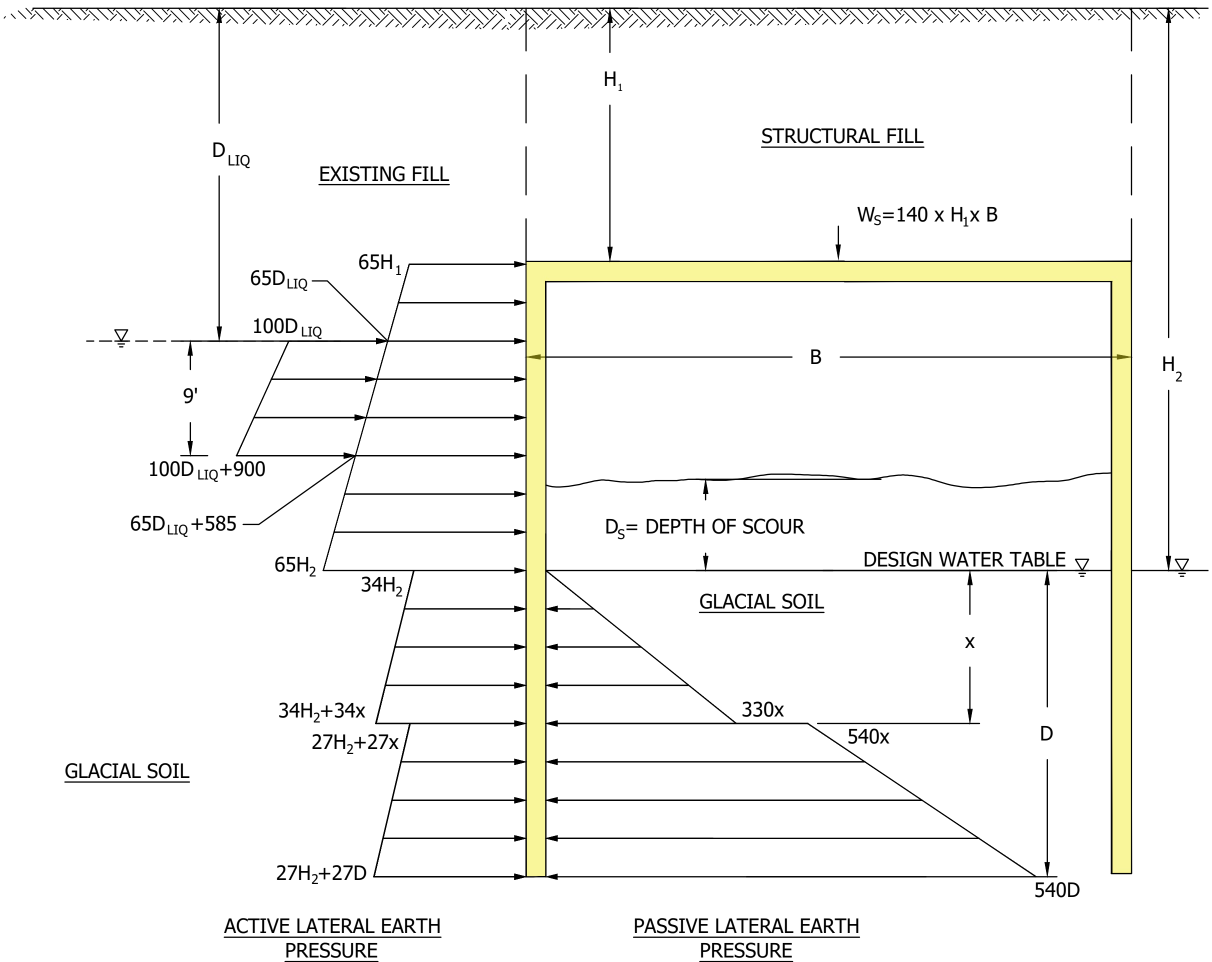
x = DIFFERENCE BETWEEN ELEV. AT DEPTH OF SCOUR AND ELEV. 165ft.

EXTREME LIMIT STATE (SEISMIC)

GENERAL NOTES:

1. H IS MEASURED IN FEET, PRESSURES SHOWN ARE IN POUNDS PER SQUARE FOOT (PSF).
2. SEISMIC CASE ASSUMES ACTIVE-SEISMIC PRESSURES ACT ON CULVERT.
3. DESIGN ASSUMES THAT GROUND WATER LEVELS WILL BE THE SAME ON THE INSIDE AND THE OUTSIDE OF THE CULVERT.
4. ALL ACTIVE-SEISMIC EARTH PRESSURES ACTING ABOVE THE BASE OF THE LAGGING SHOULD BE APPLIED ACROSS THE PILE SPACING.
5. ALL ACTIVE-SEISMIC EARTH PRESSURES ACTING BELOW THE BASE OF THE LAGGING SHOULD BE APPLIED OVER ONE PILE SHAFT DIAMETER.
6. PASSIVE PRESSURES SHOWN ACT OVER 2 TIMES THE PILE DIAMETER AND ASSUME THAT THE MATERIAL ABOVE THE DEPTH OF SCOUR WILL NOT CONTRIBUTE TO PASSIVE RESISTANCE.
7. ALL EARTH PRESSURES PROVIDED ARE ULTIMATE (UNFACTORED), THE APPROPRIATE LOAD AND RESISTANCE FACTORS SHOULD BE APPLIED FOR THE EXTREME LIMIT STATE (SEISMIC).
8. FOR EXTREME LIMIT STATE DESIGN, A RESISTANCE FACTOR (Φ) OF 1.0 SHOULD BE APPLIED TO THE PASSIVE EARTH PRESSURES SHOWN.

	SEISMIC EARTH PRESSURES FOR PERMANENT CULVERT STRUCTURE	DRAWN BY BFM CHECK BY JG
HWA GEOSCIENCES INC.	HIDDEN LAKE DAM REMOVAL AND STREAM RESTORATION PROJECT SHORELINE, WASHINGTON	FIGURE # 5 PROJECT # 2017-096-21



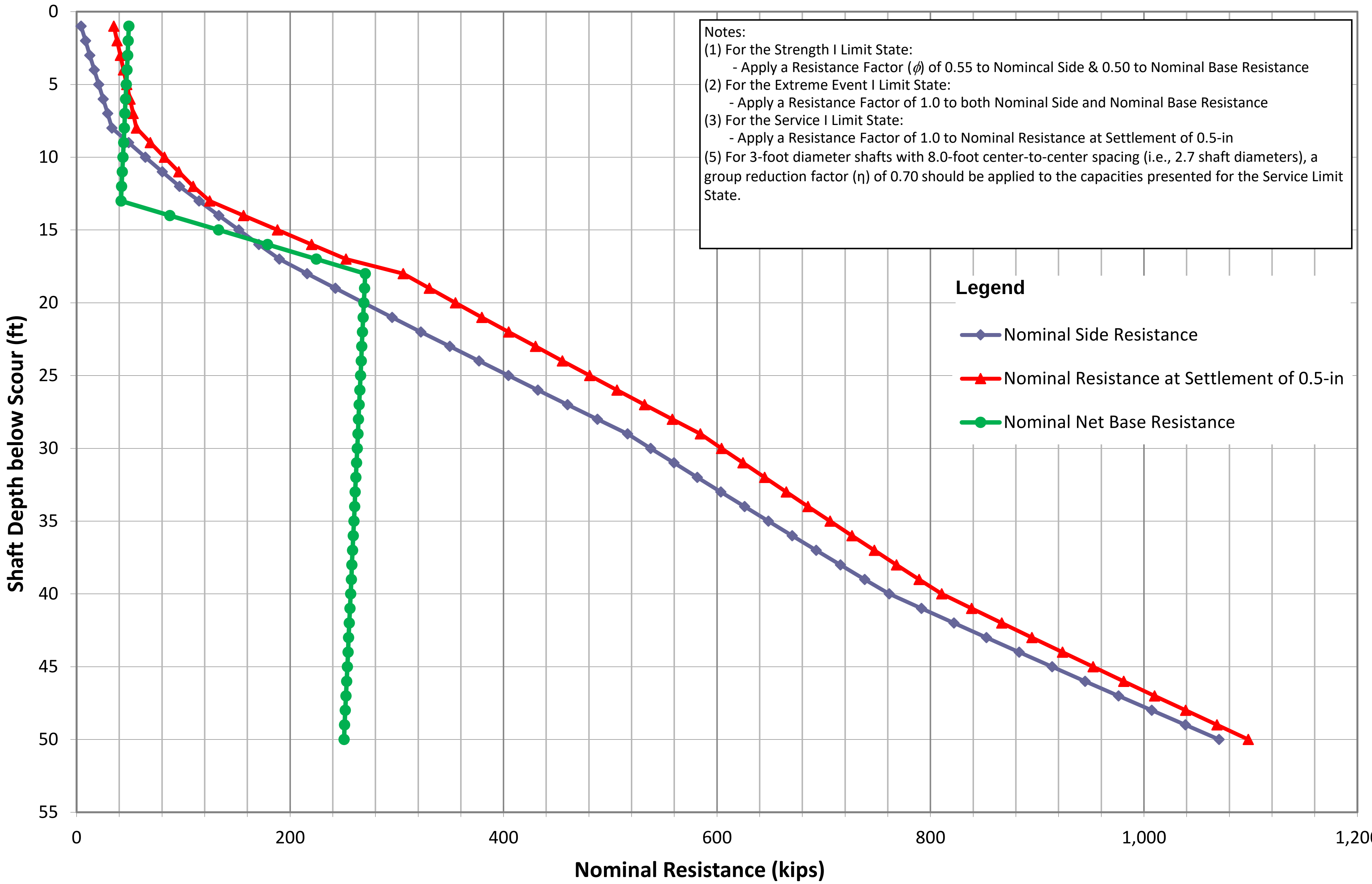
x	= DIFFERENCE BETWEEN ELEV. AT DEPTH OF SCOUR AND ELEV. 165ft.
D_{LIQ}	= DEPTH TO LIQUEFIABLE MATERIAL = DIFFERENCE BETWEEN ELEV. PF TOP OF WALL AND ELEV. OF TOP OF LIQUEFIABLE MATERIAL WHICH IS ELEV. 190ft.

EXTREME LIMIT STATE (POST-LIQUEFACTION)

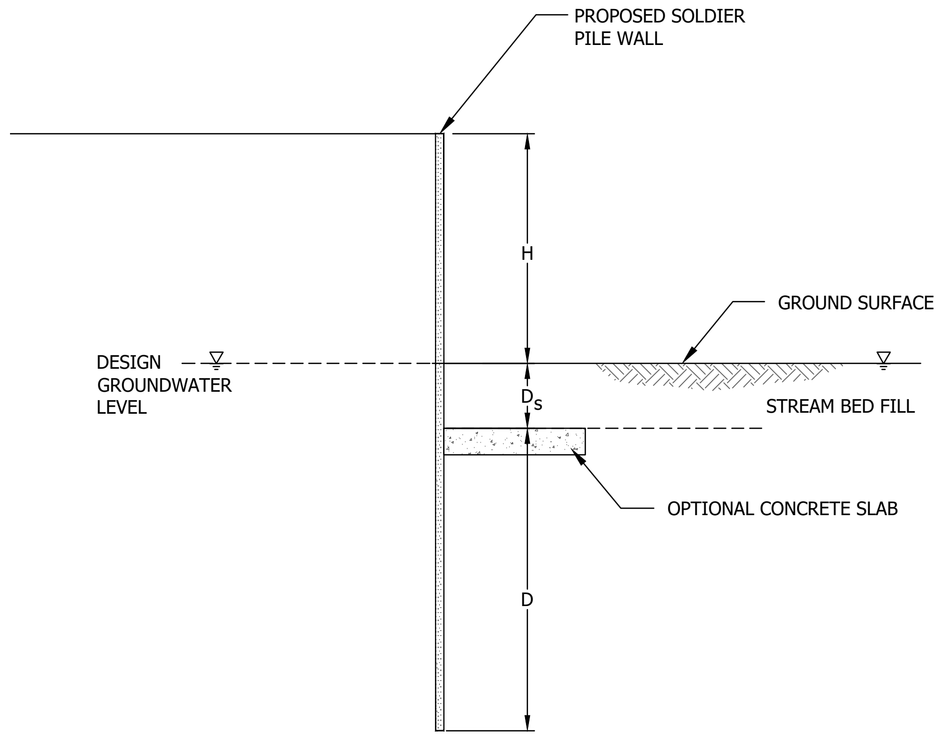
NOTES FOR POST-LIQUEFACTION EXTREME LIMIT STATE DESIGN:

1. ALL THE PRESSURES SHOWN ARE IN THE UNITS OF POUNDS PER SQUARE FOOT (PSF).
2. LATERAL EARTH PRESSURES PROVIDED HEREIN ARE BASED ON AT-REST EARTH PRESSURES.
3. ALL THE EARTH PRESSURES PROVIDED ARE ULTIMATE (UNFACTORED), THE APPROPRIATE LOAD AND RESISTANCE FACTORS SHOULD BE APPLIED FOR EACH LOAD STATE.
4. ALL AT-REST EARTH PRESSURES ACTING ON THE RETAINED PORTION OF THE WALL (ABOVE THE BASE OF THE LAGGING) SHOULD BE APPLIED ACROSS THE PILE SPACING.
5. ALL AT-REST EARTH PRESSURES ACTING BELOW THE RETAINED PORTION OF THE WALL (BELOW THE BASE OF THE LAGGING) SHOULD BE APPLIED OVER ONE PILE SHAFT DIAMETER.
6. DESIGN ASSUMES THAT THE LIQUEFIABLE MATERIALS ARE SATURATED BUT HYDROSTATIC PRESSURE DOES NOT BUILD UP BEHIND THE WALL.
7. ALL PASSIVE EARTH PRESSURES ACTING BELOW THE SCOUR DEPTH SHOULD BE APPLIED OVER TWO PILE SHAFT DIAMETERS.
8. FOR EXTREME LIMIT STATE DESIGN, A RESISTANCE FACTOR (Φ) OF 1.0 SHOULD BE APPLIED TO THE PASSIVE EARTH PRESSURES SHOWN.

HWA GEOSCIENCES INC.	POST-LIQUEFACTION EARTH PRESSURES FOR PERMANENT CULVERT STRUCTURE	DRAWN BY BFM CHECK BY JG
	HIDDEN LAKE DAM REMOVAL AND STREAM RESTORATION PROJECT SHORELINE, WASHINGTON	FIGURE # 6 PROJECT # 2017-096-21



HWA GEOSCIENCES INC.	SOLDIER PILE NOMINAL AXIAL SHAFT CAPACITIES 3-FOOT DIAMETER SHAFT	FIGURE NO. 7
	HIDDEN LAKE DAM REMOVAL AND STREAM RESTORATION PROJECT SHORELINE, WASHINGTON	PROJECT NO. 2017-096-21



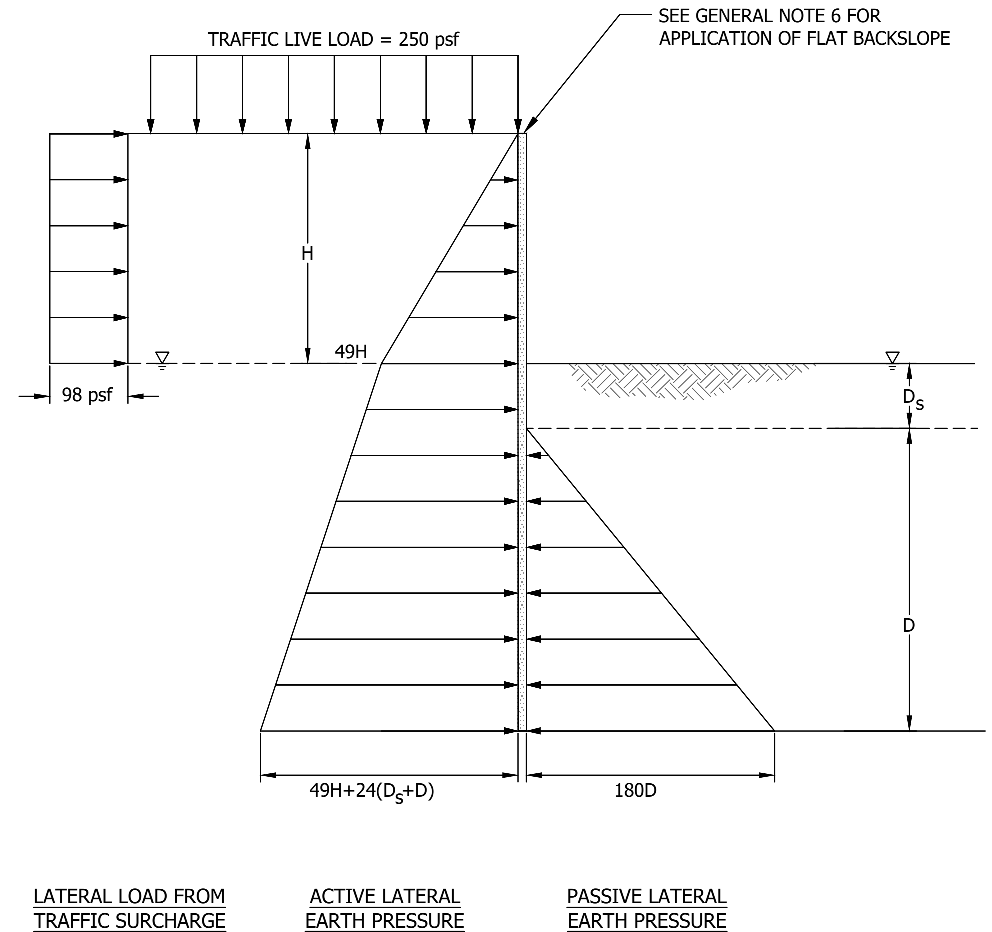
DESIGN SYMBOLS:

H = DESIGN WALL HEIGHT (FT)

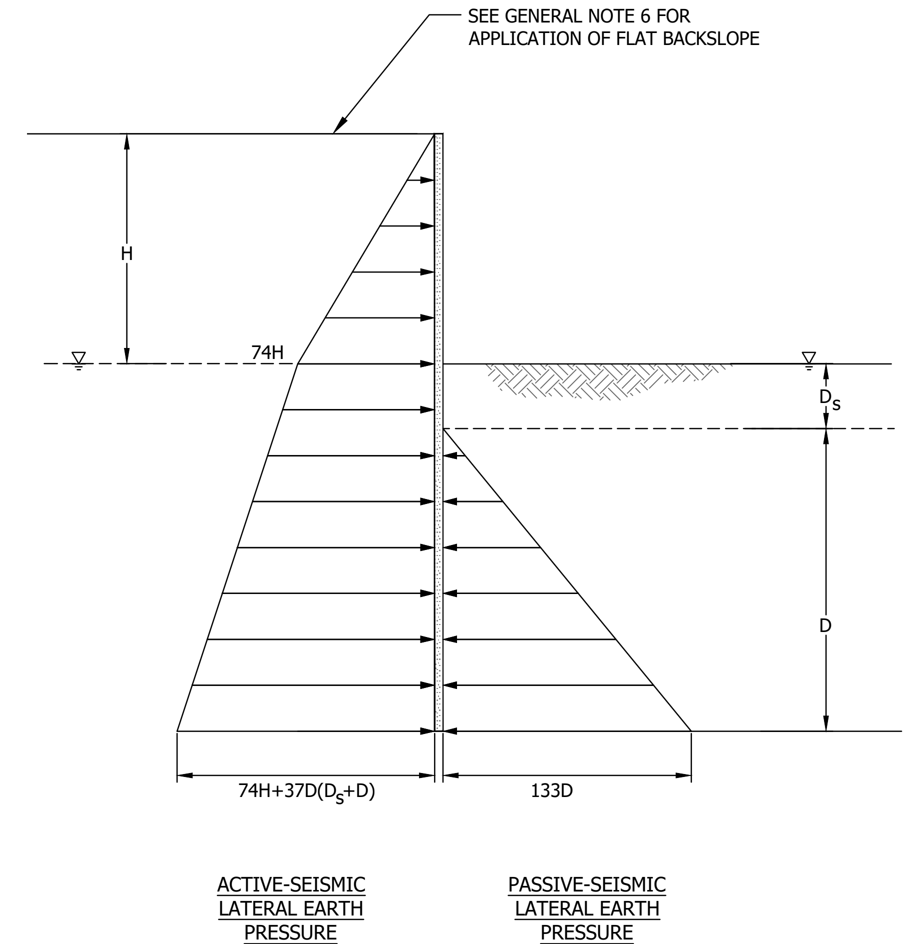
D_S = DEPTH OF SCOUR BELOW DESIGN GROUND SURFACE (FT)

D = EMBEDMENT DEPTH BELOW DEPTH OF SCOUR (FT)

DESIGN PROFILE



STRENGTH & SERVICE LIMIT STATE (STATIC)



EXTREME LIMIT STATE (SEISMIC)

GENERAL NOTES:

1. ALL THE PRESSURES SHOWN ARE IN THE UNITS OF POUNDS PER SQUARE FOOT (PSF).
2. LATERAL EARTH PRESSURES PROVIDED HEREIN ARE BASED ON ACTIVE EARTH PRESSURES AND SHOULD BE USED FOR THE DESIGN OF THE RETAINING WALL WHERE THE WALL IS FREE TO DISPLACE LATERALLY AT LEAST 0.001H, WHERE H IS THE RETAINED HEIGHT OF THE WALL.
3. ALL THE EARTH PRESSURES PROVIDED ARE ULTIMATE (UNFACTORED), THE APPROPRIATE LOAD AND RESISTANCE FACTORS SHOULD BE APPLIED FOR EACH LOAD STATE.
4. ALL ACTIVE EARTH PRESSURES ACTING ON THE RETAINED PORTION OF THE WALL (ABOVE THE BASE OF THE LAGGING) SHOULD BE APPLIED ACROSS THE PILE SPACING.
5. ALL ACTIVE EARTH PRESSURES ACTING BELOW THE RETAINED PORTION OF THE WALL (BELOW THE BASE OF THE LAGGING) SHOULD BE APPLIED OVER ONE PILE SHAFT DIAMETER.
6. DESIGN ASSUMES THAT THE LIQUEFIABLE MATERIALS ARE SATURATED BUT HYDROSTATIC PRESSURE DOES NOT BUILD UP BEHIND THE WALL.
7. THE LEVEL BACKSLOPE SHOULD EXTEND BEHIND THE WALL OVER A DISTANCE OF ⅔ TIMES THE HEIGHT OF THE WALL PLUS THE SCOUR DEPTH (H+D_S).

STRENGTH AND SERVICE STATE DESIGN NOTES:

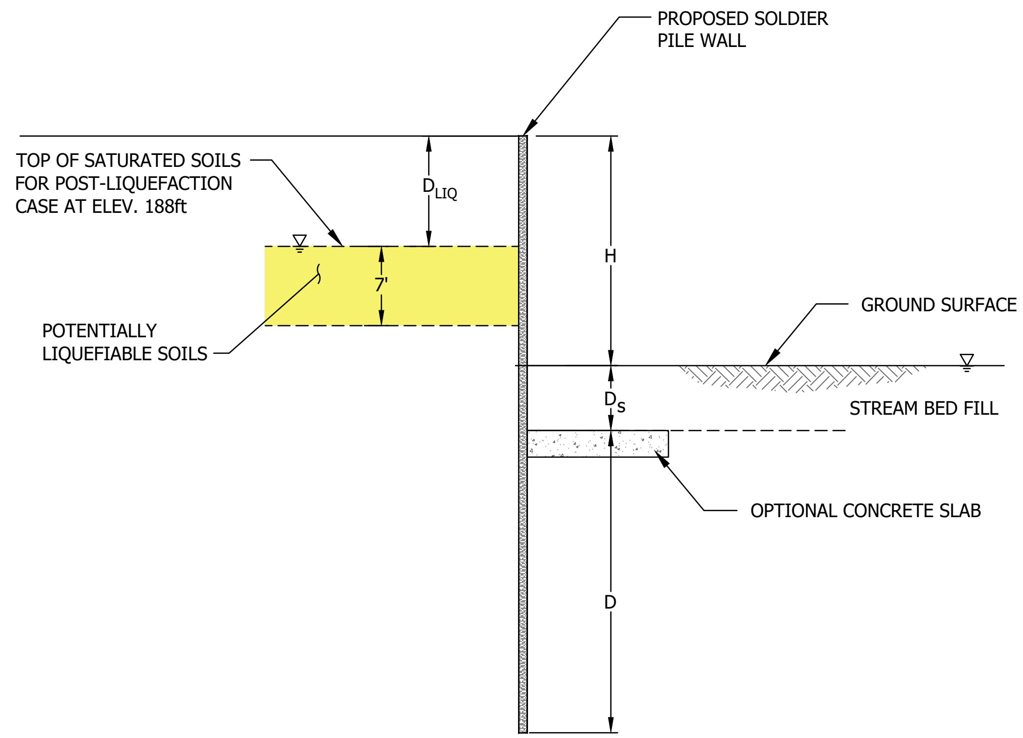
1. ALL PASSIVE EARTH PRESSURES ACTING BELOW THE SCOUR DEPTH SHOULD BE APPLIED OVER TWO PILE SHAFT DIAMETERS
2. FOR STRENGTH LIMIT STATE DESIGN, A RESISTANCE FACTOR (Φ) OF 0.75 SHOULD BE APPLIED TO THE PASSIVE EARTH PRESSURES SHOWN.
3. FOR SERVICE LIMIT STATE DESIGN, A RESISTANCE FACTOR (Φ) OF 1.0 SHOULD BE APPLIED TO THE PASSIVE EARTH PRESSURES SHOWN.

EXTREME LIMIT STATE DESIGN NOTES:

1. ALL PASSIVE EARTH PRESSURES ACTING BELOW THE SCOUR DEPTH SHOULD BE APPLIED OVER TWO PILE SHAFT DIAMETERS.
2. LATERAL EARTH PRESSURES PRESENTED UNDER THE EXTREME LIMIT STATE INCLUDE ACTIVE PLUS SEISMIC ON THE RETAINED SIDE AND PASSIVE PLUS SEISMIC ON THE CUT SIDE OF THE WALL.
3. FOR EXTREME LIMIT STATE DESIGN, A RESISTANCE FACTOR (Φ) OF 1.0 SHOULD BE APPLIED TO THE PASSIVE EARTH PRESSURES SHOWN.

NOT TO SCALE

HWA GEOSCIENCES INC.	HIDDEN LAKE DAM REMOVAL AND STREAM RESTORATION PROJECT SHORELINE, WASHINGTON	LATERAL EARTH PRESSURES FOR PERMANENT SOLDIER PILE WALLS WITH LEVEL BACKSLOPE	DRAWN BY: BFM	FIGURE NO. 8
			CHECK BY: JG	PROJECT NO. 2017-096-21



DESIGN SYMBOLS:

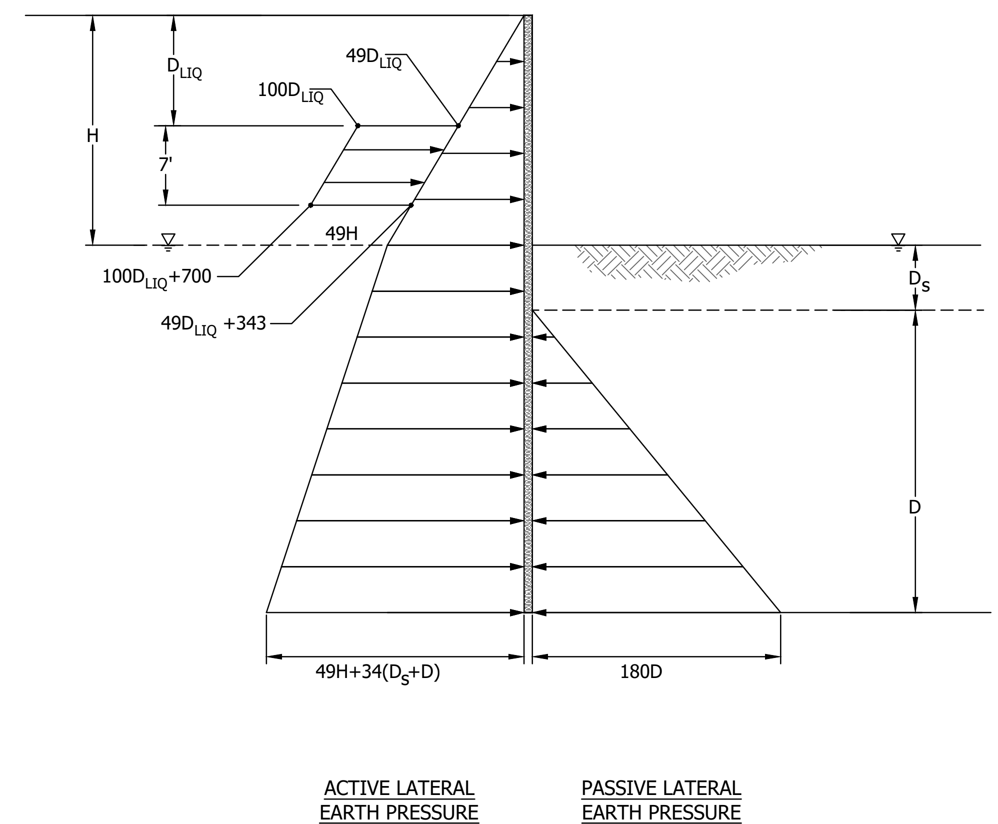
H = DESIGN WALL HEIGHT (FT)

D_S = DEPTH OF SCOUR BELOW DESIGN GROUND SURFACE (FT)

D = EMBEDMENT DEPTH BELOW DEPTH OF SCOUR (FT)

D_{LIQ} = DEPTH TO LIQUEFIABLE MATERIAL = DIFFERENCE BETWEEN ELEV. OF TOP OF WALL AND ELEV. OF TOP OF LIQUEFIABLE MATERIAL WHICH IS ELEV. 188ft.

DESIGN PROFILE



EXTREME LIMIT STATE (POST-LIQUEFACTION)

GENERAL NOTES:

1. ALL THE PRESSURES SHOWN ARE IN THE UNITS OF POUNDS PER SQUARE FOOT (PSF).
2. LATERAL EARTH PRESSURES PROVIDED HEREIN ARE BASED ON ACTIVE EARTH PRESSURES AND SHOULD BE USED FOR THE DESIGN OF THE RETAINING WALLS WHERE THE WALL IS FREE TO DISPLACE LATERALLY AT LEAST 0.001H, WHERE H IS THE RETAINED HEIGHT OF THE WALL.
3. ALL THE EARTH PRESSURES PROVIDED ARE ULTIMATE (UNFACTORED), THE APPROPRIATE LOAD AND RESISTANCE FACTORS SHOULD BE APPLIED FOR EACH LOAD STATE.
4. ALL ACTIVE EARTH PRESSURES ACTING ON THE RETAINED PORTION OF THE WALL (ABOVE THE BASE OF THE LAGGING) SHOULD BE APPLIED ACROSS THE PILE SPACING.
5. ALL ACTIVE EARTH PRESSURES ACTING BELOW THE RETAINED PORTION OF THE WALL (BELOW THE BASE OF THE LAGGING) SHOULD BE APPLIED OVER ONE PILE SHAFT DIAMETER.
6. THE LEVEL BACKSLOPE SHOULD EXTEND BEHIND THE WALL OVER A DISTANCE OF ⅔ TIMES THE HEIGHT OF THE WALL PLUS THE SCOUR DEPTH ($H+D_S$).
7. DESIGN ASSUMES THAT THE LIQUEFIABLE MATERIALS ARE SATURATED BUT HYDROSTATIC PRESSURE DOES NOT BUILD UP BEHIND THE WALL.

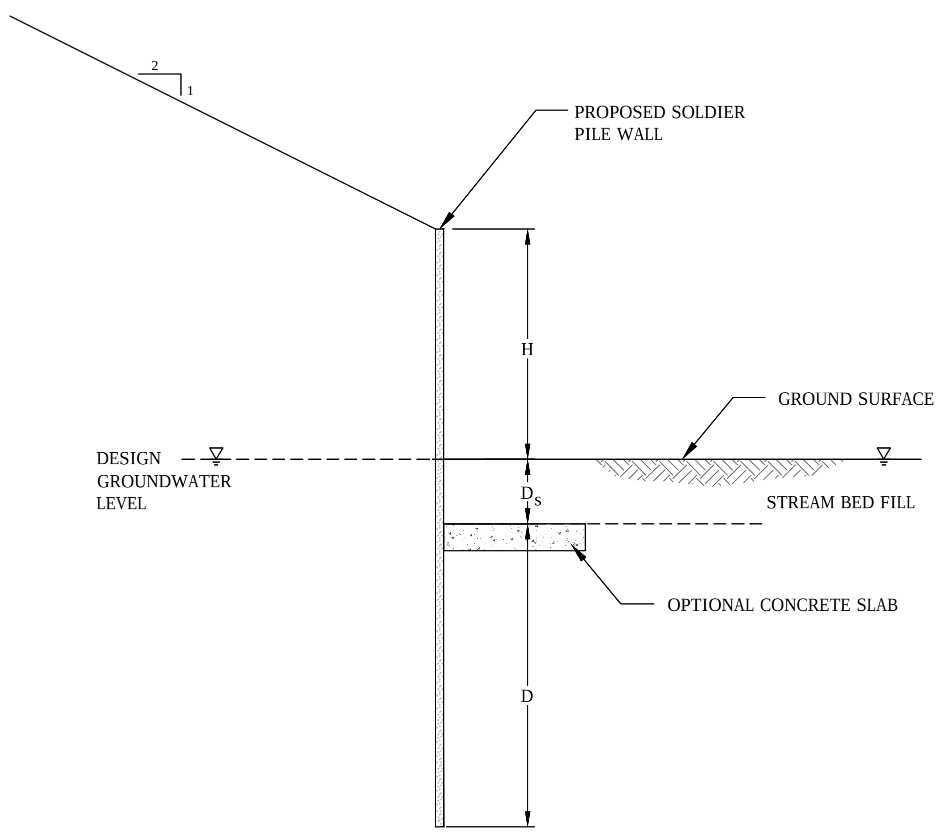
EXTREME LIMIT STATE DESIGN NOTES:

1. ALL PASSIVE EARTH PRESSURES ACTING BELOW THE SCOUR DEPTH SHOULD BE APPLIED OVER TWO PILE SHAFT DIAMETERS.
2. LATERAL EARTH PRESSURES PRESENTED UNDER THE EXTREME LIMIT STATE INCLUDE ACTIVE ON THE RETAINED SIDE AND PASSIVE ON THE CUT SIDE OF THE WALL.
3. FOR EXTREME LIMIT STATE DESIGN, A RESISTANCE FACTOR (Φ) OF 1.0 SHOULD BE APPLIED TO THE PASSIVE EARTH PRESSURES SHOWN.

NOT TO SCALE

HWA GEOSCIENCES INC.	HIDDEN LAKE DAM REMOVAL AND STREAM RESTORATION PROJECT SHORELINE, WASHINGTON	LATERAL EARTH PRESSURES FOR PERMANENT SOLDIER PILE WALLS LEVEL BACKSLOPE (POST-LIQUEFACTION)	DRAWN BY: BFM	FIGURE NO. 9
			CHECK BY: JG	PROJECT NO. 2017-096-21

S:\2017 PROJECTS\2017-096-21 HIDDEN LAKE DAM REMOVAL PROJECT\CAD\HWA 2017-096-21 EP 12.28.2018.DWG <9> Plotted: 11/22/2019 4:30 PM



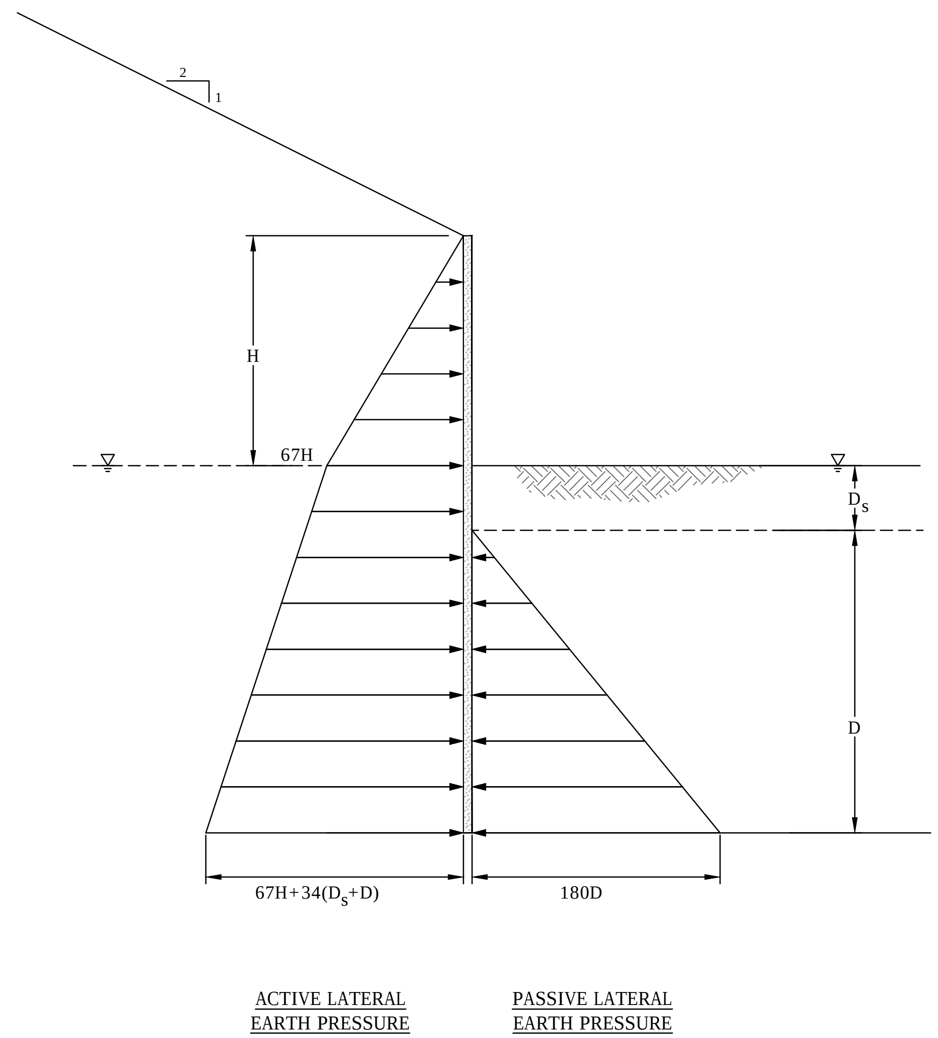
DESIGN SYMBOLS:

H = DESIGN WALL HEIGHT (FT)

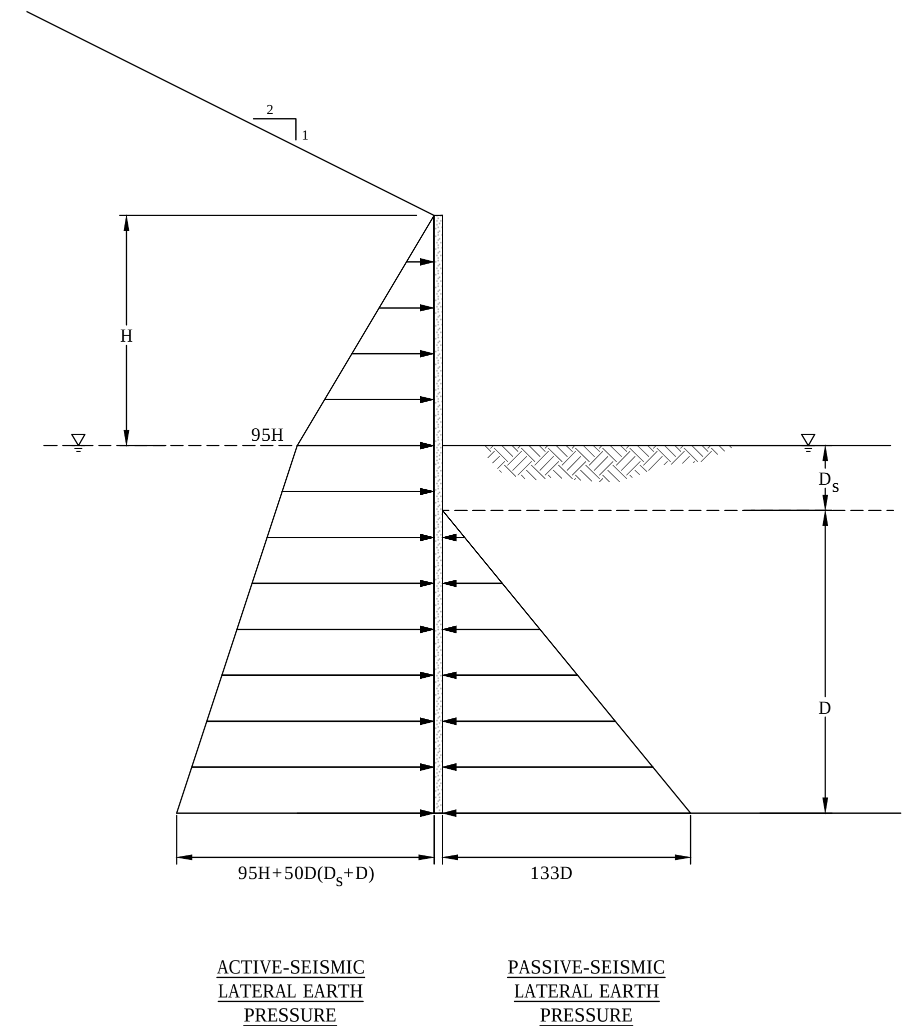
D_S = DEPTH OF SCOUR BELOW DESIGN GROUND SURFACE (FT)

D = EMBEDMENT DEPTH BELOW DEPTH OF SCOUR (FT)

DESIGN PROFILE



STRENGTH & SERVICE LIMIT STATE (STATIC)



EXTREME LIMIT STATE (SEISMIC)

GENERAL NOTES:

1. ALL THE PRESSURES SHOWN ARE IN THE UNITS OF POUNDS PER SQUARE FOOT (PSF).
2. LATERAL EARTH PRESSURES PROVIDED HEREIN ARE BASED ON ACTIVE EARTH PRESSURES AND SHOULD BE USED FOR THE DESIGN OF THE RETAINING WALLS WHERE THE WALL IS FREE TO DISPLACE LATERALLY AT LEAST 0.001H, WHERE H IS THE RETAINED HEIGHT OF THE WALL.
3. ALL THE EARTH PRESSURES PROVIDED ARE ULTIMATE (UNFACTORED), THE APPROPRIATE LOAD AND RESISTANCE FACTORS SHOULD BE APPLIED FOR EACH LOAD STATE.
4. ALL ACTIVE EARTH PRESSURES ACTING ON THE RETAINED PORTION OF THE WALL (ABOVE THE BASE OF THE LAGGING) SHOULD BE APPLIED ACROSS THE PILE SPACING.
5. ALL ACTIVE EARTH PRESSURES ACTING BELOW THE RETAINED PORTION OF THE WALL (BELOW THE BASE OF THE LAGGING) SHOULD BE APPLIED OVER ONE PILE SHAFT DIAMETER.

STRENGTH AND SERVICE STATE DESIGN NOTES:

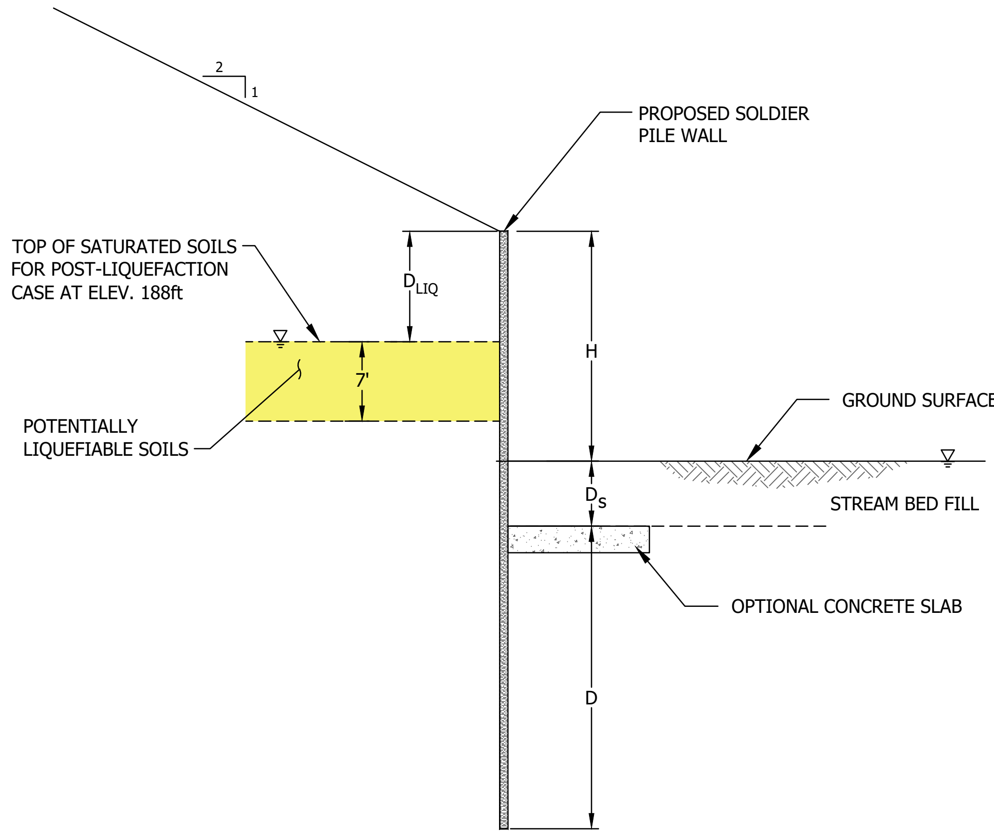
1. ALL PASSIVE EARTH PRESSURES ACTING BELOW THE SCOUR DEPTH SHOULD BE APPLIED OVER TWO PILE SHAFT DIAMETERS
2. FOR STRENGTH LIMIT STATE DESIGN, A RESISTANCE FACTOR (Φ) OF 0.75 SHOULD BE APPLIED TO THE PASSIVE EARTH PRESSURES SHOWN.
3. FOR SERVICE LIMIT STATE DESIGN, A RESISTANCE FACTOR (Φ) OF 1.0 SHOULD BE APPLIED TO THE PASSIVE EARTH PRESSURES SHOWN.

EXTREME LIMIT STATE DESIGN NOTES:

1. ALL PASSIVE EARTH PRESSURES ACTING BELOW THE SCOUR DEPTH SHOULD BE APPLIED OVER TWO PILE SHAFT DIAMETERS.
2. LATERAL EARTH PRESSURES PRESENTED UNDER THE EXTREME LIMIT STATE INCLUDE ACTIVE PLUS SEISMIC ON THE RETAINED SIDE AND PASSIVE PLUS SEISMIC ON THE CUT SIDE OF THE WALL.
3. FOR EXTREME LIMIT STATE DESIGN, A RESISTANCE FACTOR (Φ) OF 1.0 SHOULD BE APPLIED TO THE PASSIVE EARTH PRESSURES SHOWN.

NOT TO SCALE

HWA GEOSCIENCES INC.	HIDDEN LAKE DAM REMOVAL AND STREAM RESTORATION PROJECT SHORELINE, WASHINGTON	LATERAL EARTH PRESSURES FOR PERMANENT SOLDIER PILE WALLS MAXIMUM 2H:1V SLOPE	DRAWN BY: BFM	FIGURE NO. 10
			CHECK BY: JG	PROJECT NO. 2017-096-21



DESIGN SYMBOLS:

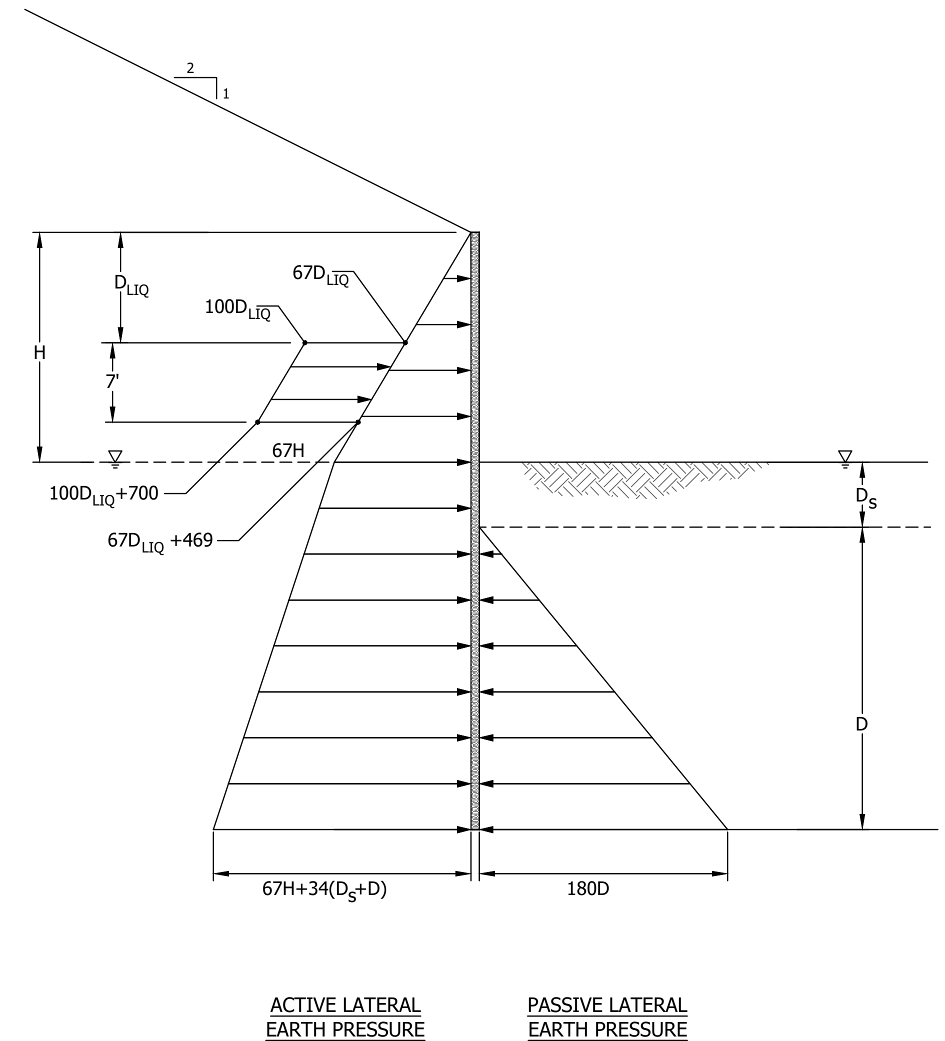
H = DESIGN WALL HEIGHT (FT)

D_S = DEPTH OF SCOUR BELOW DESIGN GROUND SURFACE (FT)

D = EMBEDMENT DEPTH BELOW DEPTH OF SCOUR (FT)

D_{LIQ} = DEPTH TO LIQUEFIABLE MATERIAL = DIFFERENCE BETWEEN ELEV. OF TOP OF WALL AND ELEV. OF TOP OF LIQUEFIABLE MATERIAL WHICH IS ELEV. 188ft.

DESIGN PROFILE



EXTREME LIMIT STATE (POST-LIQUEFACTION)

GENERAL NOTES:

1. ALL THE PRESSURES SHOWN ARE IN THE UNITS OF POUNDS PER SQUARE FOOT (PSF).
2. LATERAL EARTH PRESSURES PROVIDED HEREIN ARE BASED ON ACTIVE EARTH PRESSURES AND SHOULD BE USED FOR THE DESIGN OF THE RETAINING WALLS WHERE THE WALL IS FREE TO DISPLACE LATERALLY AT LEAST 0.001H, WHERE H IS THE RETAINED HEIGHT OF THE WALL.
3. ALL THE EARTH PRESSURES PROVIDED ARE ULTIMATE (UNFACTORED), THE APPROPRIATE LOAD AND RESISTANCE FACTORS SHOULD BE APPLIED FOR EACH LOAD STATE.
4. ALL ACTIVE EARTH PRESSURES ACTING ON THE RETAINED PORTION OF THE WALL (ABOVE THE BASE OF THE LAGGING) SHOULD BE APPLIED ACROSS THE PILE SPACING.
5. ALL ACTIVE EARTH PRESSURES ACTING BELOW THE RETAINED PORTION OF THE WALL (BELOW THE BASE OF THE LAGGING) SHOULD BE APPLIED OVER ONE PILE SHAFT DIAMETER.
6. DESIGN ASSUMES THAT THE LIQUEFIABLE MATERIALS ARE SATURATED BUT HYDROSTATIC PRESSURE DOES NOT BUILD UP BEHIND THE WALL.

EXTREME LIMIT STATE DESIGN NOTES:

1. ALL PASSIVE EARTH PRESSURES ACTING BELOW THE SCOUR DEPTH SHOULD BE APPLIED OVER TWO PILE SHAFT DIAMETERS.
2. LATERAL EARTH PRESSURES PRESENTED UNDER THE EXTREME LIMIT STATE INCLUDE ACTIVE ON THE RETAINED SIDE AND PASSIVE ON THE CUT SIDE OF THE WALL.
3. FOR EXTREME LIMIT STATE DESIGN, A RESISTANCE FACTOR (Φ) OF 1.0 SHOULD BE APPLIED TO THE PASSIVE EARTH PRESSURES SHOWN.

NOT TO SCALE

HWA GEOSCIENCES INC.	HIDDEN LAKE DAM REMOVAL AND STREAM RESTORATION PROJECT SHORELINE, WASHINGTON	LATERAL EARTH PRESSURES FOR PERMANENT SOLDIER PILE WALLS MAXIMUM 2H:1V SLOPE (POST-LIQUEFACTION)	DRAWN BY: BFM CHECK BY: JG	FIGURE NO. 11 PROJECT NO. 2017-096-21

APPENDIX A

FIELD INVESTIGATION

APPENDIX A

FIELD INVESTIGATION

The field explorations completed for this study consisted of seven borings, designated BH-1 through BH-7, drilled in three phases. The first phase consisted of two boreholes (designated BH-1 and BH-2) that were drilled on the slope east of the culverts downstream of the dam on October 31, 2017. Drilling was performed by Geologic Drill Explorations, Inc. under subcontract to HWA. They were drilled with a Bobcat Mini-track drill rig to depths of about 31½ feet. The second phase consisted of two boreholes (designated BH-3 and BH-4) that were drilled within the Innis Arden Way road prism on November 9, 2017 by Environmental Drilling, Inc. also under subcontract to HWA. These were drilled with a truck-mounted Mobile B-61 rig to depths of 49 feet. The final set of three additional boreholes, designated BH-5 through BH-7, were drilled on the slope south of Innis Arden Way on September 17, 2018. Drilling was performed by Geologic Drill Explorations, Inc. under subcontract to HWA. They were drilled with a Bobcat Mini-track drill rig to depths ranging from about 2½ feet at BH-7 to about 41½ feet at BH-6. Locations of the borings, along with previous borings by others, are shown on the Site and Exploration Plan, Figure 2.

Soil samples were collected at 2½- to 5-foot depth intervals using Standard Penetration Test (SPT) sampling methods. SPT testing consisted of using a 2-inch outside diameter, split-spoon sampler driven with a 140-pound hammer. For BH-1 and BH-2, the SPT was performed using a rope and cathead with safety hammer. For BH-3 and BH-4, the SPT was performed using an automatic hammer. During the test, each sample was obtained by driving the sampler up to 18 inches into the soil with the hammer free-falling 30 inches per blow. The number of blows required for each 6 inches of penetration was recorded. The standard penetration resistance of the soil was calculated as the number of blows required for the final 12 inches of penetration. If a total of 50 blows was recorded within a single 6-inch interval, the test was terminated, and the blow count was recorded as 50 blows/number of inches of penetration. This resistance provides an indication of the relative density of granular soils and the relative consistency of cohesive soils.

On August 12 and 15, 2019, four hand borings, designated HH-1 through HH-4, were conducted to obtain soil samples for pH and resistivity testing. The hand borings were advanced using hand tools to depths ranging from about ½ foot in HH-1 to about 8½ feet in HH-3.

All explorations were drilled under the full-time supervision and observation of an HWA engineering geologist or geotechnical engineer. 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.

Pertinent information including soil sample depths, stratigraphy, soil engineering characteristics, and ground water occurrence was recorded and used to develop logs of each of the explorations. A legend of the terms and symbols used on the exploration logs is presented on Figure A-1, and the logs are presented on Figures A-2 through A-13.

The stratigraphic contacts shown on the borehole logs represent the approximate boundaries between soil types. Actual transitions may be more gradual. The 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.

HIDDEN LAKE DAM REMOVAL
AND STREAM RESTORATION PROJECT
SHORELINE, WASHINGTON

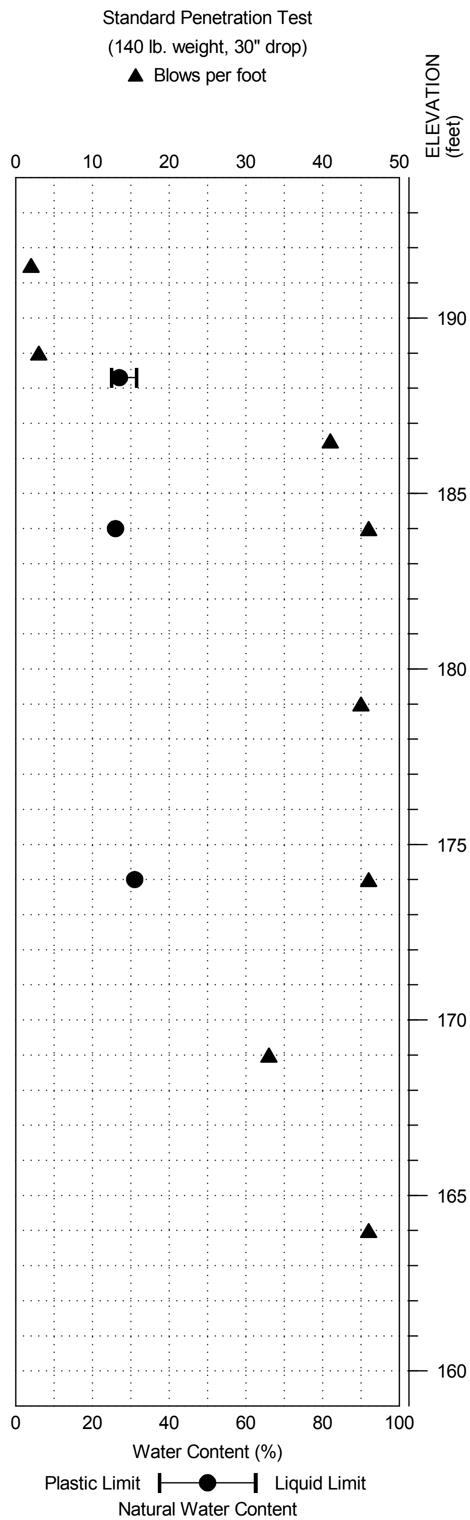
LEGEND OF TERMS AND SYMBOLS USED ON EXPLORATION LOGS

PROJECT NO.: 2017-096-21 FIGURE: A-1

DRILLING COMPANY: Geologic Drill, Inc.
DRILLING METHOD: HSA, Bobcat minitrack
SAMPLING METHOD: SPT w/ cathead
LOCATION: See Figure 2

DATE STARTED: 10/31/2017
DATE COMPLETED: 10/31/2017
LOGGED BY: B. Thurber/ S. Khandaker
SURFACE ELEVATION: 194.0 ± feet

DEPTH (feet)	USCS SOIL CLASS	DESCRIPTION	SAMPLE NUMBER	PEN. RESISTANCE (blows/6 inches)	OTHER TESTS	GROUNDWATER
0	ML	Loose, dark brown, sandy SILT, moist. **(COLLUVIUM)**				
	ML	Very loose, reddish, SILT with organics, moist. Rotten wood with topsoil.	S-1	3-1-1		
	GP GM	Very loose, olive brown, slightly silty, slightly sandy, fine GRAVEL, wet. **(FILL)**	S-2a	1-1-2		
5	ML		S-2b		AL	
	ML	Soft, gray, SILT, moist, blocky texture to massive. **(COLLUVIUM)**	S-3	19-19-22		
10		Hard, gray, SILT, moist, mostly massive. **(GLACIOLACUSTRINE)**	S-4	10-16-30		
15	ML	Hard, gray, SILT, moist. Laminated, with light gray, silt partings.	S-5	12-15-20		
20	CL	Hard, gray, lean CLAY, moist. Laminated to finely bedded with light gray, non plastic, silt partings.	S-6	12-20-26		
25		Upper 6 inches of sample S-11 consists of gray, silty, fine SAND, moist.	S-7a	12-12-21		
	CL	Hard, gray to dark gray, lean CLAY, moist. Mostly massive, with crumbly texture at transition from sand.	S-7b			
30	CL	Hard, gray, lean CLAY, moist, interbedded with dense, gray, SILT, wet.	S-8a	18-16-30		∇
			S-8b			
35		Borehole terminated at 31.5 feet. Ground water seepage encountered at approximately 30 feet.				



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.

HIDDEN LAKE DAM REMOVAL
AND STREAM RESTORATION PROJECT
SHORELINE, WASHINGTON

BORING:
BH-1

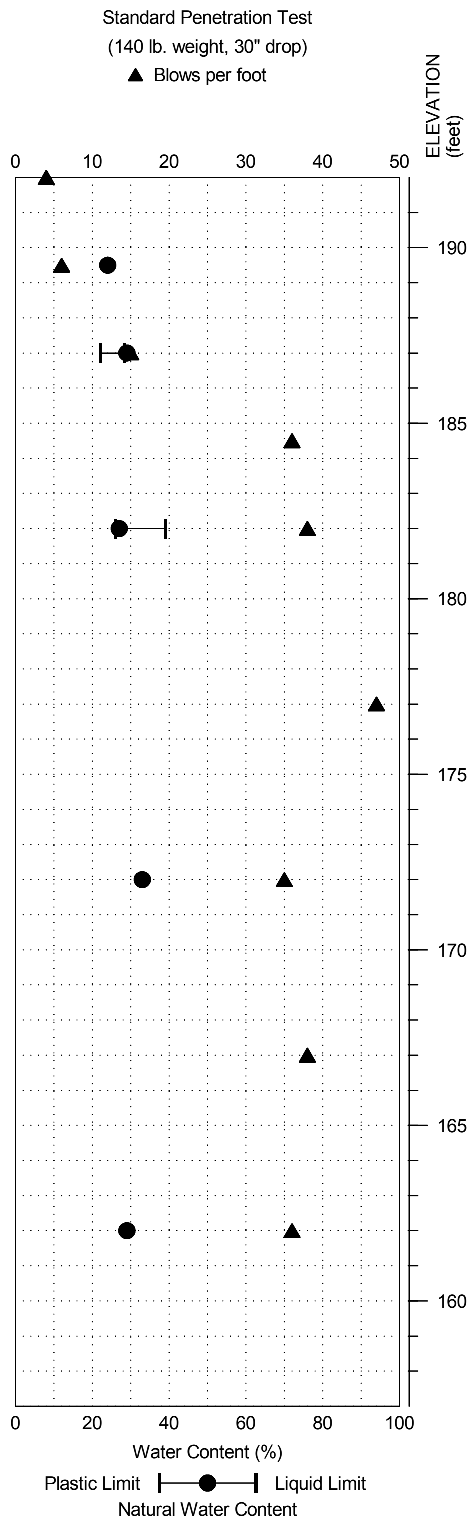
PROJECT NO.: 2017-096-21 FIGURE: A-2

DRILLING COMPANY: Geologic Drill, Inc.
DRILLING METHOD: HSA, Bobcat minitrack
SAMPLING METHOD: SPT w/ cathead
LOCATION: See Figure 2

DATE STARTED: 10/31/2017
DATE COMPLETED: 10/31/2017
LOGGED BY: B. Thurber/ S. Khandaker
SURFACE ELEVATION: 192.0 ± feet

DEPTH (feet)	USCS SOIL CLASS	DESCRIPTION	SAMPLE NUMBER	PEN. RESISTANCE (blows/6 inches)	OTHER TESTS	GROUNDWATER
0	CL	Soft, light brown, CLAY, moist, with scattered organics. **(COLLUVIUM)**	S-1	1-2-2		
	SM	Loose, brown and gray, silty, fine to coarse SAND, wet. Trace gravel. **(ALLUVIUM)**	S-2	2-4-2	GS	
5	CL ML	Stiff, gray, silty CLAY, moist to wet, with scattered organics. **(COLLUVIUM)**	S-3	5-6-9	AL	▽
	ML	Hard, gray, SILT, moist. Laminated with gray silt partings. Crumbly texture. **(GLACIOLACUSTRINE)**	S-4	10-16-20		
10		Blocky texture.	S-5	10-16-22	AL	
15	ML	Hard, gray and light gray, SILT, moist. Laminated with zones of blocky texture.	S-6	13-18-29		
20	CL	Hard, gray, lean CLAY, moist. Laminated to massive.	S-7	15-15-20		
25		Finely bedded, some lamination with zones of blocky texture.	S-8	12-15-23		
30		Some fine sandy silt at top of sample at 30 feet, with crumbly texture at sandy silt contact.	S-9	10-16-20		

Borehole terminated at 31.5 feet.
Ground water seepage encountered at 5 feet, likely perched.



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.

HIDDEN LAKE DAM REMOVAL
AND STREAM RESTORATION PROJECT
SHORELINE, WASHINGTON

BORING:
BH-2

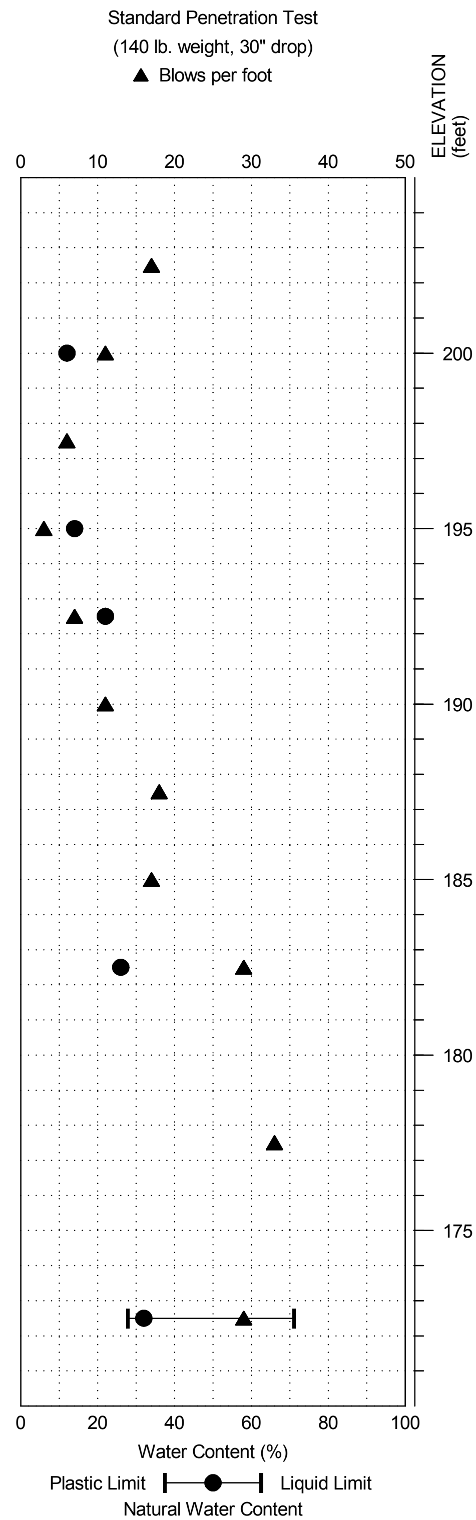
PAGE: 1 of 1

PROJECT NO.: 2017-096-21 FIGURE: A-3

DRILLING COMPANY: Environmental Drilling Inc.
DRILLING METHOD: HSA, Mobile B-61
SAMPLING METHOD: SPT w/ autohammer
LOCATION: See Figure 2

DATE STARTED: 11/9/2017
DATE COMPLETED: 11/9/2017
LOGGED BY: S. Khandaker/B. Thurber
SURFACE ELEVATION: 205.0 ± feet

DEPTH (feet)	USCS SOIL CLASS	DESCRIPTION	SAMPLE NUMBER	PEN. RESISTANCE (blows/6 inches)	OTHER TESTS	GROUNDWATER
0		9.5 inches of HMA **(ASPHALT)**				
	SM	Gravelly drilling in top 2 feet.				
		Medium dense, rust-mottled olive brown, gravelly, silty, fine to medium SAND, moist.	S-1	3-9-8		
5		**(FILL)**				
	SM	Medium dense, rust-mottled, slightly gravelly, silty, fine to medium SAND, moist, scattered organics observed.	S-2	3-4-7	GS	
	SM	Loose, rust-mottled olive brown, silty, fine to medium SAND, moist. One-inch thick, gray silt lense observed.	S-3	3-3-3		
10	SP SM	Very loose, rust-mottled olive brown, slightly silty, fine to medium SAND, moist.	S-4	1-2-1		
	SP SM	Loose, gray to olive brown, slightly silty, medium to coarse poorly-graded SAND, wet.	S-5	2-3-4	GS	∇
15		**(ALLUVIUM)**				
	SM	Loose, gray, very silty, fine to medium SAND, moist. Trace wood and gravel observed.	S-6	6-4-7		
	ML	Very stiff, gray, SILT, moist, with some organics.	S-7	5-9-11		
		(GLACIOLACUSTRINE)				
20	CL	Very stiff, gray, CLAY, moist, with light grayy silt partings. Two inch lense of dilatant, non plastic silt.	S-8	3-5-12		
		Coarse to fine bedding.	S-9	7-12-17		
25						
		Becomes hard and is laminated.	S-10	9-14-19		
30						
	CH	Very stiff, gray, fat CLAY, moist. Disturbed with interbedded lean clay and non plastic silt beds.	S-11	7-12-17	AL	
35						



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.

HIDDEN LAKE DAM REMOVAL
AND STREAM RESTORATION PROJECT
SHORELINE, WASHINGTON

BORING:
BH-3

PAGE: 1 of 2

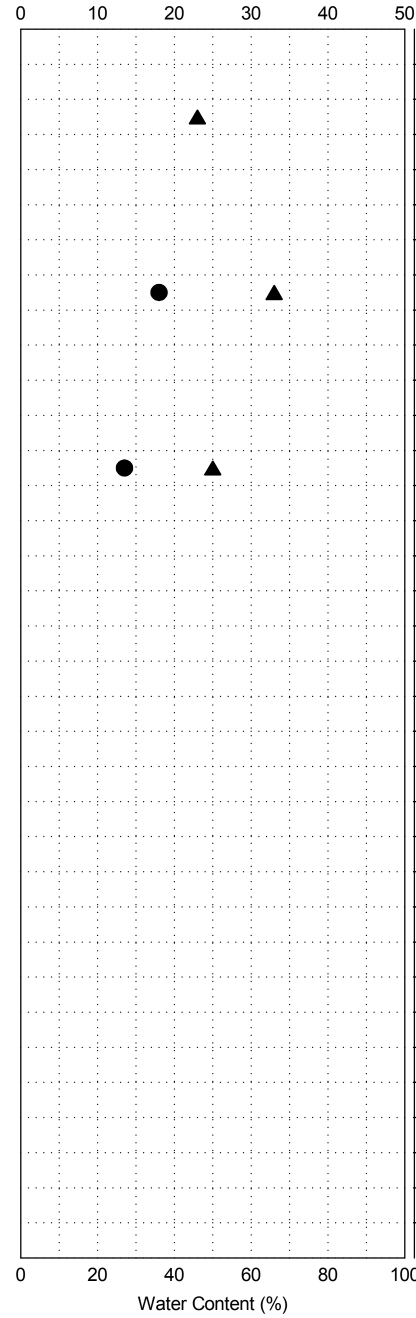
PROJECT NO.: 2017-096-21 FIGURE: A-4

DRILLING COMPANY: Environmental Drilling Inc.
DRILLING METHOD: HSA, Mobile B-61
SAMPLING METHOD: SPT w/ autohammer
LOCATION: See Figure 2

DATE STARTED: 11/9/2017
DATE COMPLETED: 11/9/2017
LOGGED BY: S. Khandaker/B. Thurber
SURFACE ELEVATION: 205.0 ± feet

DEPTH (feet)	SYMBOL	USCS SOIL CLASS	DESCRIPTION	SAMPLE TYPE	SAMPLE NUMBER	PEN. RESISTANCE (blows/6 inches)	OTHER TESTS	GROUNDWATER	ELEVATION (feet)
35									
			Variable drilling resistance observed. Laminated, with slickensides.		S-12	6-9-14			
40									165
		CH	Hard, gray, fat CLAY, moist, with slickensides.		S-13	7-15-18			
45									160
			Grades to very stiff.						
		SP SM	Medium dense, brown, slightly silty, fine poorly graded SAND, wet.		S-14a S-14b	7-8-17	GS		
50			Borehole terminated at 49 feet. Perched ground water seepage encountered at 13 feet and static ground water observed at 36 feet during drilling.						155
55									150
60									145
65									140
70									

Standard Penetration Test
(140 lb. weight, 30" drop)
▲ Blows per foot



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.

HIDDEN LAKE DAM REMOVAL
AND STREAM RESTORATION PROJECT
SHORELINE, WASHINGTON

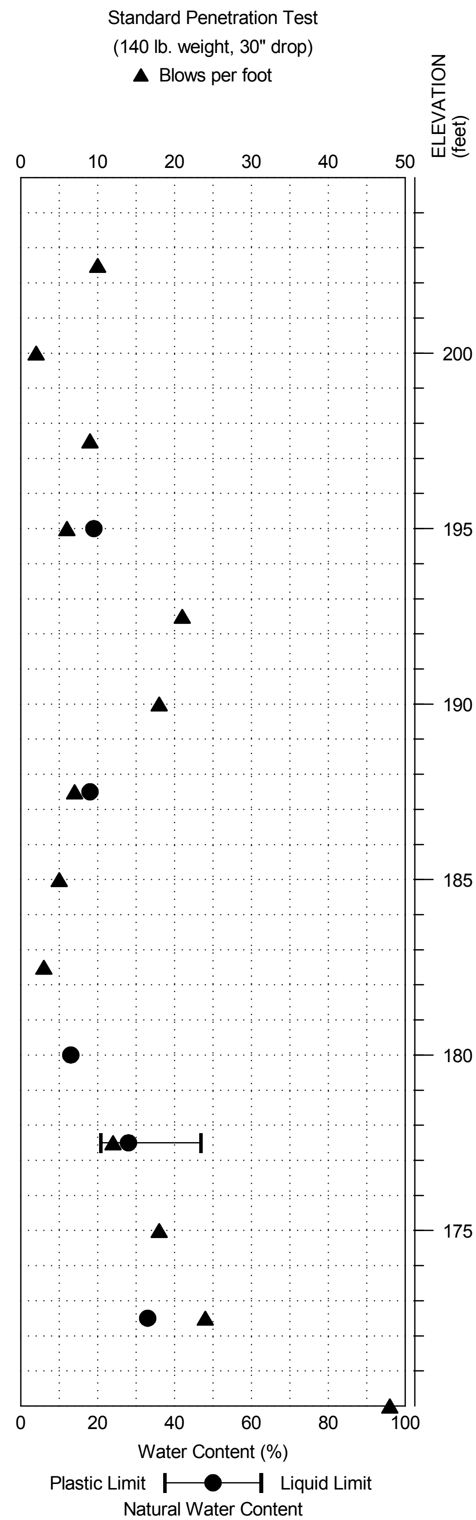
BORING:
BH-3

PROJECT NO.: 2017-096-21 FIGURE: A-4

DRILLING COMPANY: Environmental Drilling Inc.
DRILLING METHOD: HSA, Mobile B-61
SAMPLING METHOD: SPT w/ autohammer
LOCATION: See Figure 2

DATE STARTED: 11/9/2017
DATE COMPLETED: 11/9/2017
LOGGED BY: S. Khandaker
SURFACE ELEVATION: 205.0 ± feet

DEPTH (feet)	USCS SOIL CLASS	DESCRIPTION	SAMPLE NUMBER	PEN. RESISTANCE (blows/6 inches)	OTHER TESTS	GROUNDWATER
0		9.5 inches of HMA **(ASPHALT)**				
	SM	Loose, brown, silty to very silty, fine to medium SAND, moist, with 1 to 2 foot thick layer of plastic silt at 3 feet. **(FILL)**	S-1a S-1b	7-5-5		
5	SM	Very loose, olive brown, silty to very silty, fine to medium SAND, moist.	S-2	2-1-1		∇
	SM	Loose, gray, slightly gravelly, silty, fine to medium SAND, moist, with scattered silt layers.	S-3	6-5-4		
10	SM	Loose, gray, silty, fine to medium SAND, moist, with scattered organics.	S-4	3-3-3	GS	
		Becomes medium dense, with scattered silt layers.	S-5	5-10-11		
15	SM	Medium dense, gray to dark brown, silty, fine to medium SAND, moist.	S-6	5-7-9		
	SM	Loose, gray, silty, fine to medium SAND, moist, with scattered wood observed.	S-7	1-3-4		
20			S-8	3-3-2		
	SM	Very loose, very dark brown, silty, fine to medium SAND, moist, with organics. **(BURIED TOPSOIL)**	S-9	1-1-2		
25	GP GM	Loose, gray, slightly silty, sandy, poorly graded GRAVEL, wet, with dark brown organic pockets. Sampler drove on a rock. **(ALLUVIUM)**	S-10	11-16-16	GS	
	CL	Stiff, gray, lean CLAY, moist. Low recovery in sample S-11.	S-11	3-5-7	AL	
30		Sampler driven into wood.	S-12	21-9-9		
	CL	Very stiff, gray, CLAY, moist. Transition from disturbed to laminated. Wood observed at top of sample S-12.	S-13	7-10-14		
35						



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.

HIDDEN LAKE DAM REMOVAL
AND STREAM RESTORATION PROJECT
SHORELINE, WASHINGTON

BORING:
BH-4

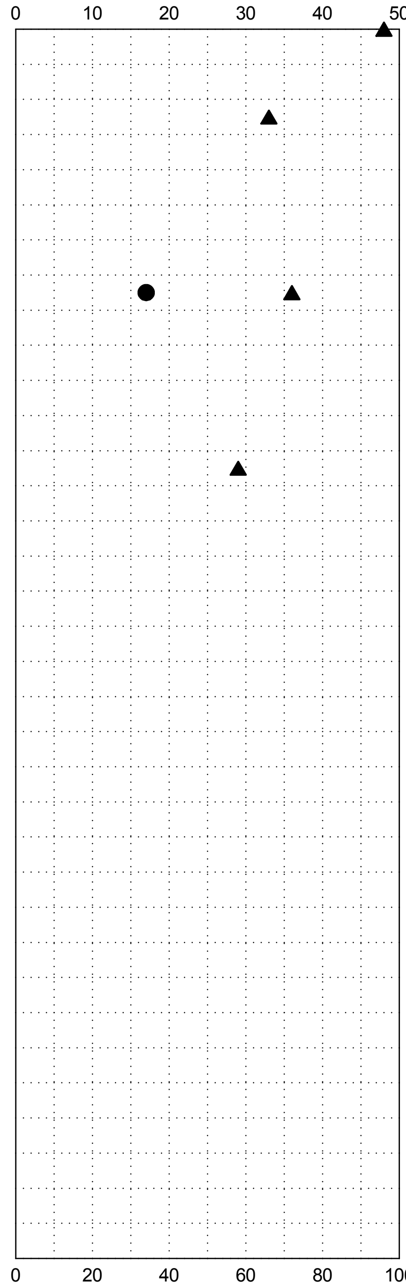
PROJECT NO.: 2017-096-21 FIGURE: A-5

DRILLING COMPANY: Environmental Drilling Inc.
DRILLING METHOD: HSA, Mobile B-61
SAMPLING METHOD: SPT w/ autohammer
LOCATION: See Figure 2

DATE STARTED: 11/9/2017
DATE COMPLETED: 11/9/2017
LOGGED BY: S. Khandaker
SURFACE ELEVATION: 205.0 ± feet

DEPTH (feet)	SYMBOL	USCS SOIL CLASS	DESCRIPTION	SAMPLE TYPE	SAMPLE NUMBER	PEN. RESISTANCE (blows/6 inches)	OTHER TESTS	GROUNDWATER	ELEVATION (feet)
35		ML	Hard, gray, coarse SILT, moist. **(GLACIOLACUSTINE)**		S-14	9-17-31			
		CH	Hard, gray, fat CLAY, moist, finely bedded to laminated, with light gray, silt partings and slickensides.		S-15	11-12-21			
40									165
					S-16	7-12-24			
45									160
		SM	Medium dense, gray, silty, fine SAND, wet.		S-17	7-11-18			
50			Borehole terminated at 49 feet. Perched ground water seepage encountered at 6 and static ground water observed at 43 feet during drilling.						155
55									150
60									145
65									140
70									

Standard Penetration Test
(140 lb. weight, 30" drop)
▲ Blows per foot



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.

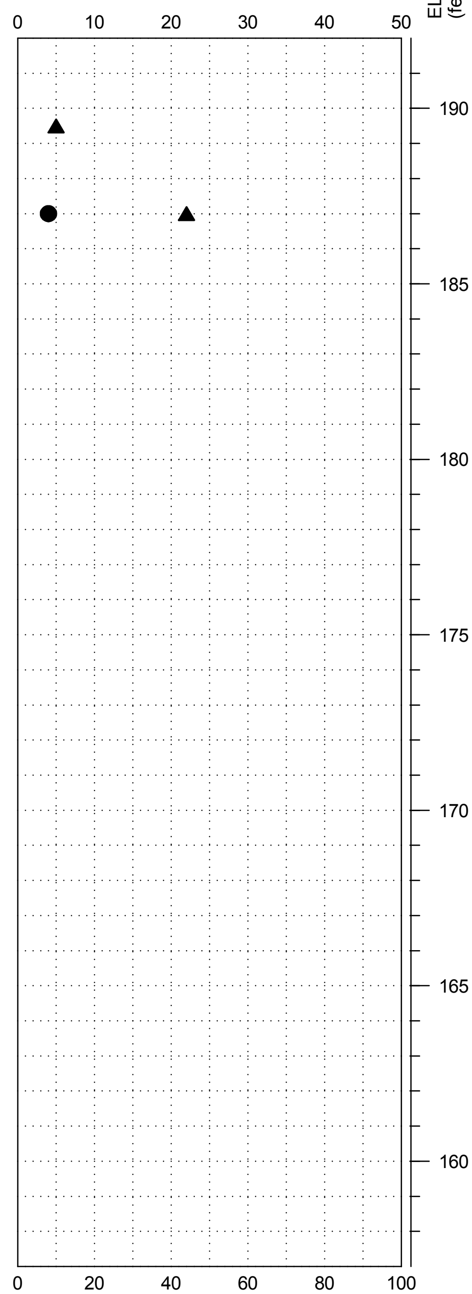
DRILLING COMPANY: Geologic Drill, Inc.
DRILLING METHOD: HSA, Bobcat minitrack
SAMPLING METHOD: SPT w/ cathead
LOCATION: See Figure 2

DATE STARTED: 9/17/2018
DATE COMPLETED: 9/17/2018
LOGGED BY: S. King
SURFACE ELEVATION: 192.0 ± feet

DEPTH (feet)	SYMBOL	USCS SOIL CLASS	DESCRIPTION	SAMPLE TYPE	SAMPLE NUMBER	PEN. RESISTANCE (blows/6 inches)	OTHER TESTS	GROUNDWATER
0		SP SM	Loose, brown, slightly silty, fine poorly graded SAND, moist.		S-1	3-2-3		
5		SM	Medium dense, olive-brown, gravelly, silty fine SAND, moist.		S-2	3-8-14		

Borehole terminated at 7 feet due to refusal on quarry spalls.
No ground water observed during drilling.

Standard Penetration Test
(140 lb. weight, 30" drop)
▲ Blows per foot



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.

HIDDEN LAKE DAM REMOVAL
AND STREAM RESTORATION PROJECT
SHORELINE, WASHINGTON

BORING:
BH-5A

PAGE: 1 of 1

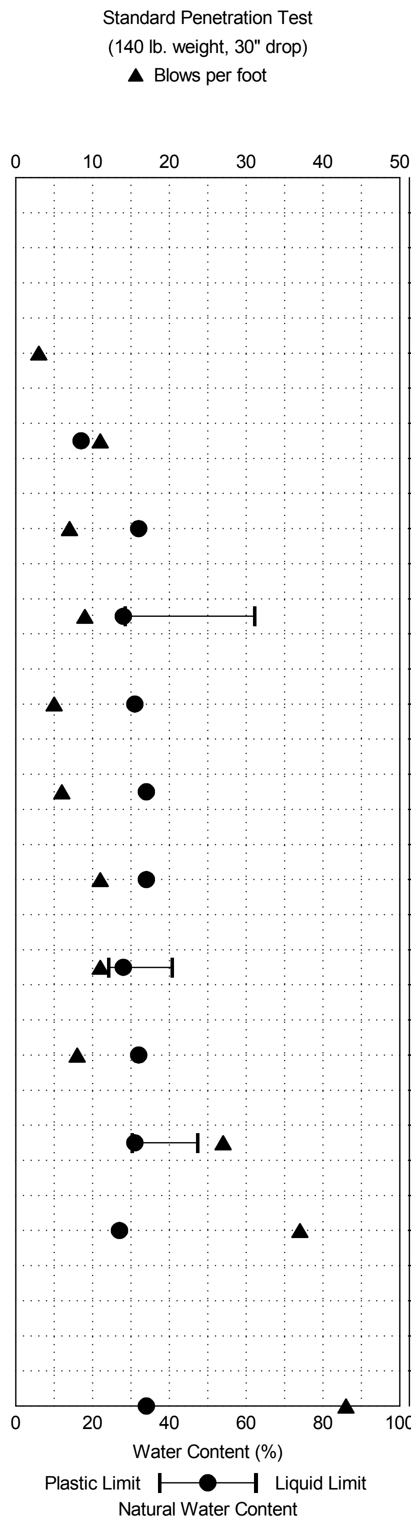
PROJECT NO.: 2017-096-21 FIGURE: A-6

BORING-DSM 2017-096-21.GPJ 2/15/19

DRILLING COMPANY: Geologic Drill, Inc.
DRILLING METHOD: HSA, Bobcat minitrack
SAMPLING METHOD: SPT w/ cathead
LOCATION: See Figure 2

DATE STARTED: 9/17/2018
DATE COMPLETED: 9/17/2018
LOGGED BY: S. King
SURFACE ELEVATION: 190.0 ± feet

DEPTH (feet)	USCS SOIL CLASS	DESCRIPTION	SAMPLE NUMBER	PEN. RESISTANCE (blows/6 inches)	OTHER TESTS	GROUNDWATER	ELEVATION (feet)
0	SM	**(FILL)** Loose, brown, silty SAND, dry to moist.					
5		Spalls observed in cuttings while drilling at 5 feet.	S-1	2-2-1			185
	CL	Medium stiff, olive-brown, sandy lean CLAY, moist.	S-2	3-7-4			
	SP	**(SLIDE DEBRIS?)** Medium dense, olive-brown, gravelly poorly graded SAND, with rust mottling, trace organics, moist.					
10	CL	Medium stiff, dark grayish-brown, lean CLAY, moist. Rust colored bedding and layers of sandy clay.	S-3	2-3-4			180
	CH	Stiff, dark grayish-brown fat CLAY, moist.	S-4	3-4-5	AL		
	ML	Stiff, dark grayish-brown sandy SILT. Trace fine bedding.					
15	CL	Medium stiff, dark grayish-brown, lean CLAY, moist.	S-5	3-2-3			175
	ML	Medium stiff, rust-mottled olive-gray, sandy SILT, moist.					
	CL	Medium stiff, dark gray, lean CLAY, moist, mostly massive.	S-6	1-3-3			
20		Becomes stiff, crumbly texture near top of sample, moist. Minimally apparent bedding.	S-7	2-5-6			170
		Becomes dark grayish-brown. Some crumbly texture and some fine bedding.	S-8	1-5-6	AL		
25	ML	Loose, dark gray, SILT, wet.	S-9	3-3-5			165
	CL	Stiff, olive gray/brown to gray, silty CLAY, wet. Decomposed wood encountered.					
	ML	Very stiff, grayish-brown SILT, moist. No apparent bedding. Woody debris at top of sampler in Sample S-10.	S-10	7-12-15	AL		
30	ML	**(GLACIOLACUSTRINE)** Hard, dark gray SILT, moist, with blocky texture. Trace sand observed.	S-11	9-14-23			160
35							



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.

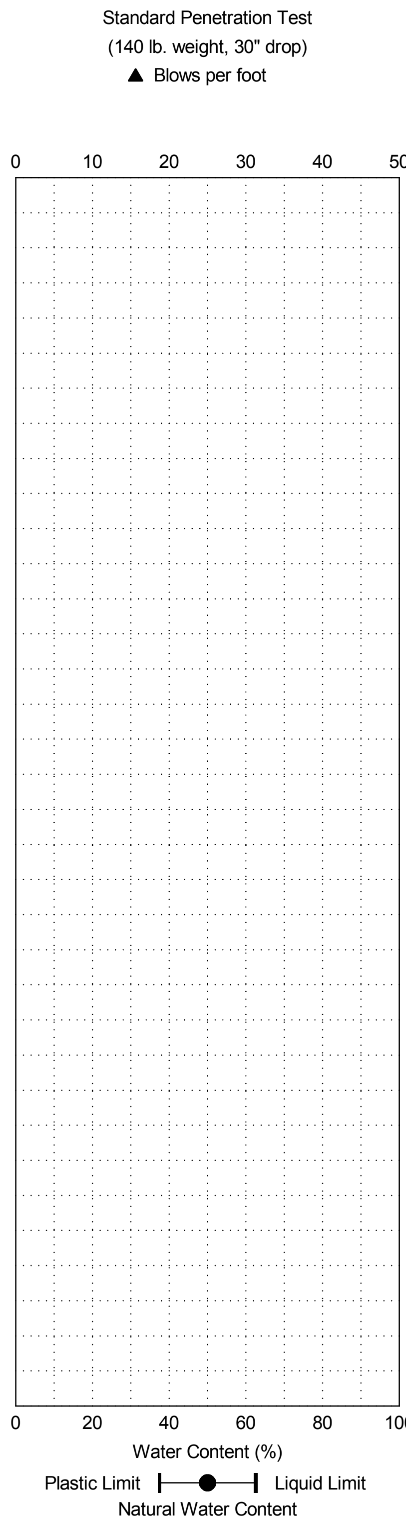
HIDDEN LAKE DAM REMOVAL
AND STREAM RESTORATION PROJECT
SHORELINE, WASHINGTON

BORING:
BH-5

PROJECT NO.: 2017-096-21 FIGURE: A-7

DRILLING COMPANY: Geologic Drill, Inc.	DATE STARTED: 9/17/2018
DRILLING METHOD: HSA, Bobcat minitrack	DATE COMPLETED: 9/17/2018
SAMPLING METHOD: SPT w/ cathead	LOGGED BY: S. King
LOCATION: See Figure 2	SURFACE ELEVATION: 190.0 ± feet

DEPTH (feet)	SYMBOL	USCS SOIL CLASS	DESCRIPTION	SAMPLE TYPE	SAMPLE NUMBER	PEN. RESISTANCE (blows/6 inches)	OTHER TESTS	GROUNDWATER	ELEVATION (feet)
35		ML	Dense, dark gray, sandy SILT, moist, interbedded with organics. **(PRE-FRASER DEPOSITS)**		S-12	15-18-25			
			Borehole terminated at 36.5 feet. No ground water encountered during drilling. Observed wet soil conditions at approximately 25 feet to 27.5 feet.						
40									150
45									145
50									140
55									135
60									130
65									125
70									

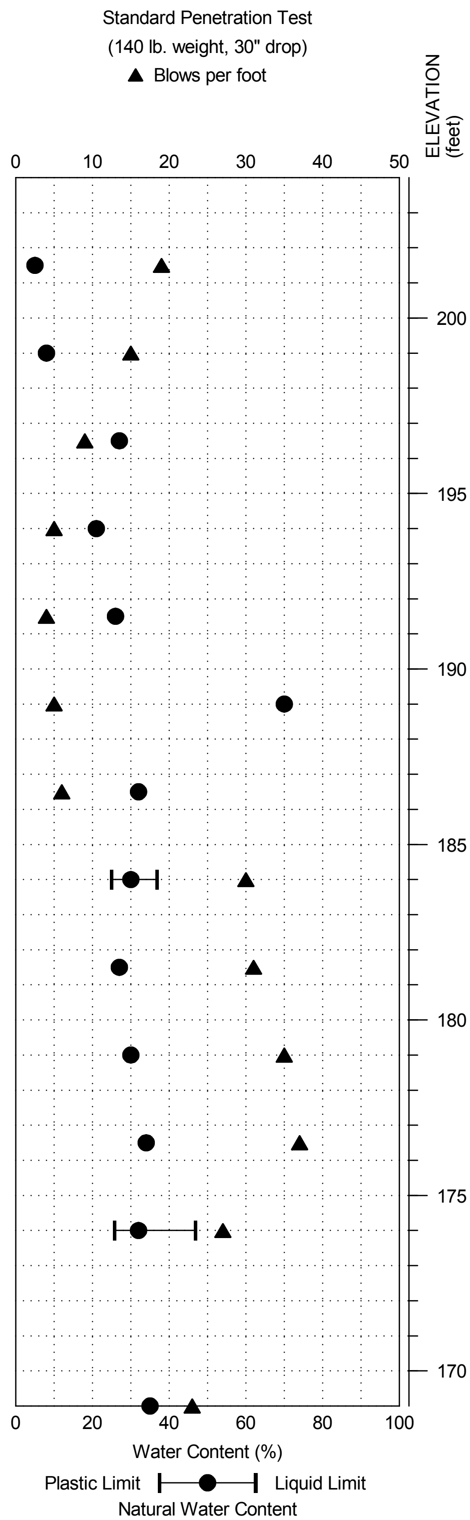


NOTE: This log of subsurface conditions applies only at the specified location and on the date indicated and therefore may not necessarily be indicative of other times and/or locations.

DRILLING COMPANY: Geologic Drill, Inc.
DRILLING METHOD: HSA, Bobcat minitrack
SAMPLING METHOD: SPT w/ cathead
LOCATION: See Figure 2

DATE STARTED: 9/17/2018
DATE COMPLETED: 9/17/2018
LOGGED BY: S. King/ B. Thurber
SURFACE ELEVATION: 204.0 ± feet

DEPTH (feet)	USCS SOIL CLASS	DESCRIPTION	SAMPLE NUMBER	PEN. RESISTANCE (blows/6 inches)	OTHER TESTS	GROUNDWATER
0	SM	Medium dense, light olive-brown, silty fine SAND, moist.	S-1	7-9-10		
		(FILL)				
5		Medium dense, light olive-brown with rust motteling, silty, fine SAND, moist. Trace organics.	S-2	6-7-8		
	ML	Medium stiff, olive-brown SILT, moist.	S-3	3-4-5		
		(COLLUVIUM)				
	SM	Loose, olive-brown, silty SAND.				
10		Becomes dark gray, wet.	S-4	2-2-3		
	SM	Loose, light brown to dark grayish-brown, silty SAND, wet.	S-5	1-1-3		
		(ALLUVIUM)				
15		Six-inch lense of soft, black PEAT at 15 feet.	S-6	2-3-2		
	SM	Loose, dark gray, silty SAND, wet.				
	ML	Medium stiff, dark gray SILT, wet.	S-7	3-3-3		∇
20	ML	Hard, grayish-brown, SILT, moist. Laminated.	S-8	8-14-16	AL	
		(GLACIOLACUSTRINE)				
			S-9	8-12-19		
25	ML	Hard, dark gray SILT, moist, no apparent bedding.	S-10	10-15-20		
	CL	Hard, dark gray, lean CLAY, moist. Finely bedded.	S-11	12-16-21		
30		Becomes very stiff.	S-12	8-12-15	AL	
35		Very finely bedded. Trace fine sand, moist.				



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.

HIDDEN LAKE DAM REMOVAL
AND STREAM RESTORATION PROJECT
SHORELINE, WASHINGTON

BORING:
BH-6

PAGE: 1 of 2

PROJECT NO.: 2017-096-21 FIGURE: A-8

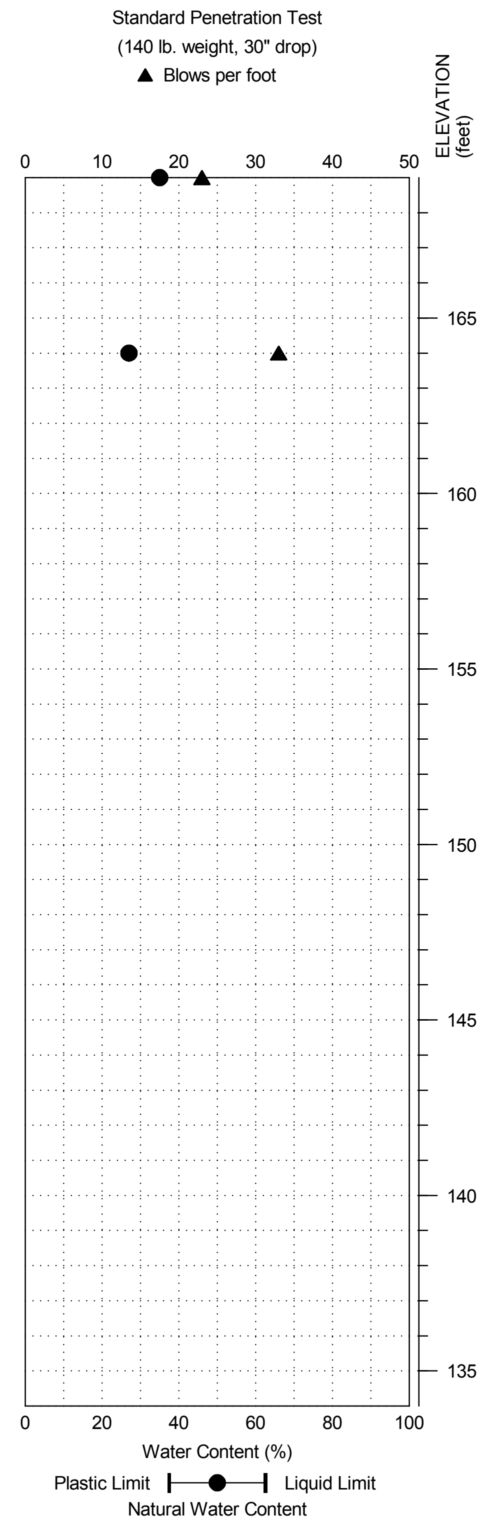
BORING-DSM 2017-096-21.GPJ 2/15/19

DRILLING COMPANY: Geologic Drill, Inc.
DRILLING METHOD: HSA, Bobcat minitrack
SAMPLING METHOD: SPT w/ cathead
LOCATION: See Figure 2

DATE STARTED: 9/17/2018
DATE COMPLETED: 9/17/2018
LOGGED BY: S. King/ B. Thurber
SURFACE ELEVATION: 204.0 ± feet

DEPTH (feet)	SYMBOL	USCS SOIL CLASS	DESCRIPTION	SAMPLE TYPE	SAMPLE NUMBER	PEN. RESISTANCE (blows/6 inches)	OTHER TESTS	GROUNDWATER
35			Lense of dark gray dilatent silt layer noted at 35.8 feet.		S-13	10-9-14		
40		CL	Hard, gray, lean CLAY, moist, laminated.		S-14	15-17-16		
			Borehole terminated at 41.5 feet. Ground water observed at 18 feet during drilling. Observed wet soil conditions at approximately 10 feet to 20 feet.					

Depth scale (feet): 35, 40, 45, 50, 55, 60, 65, 70



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.

HIDDEN LAKE DAM REMOVAL
AND STREAM RESTORATION PROJECT
SHORELINE, WASHINGTON

BORING:
BH-6

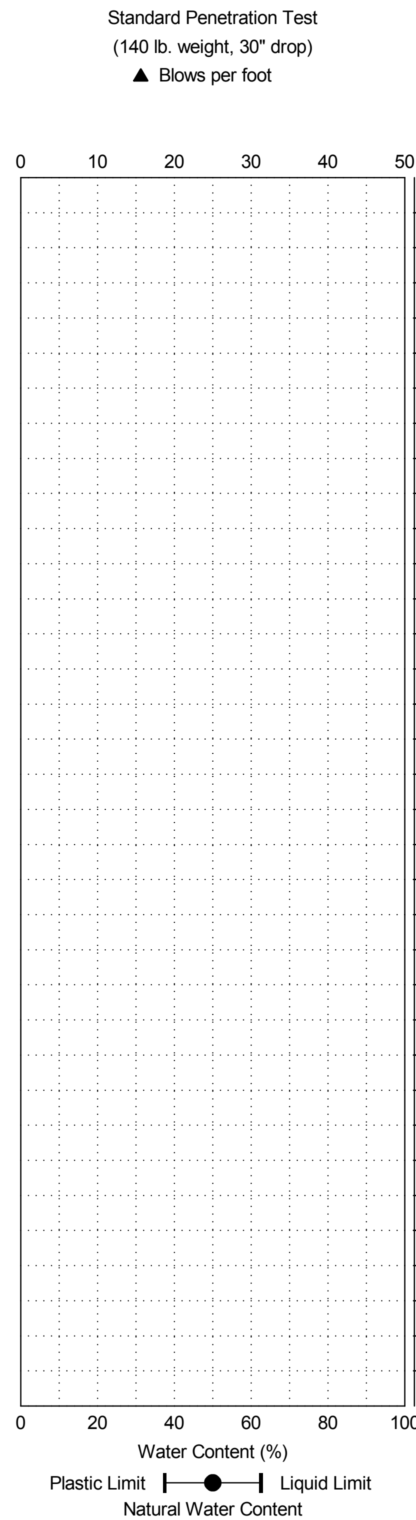
PROJECT NO.: 2017-096-21 FIGURE: A-8

BORING-DSM 2017-096-21.GPJ 2/15/19

DRILLING COMPANY: Geologic Drill, Inc.
DRILLING METHOD: HSA, Bobcat minitrack
SAMPLING METHOD: SPT w/ cathead
LOCATION: See Figure 2

DATE STARTED: 9/17/2018
DATE COMPLETED: 9/17/2018
LOGGED BY: S. King
SURFACE ELEVATION: 200.0 ± feet

DEPTH (feet)	SYMBOL	USCS SOIL CLASS	DESCRIPTION	SAMPLE TYPE	SAMPLE NUMBER	PEN. RESISTANCE (blows/6 inches)	OTHER TESTS	GROUNDWATER	ELEVATION (feet)
0		SM	Loose, light olive-brown, silty SAND, moist. **(FILL)**						200
			Borehole abandoned at 2.5 feet due to refusal on quarry spalls. No ground water encountered during drilling.						
5									195
10									190
15									185
20									180
25									175
30									170
35									



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.

HIDDEN LAKE DAM REMOVAL
AND STREAM RESTORATION PROJECT
SHORELINE, WASHINGTON

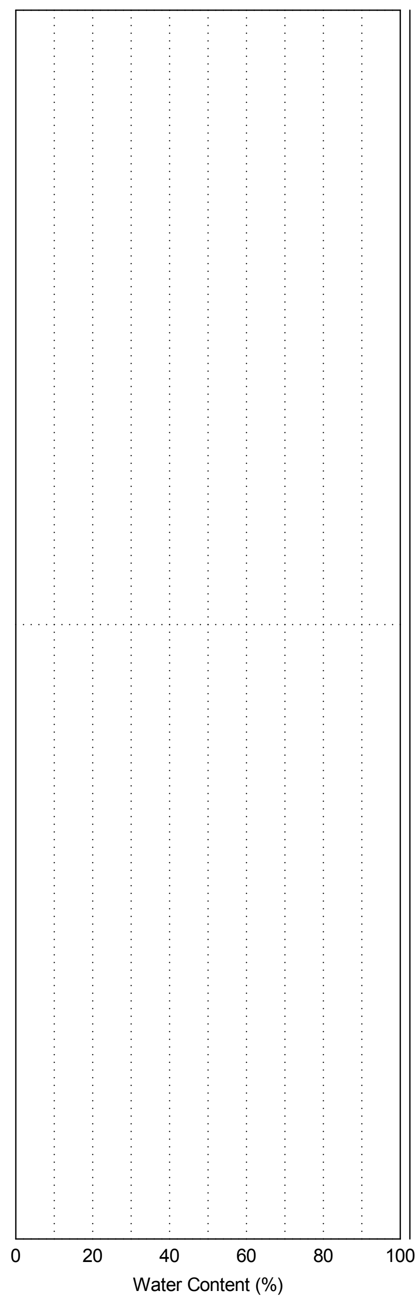
BORING:
BH-7

PROJECT NO.: 2017-096-21 FIGURE: A-9

DRILLING COMPANY: HWA GeoSciences Inc.
DRILLING METHOD: Hand Tools
SAMPLING METHOD: Grab
LOCATION: Outcrop, E of stream

DATE STARTED: 8/12/2019
DATE COMPLETED: 8/12/2019
LOGGED BY: B. Thurber/ Z. Ngoma

DEPTH (feet)	SYMBOL	USCS SOIL CLASS	DESCRIPTION	SAMPLE TYPE	SAMPLE NUMBER	PEN. RESISTANCE (blows/6 inches)	OTHER TESTS	GROUNDWATER	ELEVATION (feet)
0		CL	Hard, olive brown and gray, laminated CLAY with silt interbeds, moist. **(GLACIOLACUSTRINE)**		S-1		Ph Res		
			Sample of face of near-vertical outcrop.						
5									
10									



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.

HIDDEN LAKE DAM REMOVAL
AND STREAM RESTORATION PROJECT
SHORELINE, WASHINGTON

HAND HOLE:
HH-1

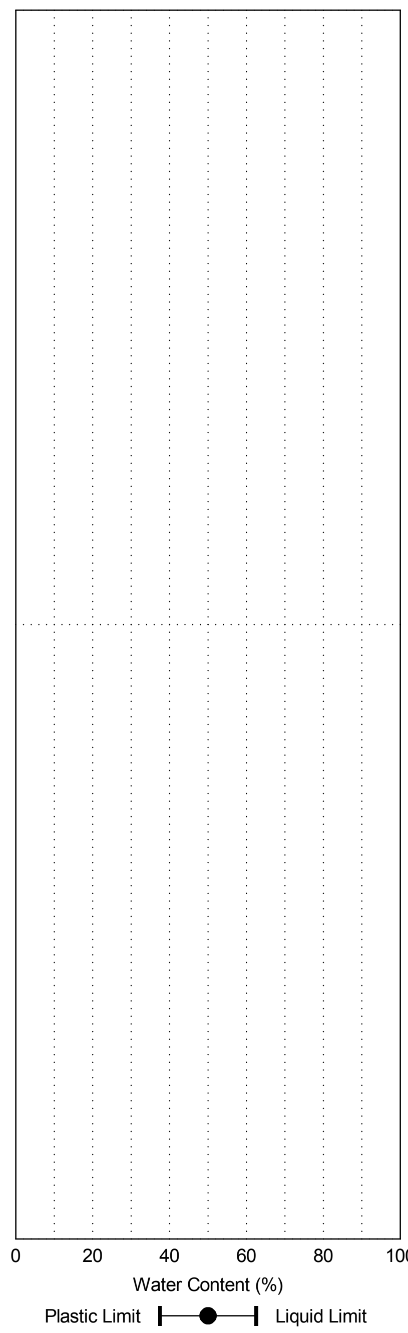
PROJECT NO.: 2017-096-21 FIGURE: A-10

DRILLING COMPANY: HWA GeoSciences Inc.
DRILLING METHOD: Hand Tools
SAMPLING METHOD: Grab
LOCATION: N. shoulder of road, W. of stream

DATE STARTED: 8/12/2019
DATE COMPLETED: 8/12/2019
LOGGED BY: B. Thurber/ Z. Ngoma

DEPTH (feet)	SYMBOL	USCS SOIL CLASS	DESCRIPTION	SAMPLE TYPE	SAMPLE NUMBER	PEN. RESISTANCE (blows/6 inches)	OTHER TESTS	GROUNDWATER	ELEVATION (feet)
0			Duff and crushed rock.						
		SM	Medium dense, olive brown, silty, gravelly, fine to medium SAND, moist. **(FILL)**						
				◯	S-1				
		SP SM	Grades to slightly silty.						
5				◯	S-2				
			Becomes wet below 5.8 feet.					∇	
		SM	Medium dense, olive brown, slightly silty to silty, gravelly, fine to medium SAND, wet.	◯	S-3				
		SM	Medium dense, grayish brown, slightly gravelly, silty, fine to medium SAND, wet.	◯	S-4		Ph Res		
10									

Handhole terminated at 8 feet due to caving / running sand filling to 7.1 feet.
Moderate ground water seepage below 5.8 feet.



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.

HIDDEN LAKE DAM REMOVAL
AND STREAM RESTORATION PROJECT
SHORELINE, WASHINGTON

HAND HOLE:
HH-2

PROJECT NO.: 2017-096-21 FIGURE: A-11

DRILLING COMPANY: HWA GeoSciences Inc.
DRILLING METHOD: Hand Tools
SAMPLING METHOD: Grab
LOCATION: S. shoulder of road, E. of stream

DATE STARTED: 8/12/2019
DATE COMPLETED: 8/12/2019
LOGGED BY: B. Thurber/ Z. Ngoma

DEPTH (feet)	SYMBOL	USCS SOIL CLASS	DESCRIPTION	SAMPLE TYPE	SAMPLE NUMBER	PEN. RESISTANCE (blows/6 inches)	OTHER TESTS	GROUNDWATER	ELEVATION (feet)
0		ML	Duff and crushed rock.						
		SM	Dense, light brown, gravelly, sandy SILT, dry. Hard digging. **(FILL)**						
		SM	Medium dense, brown, gravelly, silty, fine to medium SAND, moist.		S-1				
		CL	Very stiff, gray, silty CLAY, moist.						
		SM	Medium dense, gray, slightly gravelly, silty, fine to medium SAND, moist.		S-2				
5									
			Becomes wet below 7.1 feet.		S-3			∇	
		SP SM	Medium dense, dark yellow brown, slightly gravelly, slightly silty, fine to medium SAND, wet. Scattered wood fragments up to 1-inch diameter.		S-4				
					S-5		Ph Res		
10									

Handhole terminated at 8.8 feet due to refusal on rock.
Moderate ground water seepage below 7.1 feet.

0 20 40 60 80 100
Water Content (%)
Plastic Limit ├─●─┤ Liquid Limit
Natural Water Content

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.

HIDDEN LAKE DAM REMOVAL
AND STREAM RESTORATION PROJECT
SHORELINE, WASHINGTON

HAND HOLE:
HH-3

PAGE: 1 of 1

PROJECT NO.: 2017-096-21 FIGURE: A-12

DRILLING COMPANY: HWA GeoSciences Inc.
DRILLING METHOD: Hand Tools
SAMPLING METHOD: Grab
LOCATION: Toe of streambank at dam culvert outlet

DATE STARTED: 8/15/2019
DATE COMPLETED: 8/15/2019
LOGGED BY: B. Thurber/ Z. Ngoma

DEPTH (feet)	SYMBOL	USCS SOIL CLASS	DESCRIPTION	SAMPLE TYPE	SAMPLE NUMBER	PEN. RESISTANCE (blows/6 inches)	OTHER TESTS	GROUNDWATER	ELEVATION (feet)
0		CL	Hard, olive brown (to <1") then gray, CLAY, moist. **(GLACIOLACUSTRINE)**						
					S-1		Ph Res		
			Handhole terminated at 3.5 feet. No ground water seepage.						
5									
10									

Water Content (%): 0 20 40 60 80 100

Plastic Limit — Natural Water Content — Liquid Limit

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.

HIDDEN LAKE DAM REMOVAL
AND STREAM RESTORATION PROJECT
SHORELINE, WASHINGTON

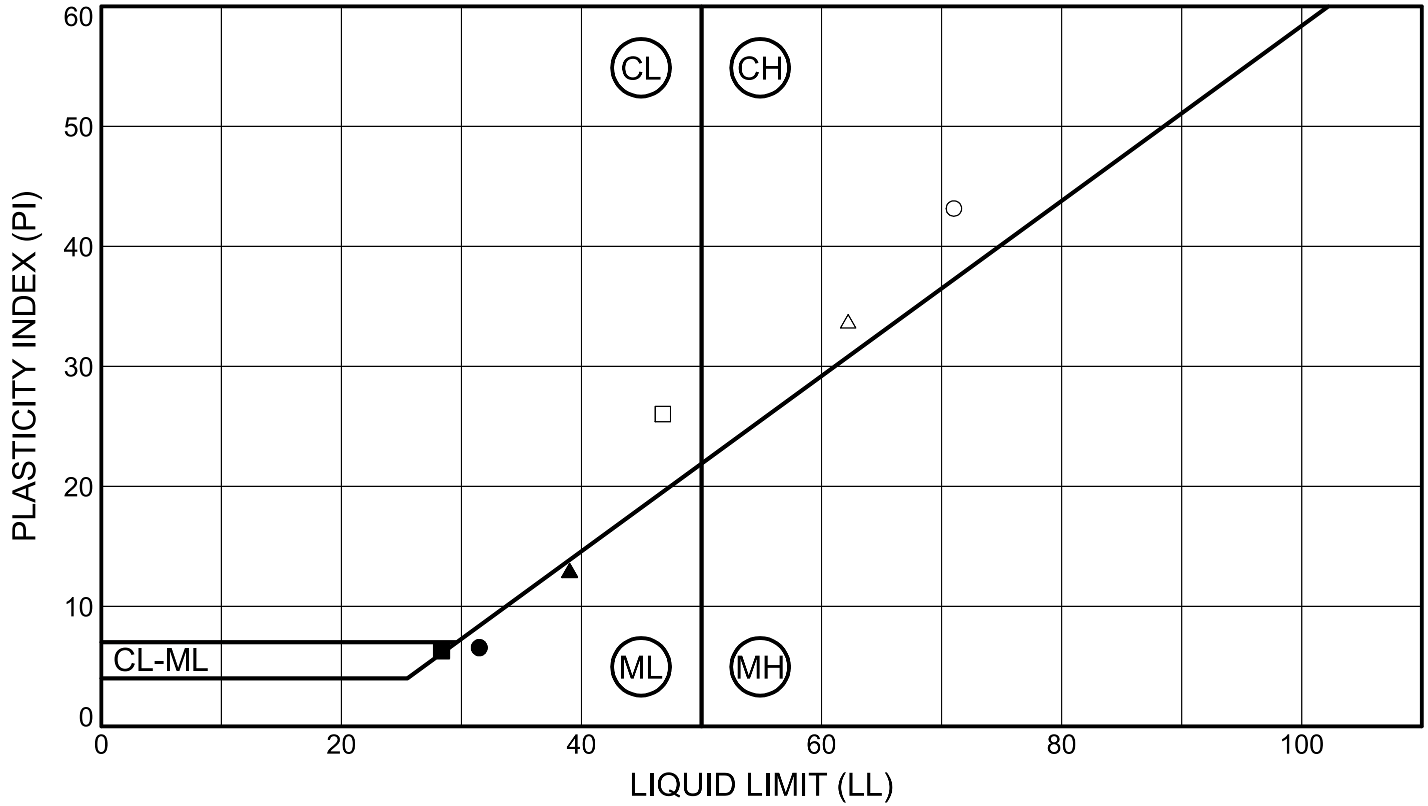
HAND HOLE:
HH-4

PAGE: 1 of 1

PROJECT NO.: 2017-096-21 FIGURE: A-13

APPENDIX B

LABORATORY INVESTIGATION



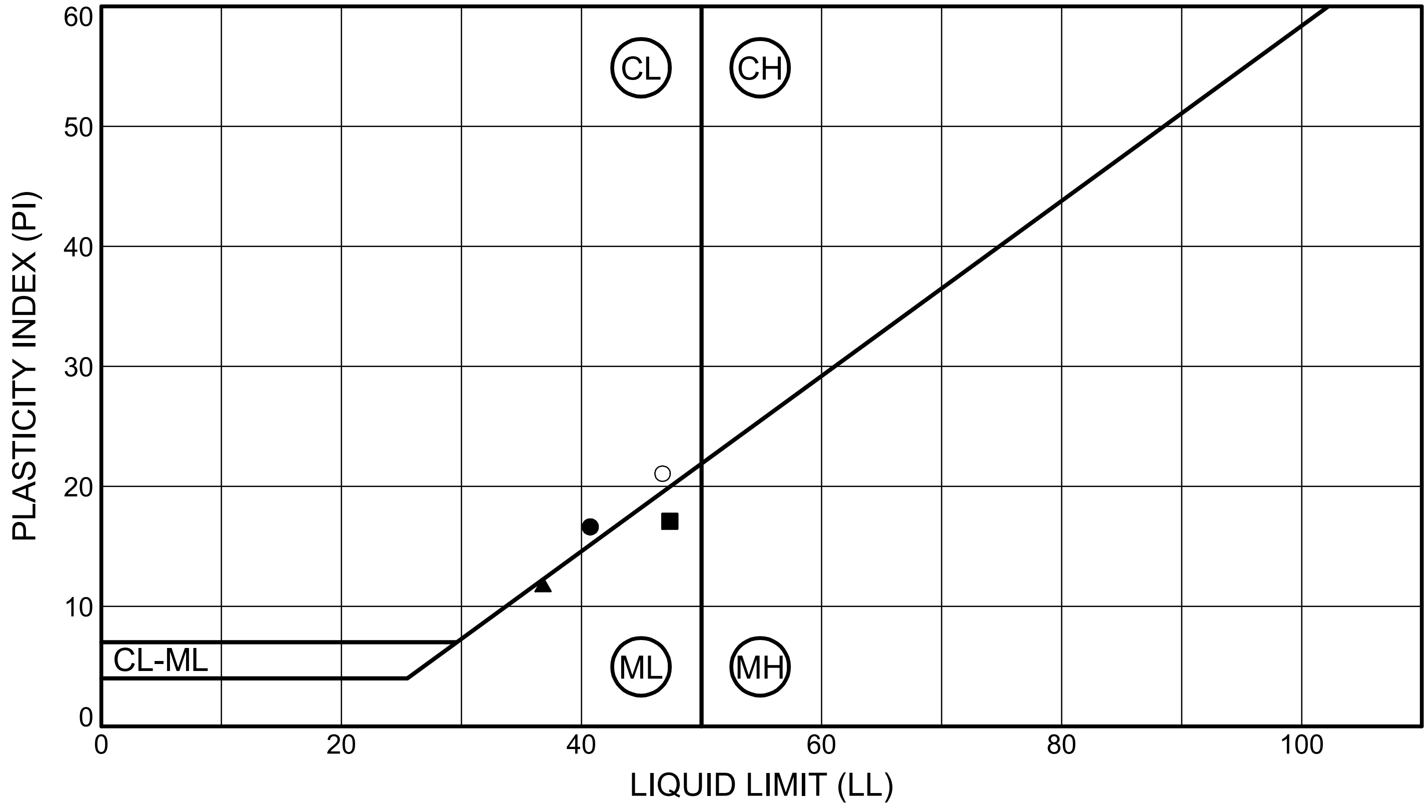
SYMBOL	SAMPLE		DEPTH (ft)	CLASSIFICATION	% MC	LL	PL	PI	% Fines
●	BH-1	S-2b	5.7 - 6.5	(ML) Dark gray, SILT	27	31	25	6	
■	BH-2	S-3	5.0 - 6.5	(CL-ML) Dark olive-gray, silty CLAY	29	28	22	6	
▲	BH-2	S-5	10.0 - 11.5	(ML) Dark gray, SILT	27	39	26	13	
○	BH-3	S-11	32.5 - 34.0	(CH) Dark gray, fat CLAY	32	71	28	43	
□	BH-4	S-11	27.5 - 29.0	(CL) Dark gray, lean CLAY	28	47	21	26	
△	BH-5	S-4	12.5 - 14.0	(CH) Dark grayish-brown, fat CLAY	28	62	28	34	

HWA GEOSCIENCES INC.

HIDDEN LAKE DAM REMOVAL
AND STREAM RESTORATION PROJECT
SHORELINE, WASHINGTON

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

PROJECT NO.: 2017-096-21 FIGURE: B-1



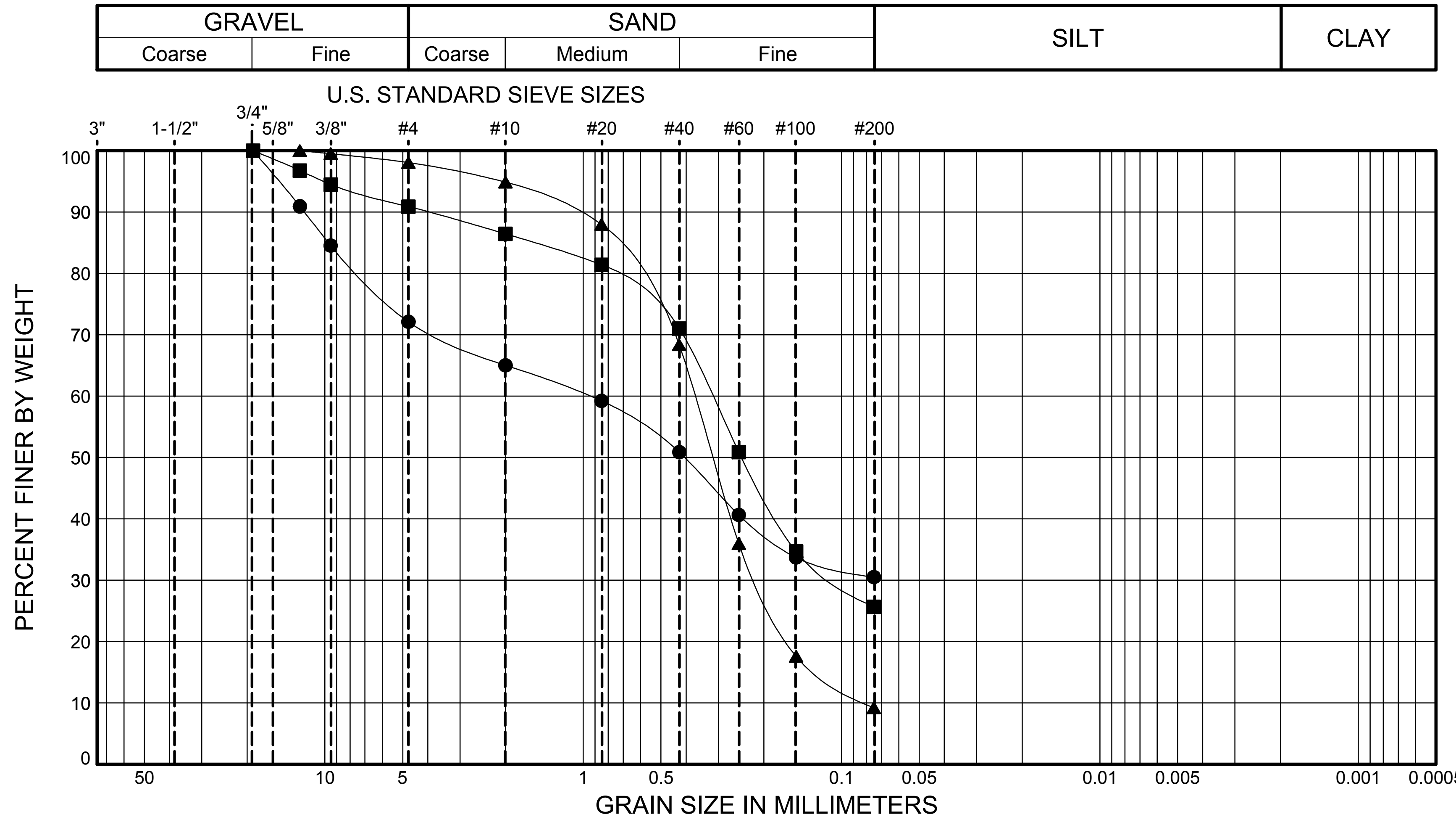
SYMBOL	SAMPLE		DEPTH (ft)	CLASSIFICATION	% MC	LL	PL	PI	% Fines
●	BH-5	S-8	22.5 - 24.0	(CL) Dark grayish-brown, lean CLAY	28	41	24	17	
■	BH-5	S-10	27.5 - 29.0	(ML) Grayish-brown, SILT	31	47	30	17	
▲	BH-6	S-8	20.0 - 21.5	(ML) Grayish-brown, SILT	30	37	25	12	
○	BH-6	S-12	30.0 - 31.5	(CL) Dark gray, lean CLAY	32	47	26	21	

HWA GEOSCIENCES INC.

HIDDEN LAKE DAM REMOVAL
AND STREAM RESTORATION PROJECT
SHORELINE, WASHINGTON

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

PROJECT NO.: 2017-096-21 FIGURE: B-2



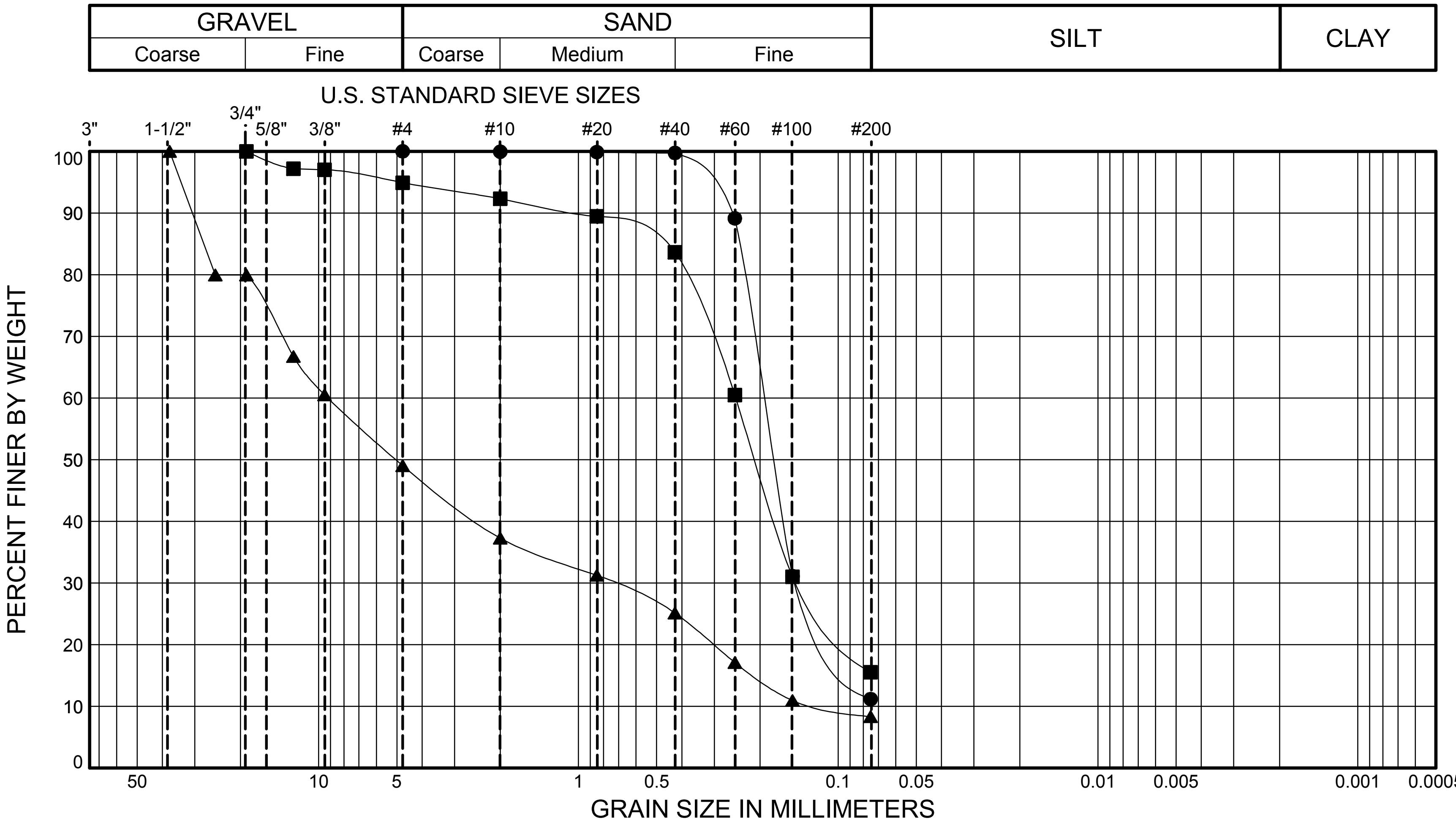
SYMBOL	SAMPLE		DEPTH (ft.)	CLASSIFICATION OF SOIL- ASTM D2487 Group Symbol and Name	% MC	LL	PL	PI	Gravel %	Sand %	Fines %
●	BH-2	S-2	2.5 - 4.0	(SM) Grayish-brown, silty SAND with gravel	24				27.9	41.6	30.5
■	BH-3	S-2	5.0 - 6.5	(SM) Olive brown, silty SAND	12				9.1	65.2	25.7
▲	BH-3	S-5	12.5 - 14.0	(SP-SM) Grayish brown, poorly graded SAND with silt	22				2.0	88.8	9.2

HWA GEOSCIENCES INC.

HIDDEN LAKE DAM REMOVAL
AND STREAM RESTORATION PROJECT
SHORELINE, WASHINGTON

PARTICLE-SIZE ANALYSIS OF SOILS METHOD ASTM D6913

PROJECT NO.: 2017-096-21 FIGURE: B-3



SYMBOL	SAMPLE		DEPTH (ft.)	CLASSIFICATION OF SOIL- ASTM D2487 Group Symbol and Name	% MC	LL	PL	PI	Gravel %	Sand %	Fines %
●	BH-3	S-14a	47.5 - 47.7	(SP-SM) Grayish brown, poorly graded SAND with silt	27					88.8	11.2
■	BH-4	S-4	10.0 - 11.5	(SM) Grayish brown, silty SAND	19				5.1	79.4	15.5
▲	BH-4	S-10	25.0 - 26.5	(GP-GM) Grayish brown, poorly graded GRAVEL with silt and sand	13				51.0	40.7	8.3

HWA GEOSCIENCES INC.

HIDDEN LAKE DAM REMOVAL
AND STREAM RESTORATION PROJECT
SHORELINE, WASHINGTON

PARTICLE-SIZE ANALYSIS
OF SOILS
METHOD ASTM D6913

PROJECT NO.: 2017-096-21 FIGURE: B-4

APPENDIX C
SITE PLAN, CROSS-SECTION AND BORINGS FROM PERRONE 2015

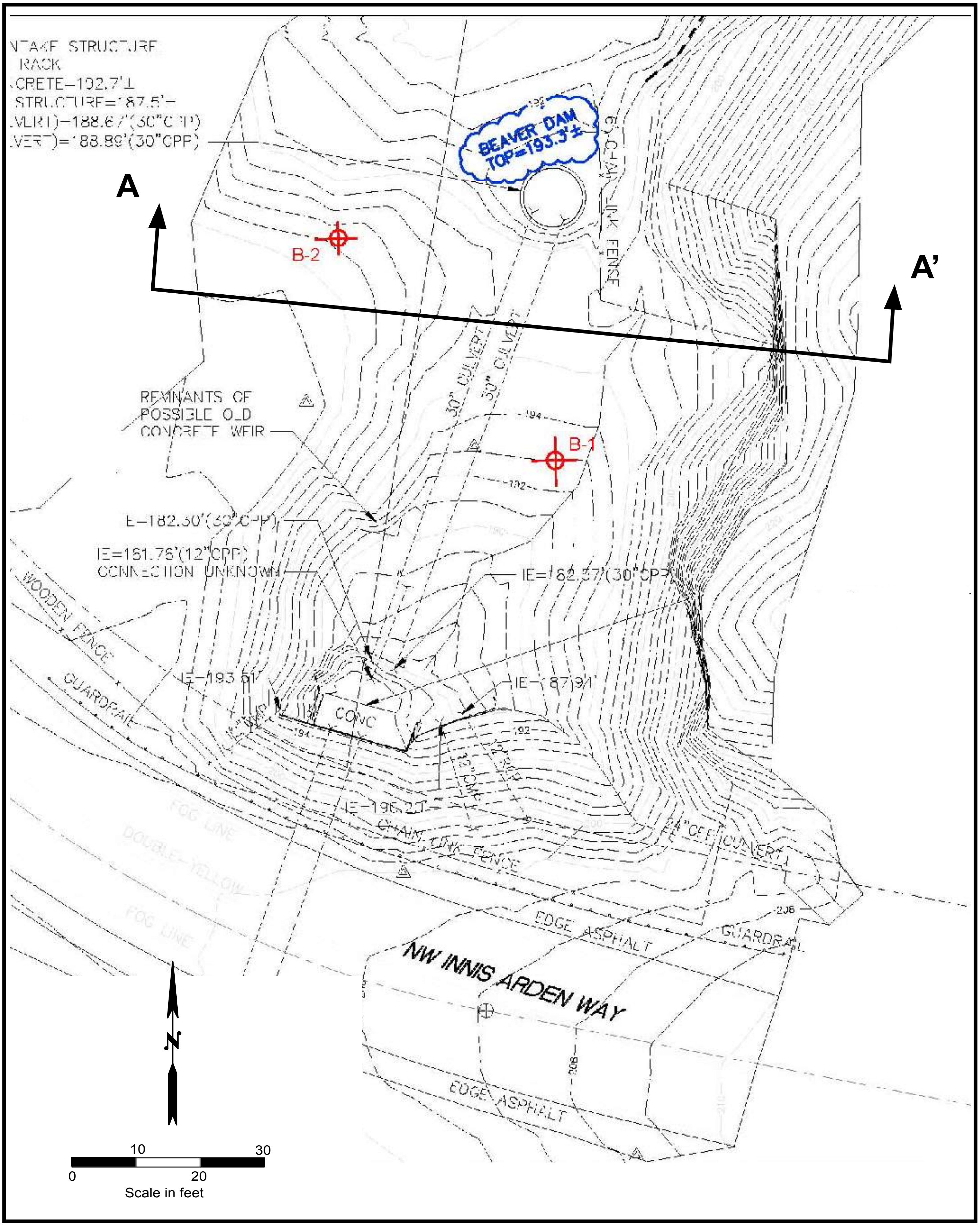


FIGURE 1
Site Plan

October 2015

PERRONE CONSULTING, INC., P.S.
Project No. 15126

Hidden Lake Dam Removal
for Herrera Environmental Consultants

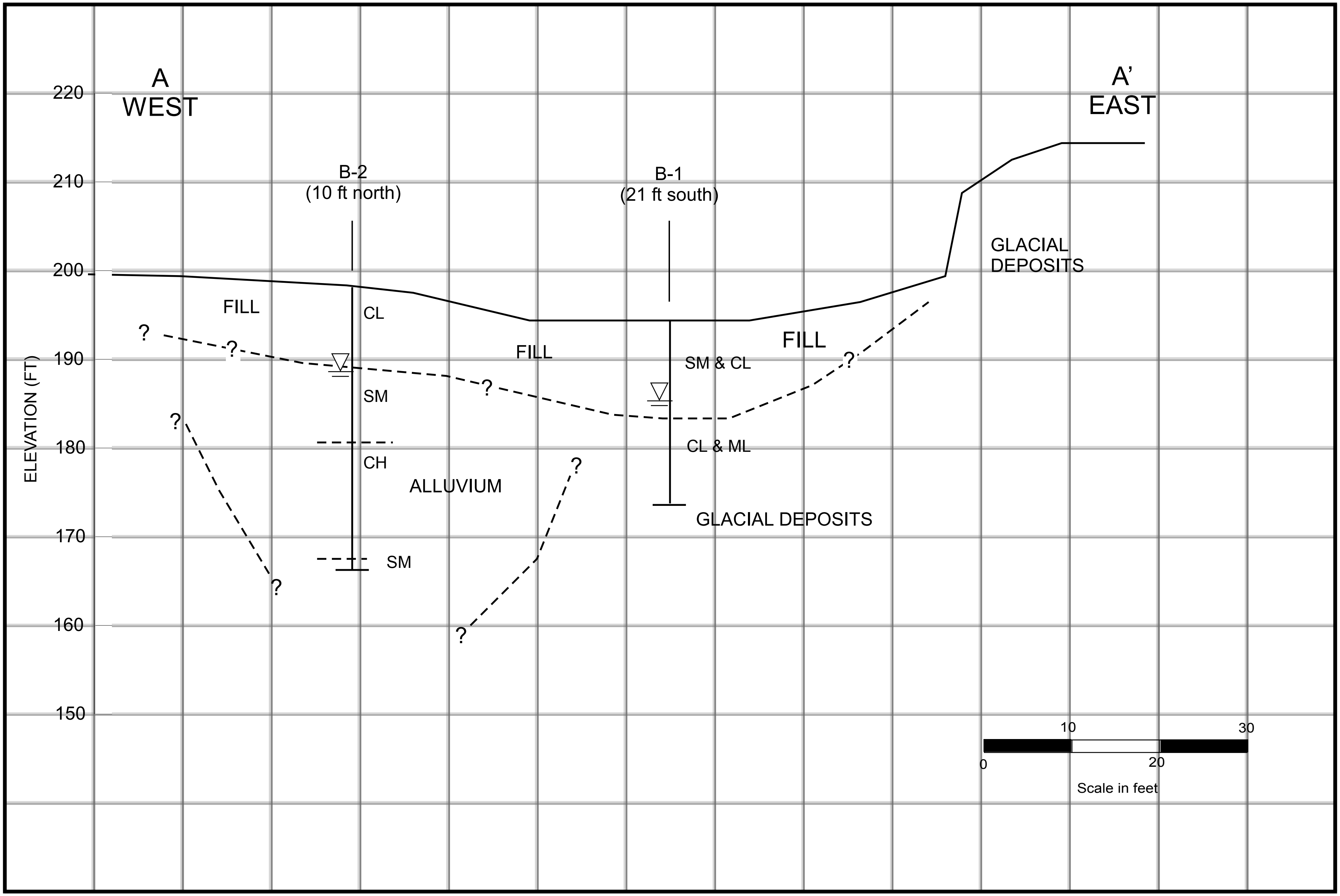


FIGURE 2
Subsurface Profile Section A-A'

October 2015

PERRONE CONSULTING, INC., P.S.
Project No. 15126

Hidden Lake Dam Removal
for Herrera Environmental Consultants

PERRONE CONSULTING, INC.
11220 Fieldstone Lane NE
Bainbridge Island, WA 98110
Telephone: (206) 778-8074

Key to Log of Boring

Project: Hidden Lake Dam Removal
Shoreline, Washington

UNIFIED SOIL CLASSIFICATION SYSTEM AND SYMBOL CHART

MAJOR DIVISIONS			SYMBOLS	DESCRIPTIONS
COARSE GRAINED SOILS MORE THAN 50% OF MATERIAL COARSER THAN NO. 200 SIEVE SIZE	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, little or no fines
			GP	Poorly graded gravels, gravel-sand mixtures, little or no fines
		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, little or no fines
			SP	Poorly graded sands, gravelly sands, little or no fines
		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% OF MATERIAL FINER THAN NO. 200 SIEVE SIZE	SILTS AND CLAYS	LIQUID LIMIT LESS THAN 50	ML	Inorganic silts, very fine sands, rock flour, silty/clayey fine sands or clayey silts of 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 fine sandy or silty soils, elastic silt
			CH	Inorganic clays of high plasticity, fat clays
			OH	Organic clays of medium to high plasticity, organic silts
HIGHLY ORGANIC SOILS			PT	Peat, humus, swamp soils with high organic content

NOTE: DUAL SYMBOLS USED FOR BORDERLINE CLASSIFICATIONS

Abbreviations

AL	Atterberg Limits
C	Consolidation
DS	Direct Shear
HA	Hydrometer Analysis
LL	Liquid Limit
LV	Laboratory Vane Shear
N	Number of hammer blows for last 12 inches driven
OVA	Organic Vapor Analyzer
Pc	Constant Head Permeability
Pf	Falling Head Permeability
PI	Plasticity Index
PP	Pocket Penetrometer
SA	Sieve Analysis
SG	Specific Gravity
TV	Torvane Shear
TX	Triaxial Shear

Sampler Symbols

- 2-inch-O.D. Split Spoon Sampler Driven with 140-lb Hammer and 30-inch Drop (SPT)
- 3-inch-O.D. Split Spoon Sampler with Brass Rings Driven with 140-lb Hammer and 30-inch Drop
- 2-inch-O.D. Split Spoon Sampler Driven with 140-lb Hammer and 18-inch Drop
- Grab Sample
- 3-inch-O.D. Shelby Tube Sampler

Piezometer Symbols

- Pipe in cement grout
- Pipe in filter pack
- Pipe in bentonite-cement
- Slotted pipe in filter pack
- Pipe in bentonite seal
- Vibrating wire piezometer

Blow Count / Density and Consistency Relationship

Coarse-Grained Soils		Fine-Grained Soils	
Relative Density	N, SPT Blows / Foot	Relative Consistency	N, SPT Blows / Foot
Very loose	0 - 4	Very soft	<2
Loose	5 - 10	Soft	2 - 4
Medium dense	11 - 30	Medium stiff	5 - 8
Dense	31 - 50	Stiff	9 - 15
Very dense	>50	Very Stiff	16 - 30
		Hard	>30

Groundwater Level Symbols

- Water level at time of drilling (ATD)
- Water level measured in piezometer

Minor Descriptors

Trace clay, silt, sand, gravel	<5%
Few clay, silt, sand, gravel	5 - 10%
Little clay, silt, sand, gravel	15 - 25%
Some clay, silt, sand, gravel	30 - 45%

Moisture Content

Dry	Absence of moisture, dusty
Moist	Damp but no visible water
Wet	Visible free water, from below the water table

General Notes

1. Descriptions and stratum lines are interpretive; field descriptions may have been modified to reflect lab test results. Descriptions on these logs apply only at the specific boring locations and at the time the borings were advanced; they are not warranted to be representative of subsurface conditions at other locations or times.

2. Soil descriptions are recorded in the following order: SOIL CLASSIFICATION (USCS Symbol), relative density or consistency, color, moisture, plasticity or gradation, angularity, minor constituents, additional comments (organics, odor, etc.) [GEOLOGIC UNIT].

PERRONE CONSULTING, INC.
11220 Fieldstone Lane NE
Bainbridge Island, WA 98110
Telephone: (206) 778-8074

Log of Boring B-1

Project: Hidden Lake Dam Removal
Shoreline, Washington

Borehole Location: **41 feet due south of dam outlet structure**
Drilling Contractor: **Geologic Drill Exploration, Inc.**
Drilling Method: **Hollow-Stem Auger**
Drill Rig Type: **Diedrich D-50 with 7-inch-OD auger**

Date(s) Drilled: **September 1, 2015**
Logged By: **V. J. Perrone**
Total Depth of Borehole: **19.0 feet**
Surface Elevation / Datum: **193 ft / NAVD88**

Elevation, feet	Depth, feet	Samples: Type / Number	Samples: Blows per 6 inches (N)	Samples: Recovery, %	MATERIAL DESCRIPTION	Lab Tests	Moisture Content, %	Dry Unit Weight, pcf	REMARKS
193	0				Organic forest duff				
					COBBLES to 6 inches, angular [FILL]				
					POORLY GRADED SAND WITH SILT (SP-SM), brownish gray, moist, fine to medium sand, few fines [FILL]				
190		1	8-12-14 (26)	44	LEAN CLAY (CL), very stiff, gray, moist [FILL]				
					SILTY SAND WITH GRAVEL (SM), medium dense, gray, moist, fine to coarse sand, some angular gravel, little fines [FILL]				
	5	2	6-8-8 (16)	33					
					SANDY LEAN CLAY WITH GRAVEL (CL), very stiff, gray, moist, little fine to coarse sand, little angular gravel [FILL]				
185		3	9-8-10 (18)	17					Redrive 7.5-10 ft with D&M sampler; piece of wire in sample. Drive another D&M 10-11 ft for more sample; recover 12 inches of pea gravel (slough?).
		3A		33	Becomes brown, wet, increased gravel				
	10	4	6-12-14 (26)	67	LEAN CLAY (CL), hard, gray, moist [GLACIAL DEPOSIT]				PP>4.5 tsf
180		5	10-13-17 (30)	67	SILT (ML), very stiff to hard, gray, moist, nonplastic, massive [GLACIAL DEPOSIT]				
	15								
175		6	10-14-18 (32)	100	LEAN CLAY (CL), hard, gray, moist [GLACIAL DEPOSIT]				PP>4.5 tsf
					Bottom of boring at depth of 19.0 feet				
	20				**Groundwater level at 9.1 feet in open hole after drilling.**				
					Borehole backfilled with bentonite chips.				
170									
	25								
165									
	30								

PERRONE CONSULTING, INC.
11220 Fieldstone Lane NE
Bainbridge Island, WA 98110
Telephone: (206) 778-8074

Log of Boring B-2

Project: Hidden Lake Dam Removal Shoreline, Washington

Borehole Location: **7 feet south, 33 feet west of dam outlet structure**
Drilling Contractor: **Geologic Drill Exploration, Inc.**
Drilling Method: **Hollow-Stem Auger**
Drill Rig Type: **Diedrich D-50 with 7-inch-OD auger**

Date(s) Drilled: **September 1, 2015**
Logged By: **V. J. Perrone**
Total Depth of Borehole: **31.5 feet**
Surface Elevation / Datum: **198 ft / NAVD88**

Elevation, feet	Depth, feet	SAMPLES: Type	SAMPLES: Number	SAMPLES: Blows per 6 inches (N)	SAMPLES: Recovery, %	Graphic Log	MATERIAL DESCRIPTION	Lab Tests	Moisture Content, %	Dry Unit Weight, pcf	REMARKS
	0						Organic forest duff				
							SILTY SAND WITH GRAVEL (SM) [FILL]				Near-surface soil logged from cuttings.
							SANDY LEAN CLAY (CL), medium stiff, brownish gray, moist, low to medium plasticity, little fine to coarse sand, few gravel [FILL]				
195			1	4-3-3 (6)	100						
	5						Becomes stiff, with trace organic pieces				
			2	4-5-5 (10)	100						
190			3	4-5-6 (11)	100						
							SILTY SAND (SM), very loose, gray, wet, fine sand, some fines [ALLUVIUM]				
	10		4	2-1-1 (2)	100						
							Becomes loose, fine to medium sand, little fines				
185			5	3-2-3 (5)	56						
	15		6	5-4-4 (8)	78						
							Tree root in tip of sampler				
							FAT CLAY WITH SAND (CH), very stiff, gray, moist, little sand and gravel [ALLUVIUM]				
180			7	1-2-4 (6)	67						PP=2.5 tsf
							Becomes medium stiff to stiff, no gravel				
	20		8	1-2-2 (4)	100						PP=0.75 tsf
											PP=1.5 tsf
175											
	25						Becomes soft				
			9	2-4-1 (5)	89						PP=0.25 tsf
							Wood in sampler shoe				
170											
	30						Becomes stiff				

Report: VP SOIL LOG; File: HIDDENLAKE.GPJ; PCI #15126; 10/3/15

Elevation, feet	Depth, feet	SAMPLES Type	Number	Blows per 6 inches (N)	Recovery, %	Graphic Log	MATERIAL DESCRIPTION	Lab Tests	Moisture Content, %	Dry Unit Weight, pcf	REMARKS
	30						FAT CLAY WITH SAND (CH) [ALLUVIUM] (continued)				PP=1.5 tsf
			10	4-7-12 (19)	100		SILTY SAND (SM), medium dense, gray, moist, fine sand [ALLUVIUM]				
							Bottom of boring at depth of 31.5 feet **Groundwater not encountered at time of drilling.** **Borehole backfilled with bentonite chips.**				
165											
	35										
160											
	40										
155											
	45										
150											
	50										
145											
	55										
140											
	60										
135											
	65										

APPENDIX D

SITE PLAN, CROSS-SECTION, BORINGS AND HANDHOLES FROM SHANNON AND WILSON 1995

7/9

W-7022-03

4180

– FILE COPY – PLEASE RETURN

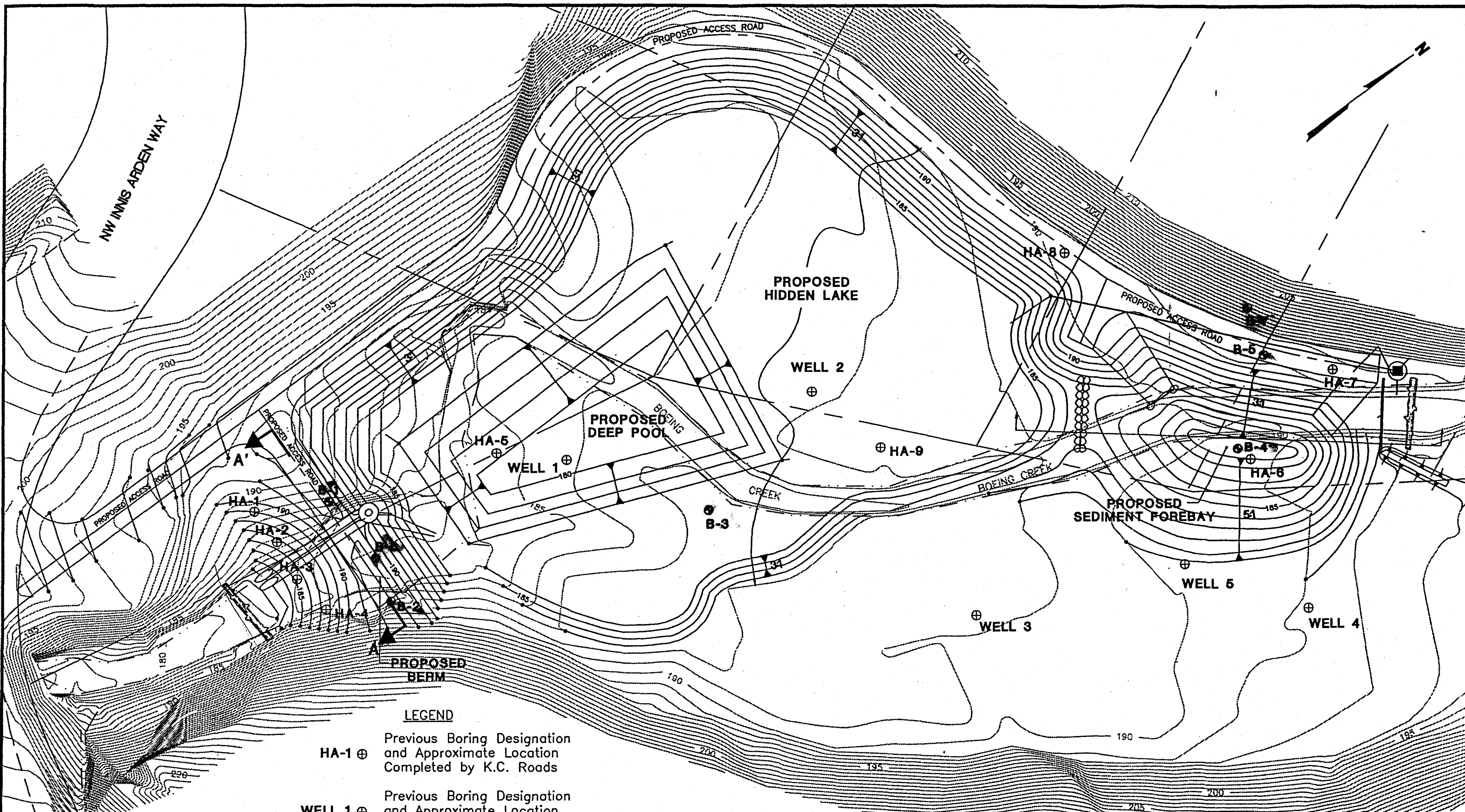
Geotechnical Engineering Report
Hidden Lake Restoration Project
King County, Washington

September 1995

Tim Kelly

R. W. Beck
2101 Fourth Avenue, Suite 600
Seattle, Washington 98121-2375

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS
400 N. 34th St. • Suite 100
P.O. Box 300303
Seattle, Washington 98103
206 • 632 • 8020



LEGEND

HA-1 ⊕ Previous Boring Designation and Approximate Location Completed by K.C. Roads

WELL 1 ⊕ Previous Boring Designation and Approximate Location Completed by SWM

B-1 Current Boring Designation and Approximate Location Completed by Shannon & Wilson, Inc.

A Generalized Subsurface Profile (See Figure 3)

0 40 80

Scale in Feet

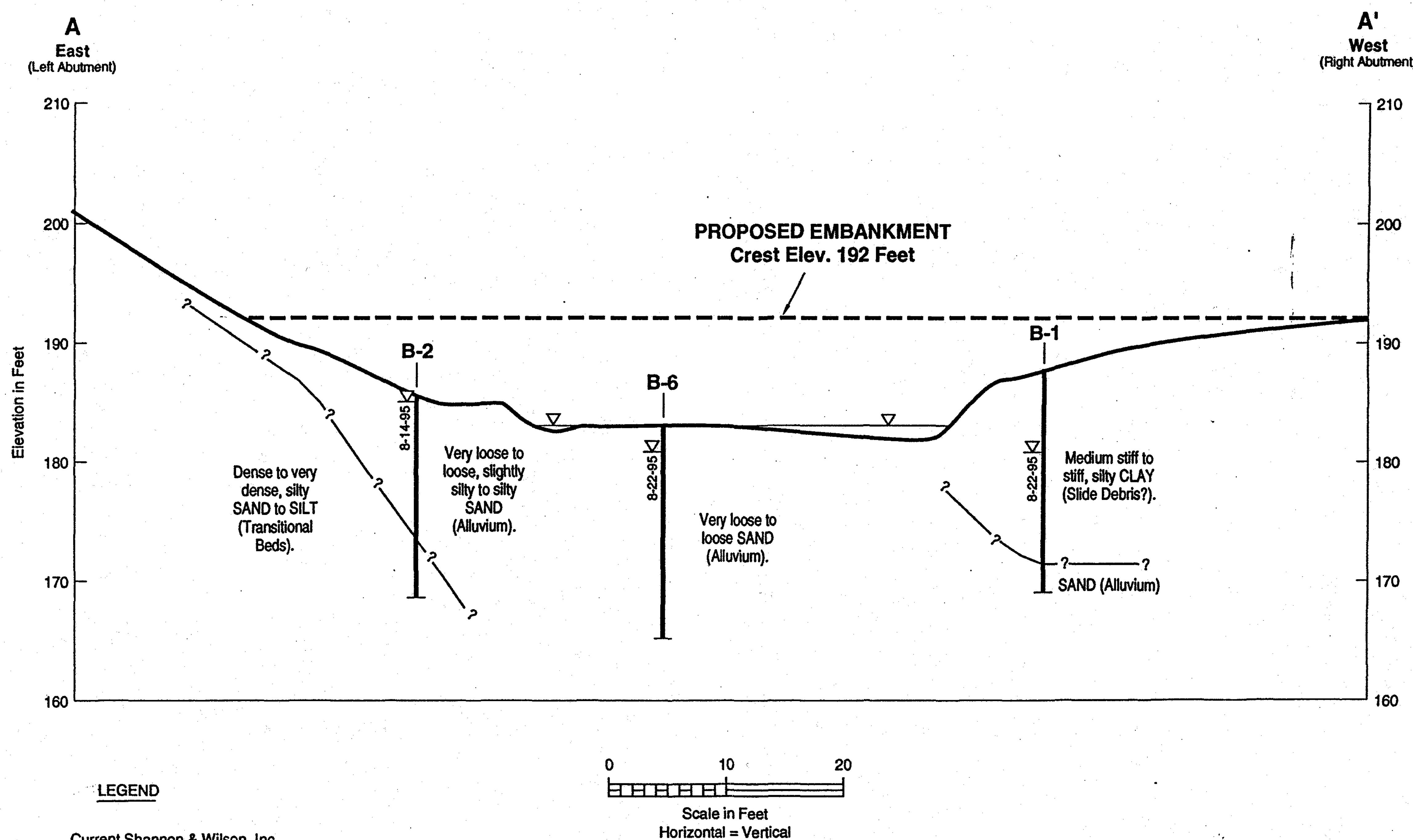
Hidden Lake Restoration Project
King County, Washington

SITE AND EXPLORATION PLAN

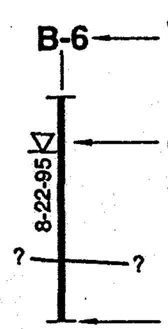
August 1995 W-7022-03

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. 2



LEGEND



- B-6 — Current Shannon & Wilson, Inc. Boring Location and Designation
- Groundwater Level and Date Recorded
- ? — ? Approximate Geologic Contact
- Bottom of Boring

NOTES

1. The profiles are generalized from materials encountered in the borings. Variations between the profiles and actual conditions may exist.
2. For clarity, the exploration logs shown on the profiles have been abbreviated and simplified. For detailed logs, see Appendix A.

Hidden Lake Restoration Project King County, Washington	
GENERALIZED SUBSURFACE PROFILE ALONG BERM ℄	
September 1995	W-7022-03
SHANNON & WILSON, INC. Geotechnical and Environmental Consultants	**FIG. 3**

APPENDIX A

FIELD EXPLORATION AND TESTING PROGRAM

A.1 GENERAL

The field program for this project consisted of drilling seven borings, installing three observation wells, and performing field permeability tests in these wells. A description of the procedures associated with each of these activities is described in the following sections.

A.2 BORINGS

Subsurface conditions were explored by drilling seven borings at the approximate locations shown on the Site and Exploration Plan, Figure 2. The borings were drilled on August 14, 15, 22, and 23, 1995, and advanced to depths ranging from 10.7 to 18.5 feet below the existing ground surface. Many of the borings encountered wood, resulting in drilling refusal. Three borings, B-1, B-4, and B-6, were moved short distances and redrilled in an attempt to avoid the obstructions.

Six borings were drilled by CN Drilling, Inc. of Seattle, Washington, under subcontract to Shannon & Wilson, Inc. The borings were accomplished using a hand-operated Acker Soil Mechanic drill rig and hollow-stem augers. The seventh boring (B-7) was completed without sampling by Shannon & Wilson, Inc. personnel using hand auger equipment.

Standard Penetration Tests (SPTs) were performed in the borings at 2.5- to 5-foot intervals. The tests were performed in general accordance with ASTM Designation: D 1586. The SPT consisted of driving a 2-inch outside diameter (O.D.) split-spoon sampler a distance of 18 inches into the bottom of the borehole with a 140-pound hammer falling 30 inches. The number of blows required to drive the sampler each of three 6-inch increments was recorded, and number of blows required to cause the last 12 inches of penetration was termed the Standard Penetration Resistance (N-value). This value is an indicator of the relative density or consistency of the soils. Samples recovered from the split spoon sampler were disturbed but representative of the soils encountered.

Samples obtained in the field were classified by a geologist, sealed in glass jars, and returned to our laboratory for further observation and testing. Visual classification was based on ASTM Designations: D 2487 and D 2488. Figure A-1 presents a Soil Classification and Log Key for an explanation of the descriptions used on the boring logs. Logs of the borings are presented as Figures A-2 through A-8, which represent our interpretation of the contents of the field logs and the results of laboratory testing.

The locations of the explorations were obtained by tape measurement and pacing from existing topographic and physical features. The ground surface elevation at the exploration locations, as presented on the logs, was approximately determined to the nearest foot using the topography mapping provided by SWM (see Figure 2). The location and elevation of the explorations should be considered accurate to the degree implied by the method used.

A.3 OBSERVATION WELLS

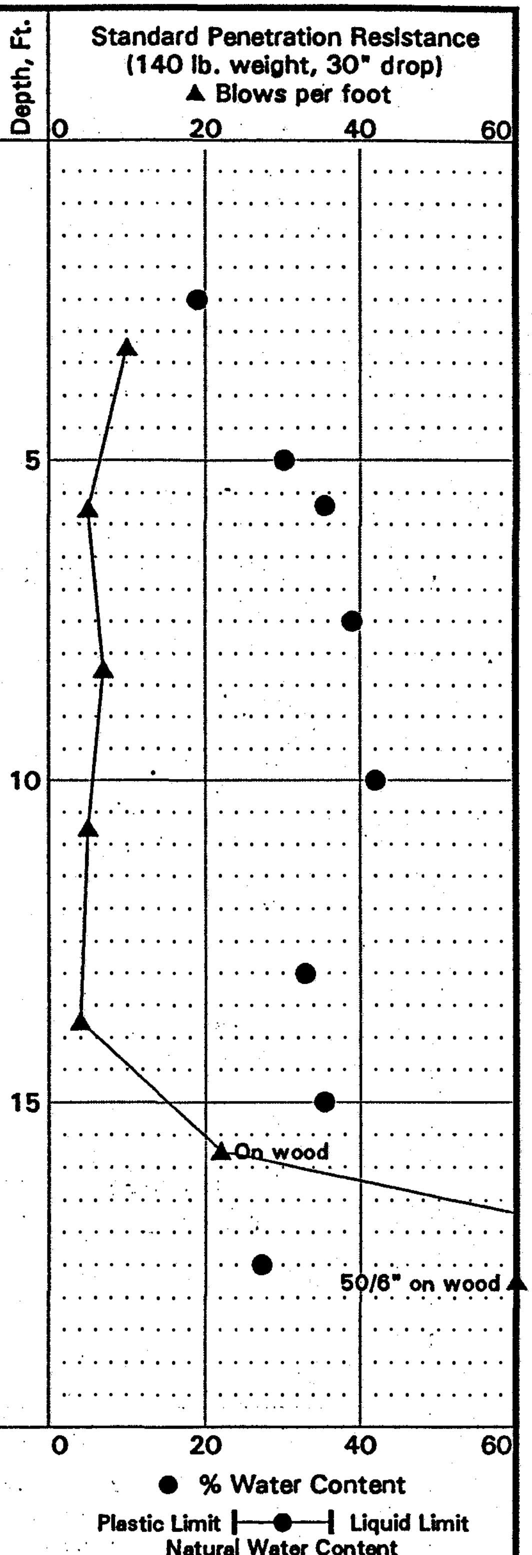
Temporary observation wells were installed in borings B-2 through B-4 upon completion of drilling to allow measurement of groundwater levels and for field permeability testing of in-situ soils. Each well was constructed of flush-threaded, schedule 80, 1-inch nominal diameter PVC pipe with a 0.02-inch machine-slotted screen and a slip end cap. The top of the screen of each well was located below the static water level to allow measurement of groundwater levels in designated zones of the subsurface profile. Because of the small inside diameter of the hollow stem auger used to drill the boreholes, it was not possible to place a filter pack around the screen as the auger was withdrawn from the ground. As a result, the material in the annulus around the well screen (the space between the well pipe and the borehole wall) filled primarily with sloughed material at each of the three locations. A graphical description of each well installation is presented on Figures A-3 through A-5.

A.4 FIELD PERMEABILITY TESTING

Prior to permeability testing, the observation wells were developed both by adding water to the wells to flush the screens and by bailing to remove sediment. Development was difficult because of the small internal diameter of the wells (0.957-inch). Based on our observations, it is likely that some borehole caking associated with the drilling activities remained at each of the well locations.

MASTERLG 8/24/95

MATERIAL DESCRIPTION Surface Elevation: Approx. 188 Feet	Depth, Ft.	Symbol	Samples	Ground Water
Stiff, brownish gray, sandy, silty CLAY; moist; iron-stained; CL.				
Medium stiff, gray, silty CLAY; with zones of blocky and slickensided structure; with layers of silty, fine sand; moist to wet; CL.	3.0		1, 2, 3, 4, 5, 6	Observed During Drilling
Gray, fine SAND, trace of silt, with wood fragments; wet. - Refusal on wood at 18.0 feet.	16.0		7	
BOTTOM OF BORING COMPLETED 8/22/95 Boring moved 1 foot north for drilling below 14.5 feet.	18.0			



LEGEND

- * Sample Not Recovered
- 2" O.D. Split Spoon Sample
- 3" O.D. Shelby Tube Sample
- Surface Seal
- Annular Sealant
- Piezometer Screen
- Grout
- Water Level

NOTES

1. The stratification lines represent the approximate boundaries between soil types, and the transition may be gradual.
2. The discussion in the text of this report is necessary for a proper understanding of the nature of subsurface materials.
3. Water level, if indicated above, is for the date specified and may vary.
4. Refer to KEY for explanation of 'Symbols' and definitions.
5. USC letter symbol based on visual classification.

Hidden Lake Restoration Project
King County, Washington

LOG OF BORING B-1

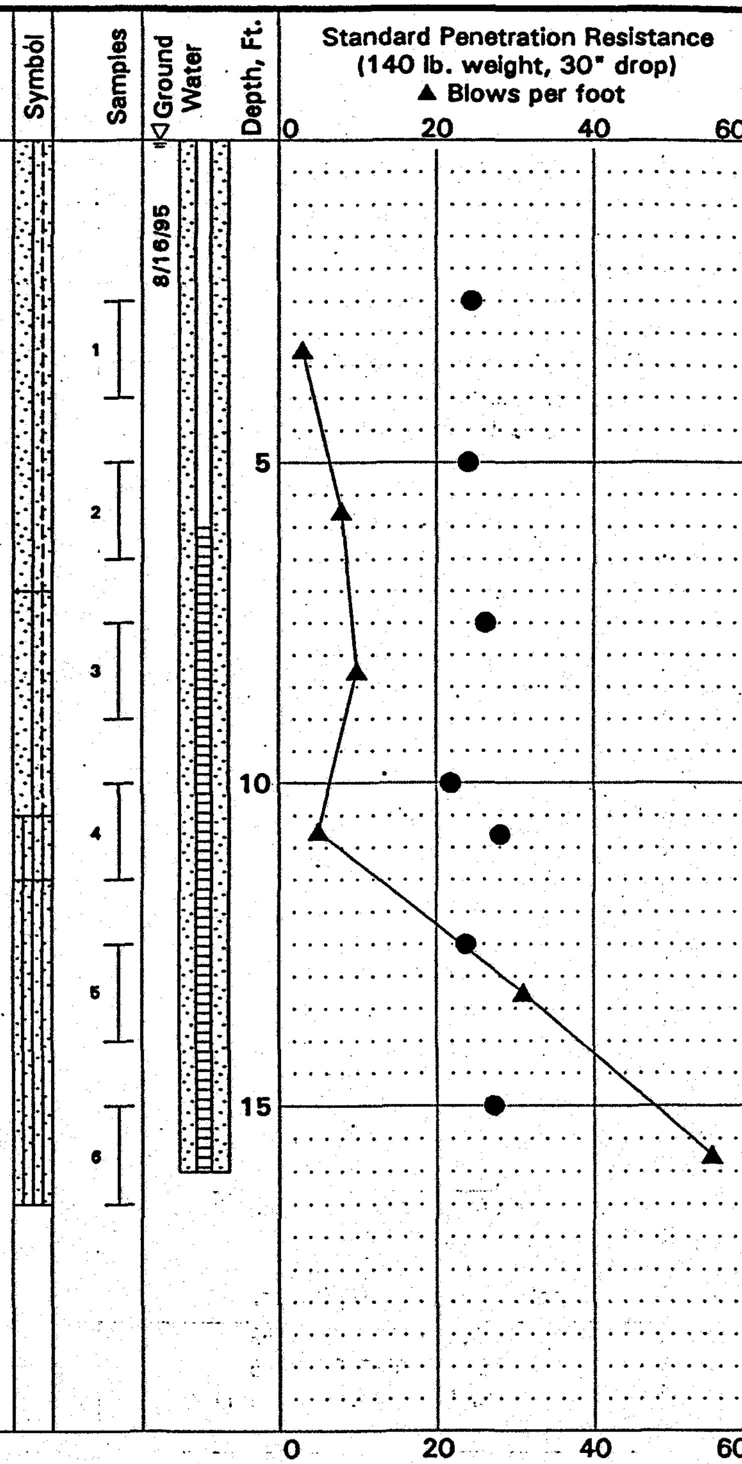
August 1995 W-7022-03

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. A-2

MASTERLG 8/24/95

MATERIAL DESCRIPTION Surface Elevation: Approx. 185 Feet	Depth, Ft.
Very loose to loose, brown, clean to slightly silty, fine to medium SAND, trace of gravel; moist to wet below 1 foot; SP/SP-SM.	
Loose, gray, slightly silty to silty, fine SAND; wet; SP-SM/SM. - Gravelly, slightly silty, fine to medium SAND from 9.5 to 10.5 feet.	7.0
Loose, gray, interbedded silty, fine SAND and fine sandy SILT; wet; SM/ML.	10.5
Dense to very dense, gray, silty, fine SAND; wet; SM/ML. - Grades to SILT with trace of fine sand by 14.0 feet.	11.5
BOTTOM OF BORING COMPLETED 8/14/95	16.5



LEGEND

- * Sample Not Recovered
- ⌶ 2" O.D. Split Spoon Sample
- Ⅱ 3" O.D. Shelby Tube Sample
- Surface Seal
- Annular Sealant
- Piezometer Screen
- Grout
- Water Level

● % Water Content

Plastic Limit ├──●──┤ Liquid Limit
Natural Water Content

NOTES

1. The stratification lines represent the approximate boundaries between soil types, and the transition may be gradual.
2. The discussion in the text of this report is necessary for a proper understanding of the nature of subsurface materials.
3. Water level, if indicated above, is for the date specified and may vary.
4. Refer to KEY for explanation of 'Symbols' and definitions.
5. USC letter symbol based on visual classification.

Hidden Lake Restoration Project
King County, Washington

LOG OF BORING B-2

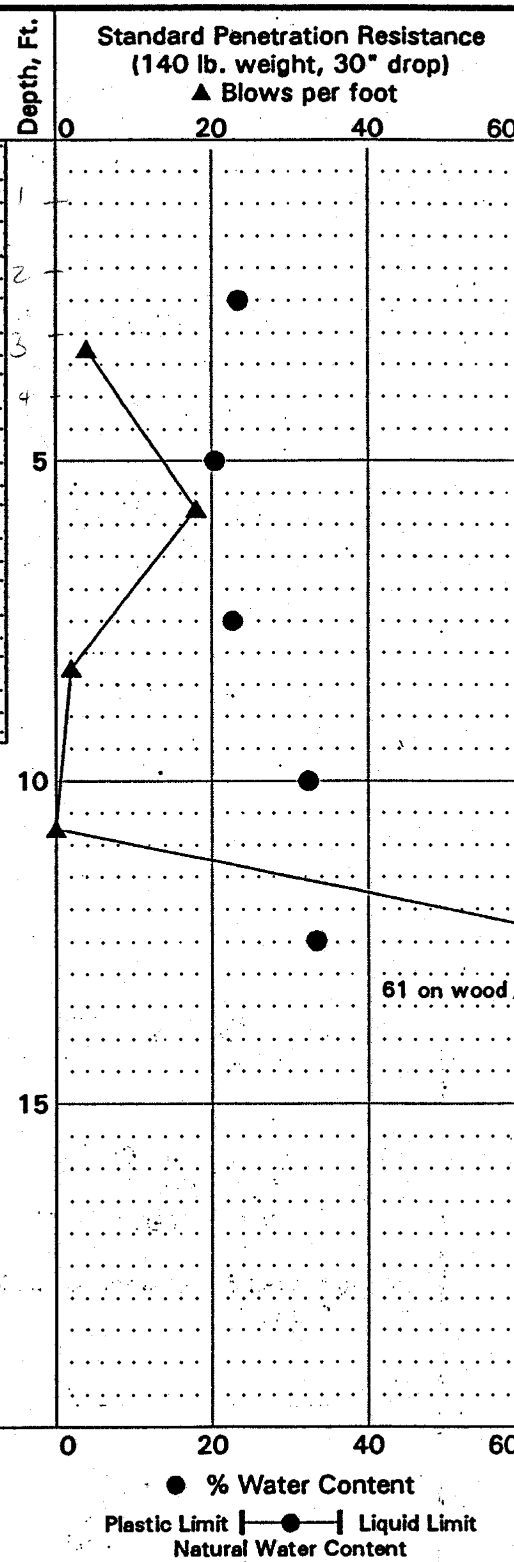
August 1995 W-7022-03

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. A-3

MASTERLG 8/24/95

MATERIAL DESCRIPTION Surface Elevation: Approx. 187 Feet	Depth, Ft.	Symbol	Samples	Ground Water
Loose, brown, fine to medium SAND, trace of silt; moist to wet below 1 foot; SP.				8/16/95
Very loose to medium dense, gray, fine to medium SAND, clean to trace of silt, trace of gravel; wet; SP. - Wood and organic silt layers below 8.5 feet.	3.0		1, 2, 3, 4	
PEAT and wood, possibly with fine to medium sand interbeds, refusal on wood at 14.0 feet; PT.	12.5		5	
BOTTOM OF BORING COMPLETED 8/14/95	14.0			



LEGEND

- • Sample Not Recovered
- ⌶ 2" O.D. Split Spoon Sample
- Ⅱ 3" O.D. Shelby Tube Sample
- Surface Seal
- Annular Sealant
- Piezometer Screen
- Grout
- ∇ Water Level

NOTES

1. The stratification lines represent the approximate boundaries between soil types, and the transition may be gradual.
2. The discussion in the text of this report is necessary for a proper understanding of the nature of subsurface materials.
3. Water level, if indicated above, is for the date specified and may vary.
4. Refer to KEY for explanation of 'Symbols' and definitions.
5. USC letter symbol based on visual classification.

Hidden Lake Restoration Project
King County, Washington

LOG OF BORING B-3

August 1995 W-7022-03

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. A-4

MASTERLG 8/24/95

MATERIAL DESCRIPTION

Surface Elevation: Approx. 190 Feet

Loose to very loose, brown to gray, gravelly SAND, clean to trace of silt; wet; SP/SP-SM.

- Trace to slightly silty below 3 feet.

- Wood and organic silt lenses below 6 feet.

- Refusal on wood at 9.0 feet.

14.0

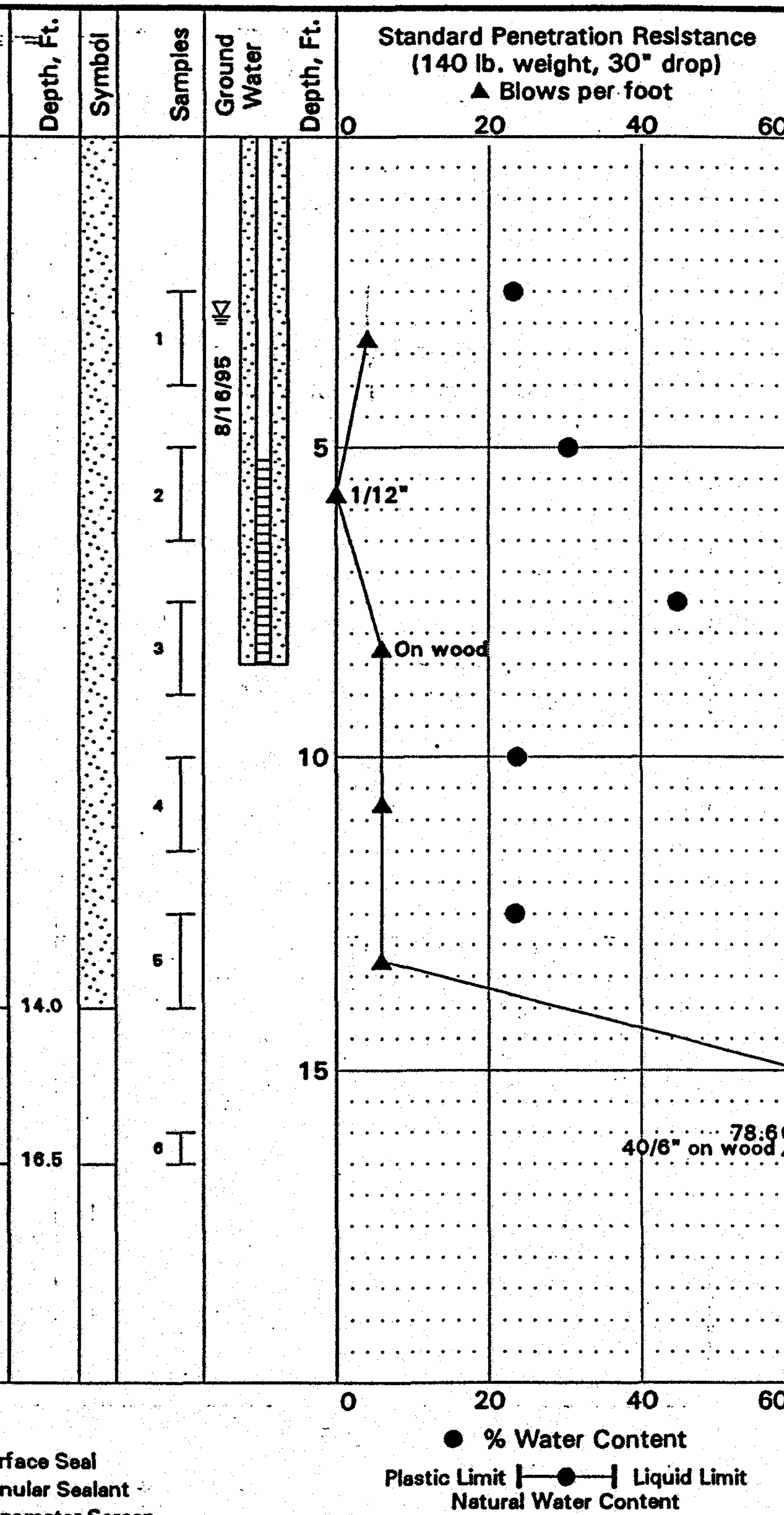
Dark brown, slightly sandy, organic SILT; with wood; wet.

- Refusal on wood at 16.5 feet.

16.5

BOTTOM OF BORING
COMPLETED 8/23/95

Boring moved 8 feet west for drilling below 9.0 feet.



LEGEND

- Sample Not Recovered
- 2" O.D. Split Spoon Sample
- 3" O.D. Shelby Tube Sample
- Surface Seal
- Annular Sealant
- Piezometer Screen
- Grout
- Water Level

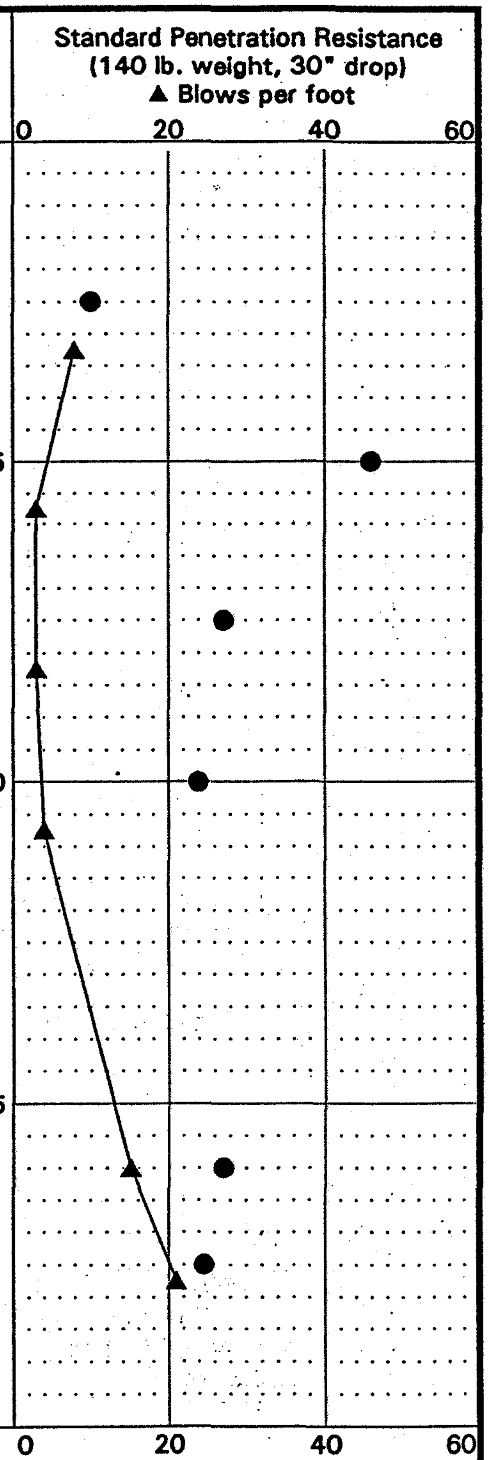
NOTES

1. The stratification lines represent the approximate boundaries between soil types, and the transition may be gradual.
2. The discussion in the text of this report is necessary for a proper understanding of the nature of subsurface materials.
3. Water level, if indicated above, is for the date specified and may vary.
4. Refer to KEY for explanation of 'Symbols' and definitions.
5. USC letter symbol based on visual classification.

Hidden Lake Restoration Project King County, Washington	
LOG OF BORING B-4	
August 1995	W-7022-03
SHANNON & WILSON, INC. Geotechnical and Environmental Consultants	FIG. A-5

MASTERLG 8/24/95

MATERIAL DESCRIPTION Surface Elevation: Approx. 191 Feet	Depth, Ft.	Symbol	Samples	Ground Water	Depth, Ft.
Loose, brown, fine to medium SAND, clean to trace of silt; with wood fragments; moist to wet; SP.			1, 2	Observed During Drilling ▽	5
Very loose, gray, trace of silt to silty, fine to medium SAND, trace of wood; wet; SP/SM.	6.0		3, 4		10
Medium dense, gray, fine sandy SILT; wet; ML.	14.0		5, 6		15
BOTTOM OF BORING COMPLETED 8/15/95	18.5				



LEGEND

- • Sample Not Recovered
- I 2" O.D. Split Spoon Sample
- II 3" O.D. Shelby Tube Sample
- Surface Seal
- Annular Sealant
- Piezometer Screen
- Grout
- ▽ Water Level

NOTES

1. The stratification lines represent the approximate boundaries between soil types, and the transition may be gradual.
2. The discussion in the text of this report is necessary for a proper understanding of the nature of subsurface materials.
3. Water level, if indicated above, is for the date specified and may vary.
4. Refer to KEY for explanation of 'Symbols' and definitions.
5. USC letter symbol based on visual classification.

Hidden Lake Restoration Project
King County, Washington

LOG OF BORING B-5

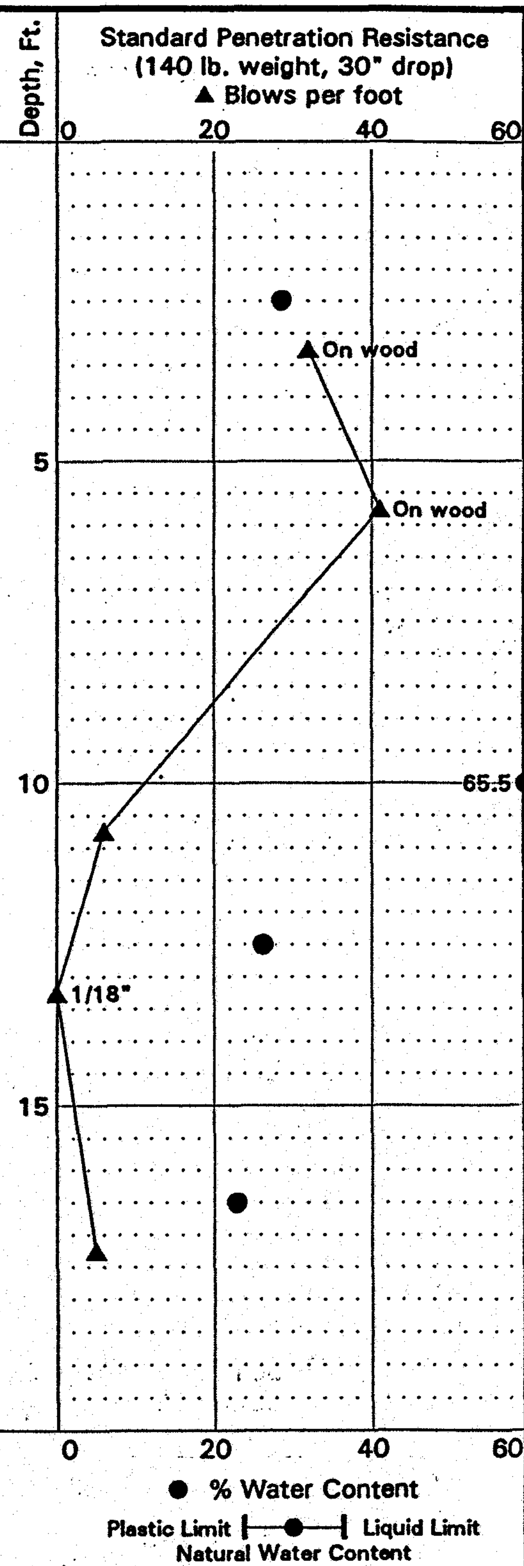
August 1995 W-7022-03

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. A-6

MASTERLG 8/24/95

MATERIAL DESCRIPTION Surface Elevation: Approx. 183 Feet	Depth, Ft.	Symbol	Samples	Ground Water
Loose, brown, gravelly, fine to medium SAND, trace of silt, with wood fragments; moist to wet below 1.5 feet; SP. - Refusal on wood at 6.5 feet.			1 2 3	⊻ Observed During Drilling
Very loose to loose, gray, slightly silty, fine to medium SAND; with wood fragments; wet. - Silt seams at 14.0 feet.	12.0		4 5	
BOTTOM OF BORING COMPLETED 8/22/95 - Boring moved 5 feet south for drilling below 6.5 feet.	18.0			



LEGEND

- * Sample Not Recovered
- Ⅰ 2" O.D. Split Spoon Sample
- Ⅱ 3" O.D. Shelby Tube Sample
- Surface Seal
- Annular Sealant
- Piezometer Screen
- Grout
- ⊻ Water Level

NOTES

1. The stratification lines represent the approximate boundaries between soil types, and the transition may be gradual.
2. The discussion in the text of this report is necessary for a proper understanding of the nature of subsurface materials.
3. Water level, if indicated above, is for the date specified and may vary.
4. Refer to KEY for explanation of 'Symbols' and definitions.
5. USC letter symbol based on visual classification.

Hidden Lake Restoration Project
King County, Washington

LOG OF BORING B-6

August 1995 W-7022-03

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. A-7

MATERIAL DESCRIPTION Surface Elevation: Approx. 198 Feet	Depth, Ft.	Symbol	Samples	Ground Water	Depth, Ft.	Standard Penetration Resistance (140 lb. weight, 30" drop) ▲ Blows per foot (0 20 40 60)
Loose, brown, fine to medium SAND; trace to slightly silty with wood fragments and occasional iron-stain; moist to wet below 9.5 feet; SP/SP-SM.					5	
Hard, gray-brown, clayey SILT; moist; ML.	10.0			Observed During Drilling	10	
- Refusal at 10.7 feet.	10.7					
BOTTOM OF BORING COMPLETED 8/22/95						
BORING COMPLETED WITHOUT SAMPLING					15	

0 20 40 60

● % Water Content

Plastic Limit ├──●──┤ Liquid Limit

Natural Water Content

LEGEND

- • Sample Not Recovered
- I 2" O.D. Split Spoon Sample
- II 3" O.D. Shelby Tube Sample
- Surface Seal
- Annular Sealant
- Piezometer Screen
- Grout
- ▽ Water Level

NOTES

1. The stratification lines represent the approximate boundaries between soil types, and the transition may be gradual.
2. The discussion in the text of this report is necessary for a proper understanding of the nature of subsurface materials.
3. Water level, if indicated above, is for the date specified and may vary.
4. Refer to KEY for explanation of 'Symbols' and definitions.
5. USC letter symbol based on visual classification.

Hidden Lake Restoration Project
King County, Washington

LOG OF BORING B-7

August 1995 W-7022-03

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. A-8

KEY TO SYMBOLS

Symbol	Description
Strata symbols	
	Poorly graded sand with silt
	Silt
	Low plasticity clay
	Silty sand
	Poorly graded sand
	Low plasticity organic silts
	Poorly graded gravel
Misc. Symbols	
	Water table during drilling.
	End of Boring
1	The boring caved

Symbol	Description
Soil Samplers	
	Bulk/Grab sample

Notes:

1. Exploratory borings were drilled on 7-7-95 using hand augers.
2. All exploration is located relative to the centerline of the proposed berm.
3. These logs are subject to the limitations, conclusions, and recommendations in this report.

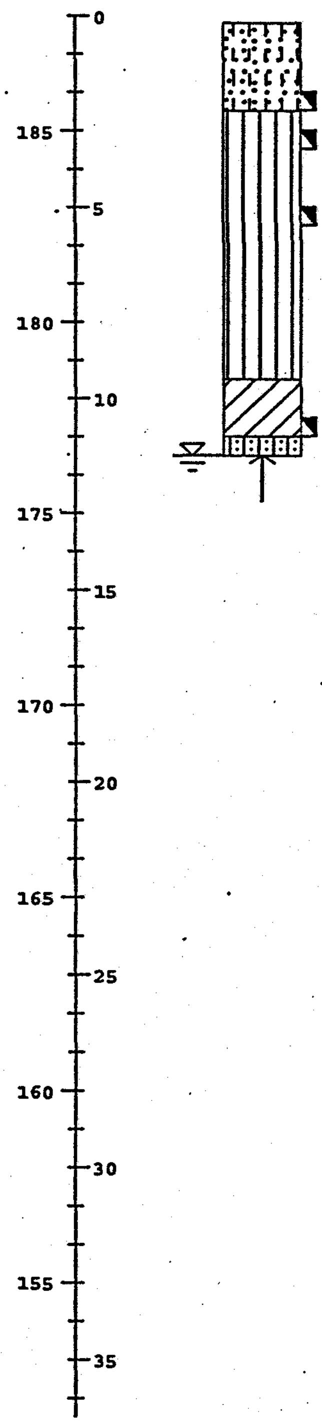
FIG. C-1

LOG OF BORING

BORING HA - 1

PROJECT: Hidden Lake Restoration
BORING LOCATION: 45ft NW of left abutment
DRILL METHOD: Hand auger
DRILLER: King County Materials Laboratory
DEPTH TO - Water: 11.5 Caving:

DATE: 7-7-95
START:
FINISH:
LOGGER: DA
DATE CHECKED:



ELEVATION/ DEPTH	SOIL SYMBOLS SAMPLER SYMBOLS AND FIELD TEST DATA	USCS	Description	Moist (%)	-200 (%)	Remarks
		SP-SM	Topsoil			
			Gray brown, fine to medium sand, dry to moist, loose.	4.0	8.9	
		ML	Tan to gray, iron stained, fine sandy silt, trace organic debris, moist, loose to medium dense.	20.0 18.0		
		CL	Bluish gray, sandy silt, wet, medium Stiff	31.4		LL = 41 PI = 19
		SM	Gray, silty sand, wet, medium dense.			

Elevation based on the Hidden Lake Landscape Plan Provided by King County Public Works. Hand Auger locations measured from the Left abutment.

KING COUNTY MATERIALS LABORATORY

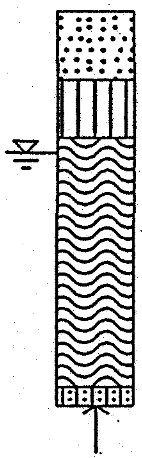
FIG. C-2

LOG OF BORING

BORING HA - 2

PROJECT: Hidden Lake Restoration
BORING LOCATION: 35ft NW of left abutment
DRILL METHOD: Hand auger
DRILLER: King County Materials Laboratory
DEPTH TO - Water: 3.9 Caving:

DATE: 7-7-95
START:
FINISH:
LOGGER: DA
DATE CHECKED:

ELEVATION/ DEPTH	SOIL SYMBOLS SAMPLER SYMBOLS AND FIELD TEST DATA	USCS	Description	Moist (%)	-200 (%)	Remarks
185 / 0		SP	Topsoil			
			Gray brown, medium sand, trace roots dry to moist, loose.			
		ML	Dark brown fine sandy organic silt with roots and branches wet loose. (topsoil)			
180 / 5		OL	Dark brown organic silt wet soft. Logs at four feet Interbedded with sand and silt lenses.			
175 / 10		SM	Gray, fine to medium sand, trace silt wet, loose to medium dense.			
170 / 15						
165 / 20						
160 / 25						
155 / 30						
150 / 35						

** Elevation based on the Hidden Lake Landscape Plan Provided by Public Works. Hand Auger locations measured from the Left abutment.*

LOG OF BORING

BORING HA - 3

PROJECT: Hidden Lake Restoration
BORING LOCATION: 20ft NW of left abutment
DRILL METHOD: Hand auger
DRILLER: King County Materials Laboratory
DEPTH TO - Water: 0.7 Caving:

DATE: 7-7-95
START:
FINISH:
LOGGER: DA
DATE CHECKED:

ELEVATION/ DEPTH	SOIL SYMBOLS SAMPLER SYMBOLS AND FIELD TEST DATA	USCS	Description	Moist (%)	-200 (%)	Remarks
0		GP	Medium to coarse gravel, some sand, wet loose.			
180		SP	Gray brown, medium sand, some gravel, wet, loose.			
5						
175						
10						
170						
15						
165						
20						
160						
25						
155						
30						
150						
35						

** Elevation based on the Hidden Lake Landscape Plan Provided by Public Works.*
BORING CAVED AT 0.7ft.

KING COUNTY MATERIALS LABORATORY

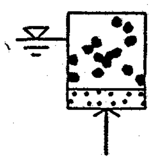
FIG. C-4

LOG OF BORING

BORING HA - 4

PROJECT: **Hidden Lake Restoration**
BORING LOCATION: **2.0ft NW of left abutment**
DRILL METHOD: **Hand auger**
DRILLER: **King County Materials Laboratory**
DEPTH TO - Water: **0.7** Caving:

DATE: **7-7-95**
START:
FINISH:
LOGGER: **DA**
DATE CHECKED:

ELEVATION/ DEPTH	SOIL SYMBOLS SAMPLER SYMBOLS AND FIELD TEST DATA	USCS	Description	Moist (%)	-200 (%)	Remarks
0		GP	Gray brown, sandy gravel, wet, loose.			
180		SP	Gray, fine sand, saturated,loose.			
5						
175						
10						
170						
15						
165						
20						
160						
25						
155						
30						
150						
35						

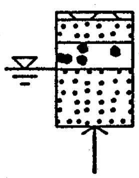
** Elevation based on the Hidden Lake Landscape Plan Provided by Public Works. Hand auger hole caved at the water table.*
BORING CAVED AT 0.7ft

LOG OF BORING

BORING HA - 5

PROJECT: Hidden Lake Restoration
BORING LOCATION: 100ft West of Berm alignment
DRILL METHOD: Hand auger
DRILLER: King County Materials Laboratory
DEPTH TO - Water: 1.5 Caving:

DATE: 7-7-95
START:
FINISH:
LOGGER: DA
DATE CHECKED:

ELEVATION/ DEPTH	SOIL SYMBOLS SAMPLER SYMBOLS AND FIELD TEST DATA	USCS	Description	Moist (%)	-200 (%)	Remarks
185 — 0		OL	Forrest Duff.			
		SP	Brown, fine to medium sand, moist, loose.			
		GP	Gray, sandy fine to medium gravel, moist, loose.			
		SP	Gray, fine to medium sand, saturated, loose.			
180 — 5						
175 — 10						
170 — 15						
165 — 20						
160 — 25						
155 — 30						
150 — 35						

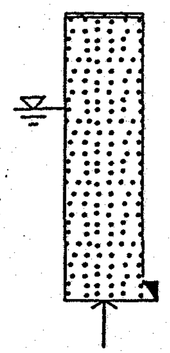
** Elevation based on the Hidden Lake Landscape Plan Provided by Public Works. Hand auger locations measured from the centerline of the berm. BORING CAVED AT 1.5ft*

LOG OF BORING

BORING HA - 6

PROJECT: Hidden Lake Restoration
BORING LOCATION: 460ft East of Berm alignment
DRILL METHOD: Hand auger
DRILLER: King County Materials Laboratory
DEPTH TO - Water: 2.5 Caving:

DATE: 7-7-95
START:
FINISH:
LOGGER: DA
DATE CHECKED:



ELEVATION/ DEPTH	SOIL SYMBOLS SAMPLER SYMBOLS AND FIELD TEST DATA	USCS	Description	Moist (%)	-200 (%)	Remarks
190 — 0		OL	Forrest Duff.			
		SP	Gray brown, fine to medium sand, moist,loose. Trace of Iron staining at 5.0ft, coarse sand in lenses.	29.0	2.8	
185 — 5						
180 — 10						
175 — 15						
170 — 20						
165 — 25						
160 — 30						
155 — 35						

** Elevation based on the Hidden Lake Landscape Plan Provided by Public Works. Hand auger locations measured from the centerline of the berm. BORING CAVED BELOW 2.5ft*

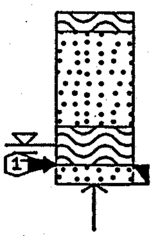
KING COUNTY MATERIALS LABORATORY

LOG OF BORING

BORING HA - 7

PROJECT: Hidden Lake Restoration
BORING LOCATION: 460ft East of Berm *
DRILL METHOD: Hand auger
DRILLER: King County Materials Laboratory
DEPTH TO - Water: 3.5 Caving: 4.0

DATE: 7-7-95
START:
FINISH:
LOGGER: DA
DATE CHECKED:

ELEVATION/ DEPTH	SOIL SYMBOLS SAMPLER SYMBOLS AND FIELD TEST DATA	USCS	Description	Moist (%)	-200 (%)	Remarks
190 — 0		OL	Forrest Duff.			
		SP	Brown, fine to medium sand, trace silt large roots, wood debris, moist, loose.			
		OL	Dark brown organic silt. (topsoil)			
		SP	Gray, fine to mediun sand, wet, loose.	25.0		
185 — 5						
180 — 10						
175 — 15						
170 — 20						
165 — 25						
160 — 30						
155 — 35						

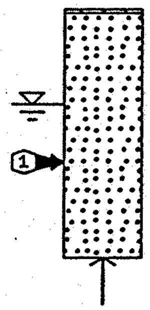
Elevation based on the Hidden Lake Landscape Plan Provided by Public Works. * *Hand auger locations measured fron the centerline of the berm, and against the toe of South facing slope.*

LOG OF BORING

BORING HA - 8

PROJECT: **Hidden Lake Restoration**
BORING LOCATION: **350ft East of Berm ***
DRILL METHOD: **Hand auger**
DRILLER: **King County Materials Laboratory**
DEPTH TO - Water: **2.5** Caving: **4.0**

DATE: **7-7-95**.
START:
FINISH:
LOGGER: **DA**
DATE CHECKED:

ELEVATION/ DEPTH	SOIL SYMBOLS SAMPLER SYMBOLS AND FIELD TEST DATA	USCS	Description	Moist (%)	-200 (%)	Remarks
190 — 0		OL	Forrest Duff.			
		SP	Brown, fine to medium sand, trace silt large roots, wood debris, moist, loose.			
185 — 5						
180 — 10						
175 — 15						
170 — 20						
165 — 25						
160 — 30						
155 — 35						

Elevation based on the Hidden Lake Landscape Plan Provided by Public Works. Hand auger locations measured from the centerline of the berm and at the toe of the south facing slope.*

LOG OF BORING

BORING HA - 9

PROJECT: Hidden Lake Restoration
BORING LOCATION: 260ft East of Berm
DRILL METHOD: Hand auger
DRILLER: King County Materials Laboratory
DEPTH TO - Water: 2.5 Caving:

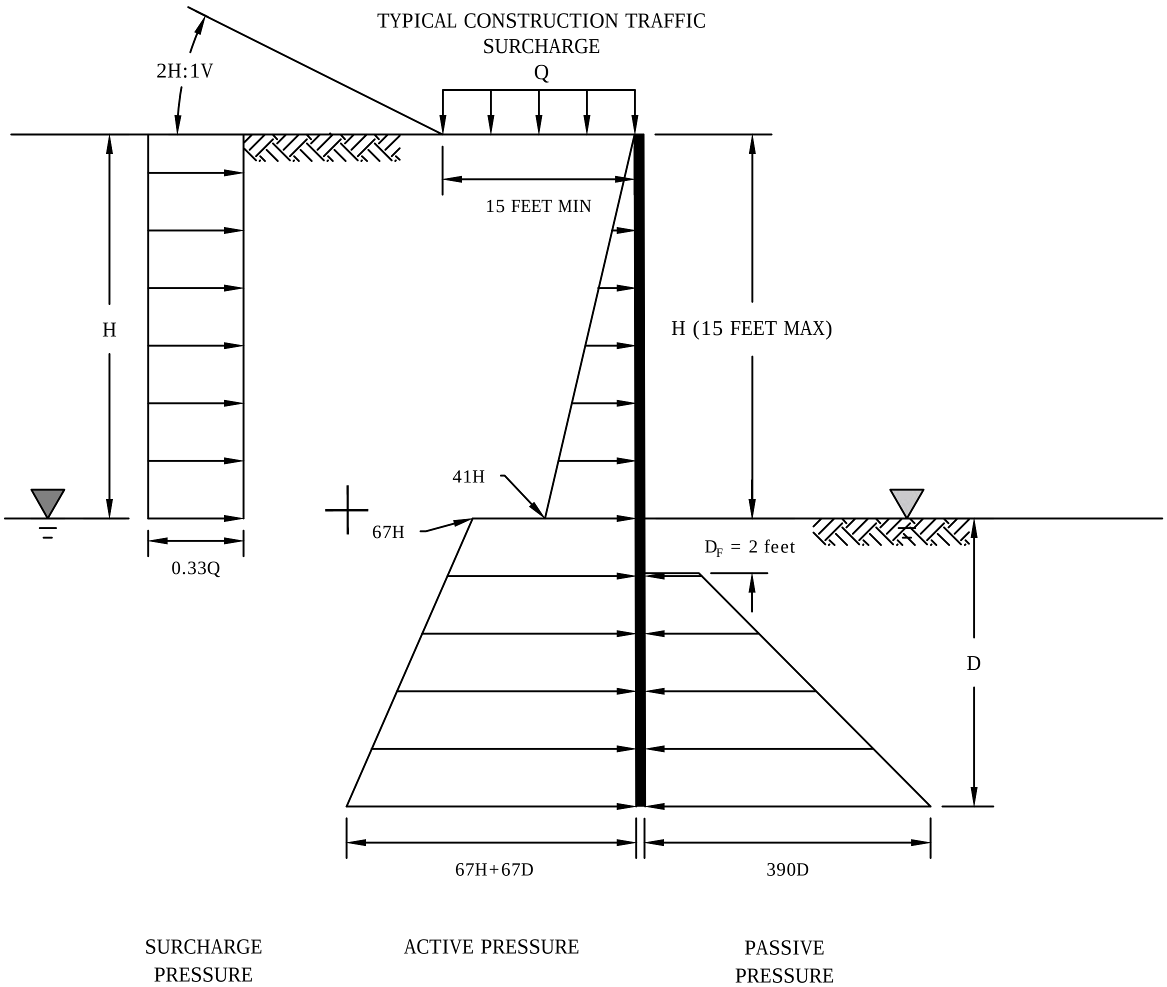
DATE: 7-7-95
START:
FINISH:
LOGGER: DA
DATE CHECKED:

ELEVATION/ DEPTH	SOIL SYMBOLS SAMPLER SYMBOLS AND FIELD TEST DATA	USCS	Description	Moist (%)	-200 (%)	Remarks
0		OL	Forrest Duff.			
		SP	Brown, to gray, fine to medium sand, trace silt scattered roots, moist, loose.			
185			Gray, fine to medium sand, scattered roots, saturated, loose.	29.0	3.8	
5						
180						
10						
175						
15						
170						
20						
165						
25						
160						
30						
155						
35						

** Elevation based on the Hidden Lake Landscape Plan Provided by Public Works. Hand auger location measured from the centerline of the berm. BORING CAVED BELOW 2.5ft.*

APPENDIX E

TEMPORARY SHORING EARTH PRESSURE DIAGRAMS FOR PROPOSED CULVERT EXCAVATION

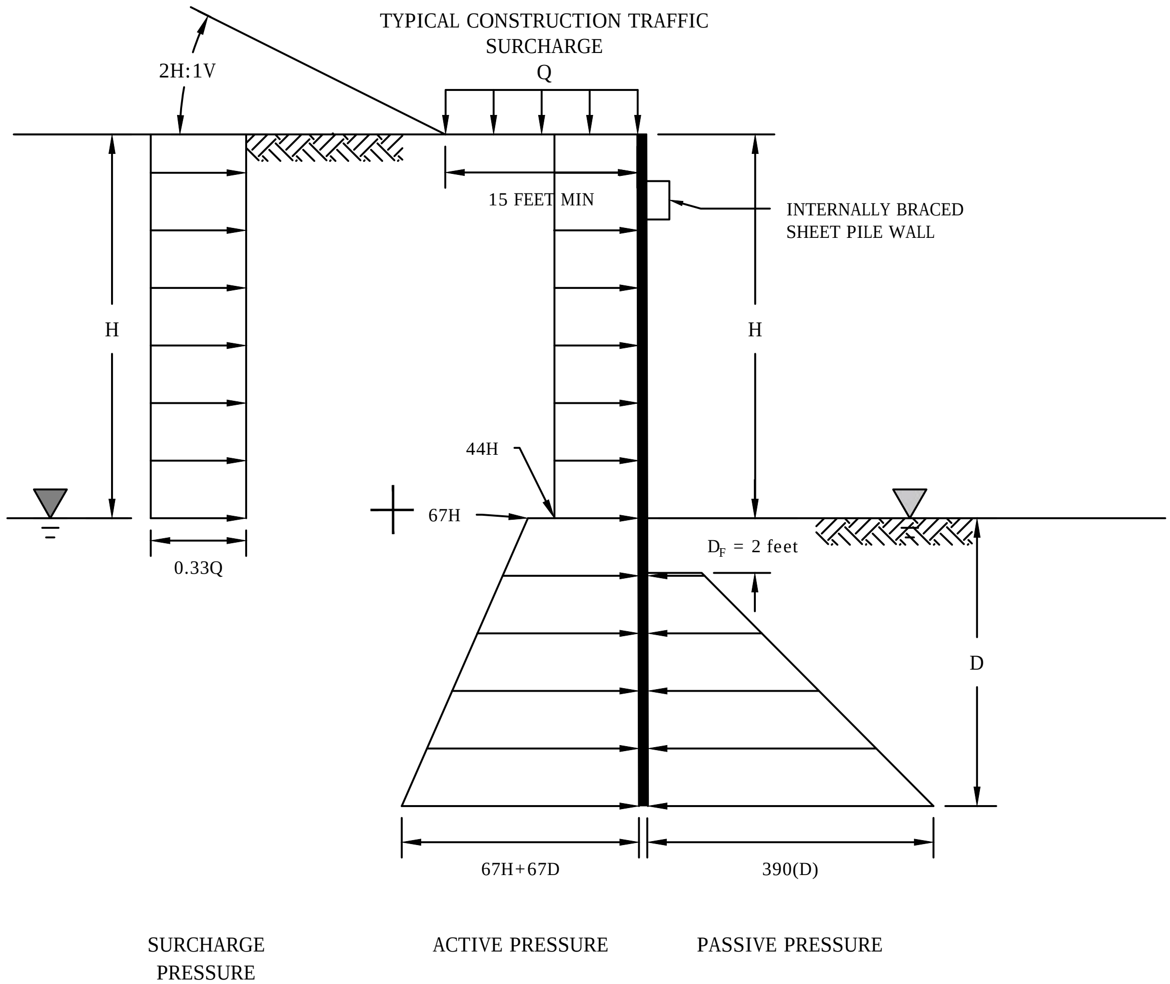


NOTES:

1. GROUND WATER OUTSIDE SHORING ASSUMED TO BE AT SAME ELEVATION OF EXCAVATION.
2. DESIGN PRESSURES ARE IN UNITS OF PSF; DISTANCES IN UNITS OF FEET.
3. SURCHARGE LOAD SHOULD BE ADJUSTED BASED ON THE ANTICIPATED CONSTRUCTION SURCHARGE.
4. THE UPPER TWO FEET BENEATH THE EXCAVATION SUBGRADE SHOULD BE IGNORED FOR THE PURPOSE OF PASSIVE PRESSURE RESISTANCE (D_F).
5. ALL THE EARTH PRESSURES PROVIDED ARE ULTIMATE (UNFACTORED), THE APPROPRIATE LOAD AND RESISTANCE FACTORS SHOULD BE APPLIED FOR EACH LOAD STATE.
6. ACTIVE PRESSURE ABOVE BASE OF EXCAVATION SHOULD BE APPLIED OVER THE PILE SPACING. ACTIVE PRESSURE BELOW BASE OF EXCAVATION SHOULD BE APPLIED OVER THE PILE DIAMETER. PASSIVE PRESSURE SHOULD BE APPLIED OVER TWO TIMES THE PILE DIAMETER.
7. EARTH PRESSURE PROVIDED ASSSUME A MINIMUM BENCH WIDTH OF 15 FEET AND A MAXIMUM RETAINED HEIGHT OF 15 FEET FOR CANTILEVEL CONDITION.

NOT TO SCALE

HWA GEOSCIENCES INC.	LATERAL EARTH PRESSURES FOR CANTILEVERED TEMPORARY SHORING HIDDEN LAKE DAM REMOVAL PROJECT SHORELINE, WASHINGTON	DRAWN BY SKS CHECK BY ZN DATE: 02.05.2019	FIGURE # E-1 PROJECT # 2017-096-21



NOTES:

1. GROUND WATER OUTSIDE SHORING ASSUMED TO BE AT SAME ELEVATION OF EXCAVATION.

2. DESIGN PRESSURES ARE IN UNITS OF PSF; DISTANCES IN UNITS OF FEET.

3. SURCHARGE LOAD SHOULD BE ADJUSTED BASED ON THE ANTICIPATED CONSTRUCTION SURCHARGE.

4. THE UPPER TWO FEET BENEATH THE EXCAVATION SUBGRADE SHOULD BE IGNORED FOR THE PURPOSE OF PASSIVE PRESSURE RESISTANCE (D_F).

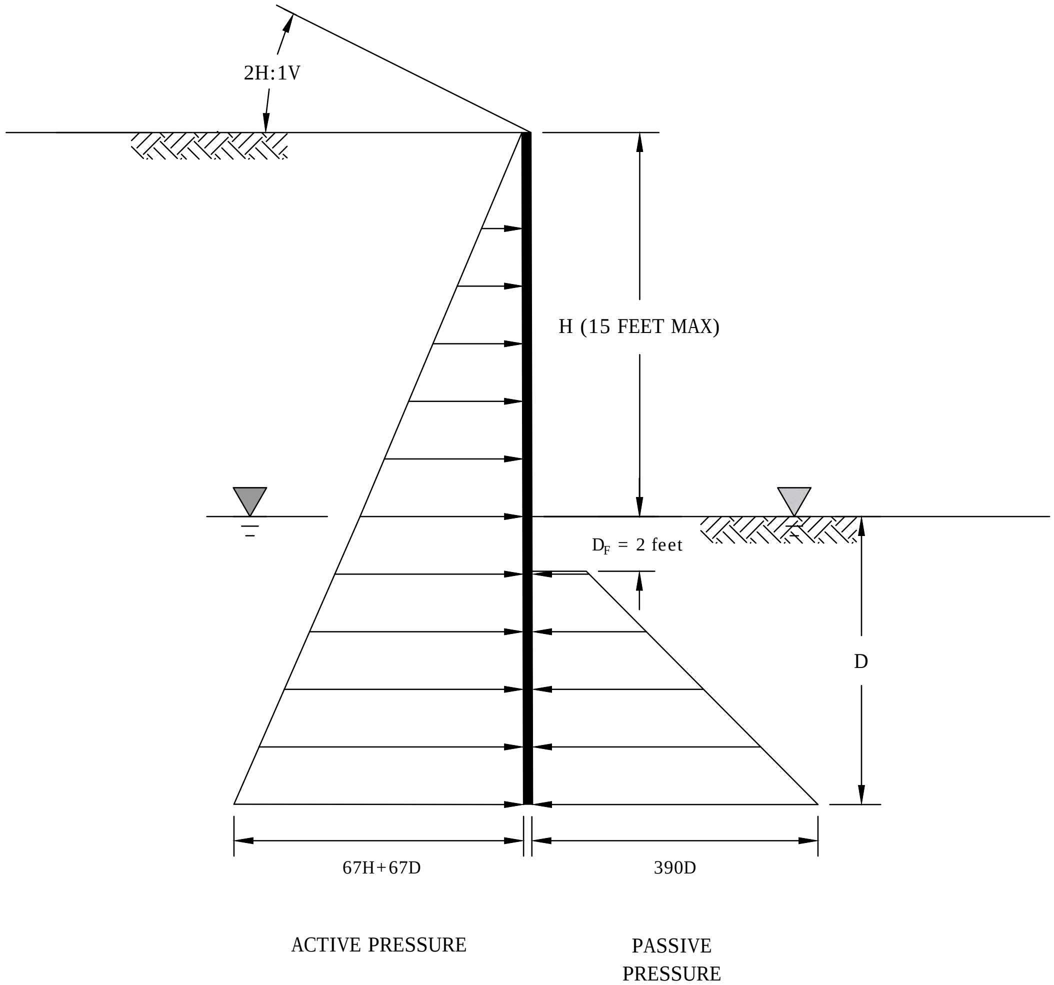
5. ALL THE EARTH PRESSURES PROVIDED ARE ULTIMATE (UNFACTORED), THE APPROPRIATE LOAD AND RESISTANCE FACTORS SHOULD BE APPLIED FOR EACH LOAD STATE.

6. EARTH PRESSURE CONDITIONS ILLUSTRATED APPLY FOR A SINGLE ROW OF BRACING; ADDITIONAL ROWS OF INTERNAL BRACES ARE REQUIRED IF THE HEIGHT OF THE EXCAVATION EXCEEDS APPROXIMATELY 15 FEET.

7. ACTIVE PRESSURE ABOVE BASE OF EXCAVATION SHOULD BE APPLIED OVER THE PILE SPACING. ACTIVE PRESSURE BELOW BASE OF EXCAVATION SHOULD BE APPLIED OVER THE PILE DIAMETER. PASSIVE PRESSURE SHOULD BE APPLIED OVER TWO TIMES THE PILE DIAMETER.

NOT TO SCALE

HWA GEOSCIENCES INC.	LATERAL EARTH PRESSURES FOR INTERNALLY STABILIZED TEMPORARY SHORING	DRAWN BY SKS	FIGURE # E-2
	HIDDEN LAKE DAM REMOVAL PROJECT SHORELINE, WASHINGTON	CHECK BY ZN	PROJECT # 2017-096-21
		DATE: 02.05.2019	



NOTES:

1. GROUND WATER OUTSIDE SHORING ASSUMED TO BE AT SAME ELEVATION OF EXCAVATION.

2. DESIGN PRESSURES ARE IN UNITS OF PSF; DISTANCES IN UNITS OF FEET.

3. SURCHARGE LOAD SHOULD BE ADJUSTED BASED ON THE ANTICIPATED CONSTRUCTION SURCHARGE.

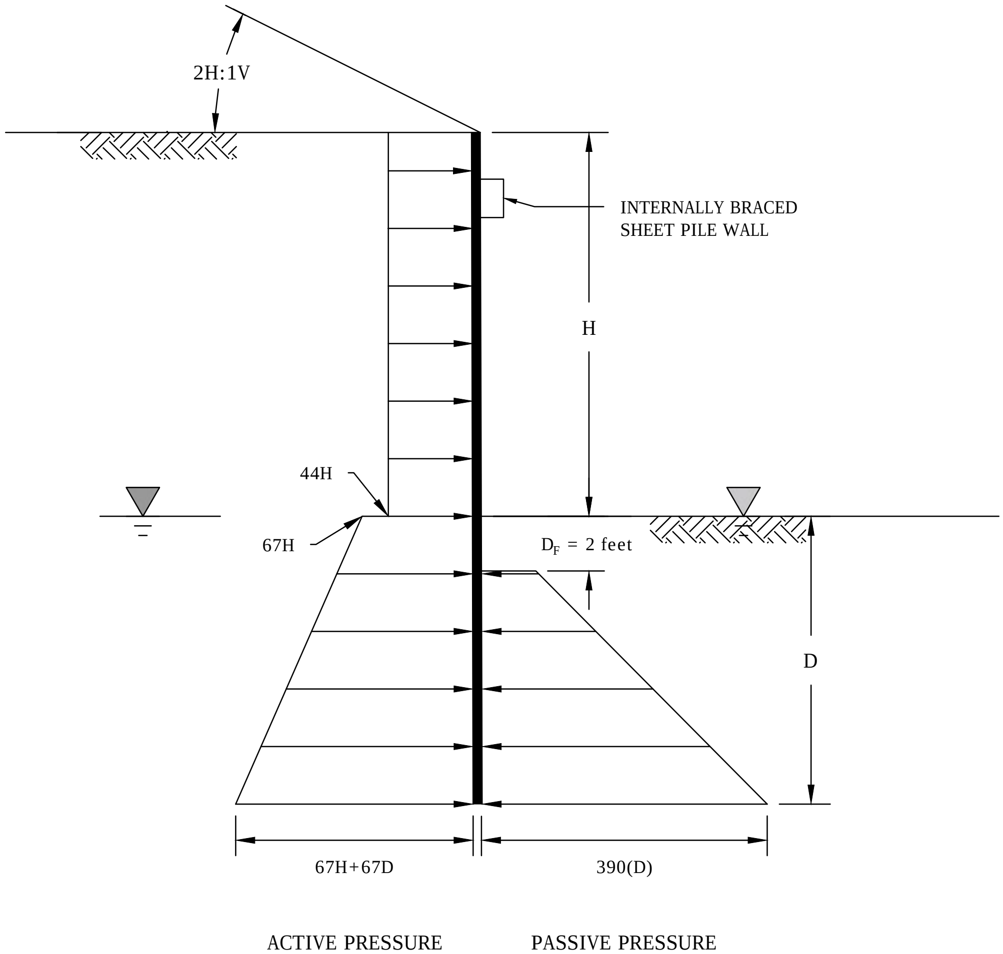
4. THE UPPER TWO FEET BENEATH THE EXCAVATION SUBGRADE SHOULD BE IGNORED FOR THE PURPOSE OF PASSIVE PRESSURE RESISTANCE (D_F).

5. ALL THE EARTH PRESSURES PROVIDED ARE ULTIMATE (UNFACTORED), THE APPROPRIATE LOAD AND RESISTANCE FACTORS SHOULD BE APPLIED FOR EACH LOAD STATE.

6. ACTIVE PRESSURE ABOVE BASE OF EXCAVATION SHOULD BE APPLIED OVER THE PILE SPACING. ACTIVE PRESSURE BELOW BASE OF EXCAVATION SHOULD BE APPLIED OVER THE PILE DIAMETER. PASSIVE PRESSURE SHOULD BE APPLIED OVER TWO TIMES THE PILE DIAMETER.

NOT TO SCALE

HWA GEOSCIENCES INC.	LATERAL EARTH PRESSURES FOR CANTILEVERED TEMPORARY SHORING	DRAWN BY SKS	FIGURE # E-3
	HIDDEN LAKE DAM REMOVAL PROJECT SHORELINE, WASHINGTON	CHECK BY ZN	PROJECT # 2017-096-21
		DATE: 02.05.2019	



NOTES:

1. GROUND WATER OUTSIDE SHORING ASSUMED TO BE AT SAME ELEVATION OF EXCAVATION.

2. DESIGN PRESSURES ARE IN UNITS OF PSF; DISTANCES IN UNITS OF FEET.

3. SURCHARGE LOAD SHOULD BE ADJUSTED BASED ON THE ANTICIPATED CONSTRUCTION SURCHARGE.

4. THE UPPER TWO FEET BENEATH THE EXCAVATION SUBGRADE SHOULD BE IGNORED FOR THE PURPOSE OF PASSIVE PRESSURE RESISTANCE (D_F).

5. ALL THE EARTH PRESSURES PROVIDED ARE ULTIMATE (UNFACTORED), THE APPROPRIATE LOAD AND RESISTANCE FACTORS SHOULD BE APPLIED FOR EACH LOAD STATE.

6. EARTH PRESSURE CONDITIONS ILLUSTRATED APPLY FOR A SINGLE ROW OF BRACING; ADDITIONAL ROWS OF INTERNAL BRACES ARE REQUIRED IF THE HEIGHT OF THE EXCAVATION EXCEEDS APPROXIMATELY 15 FEET.

7. ACTIVE PRESSURE ABOVE BASE OF EXCAVATION SHOULD BE APPLIED OVER THE PILE SPACING. ACTIVE PRESSURE BELOW BASE OF EXCAVATION SHOULD BE APPLIED OVER THE PILE DIAMETER. PASSIVE PRESSURE SHOULD BE APPLIED OVER TWO TIMES THE PILE DIAMETER.

NOT TO SCALE

HWA GEOSCIENCES INC.	LATERAL EARTH PRESSURES FOR INTERNALLY STABILIZED TEMPORARY SHORING	DRAWN BY SKS	FIGURE # E-4
	HIDDEN LAKE DAM REMOVAL PROJECT SHORELINE, WASHINGTON	CHECK BY ZN	PROJECT # 2017-096-21
		DATE: 02.05.2019	

S:\2017 PROJECTS\2017-096-21 HIDDEN LAKE DAM REMOVAL PROJECT\CAD\HWA 2017-096-21 LEP.DWG <Internal> Plotted: 2/9/2019 9:57 AM