Lower Columbia Estuary Partnership

WOLF WATER RESOURCES

Steigerwald Levee Design
Washougal, Washington

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100% DESIGN REPORT
STEIGERWALD LEVEE DESIGN – PHASE 2
WASHOUGAL, WASHINGTON

August 20, 2018 (Rev. January 7, 2019)

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ADDENDA for 100% Design (August 20, 2018)

This addenda describes the additional materials and changes included in this iteration of the basis of design report. A description of the changes and the affected section to the report are provided below:

Section 5.1 and 5.2: Laborartory Testing

- Revised paragraphs to direct the reader to Appendix D for laboratory testing results on test pit samples.

Appendices

- Appendix D: Added figure to include gradation curves from test pit samples.
- Appendix A: Amended the soil descriptions on Summary Boring Logs to include full range of classifactions based on the laboratory testing.

January 7, 2019

Section 6.3: Deleted sentence that stated analyses for the floodwall and closure structure were still "pending".

Section 9.2.1: Updated the recommendation for the foundation of the closure structure to read, "The footing of the closure structure should be embedded a minimum of 6 feet below the current pavement surface at highway centerline to act as a seepage cutoff. The critical exit gradient was calculated to be 0.2 with the footing embedded to the elevation 32.5 feet."

1. EXECUTIVE SUMMARY

The Steigerwald Levee Project features the design of two new setback levees within the Camas-Washougal Diking District in Washougal, Washington. The intent of the project is to restore wetland areas within the Steigerwald National Wildlife Refuge (Refuge). The design of the two setback levees was performed in accordance with the USACE manual, Design and Construction of Levees (EM 1110-2-1913) and other USACE resources. USACE's guidelines recommend that levee designs consider and analyze: (i) underseepage and through seepage; (ii) slope stability; and (iii) settlement (i.e. loss of freeboard) of representative sections of the levee. These analyses were performed on eight levee sections that represent the various foundation conditions and embankment height combinations along the two levee alignments.

A field exploration and laboratory testing program was performed to develop foundation subsurface conditions and soil parameters to use in the design of the setback levees. The field explorations consisted of a site reconnaissance, drilling 44 exploratory boreholes, and excavation of 30 test pits. The boreholes were performed along the levee centerlines, landside and waterside toes of each setback levee. Soil samples were collected using Standard Penetration Tests (SPT) and thin-walled Shelby tubes. Representative permeability of the foundation soils was determined by performing falling head field tests at select locations and depths throughout the site. The drilling program included installation of six standpipes with vibrating wire piezometers (VWPs) and dataloggers to monitor the seasonal groundwater fluctuation. Test pits were excavated in potential borrow source areas, expanded habitat zones, and near a proposed SR-14 closure structure. Representative bulk samples were collected from geologic layers encountered in each test pit.

Soil samples were transported to Cornforth Consultants' laboratory where various soil properties were tested. Laboratory testing consisted of grain size distribution (mechanical sieve and hydrometers), natural water content determinations, consolidated-undrained triaxial tests, one-dimension consolidation tests, soil-moisture compaction tests, and Atterberg Limits determination. These laboratory tests were used to determine the foundation soils characteristics, permeability, plasticity, shear strength, and compressibility.

Results of the field investigations and laboratory testing were used to develop geologic/analysis model sections of the site along both setback levee alignments. The geologic models show that the southern half of the Refuge has relatively thick deposits of compressible soil. The northern half of the site typically has thinner deposits of compressible soils, as denser soil layers were encountered at shallower depths to the north. Groundwater is relatively shallow across the site with monitoring data showing that the seasonal high groundwater was at the ground surface to 12.5 feet below the ground surface. Seasonal low groundwater ranged from 5 to 23 feet below the ground surface. In localized areas toward the southeast of the project, groundwater is deeper, with seasonal highs measured 12.5 feet below the ground surface.

The soil parameters and geologic models were used to develop cross-sections to analyze for embankment stability, through or under seepage and potential settlement of each embankment segment (referred to as a "Reach" in the report) of the setback levees using the design flood level. Seepage and slope stability analyses were performed on each section using SEEP/W and SLOPE/W (part of a bundle of geo-engineering software programs created by GeoStudio, Inc) to determine the seepage and slope stability of the levee under design flood conditions. A limit equilibrium method was used to calculate the stability factors of safety for the landside and waterside slopes of the levees at the USACE design flood levels. The settlement due to embankment loading was approximated using soil consolidation parameters, a (modified) Boussinesq pressure distribution, and a spreadsheet program for each segment of the levee. The maximum settlement occurs at the centerline and approaches zero settlement a short distance beyond the toes of the levee.

In general, setback levees were designed using 12-feet wide crests with 4H:1V (horizontal:vertical) landside and 3H:1V waterside slopes to satisfy the conditions of stability and seepage outlined by the USACE. A summary of the analyses results on select design levee sections are summarized in the table below:

Table 1: Analyses Results on the Design Levee Sections at Design Flood Conditions

Reach	Station	Steady-State Seepage Exit Gradient	Slope Stability Factor of Safety		Settlement (ft)
			Landside	Waterside	
E-1	E 2+41	0.29	1.8	2.1	1.0
E-2	E 12+41	0.40	1.6	2.1	2.5
E-3	E 17+41	0.37	1.6	2.3	2.0
E-4	E 20+99	0.39	1.6	2.3	1.0
W-1	W 8+36	0.31	1.6	2.2	3.5
W-2	W 26+37	0.35	1.5	2.3	3.0
W-3	W 33+36	0.33	1.5	2.3	2.7
W-4	W 43+37	0.32	1.6	2.3	0.6

Analyses of the embankment and foundation for slope stability and the potential seepage through both of these areas indicate that the critical factors of safety for slope stability at all locations exceed the minimum requirements established by the USACE in their engineering guidelines (FS > 1.4). The seepage analyses demonstrate exit gradients at the landside toe of the embankment slope are less than the maximum value of 0.5, as recommended by USACE guidelines.

The calculated settlement of the levees varies along the reaches depending on foundation conditions and levee height. The settlement values in some areas (summarized above) would result in inadequate freeboard (i.e. less than 3 feet) if only constructed to the initial design height. Therefore, a design/construction strategy has been developed to mitigate the loss of freeboard by overbuilding the levee height by the estimated amount foundation settlement.

The explorations of the on-site soils and the existing Camas-Washougal Levee show that these materials could be used as borrow sources for setback levee construction. The existing levee materials tend to be dry because the embankment is generally on higher native ground and above the 100-year Columbia River flood level. Soils from the interior of the site tend to be wet and laboratory testing shows they are typically wet of the optimum water content. Borrow materials from the Refuge interior will need conditioning (i.e. aerating, discing, etc) prior to compaction in the setback levee embankment.

2. INTRODUCTION

The Lower Columbia Estuary Partnership (LCEP) is proposing to return approximately 1,000 acres of the Steigerwald National Wildlife Refuge (Refuge) to a natural Columbia River floodplain habitat. The Refuge is located in Clark County east of Washougal, Washington on the north bank of the Columbia River from river mile 122.5 to 128. The Refuge is bordered on the north side by Washington State Highway Route 14 (SR-14) and a Burlington Northern Santa Fe (BNSF) railroad line. The south side of the Refuge has an existing flood protection levee along the bank of the Columbia River. The Refuge is bordered by the Port of Camas-Washougal and private ranch properties to the west and east, respectively. A Vicinity Map is shown on Figure 1.

The project consists of returning the Refuge back to hydrologic connectivity to the Columbia River by removing the existing Camas-Washougal Drainage District levee that currently provides flood protection to the area. Two new setback levees will be constructed on the east and west side of the Refuge to allow natural flooding while providing flood protection to the Port of Camas-Washougal facilities and the private ranch property. The East Setback Levee will extend across existing grassland and tie into high ground adjacent to the BNSF rail line. The West Setback Levee will tie into a closure structure that extends across SR-14. The closure structure will tie into a floodwall that extends north along the west bank of Gibbons Creek. The Refuge location and layout of the proposed setback levees are shown on the Location Map (Figure 1).

The existing levee height and design flood level were set by the Washougal Flood Damage Reduction (FDR) Project authorized by the Flood Control Act of 1950. Therefore, the design height of the setback levees, closure structure and floodwall are based on the height of the existing Camas-Washougal Levee. The project design procedures described herein are in accordance with the US Army Corps of Engineers design manual, “Design and Construction of Levees”, EM 1110-2-1913, dated April 30, 2000. The analyses and supporting information must show that the levee system will provide protection under the design flood event that is identified in the Flood Control Act of 1950.

This report summarizes the engineering tasks and analyses that have been completed, and presents the results and conclusions that were used for design of the setback levees and other pertinent structures.

Design of the setback levees and the other flood retention structures are being performed by consultant team consisting of the following firms:

- Wolf Water Resources (W2r): Hydraulic engineering, restoration design, stormwater design, permitting, and project management
- Cornforth Consultants, Inc: Setback levee design and geotechnical engineering
- KPFF Consulting Engineers: Flood wall design, roadway and closure structure design, and structural engineering

- WEST Consultants: Interior drainage analysis, risk and uncertainty analysis, and Columbia River and Gibbons Creek floodplain mapping
- Laura Herbon, Landscape Architect: Landscape architecture design
- Statewide Land Surveying (SWLS) and David Smith & Associates (DSA): Survey and photogrammetry
- Murraysmith: East setback levee interior drainage pump station design

2.1 Project Description

The Steigerwald National Wildlife Refuge restoration project is being performed in three phases. The Phase 1 work (completed earlier) consisted of an initial feasibility study performed by ESA of Portland, Oregon and Cornforth Consultants. Results of the study were summarized in the report for LCEP titled, "Steigerwald Lake National Wildlife Refuge Restoration Project – Initial Feasibility Assessment" dated December 2014. The current phase is being performed by a design team led by Wolf Water Resources of Portland, Oregon, with Cornforth Consultants, Inc. serving as the geotechnical subconsultant. The Phase 2 work consists of the design of two setback levees (East and West), a closure structure on State Route 14, and a floodwall along Gibbons Creek. The proposed levee lengths are 2,410 and 5,213 feet for the East and West Setback Levees, respectively. The design will address the internal drainage of the Refuge and breaching of the existing levee to restore natural habitat. Phase 2 also includes producing construction plans and specifications. Construction of the restoration project will be performed in Phase 3.

2.2 Scope of Work

The Phase 2 geotechnical engineering studies included the following tasks:

Field Investigations. The field investigation program consisted of drilling 44 exploratory borings and excavating 30 test pits. The borings were performed at select locations along the centerline, waterside and landside toes of the proposed setback levees. Test pits were excavated at potential borrow areas and extended habitat areas. The results of the field explorations were used to determine site stratigraphy, develop geologic sections and determine the suitability of borrow materials. A detailed summary of the field investigations are provided in Section 3 of this report.

Site Geology and Subsurface Conditions. The geologic and subsurface conditions at the site were determined using the information available in published geological reports and mapped units. The results field investigations and laboratory testing were used to confirm the geologic interpretations and soil contacts. A discussion of subsurface conditions encountered is provided in Section 4.

Laboratory Testing. The engineering parameters of the foundation soils and proposed borrow areas were evaluated through a detailed laboratory testing program, which included: natural water contents, grain size analyses, Atterberg limits plasticity tests, soil unit weights, consolidation tests, triaxial shear strength tests, and soil-moisture-density relationship curves. The laboratory testing program results are summarized in Section 5.

Embankment and Foundation Seepage and Stability. Engineering studies included seepage and stability analyses of the proposed setback levee embankments and foundation materials subjected to the Levee Design Flood. These analyses were performed on representative reaches of the two levee alignments (the levee "reaches" are defined in Section 6 of this report) using information obtained from the comprehensive field and laboratory investigation programs.

Potential Settlement and Loss of Freeboard. The engineering studies also evaluated the potential magnitude of settlement of the foundation soils due to the added load of 10- to 30-foot tall setback levee embankments. The studies determined the potential loss of freeboard due to settlement through long-term consolidation.

3. GEOTECHNICAL INVESTIGATION

3.1 Borehole Explorations

A field exploration program for the Steigerwald Setback Levee Design was completed during the period of July 27 through August 27, 2015. Western States Soil Conservation, Inc of Hubbard, Oregon performed the borehole drilling using CME 850 and CME 55 rubber track-mounted drill rigs. The boreholes were drilled using mud-rotary and hollow stem auger (HSA) drilling techniques.

The program consisted of 44 exploratory borings mostly grouped into rows of one to three borings per cross section location at intervals varying from approximately 500 to 1000 feet along the proposed levee alignments. Nine of the borings were located for appurtenant structures such as a flood wall, closure structure and pedestrian bridges. The boring locations for all areas except the pedestrian bridges are shown on the Site Maps, Figures 2 through 7. The pedestrian bridge borings are on the interior of the site and shown on Figure 11. The boring locations were survey-located by ESA. The borings are designated as WL-01 through WL-23 for the West Setback Levee; EL-01 through EL-12 for the East Setback Levee; CS-01 and CS-02 for the SR-14 Closure Structure; GF-01 through GF-05 for the Gibbons Creek Floodwall; and BR-01 and BR-02 for two pedestrian bridge locations. In general, numbering begins at the south end of the proposed levees and continues sequentially to the north end toward SR-14. However, some boreholes were drilled in-between previously drilled locations and, therefore, have a number that is out-of-sequence.

Samples were typically taken at approximately 5-foot intervals using Standard Penetration Tests (SPT). In addition, 3-inch diameter, thin-walled Shelby tube sample were obtained at select depths to acquire relatively undisturbed soil samples when fine grained soils were encountered. Where gravel and cobbles were encountered a 3-inch diameter split-spoon sampler (Dames & Moore sampler) was driven in an effort to retrieve soil samples for classification. The exploratory boring depths ranged from 40 to 100 feet. The total drilling footage was approximately 2,565 feet. The exploratory borings were backfilled with cement-bentonite grout. Six standpipe piezometers were installed to monitor groundwater levels at the locations shown (different symbol) on the Site Map Figures.

Representatives from our firm were present throughout the field explorations to collect and log the recovered soil samples, prepare a descriptive field log of the subsurface conditions encountered, and to collect digital data during field falling head permeability testing. Our field representatives also coordinated and assisted the driller during the backfilling and clean-up efforts for each boring site.

A summary log of the subsurface conditions encountered in each boring are shown on Summary Boring Logs, Figures A1 through A44 in Appendix A, included at the end of this report. The Summary Boring Logs describe the drilling methods, materials encountered, depths and types of samples, SPT blowcounts, interpretive layer thicknesses, and natural water contents of collected samples. The ground surface elevations noted on the Summary Boring Logs were provided by ESA, Inc.

3.1.1 Field Permeability Testing

A total of 10 falling head field permeability tests were performed in 5 borings to evaluate the permeability of the soil layers at selected depths. The falling head tests were conducted in borings that correspond to the cross-section locations where seepage and slope stability analyses were performed (see Section 6 of this report). In general, testing was performed through the hollow-stem auger with the cutting shoe resting on the base of the drilled hole, making the seepage area equal to the base area inside the auger casing. Occasionally, the rate of seepage was slow and the casing was raised above the base of the drill hole a short length, making the seepage area equal to the base area and the exposed sidewall surface area of the hole. The soil type encountered and field permeability measurements are summarized in Table 2. These measurements were used as an index for developing soil properties in the seepage analyses.

Table 2: Falling Head Field Permeability Test Results

Boring	Soil Type	Test Depth (ft)	"k" value (cm/sec)	"k" value (ft/min)
EL-06	clayey silt	15	1.38E-04	2.72E-04
EL-06	clayey silt	25	1.28E-06	2.53E-06
EL-08	sandy silt	15	6.10E-04	1.20E-03
EL-08	sandy gravel	25.5	2.80E-04	5.52E-04
EL-08	sandy gravel	40	5.23E-05	1.03E-04
WL-04	clayey silt	15	1.25E-03	2.47E-03
WL-12	clayey silt	10	7.34E-06	1.45E-05
WL-12	clayey silt	16	2.72E-04	2.72E-04
WL-19	sandy silty gravel	15	5.54E-05	1.09E-04
WL-19	sandy silty gravel	18	3.50E-06	6.85E-06

3.2 Test Pit Explorations

The test pit program was completed was completed during two time periods. The first test pits were performed between November 21 through 29, 2016 by Western States Soil Conservation, Inc of Hubbard, Oregon. The work was performed using a Hitachi ZX-135 and a Komatsu PC40 excavator with a smooth bucket. The second stage of test pits were performed by Stratus Corporation of Gaston, Oregon between September 19 and September 21, 2017 using a Caterpillar 305E excavator. The program consisted of excavating 45 exploratory test pits spread across the interior of the Refuge.

The test pits were performed in a grid pattern to characterize potential borrow areas, extended habitat areas, and proposed channels. The test pit locations are shown on the Site Maps, Figures 11 through 16. Bulk samples were collected from the excavations for each material encountered. The test pit depths ranged from 3.5 to 10 feet and were backfilled with the cuttings that were replaced in lifts and tamped with the excavator bucket until firm and unyielding.

A field representative from our firm was present throughout the test pit explorations to collect and log the subsurface soils and prepare a descriptive field log. Our field representative coordinated and assisted during the backfilling and clean-up efforts for each test pit.

A summary of the subsurface conditions encountered in each test pit are included on tables in Appendix B, included at the end of this report. The Test Pit Logs describe the materials and the approximate depths where different materials were encountered.

4. SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Site Geology

The project site is located on the north shoreline of the Columbia River from River Mile 122.5 to 128.0. The Refuge is at the east end of the Portland Basin, which is part of the Puget-Willamette Lowland physiographic region that lies between the Coast Range and the Cascade Range. The Puget-Willamette Lowland is a forearc basin of the Cascadia Subduction Zone. The Columbia River, which emerges from the gorge just to the east of the site, has been a major agent that has controlled the geology of the site. The following descriptions of geology are based on Evarts et al (2013), supplemented by Phillips (1987), Fiksdal (1975), and Trimble (1963).

Hills to the north of the site, which is the drainage basin of Gibbons and Campen Creeks, consist of the Conglomerate Member of the Troutdale Formation (Pliocene and/or Miocene) and unnamed conglomerate (Pleistocene and Pliocene?). These rocks represent the Basin-Fill Deposits contributed by the ancestral Columbia River in late Tertiary to early Pleistocene. The peaks of the hills (including Mount Norway and Nicols Hill) are capped by the younger basaltic andesites of the Volcanic Rocks of the Boring Field (Pleistocene).

The foothills of the Gibbons and Campen Creek drainage basins consist primarily of the gravel facies of the Cataclysmic-Flood Deposits (Pleistocene) that resulted from the outburst floods of Glacial Lake Missoula, which occurred multiple times between about 16,000 to 12,000 years before present (B.P.). These floods emerged from the Columbia River gorge and scoured the landscape near Washougal, completely denuding Tertiary bedrock and the Troutdale Formation of soil and other surficial material to elevations as high as 400 feet, and deposited their outwash flood debris. The gravel facies consists of unconsolidated, bouldery to cobbly gravel and sand organized into prominent large bars along the lower reach of the Washougal River.

At the eastern part of the Refuge, the steep hills of the Troutdale Formation to the north make direct contact with the flat Holocene alluvium discussed below, and there are no mapped Cataclysmic-Flood Deposits.

At lower elevations at the Refuge, surficial deposits consist of Holocene alluvium of Gibbons Creek (central part), Lawton Creek (east end), and the Columbia River floodplain. The Gibbons Creek alluvium forms a fan and includes debris flow deposits that incorporate clasts that originate from the Cataclysmic-Flood Deposits and the conglomerates of the Troutdale Formation at higher elevations in the drainage basin. The Lawton Creek alluvium also forms a fan and includes debris flow deposits that incorporate clasts that originate from the conglomerates of the Troutdale Formation at higher elevations in its drainage basin. The Columbia River floodplain alluvium consists primarily of deposits of silts and sands that resulted from river aggradation during the sea level rise since the last glacial sea-level low stand of about 112 m (367 ft) below the present sea level at 15,000 years B.P.

4.2 General Stratigraphy

The subsurface conditions are similar at each of the proposed setback levees and consist of Holocene alluvium overlying the Conglomerate Member of the Troutdale Formation (Troutdale). The Holocene alluvium consists of (i) the Columbia River alluvium and (ii) alluvial fan deposits (of Gibbons or Lawton Creeks at the West and East Setback Levee, respectively). Geologic profiles along the East and West Setback Levees are provided on Figures 8 through 10.

The area of the East Setback Levee between E 9+00 and E 11+25 is where an existing drainage channel is underlain by deposits of gravel alluvium. This is likely a relict channel that was open to Columbia River flooding. The existing channel drains to the west into Steigerwald Lake.

The area of the West Setback Levee between about Sta. W 23+00 and W 39+00 is where a shallow lake and former Gibbons Creek channel existed, which had connections with the Columbia River before the Camas-Washougal levee system was completed and the landward areas were diked for development. Subsequent pumping operations drained the diked region and probably lowered the water level in this area, exposing the alluvial soils. Currently, there is a waterway 10 to 30 feet wide at about Sta. W 25+75 that channels water to the pumping station about 1.5 miles to the west.

4.2.1 Columbia River Alluvium

The Columbia River Alluvium (CRA) consists of interlayered fine sands and silts, with occasional gravel toward the bottom of the deposit, and frequently contains mica flakes. Fine sands are typically silty and are very loose to loose. Silts are typically fine-sandy, slightly clayey, and are soft to medium stiff. The thickness of the Columbia River Alluvium is estimated to be about 100 feet at the south end of the proposed levees (about Sta. W 0+00 to W 2+00), gradually decreasing to about 20 feet in the vicinity of Sta. W 36+00. On the East Setback Levee the CRA gradually decreases from approximately 90 feet thick at Sta. E 2+00 to 20 feet thick at Sta. E 22+00.

4.2.2 Gibbons Creek Alluvium

The alluvial fan deposits of Gibbons Creek underlies the slightly higher areas north of the exposed lake bed from about Sta. W 37+00 northward on the west levee alignment. It consists of a medium dense to dense mixture of gravel, rock fragments, and silty sand; which is presumed to be debris flow deposits from Gibbons Creek. The fan deposit also contains loose sands and silts. The thickness of the alluvial fan is about 15 feet in the vicinity of Sta. W 3+00, and increases toward the northeast to about 30 feet at the north end of the proposed levee (Sta. W 51+70).

4.2.3 Lawton Creek Alluvium

The Lawton Creek Alluvium underlies the slightly higher areas at the northeast side of the Refuge (Sta. E 22+00 northward) on the East Setback Levee alignment. It consists of a medium dense to dense mixture of gravel, rock fragments, and silty sand; which is presumed to be debris flow deposits from Lawton Creek. The alluvium is likely a redeposited soil scoured from the

Troutdale Formation, which forms the hills to the north. The thickness of the alluvial fan is about 15 feet in the vicinity of Sta. E 22+00.

4.2.4 Conglomerate Member of Troutdale Formation

A conglomerate underlies the recent Holocene alluvium and consists of dense subrounded gravel and cobbles in a matrix of slightly cemented sand. This unit contains clasts of Columbia River Basalt Group with quartzite and granitic and felsic metamorphic clasts and is equivalent in part to the Troutdale Formation (Evarts et al., 2013). The conglomerate contact generally dips to the south. On the West Setback Levee the contact was encountered at approximately 80 feet and 20 feet below the ground surface on Sta. W 3+00 and W 33+36, respectively. The conglomerate contact was encountered at 100 feet and 30 feet below the ground surface at Sta. E 2+00 and E 22+50, respectively. The conglomerate forms the steep slopes to the north of the Refuge where it is more than 600 feet (200 meters) thick. This unit is believed to be much thinner at the Refuge location and has only been mapped on the north side of the Columbia River (Evarts et al, 2013). For simplicity, this unit will be referred to as “Troutdale Formation” throughout the report.

4.3 Standpipe Piezometers and Groundwater Monitoring

Standpipe piezometers were installed in two boreholes (EL-04 and EL-08) on the East Setback Levee alignment and four boreholes (WL-04, WL-11, WL-16, and WL-20) on the West Setback Levee at the time of drilling. The standpipe piezometers consist of 1-inch diameter PVC pipe with a slotted screen. A sand filter zone was created by using coarse sand to backfill around the slotted screen in each boring. Bentonite grout or bentonite chips were used to seal the borehole above and below the sand filter zone. Details of the standpipe piezometers are provided in Table 3 and on the Summary Boring Logs in Appendix A.

Table 3: Standpipe Piezometer Details

Boring	Ground Surface Elev, (feet)	Top of Filter Zone (Elev)	Bottom of Filter Zone (Elev)	Piezometer Tip Elevation (ft)
EL-04	37.5	12.5	-24.0	-19.2
EL-08	23.0	6.0	-17.3	-12.8
WL-04	27.2	20.2	6.2	9.1
WL-11	17.7	-4.3	-17.3	-11.6
WL-16	18.7	1.7	-22.8	-20.2
WL-20	28.2	-8.8	-21.8	-18.7

Vibrating Wire Piezometers (VWPs) with dataloggers were installed into the standpipes on October 1, 2015 to monitor groundwater fluctuations. The groundwater data were collected from initial installation of the VWPs to the most recent reading on September 25, 2017. A summary of the high and low groundwater at each piezometer is shown in Table 4.

Table 4: Groundwater Fluctuation at Each Vibrating Wire Piezometer Location.

Boring	Ground Surface Elev, (feet)	Approx. High Groundwater Elev, (feet)	Approx. Low Groundwater Elev, (feet)	Piezometer Tip Elevation (ft)
EL-04	37.5	27.6	13.1	-19.2
EL-08	23.0	26	9.7	-12.8
WL-04	27.2	27.7	20.5	9.1
WL-11	17.7	20.7	9.4	-11.6
WL-16	18.7	22	13.2	-20.2
WL-20	28.2	25.6	18.4	-18.7

Groundwater levels are typically highest from January to May and tend to be heavily influenced by the water levels in the Columbia River. The groundwater data plots are provided in Appendix C.

4.4 Geologic Sections

The information collected from the borings was used to develop typical geologic/analysis cross sections at select locations along the levees to use in the engineering evaluations of embankment stability, seepage and potential settlements. The subsurface conditions summarized above are shown graphically on the geologic/analysis sections. The typical sections with the subsurface conditions included at specific embankment locations are shown on the Geologic/Analysis Cross Sections provided in Appendix E.

5. LABORATORY TESTING

Laboratory testing was performed to determine soil index and engineering properties on selected samples. All testing was performed at Cornforth Consultants' soil testing laboratory in Portland, Oregon in general accordance with ASTM standards, and with the USACE's EM 1110-2-1906, Laboratory Testing Procedures (USACE, 1986). Tests were conducted on samples selected from the field explorations to verify field classifications and to determine the following properties:

- natural moisture contents
- grain-size distribution (gradations)
- Atterberg limits
- unit weights
- consolidation properties
- shear strength parameters: angle of internal friction and cohesion intercept, (consolidated-undrained triaxial shear strength testing and direct shear testing)
- Standard Proctor compaction test

All laboratory test plots, except moisture contents, are included in Appendix D.

5.1 Soil Classification

All soil samples obtained from the field explorations were visually re-examined in the laboratory to confirm the field classifications, using ASTM guidelines. Final soil descriptions were prepared based on a combination of the visual examination and laboratory testing of index properties. The final classifications, layer descriptions, and interpretive layer contacts are presented on the Summary Boring Logs, Figures A1 to A44 in Appendix A. The soil classifications are presented on the Test Pit Summary Logs in Appendix B.

5.2 Natural Moisture Content

All soil samples collected from the borings were tested to determine their natural moisture contents in general accordance with ASTM D-2216-10. The results of these tests are plotted graphically on the Summary Boring Logs (Figures A1 to A44, Appendix A) and Test Pit Logs (Appendix B).

5.3 Grain-Size Distribution (Gradations)

Grain-size distribution analyses (gradation analyses) by both mechanical-only and combined mechanical/hydrometer test methods were performed on select samples in general accordance with ASTM D-422-63R07. Gradation analyses by mechanical-only were completed on 22 soil samples and by combined mechanical/hydrometer tests on 24 soil samples. The samples were selected with preference to characterize the near surface soils (i.e. upper 60 feet) in order to better predict seepage through these soils. Deeper deposits and coarser grained soil were tested where possible and where adequate sample was recovered. The results of the gradation tests on foundation soils are plotted on Gradation Graphs, Figures D-1 through D-8 in Appendix D.

5.4 Atterberg Limits

Liquid and plastic limits (Atterberg limits) were determined for 27 soil samples collected during the field investigations. Test procedures were in general accordance with ASTM D-4318-10. Results of this testing are shown in Table 5 below and plotted graphically on Plasticity Charts, Figures D-9 through D-11.

Table 5: Atterberg Limits and Natural Moisture Contents of Select Foundation Soils

Boring No.	Sample No.	Depth (ft)	Natural Moisture (%)	LL (%)	PL (%)	PI (%)	Atterberg Limit Classification
EL-01	S-3	15	45	43	30	13	ML
EL-04	S-6	25	41	41	27	14	ML
EL-05	S-3	15	51	67	36	31	MH
EL-06	S-2	10	44	44	29	15	ML
EL-06	S-5	22	42	53	30	23	CH
EL-07	S-6	25	45	50	29	21	ML
EL-10	S-2	10	32	42	30	12	ML
EL-12	S-8	40	51	51	32	19	MH
WL-01	S-4	20	71	65	37	28	MH
WL-02	S-6	28	61	83	38	45	CH
WL-03	S-5	25	41	40	30	10	ML
WL-04	S-3	21	57	58	32	26	MH
WL-06	S-4	18	37	57	31	26	MH
WL-07	S-3	16	40	50	28	22	CL
WL-07	S-14	61	52	52	31	21	MH
WL-08	S-2	11	44	46	27	19	CL
WL-09	S-2	11	40	35	26	9	ML
WL-10	S-1	6	36	35	26	9	ML
WL-10	S-4	19	48	55	31	24	MH
WL-10	S-4b	19	48	50	27	23	CL
WL-12	S-3	11	44	51	32	19	MH
WL-17	S-1	5	36	43	24	19	CL
WL-21	S-7	20	77	70	37	33	MH
WL-22	S-3	20	52	45	34	11	ML
WL-23	S-1	8	45	45	30	15	ML
WL-23	S-3	20	47	66	36	30	MH
BR-02	S-2	7	38	57	35	22	MH

5.5 Unit Weights

Unit weight determinations were performed on six samples used for the consolidation tests, eight samples used in the consolidated-undrained triaxial shear tests (both discussed below) and two tests performed only to obtain unit weights. These analyses were performed in general accordance with ASTM D-7263-09. The results of these tests are summarized in Table 6 below.

Table 6: Moist and Dry Unit Weights of Select Samples

Boring No.	Sample No.	Depth (ft)	Moist Unit Weight (pcf)	Dry Unit Weight (pcf)	Summary Log Classification
EL-01	S-6	30.0-31.5	118	83	sl. clayey, sl. sandy silt
EL-01	S-6	30-31.5	111	78	sl. clayey, sl. sandy silt
EL-03	S-3	15.0-17.0	109	75	Silt
EL-03	S-3	15.0-17.0	110	76	Silt
EL-03	S-3	15.0-17.0	109	74	Silt
EL-04	S-3	15.0-17.0	115	87	Silt
EL-07	S-6	25.0-27.0	109	76	Silt (ML)
WL-03	S-5	25.0-27.0	106	70	clayey silt (ML)
WL-03	S-5	25.0-27.0	108	75	clayey silt (ML)
WL-06	S-4	18.0-20.0	121	84	clayey silt (MH)
WL-06	S-4	18.0-20.0	107	73	clayey silt (MH)
WL-10	S-4	18.0-19.5	115	82	clayey silt (MH)
WL-21	S-2	5.0-7.0	116	83	silty sand
WL-21	S-2	5.0-7.0	114	80	silty sand
WL-21	S-5	15.0-61.5	110	75	silty sand
WL-23	S-1	8.0-10.0	109	75	Silt (ML)

5.6 Consolidation Tests

One-dimensional consolidation tests were performed on six samples in general accordance with ASTM D-2435-04. The test samples were selected to characterize the clayey silt interbeds encountered in the thick deposits of the Columbia River Alluvium layer that underlies the south end of the Refuge. Samples were tested from different boreholes and depths along the southern end of the West and East Setback Levees to determine how soil parameters vary along the alignment and within the soil layer. Preference was given to shallower soil samples where available.

Samples were collected in the field using a 3-inch diameter, thin-walled, Shelby tube sampler, and extruded in the laboratory prior to testing. The samples were tested under an incrementally-applied controlled stress load. Compressibility and permeability parameters calculated from the consolidation tests are shown in Table 7 and Table 8 below, respectively. Graphical plots of the consolidation test results are shown on Consolidation Test plots, Figures D-12 through D-17.

Table 7: Summary of Consolidation Test Compressibility Parameters

Boring No.	Sample No.	Depth (ft)	$C_{\varepsilon c}$	$C_{\varepsilon r}$	OCR	C_{α}^{1}	Summary Log Classification
EL-01	S-6	30	0.15	0.016	1.92	0.0027	sl. clayey, sl. sandy silt
EL-04	S-3	15	0.13	0.016	2.24	0.0014	sl. clayey, sl. sandy silt
EL-07	S-6	25	0.18	0.025	1.75	0.0020	clayey silt (ML)
WL-03	S-5	27	0.16	0.020	1.32	0.0036	clayey silt (ML)
WL-06	S-4	20	0.19	0.030	2.03	0.0025	clayey silt (MH)
WL-23	S-1	10	0.16	0.027	3.08	0.0017	clayey silt (ML)

[1] For 1 tsf loading

Table 8: Summary of Consolidation Test Permeability Parameters (at 1 tsf loading)

Boring No.	Sample No.	Depth (ft)	c_v^1 (ft^2/yr)	k^1 (cm/sec)	k^1 (ft/min)	Summary Log Classification
EL-01	S-6	30	418	$6.69\text{x}10^{-4}$	$1.32\text{x}10^{-3}$	sl. clayey, sl. sandy silt
EL-04	S-3	15	468	$6.59\text{x}10^{-4}$	$1.30\text{x}10^{-3}$	sl. clayey, sl. sandy silt
EL-07	S-6	25	162	$3.22\text{x}10^{-4}$	$6.34\text{x}10^{-4}$	clayey silt (ML)
WL-03	S-5	27	708	$1.64\text{x}10^{-3}$	$3.23\text{x}10^{-3}$	clayey silt (ML)
WL-06	S-4	20	255	$5.90\text{x}10^{-4}$	$1.16\text{x}10^{-3}$	clayey silt (MH)
WL-23	S-1	10	209	$3.82\text{x}10^{-4}$	$7.52\text{x}10^{-4}$	clayey silt (ML)

[1] For 1 tsf loading

5.7 Consolidated-Undrained Triaxial Shear Tests

Eight consolidated-undrained triaxial compression shear tests were performed at incremental confining pressures to evaluate typical shear strength parameters of the levee foundation soils. The test samples were selected from the southern end of the West and East Levees to characterize the clayey silt encountered in the thick deposits of the Columbia River Alluvium layer. CU triaxial testing was limited to the primarily fine grained samples where adequate amounts of undisturbed samples could be recovered. Preference was given to shallower soil samples on the south end of either levee or where the levee height is tallest.

Each soil sample was collected in the field using a 3-inch diameter thin-walled Shelby tube sampler, and extruded in the laboratory prior to testing. The consolidated-undrained tests were divided between two samples with three tests each and one sample with two tests. Two samples, EL-03:S-3 and WL-10:S-4, were tested for a 3-point strength envelope under the same series of confining pressures, consisting of 1,000 pounds per square foot (psf), 2,000 psf, and 4,000 psf. Testing was performed in general accordance with ASTM D-4767-11. The final sample WL-21:S-2 was tested at 2,000 psf and 4,000 psf. A third point was not performed for WL-21:S-2 because a third undisturbed sample could not be extruded from the sample tube. The two point strength envelope is included for reference.

The key results from the triaxial shear testing are summarized in terms of the internal angle of friction (ϕ') and the cohesion intercept (c') as determined from a Mohr Diagram plot. The results from the testing are presented below in Table 9, and the Mohr Diagram plots and supporting stress-strain diagrams for the three samples as shown on Figures D-18 through D-23.

Table 9: Summary of Consolidated-Undrained Triaxial Shear Test Results

Boring No.	Sample No.	Depth (ft)	Internal Angle of Friction ϕ' (degrees)	Cohesion Intercept c' (psf)	Summary Log Classification
EL-03	S-3	15.0-17.0	35	0	slightly sandy silt
WL-10	S-4	18.0-20.0	37	0	clayey silt (MH)
WL-21*	S-2	5.0-7.0	41	0	silty sand

*Based on two points tested at confining pressures 14 and 28 psi

5.8 Standard Proctor Moisture-Density Test

Two standard Proctor moisture-density tests were performed on samples collected from test pit explorations. Bulk samples from several test pits were combined to create test samples. These analyses were performed in general accordance with ASTM D698 (Method A) to determine the maximum dry density and optimum water content. The results of these tests are summarized in Table 10 below and the compaction test plots are shown in Appendix D (Figures D-23 and D-25). The test data indicates that the bulk samples were wet of optimum at the time of sampling.

Table 10: Standard Proctor Compaction Test Results

Specimen No.	Test Pits	Sample No.	Depth (ft)	Natural Water Content (%)	Optimum Water Content (%)	Maximum Dry Density (lb/ft^3)
Test 1	TP-E2	S-3	7	41	24	94.1
	TP-G2	S-2	5.5	65		
	TP-I2	S-2	6	53		
	TP-J2	S-2	7	53		
Test 2	TP-A1	S-1	5	29	17.5	104.7
	TP-C1	S-1	5	28		
	TP-D1	S-1	5	29		
	TP-D2	S-3	2.5	32		

6. LEVEE EMBANKMENT STABILITY AND POTENTIAL SEEPAGE

6.1 Levee Height and Design Flood

The design criteria for the new setback levees is that the overall stability and potential seepage through and under the new levees need to be evaluated under the Design Flood Level loading conditions.

The design setback levee heights are based on maintaining a minimum 3 feet of freeboard for the design flood. The Levee Design Flood (LDF) water level based on a flow of 940,000 cubic feet per second (cfs) in the Columbia River measured at The Dalles according to the USACE Design Memorandum (USACE, 1964). The design water surface varies from elevation 43.3 feet (NAVD88) on the east end of the Refuge (RM 128) to 42.7 feet on the west end (RM 122.86).

The design heights for the East and West Setback Levees are set at elevation 46.3 feet and 45.7 feet (NAVD88), respectively. The new setback levees closely match the design crest elevation of the existing Camas-Washougal levee. The existing levee is taller on the east side than it is on the west, which is why the heights of the setback levees differ.

6.2 Levee Reaches

To facilitate the design and analyses of the proposed setback levees, each levee was divided into segments with similar features and soil conditions. These segments with similar properties are generally referred to as “reaches”. This method allows the setback levee alignments to be analyzed in manageable pieces. For the purposes of this design, we partitioned the new setback levees into four reaches each. These reaches have been grouped based on: (i) levee embankment configuration; (ii) subsurface conditions, and (iii) levee height. The limits of each reach are shown on the Geologic Profiles for the East and West Setback Levees included on Figures 8 through 10. Design changes deemed necessary based on the analysis of a representative section of a reach will be applied to the entire reach.

The approximate limits and a description of each reach is provided below. The general shape of proposed setback levees are consistent along the length with 4H:1V (horizontal:vertical) and 3H:1V landside and riverside side slopes, respectively. The width of the design levee crest is 12 feet and the base width will vary with overall height of the levee. Levee reaches are designated with “E” and “W” to represent the East and West Setback Levees, respectively.

6.2.1 Reach E-1

This segment is located from STA E 0+00 to E 8+00 and is where the existing levee transitions to the new East Setback Levee. This segment of levee is approximately 12 to 14 feet tall and is overlying more than 75 feet of compressible interbedded silts and sands of Columbia River Alluvium.

6.2.2 Reach E-2

This segment is located from STA E 8+00 to E 16+00. The levee height increases from south to north from 14 to 25 feet tall, respectively. The levee crosses the drainage channel of diverted irrigation water from Lawton Creek. Reach E-2 transverses 75 to 28 feet of compressible Columbia River Alluvium from south to north, respectively.

6.2.3 Reach E-3

This segment is located from STA E 16+00 to E 20+00. This segment of the levee varies in height from 25 to 27 feet as it transverses a slight depression in the ground surface. The thickness of compressible Columbia River Alluvium gradually decreases from 26 to 21 feet from south to north, respectively.

6.2.4 Reach E-4

This segment is located from STA E 20+00 to E 24+50. This segment of the levee varies from 24 feet tall at STA E 20+00 (southern end) and ties into the native high round at the northern extent. The levee fill will overlie approximately 5 to 15 feet of Lawton Creek Alluvium consisting of gravel and cobbles in a matrix of silty sand. A compressible layer of Columbia River Alluvium that varies from 16 to 20 feet thick is present beneath the Lawton Creek alluvial fan materials.

6.2.5 Reach W-1

Reach W-1 is the southernmost segment on the West Setback Levee and extends from Station W 0+00 to W 18+00. This segment of levee varies over undulating ground from 10 to 24 feet tall and is overlying more than 65 feet of compressible interbedded silt and sand deposits of Columbia River Alluvium.

6.2.6 Reach W-2

The segment for Reach W-2 is located from STA W 18+00 to W 28+00 and is where the levee curves to the west trending to the NNW. The levee height increases from south to north from 18 to 30 feet tall, respectively. The levee crosses the west drainage waterway where soft saturated sediments overlie approximately 65 to 25 feet thick deposits of compressible Columbia River Alluvium from south to north, respectively. Thus, the levee height increases as the compressible soil thickness decreases.

6.2.7 Reach W-3

This reach is located from Station W 28+00 to W 37+00. This segment of the levee curves back to the north and the height varies from 30 to 26 feet from south to north, respectively. The thickness of compressible Columbia River Alluvium gradually decreases from 25 feet at STA W 27+00 to 19 feet at STA W 37+00.

6.2.8 Reach W-4

This reach is located from Station W 37+00 to W 52+30 and terminates at the SR-14 closure structure abutment wall. This segment of the levee varies from 30 to 10 feet tall from south to north, respectively. The levee fill is overlying approximately 10 to 30 feet of Gibbons Creek Alluvium consisting of gravel and cobbles in a matrix of silty sand. There are thin deposits of compressible Columbia River Alluvium on the south end of this segment. The alluvial deposits are underlain by Troutdale Formation.

6.3 Analyses Models

Stability and seepage analyses were performed on representative geologic/analysis cross-sections through the proposed setback levee embankments and the proposed closure structure. These sections were developed using topographic information obtained by Statewide Surveying and the proposed setback levee alignments provided by Wolf Water Resources. Subsurface information was obtained from our field investigation program discussed earlier. Analyses were performed on four representative cross-sections for the West Setback Levee (Reaches W-1 through W-4) and four representative cross-sections for the East Setback Levee (Reaches E-1 through E-4) as shown in Appendix E.

6.4 Design Flood Elevations

As discussed in the introduction the design flood level was set by the Washougal Flood Damage Reduction (FDR) Project authorized by the Flood Control Act of 1950 using a Columbia River flow of 940,000 cfs as measured at The Dalles. The design flood elevation at each setback levee was calculated using linear interpolation and the approximate levee locations on the Columbia River. The East and West Setback Levees are located at approximately RM 127.4 and RM 125.0, respectively. Thus, the design flood elevation used to analyze the seepage and slope stability of the east and west setback levees are 43.3 feet and 42.7 feet, respectively.

6.5 Analysis Methods

The geologic/analysis cross-sections were used as the basis for developing analytical models in seepage and slope stability software programs SEEP/W and SLOPE/W (2012), respectively. Soil properties for unit weight and permeability were developed from field and laboratory testing of the foundation materials. Columbia River Alluvium strength parameters were selected from Consolidated Undrained (CU) triaxial test data performed on undisturbed samples as reported in Section 5.7. We made conservative assumptions for the strength of alluvial fan material and Troutdale Formation based on field density testing (SPT) correlations.

The embankment fill properties were estimated from investigations performed by Cornforth Consultants in 2012 as part of a recertification study on the existing Camas-Washougal levee and investigations of subsurface soils on the Refuge performed for the setback levee design (Cornforth, 2012). Existing levee fill material was predominantly dense, slightly silty sand. Investigations along the interior of the site indicated potential borrow sources tend to be predominantly fine sandy silt. These materials will be generally less dense and lower strength, but have a lower permeability. Final soil properties were developed considering a probable blend of borrow materials from the existing levee and from within interior borrow pits. The typical material descriptions and estimated properties are summarized below in Table 11.

Table 11: Summary of Estimated Soil Properties for Stability and Seepage Analyses

Material Descriptions	Unit Weight, γ (pcf)	Friction Angle, φ' (degrees)	Cohesion Intercept, c' (psf)	Permeability, k (ft/min)	Permeability Ratio, k_h/k_v
Embankment Fill: silty Sand to sandy Silt (Compacted Fill)	115	34	0	2.0×10^{-2}	4
Columbia River Alluvium: slightly sandy Silt	110	35	0	7.8×10^{-4}	4
Gibbons/Lawton Creek Alluvial Fan: gravelly, silty Sand	120	38	0	4.0×10^{-3}	4
Troutdale Formation: gravel and cobbles in a matrix of Sand	120	40	0	1.9×10^{-4}	4

6.6 Seepage Analyses

Seepage analyses were performed on typical setback levee cross-sections to model potential seepage flow through the foundation and embankment soils due to the design flood level. The finite element mesh used in the SEEP/W program was adjusted to 2 feet x 2 feet elements or smaller sizes in some instances. The design flood elevation was modeled as 43.3 feet and 42.7 feet on the East and West Setback Levees, respectively. The seepage through the embankment and foundations soils was calculated assuming saturated, steady-state conditions. The exit gradients at the inboard toe of the levee were averaged over 2 mesh units (approx. 4 feet). The exit gradients from these analyses were then compared to the recommended maximum exit gradient suggested by the USACE Design Manual for Level Design (EM 1110-2-1913), USACE, 2000.

For all analysis sections, the calculated exit gradients were lower than the maximum recommended value of 0.5 (USACE, 2000). The exit gradients for the analysis sections varied from 0.29 to 0.40 as shown on Table 12 and the results of the seepage analyses are shown on each of the individual Geologic/Analysis Cross Sections in Appendix E.

Table 12: Summary of Steady-State Seepage Exit Gradients

Reach	Station	Steady-State Seepage Exit Gradient
E-1	E 2+41	0.29
E-2	E 12+41	0.40
E-3	E 17+41	0.37
E-4	E 20+99	0.39
W-1	W 8+36	0.31
W-2	W 26+37	0.35
W-3	W 33+36	0.33
W-4	W 43+37	0.32

6.7 Embankment Stability Analyses

Slope stability analyses were performed using SLOPE/W to calculate the factor of safety (FS) for potential unstable slope conditions using limit equilibrium methods. The steady-state seepage data generated from the SEEP/W models were imported directly into SLOPE/W to provide a pore-pressure profile through the embankment and foundation. The rapid drawdown analysis assumed a 10% reduction in the steady state seepage piezometric surface due to the largely sandy silt, nature of the embankment materials. The embankment stability was analyzed using Spencer's method to find the critical slip surfaces on the waterside and landside slopes of the levee. The critical slip surface with the lowest FS for specific embankment conditions was determined using an entry and exit search routine with FS calculated for multiple circular slip-surfaces. The failure surfaces pass through the levee crest with a minimum depth of 5 feet to prevent shallow surficial surfaces from controlling the analyses. Surficial failure surfaces may show lower factors of safety, however, they are considered to be a less critical threat to the integrity of the levee than deeper failures. Surficial failures can generally be mitigated sufficiently with inspections and routine maintenance.

Slope stability assessments were performed for the waterside and landside slopes of each typical cross-section for each levee reach. Several combinations of slip surfaces were analyzed to determine the location of the critical slip surface. Factors of safety were calculated for shallow and deep circular slip surfaces that originate at the crest and/or on the side slopes. Where lower FS were encountered, the search entry-exit grid was adjusted to refine the search near the areas of lower stability.

The USACE Engineer Manual EM 1110-2-1913 specifies minimum FS for slope stability for new levees. The required minimum FS for the three static load conditions are shown in Table 13 below.

Table 13: Minimum Slope Stability Factors of Safety for New Levees.

Stability Condition	Required Factors of Safety (FS)
End-of-Construction	1.3
Long-Term (Steady State Seepage)	1.4
Rapid Drawdown	1.0 to 1.2

The inboard and waterside slopes were analyzed under these three conditions. The results of the stability analyses are summarized in Table 14 below. The individual Geologic/Analysis Cross Sections and the tabulated results for each stability analyses are shown in Figures E-1 through E-8 (Appendix E). All calculated factors of safety were greater than the minimum values required for the static slope stability.

Table 14: Summary of Factors of Safety for Slope Stability Analyses.

Reach	Station	End-of-Construction		Long-Term (Steady State Seepage)		Rapid Drawdown	Meets USACE Criteria?
		Land side	Water side	Landside	Waterside	Waterside	
E-1	E 2+41	2.8	2.2	1.8	2.1	2.1	Yes
E-2	E 12+41	2.7	2.1	1.6	2.1	1.2	Yes
E-3	E 17+41	2.7	2.1	1.6	2.3	1.2	Yes
E-4	E 20+99	2.8	2.1	1.6	2.3	1.3	Yes
W-1	W 8+36	2.6	2.1	1.6	2.2	1.2	Yes
W-2	W 26+37	2.7	2.1	1.5	2.3	1.2	Yes
W-3	W 33+36	2.6	2.1	1.5	2.3	1.2	Yes
W-4	W 43+37	2.8	2.1	1.6	2.3	1.2	Yes

6.8 Uncertainty and Reliability of Setback Levees

Reliability analyses were performed on a representative levee section (W26+37) to assess the seepage and slope stability reliability of the setback levees. The analyses consisted of varying the angle of internal friction, unit weight and hydraulic conductivity of the levee embankment and foundation soils to determine the influence of each parameter on the factor of safety. Stability and seepage analyses were performed using three Columbia River flood stages for each soil parameter. The variability in factors of safety were used to determine the reliability and the probability of failure by a method described by Duncan (2000). A detailed discussion of the reliability analyses for the Steigerwald setback levees is provided in a letter report titled, "Levee Reliability Analysis, Steigerwald Levee Design", dated April 14, 2017, by Cornforth Consultants.

The reliability analysis results show that the setback levees are designed using materials and geometry to give a sufficiently low probability of failure. The seepage failure mode was assessed using the most likely value (MLV) of permeability of the soils and the plus and minus one order of magnitude of permeability values with flood levels up to the top of the levee. The slope stability was analyzed using the MLVs of angle of internal friction and unit weight and plus/minus one standard deviation of each parameter. The MLVs were taken as the values provided in Table 11. For the reliability study, flood levels were set at 45.7, 42.7 and 39.5 feet. These flood elevations were chosen based on a water surface at the top of the levee (45.7 feet), the levee design flood (LDF) at 42.7 feet, and 3 feet below the LDF.

The combined probability of failure for seepage and stability of the representative levee section with the flood stage at the top of levee (Elev 45.7 feet) is 5.8 percent. The combined probability of seepage/stability failure that was calculated is irrespective of the probability of the flood levels.

6.9 Earthquake Analyses

A pseudo-static seismic slope stability analysis was performed on the each analysis cross section using a horizontal coefficient (k) of 0.15g. The horizontal acceleration was applied to the critical slip surface assuming flood water was not acting on the levee at the time of the earthquake. The factors of safety calculated using the pseudo-static method were greater than the USACE required minimum FS=1.0. The FS against earthquake slope failure are shown on the Analysis Cross Sections on Figures E-1 through E-8 provided in Appendix E.

Earthquake loadings are not normally considered in analyzing the stability of levees due to the low probability of an earthquake coinciding with periods of high flood water, as stated in the USACE's manual EM 1110-2-1913. In addition, the USACE's publication for the National Flood Insurance Program (NFIP) Levee System Evaluation circular (EC 1110-2-6067) says that no seismic stability of levee systems is required if the 1 percent annual chance exceedance earthquake (100yr return period) produces a peak ground acceleration (PGA) less than 0.10g. The PGA values at the site were determined using the current United States Geological Survey (USGS) ground-motion database ground motion parameter calculator. A 108yr recurrence interval earthquake produces PGA values of approximately 0.07g according to the USGS calculator.

7. LEVEE SETTLEMENT ANALYSES

7.1 Analysis Procedure

The typical levee sections within each reach were analyzed for potential loss of freeboard due to post-construction settlement of the embankment fill and foundation soils. The settlement analyses were completed in general accordance with procedures outlined in the USACE’s Manual EM 1110-1-1904 (USACE, 1990). The magnitude and rate of consolidation were estimated using laboratory consolidation data from relatively undisturbed soil samples obtained during field explorations.

Settlement analyses were performed on the eight representative cross-sections used for seepage and stability analyses (Appendix E). The initial geometries of the setback levee sections were selected based on the general shape of the existing Camas-Washougal levee sections and a topographic survey of the existing ground surface along the setback levee alignments. The stress increase resulting from placement of the new levee was approximated using an elastic solution for a trapezoidal embankment load by Gray (1936). This method permits the stress increase to be calculated at various depths and distance from levee centerline, although settlement was generally evaluated only at the levee’s centerline. Settlement magnitude calculations proceeded in general accordance with the procedures outlined in USACE EM 1110-1-1904 for fine-grained soils.

Time rate of settlement analyses for a doubly drained soil deposit were performed using the method developed by Janbu (1965) to account for the beneficial contributions of a non-linear strain profile. The effects of horizontal drainage were evaluated using the method of Davis and Poulos (1972); however, the proposed levees are wide enough that this contribution is minimal and was neglected.

7.2 Compressibility of Embankment and Foundation Soils

Embankment soils will likely be a mix of the existing Camas-Washougal levee materials and onsite borrow materials excavated from various parts of the site. The existing levee materials generally consist of hydraulically placed dredge sand from the Columbia River channel. Borrow source materials generally consist of slightly clayey silt to silty fine sand. Embankment soils will consist of these available onsite materials, compacted to a minimum compaction, and thus settlement within the embankment is likely to occur as construction progresses or within a short time thereafter.

Field explorations and laboratory one-dimensional consolidation tests indicate that the Columbia River Alluvium deposits tend to be moderately compressible. In some locations, the Gibbons Creek Alluvium consists of loose silt and fine sands. In these locations, the material was assigned the same compressibility parameters as the Columbia River Alluvium. The compressibility of the dense, coarser-grained portions of the Gibbons Creek Alluvium; the Lawton Creek Alluvium; and the Troutdale Formation were estimated from SPT blow counts. Compressibility and other material parameters used in the analyses are summarized in Table 15.

Table 15: Compressibility Parameters for Settlement Analyses

Unit	Unit Weight (pcf)	$C_{\varepsilon c}$	$C_{\varepsilon r}$	OCR	C_{α}
Loose Alluvium (Columbia River Alluvium & some zones of Gibbons Creek Alluvium)	110	0.17	0.026	1.2 to 2.1	0.003
Dense Alluvium (some zones of Gibbons Creek Alluvium and Lawton Creek Alluvium)	120	0.03	0.03	-	-
Troutdale Formation	125	0.01	0.01	-	-

7.2.1 Estimated Total Settlement

The estimated magnitude and time rate of settlement within the foundation soils are controlled primarily by the thicker deposits of the Columbia River Alluvium. These deposits of interbedded silty sand to clayey silt are considerably more compressible than the Troutdale Formation and denser alluvial fan deposits consisting of gravels and cobbles. Estimates of settlement using the idealized shape of the design levee are summarized in Table 16 below and range from 0.6 to 3.5 feet. The larger settlements tend to occur on the south end of each levee and at low-lying areas in the middle of the site where the levee heights are greatest. These estimates are consistent with the existing Camas-Washougal levees, which have settled an average of 1.1 feet and up to 3.2 feet total, according to survey monitoring reports. Settlements reported in Table 16 include the effects of secondary compression in the compressible soils.

Table 16: Summary of Levee Settlement by Levee Reach

Reach	Section Station	Levee Height (ft)	Thickness of Compressible Soils (ft)	Estimated Settlement (ft)	Time to 90% Consolidation (months)
E-1	E 2+41	10	10	1	74
E-2	E 12+41	23	40	2.5	18
E-3	E 17+41	24	25	2	7
E-4	E 20+99	21	18	1	3
W-1	W 8+36	18	85	3.5	72
W-2	W 26+37	30	35	3	15
W-3	W 33+36	30	25	2.7	7
W-4	W 43+37	22	14	0.6	3

7.2.2 Time Rate of Settlement

The estimated time required for 90 percent consolidation of the foundation layers ranges from 3 to 74 months for the typical sections of the setback levees (see Table 16 above). These estimates assume double drained conditions using a coefficient of consolidation (c_v) of 200 square feet per year. The height of the levee embankment and thickness of the compressible foundation layers vary from section to section. These calculations may be conservative (i.e. longer than actual) considering the presence of sandy layers in the alluvial deposits that should help dissipate excess pore-water pressures (and thus consolidate) at a faster rate.

7.2.3 Loss of Freeboard

The proposed setback levees will continue to settle after the completion of construction, based on the current analyses. The magnitude of anticipated settlement is greater than could be tolerated while maintaining adequate freeboard relative to the design flood event. Several strategies could be used to mitigate the risk of freeboard loss, including foundation improvement, staged construction sequencing, or overbuilding the levee section with additional fill. Based on discussions with LCEP and the design team, it is our understanding that the preferred option is to overbuild the levee sections to accommodate the overall estimated total settlement through primary and secondary consolidation of the foundation. The overbuild amount will need to be approximately 1 to 4 feet in additional height, depending on each reach location, to maintain adequate freeboard throughout the design life of the levee.

7.2.4 Test Fill

The consolidation estimates and much of the strength data of the Columbia River Alluvium presented in this report are based on laboratory tests on samples that were carefully collected, transported, and tested. Laboratory testing has some inherent limitations for a large projects that consist of varying heights of fill and extending over variety of foundation materials. As a result, the behavior of the deep alluvium during construction could be different than predicted.

The construction of one or more test fills over the deep deposits of soft soils at the south end of the site, and/or in the low lying areas in the middle of the site where levee embankments will be quite tall, would provide an opportunity to directly observe and track the behavior of the soil under field conditions, and more accurately gauge the time required for consolidation between lifts.

A test fill program would also allow observation of the work required to excavate, haul, place, and compact on-site soils within the levee prism. As discussed later in this report, the native soils in proposed borrow and expanded habitat areas have natural water contents that are significantly wetter than optimum for compaction. It is possible that these soils will require aerating prior to achieve targeted densities. Test fill program would allow the design team and contractor to try several methods and develop the correct approach for overall construction.

We recommend that a test fill program be incorporated into the fill embankment on the East and West Setback Levee alignments. For planning purposes, we recommend a test program consisting of three test fills, each with an area of approximately 100 feet by 150 feet in plan dimension. The test fills should be constructed to heights of 15 to 25 feet with a cross-section shape similar to the proposed setback levees. The contractor should use the same construction equipment and compaction specifications that are to be used during full construction. Ideally, test fills would be constructed in the vicinity of boreholes so that the subsurface conditions are known.

We suggest the fill area be instrumented with the following equipment: (i) a minimum of two vibrating wire settlement sensors installed at the center and offset, (ii) a reservoir equipped with a datalogger that can record near continuous settlement data.

The settlement sensor could consist of a sensor attached to a flat base (heavy plywood or steel) that is placed in a trench in the foundation prior to test fill construction. Fluid-filled tubes would be connected to the sensors, placed in a trench extends outside the footprint of the test fill, and connected to the reservoir with a datalogger. The trench would be backfilled to the surrounding ground surface and the test fill would be constructed over the settlement sensor locations. Data could be collected and analyzed during construction of the test fill to develop a consolidation curve during active compaction and under static conditions (post-construction). The data could be used to compare the calculated and actual consolidation behavior, total settlement, and time to achieve 90% of overall primary consolidation.

8. OTHER LEVEE CONSIDERATIONS

8.1 Railroad Tie-in for East Setback Levee

The north side of the East Setback Levee ties into the high ground, which is located on the railroad right-of-way. Explorations have not been permitted on the railroad right of way at the time of this report and, thus, the north tie in requires some engineering judgement. The basis for the design of the tie-in is a site reconnaissance that included an attempt to perform several hand auger boreholes.

The visual interpretation of the area is that the levee is not likely to tie into fill or railroad ballast. Several attempts to advance hand augers were unsuccessful due to gravel and cobbles near the surface. The site reconnaissance combined with review of the surficial topography indicate that the area could be underlain by colluvium. Based on nearby boring that penetrated into colluvium, the material could be coarser grained and more permeable than the finer Columbia River Alluvium.

Design of the railroad tie-in considers potential adverse soil conditions that could affect the settlement or seepage stability of the levee. The levee fill will include a seepage cutoff into the foundation soils extending through the coarse materials and into the finer grained alluvium. The depth of the seepage cutoff trench will be dependent on the conditions encountered at the time of construction. Our seepage analyses show that a cutoff trench a minimum of 8 feet wide and embedded into finer alluvium will provide a sufficient barrier of low permeability soil beneath the levee embankment that acts to reduce seepage and uplift pressures on the landward side.

An additional measure to prevent seepage and slope stability issues on the railroad tie-in is a railroad overbuild bench. The bench will consist of a 150-foot long and 50-foot wide (perpendicular and parallel to levee centerline, respectively) fill that effectively raises the levee height to elevation 52 feet. This overbuild area is primarily an effort to assist the Burlington Northern Sante Fe (BNSF) railroad with future expansion efforts. However, this overbuild will buttress the existing slope and provide additional seepage protection for the anticipated soil conditions.

9. FLOOD PREVENTION STRUCTURES

9.1 Closure Structure and Abutment Walls

As part of the levee project, a closure structure will be constructed across SR-14 to prevent flooding west of the levee system that ties into abutment walls on the north and south sides. The closure structure will consist of a concrete panel system that is supported by removable steel H-piles embedded into the highway embankment. The concrete panels and steel H-piles will be stored nearby and placed into position as anticipated flood conditions dictate. Abutment walls will consist of concrete cantilever walls that support levee embankment on the south side and tie into the floodwall on the north side.

The closure structure and abutment walls are being designed by the project structural engineer, KPFF, to withstand flood elevation up to 42.7 feet, which is defined as the levee design flood (LDF) mandated by the Washougal Flood Damage Reduction (FDR) Project authorized by the Flood Control Act of 1950. Seepage, uplift and stability of the closure structure were all analyzed using this LDF elevation.

9.1.1 Geotechnical Design Recommendations

Specific geotechnical design recommendations for the proposed closure and abutment wall structures are presented in the following paragraphs.

Geotechnical Parameters. The subsurface properties used to develop parameters for the foundation recommendations were determined from the borehole and test pit explorations performed near the proposed location of the SR-14 closure structure. Borings CS-01 and CS-02 were performed on the south and north side of SR-14, respectively. Test pits TP-R1 through TP-R3 were excavated on either side of the SR-14 embankment. The Summary Boring Logs and Test Logs are included in Appendix A and Appendix B, respectively. The properties developed for the closure structure foundation conditions are shown in Table 17 below.

Table 17: Summary of Estimated Soil Properties for Closure Structure

Material Descriptions	Unit Weight, γ (pcf)	Friction Angle, φ' (degrees)	Cohesion Intercept, c' (psf)	Permeability, k (ft/min)	Permeability Ratio, k_h/k_v
Gibbons Creek Alluvium: gravelly Sand to sandy Gravel	125	36	0	2.0×10^{-2}	4

Foundation Design. The proposed structures can be founded on shallow foundations bearing on compacted base material overlying prepared subgrade native soil. For the closure structure and the north abutment wall bearing on a 6 inches of compacted, uniformly-graded sand (ASTM C33 fine aggregate) over scarified and compacted native soil, we recommend using an allowable bearing pressure of 2,500 pounds per square foot (psf). The south abutment wall footing can be designed using allowable bearing pressures of 3,000 psf. These bearing capacities include a factor of safety of 3. With the allowable bearing pressures provided, we estimate total settlements will be less than one inch.

The stability of the closure structure and abutment walls should be checked assuming they are subjected to uplift pressures caused by impounding of flood water. Uplift loads on footings would be resisted by the weight of the structure, pavement structures and soil backfill directly above the footing. The uplift loads on the footings should be determined using the loading cases described in Chapter 4 for Inland Flood Walls and Figure 4-2 in USACE EM 1110-2-2502.

Lateral Resistance. Lateral resistance would be developed by friction along the base of the closure structure. Friction between the cast-in-place concrete and the base pad structural fill can be modeled using an allowable friction coefficient of 0.3.

Lateral Earth Pressures. To analyze the effect of soil on the abutment walls, the following earth pressure coefficients should be used structural design:

- Active Earth Pressure (K_a) = 0.26
- At-rest Earth Pressure (K_o) = 0.41
- Passive Earth Pressure (K_p) = 3.85

These earth pressures can be used to determine the stresses imposed by the levee embankment fill on the back of the wall. We recommend design the wall using active earth pressures (K_a) coefficient for walls that are allowed to deflect more than 0.001 times the height of the wall. If less deformation is allowed, then the design should be performed using at-rest (K_o) earth pressure coefficient.

9.1.2 Closure Structure Seepage Analyses

Seepage analyses were performed a cross section through the closure structure to model potential underseepage flow through the foundation due to the design flood level. These analyses were performed using the finite element mesh software program SEEP/W and in the same general procedure used for levee embankments as discussed in Section 6.6. The design flood elevation was modeled as 42.7 feet, which is consistent with the Columbia River flood elevation for the West Setback Levee. The seepage through the foundations soils was calculated assuming saturated, steady-state conditions. The exit gradients at the inboard toe of the levee were averaged over 2 mesh units (approx. 4 feet).

The seepage analyses showed that a seepage cutoff was necessary to prevent exit gradients from exceeding the maximum recommended value of 0.5 (USACE, 2000). The seepage cutoff needs only extend through the highway embankment fill and into the existing native soils. The footing of the closure structure should be embedded a minimum of 6 feet below the current pavement surface at highway centerline to act as a seepage cutoff. The critical exit gradient was calculated to be 0.2 with the footing embedded to the elevation 32.5 feet.

9.2 Gibbons Creek Floodwall

The area north of Washington State Route (SR) 14 will be protected from flooding by a cantilever T-type reinforced concrete wall. The floodwall will tie into the north side of the SR-14 closure structure and extend north into high ground. The floodwall will be designed in conjunction with a realignment of the Gibbons Creek channel that is intended to increase flood water storage and reduce the impact catastrophic flooding of Gibbons Creek.

The overall design of the floodwall was performed in accordance with USACE EM 1110-2-2502. The existing ground conditions were analyzed to develop geotechnical parameters that were used to assess the stability of the floodwall under the design flood.

9.2.1 Geotechnical Design Recommendations

Specific geotechnical design recommendations for the proposed floodwall are presented in the following paragraphs.

Geotechnical Parameters. The subsurface properties used to develop parameters for the foundation recommendations were determined from the borehole explorations performed near Gibbons Creek. Borings GF-01 through GF-05 were performed along the east and west sides of Gibbons Creek. The Summary Boring Logs are included in Appendix A. The properties developed for the floodwall foundation conditions are shown in Table 18 below.

Table 18: Summary of Estimated Soil Properties for Floodwall Analyses

Material Descriptions	Unit Weight, γ (pcf)	Friction Angle, φ' (degrees)	Cohesion Intercept, c' (psf)	Permeability, k (ft/min)	Permeability Ratio, k_h/k_v
Gibbons Creek Coarse Alluvium: silty sandy Gravel	110	30	0	2.0×10^{-2}	4

Foundation Design. The proposed floodwall could be founded on shallow foundations bearing on compacted base material overlying prepared subgrade native soil. The bearing capacity varies along the alignment due to slight variations in the subsurface conditions. For footings bearing on a 6 inches of compacted, uniformly-graded sand (ASTM C33 fine aggregate) over scarified and compacted native soil, we recommend using an allowable bearing pressure of 2,500 pounds per square foot (psf) from the north end of the closure structure to Station 53+50. The foundations from Station 53+50 to 59+00 can be designed for an allowable bearing pressure of 3,000 psf for structural design. These allowable bearing capacities includes a factor of safety of 3.

Footings should be a minimum of 48 inches wide and be embedded a minimum of 36 inches below the lowest adjacent grad. Footing excavations should be cleared of any loose material prior to the placement of concrete. With the allowable bearing pressures provided, we estimate total settlements will be less than one inch.

Uplift pressures will generally be controlled by installation of a lateral drain placed on the landside toe of the wall designed to collected underseepage. However, the stability of the wall should be checked assuming the drain is not functioning would be subjected to uplift pressures caused by impounding of flood water. Uplift loads on footings would be resisted by the weight of the structure and the soil directly above the footing. The uplift loads on the footing should be determined using the loading cases described in Chapter 4 for Inland Flood Walls and Figure 4-2 in USACE EM 1110-2-2502.

Lateral Resistance. Lateral resistance would be developed by friction along the base of the footings. Friction between the cast-in-place concrete and the base pad structural fill can be modeled using an allowable friction coefficient of 0.3. This allowable value includes a factor of safety equal to 1.5.

Lateral Earth Pressures. To analyze the effect of soil on the wall, the following earth pressure coefficients should be used structural design:

- Active Earth Pressure (K_a) = 0.33
- At-rest Earth Pressure (K_o) = 0.50
- Passive Earth Pressure (K_p) = 3.0

The floodwall is not intended to retain a significant mass of soil on one side of the wall and, thus, the design should include grading of approximate equal heights on both sides. The earth pressure coefficients can be to determine the soil forces acting on the wall for overturning and sliding stability.

9.2.2 Floodwall Seepage Analyses

Seepage analyses were performed on two sections through the floodwall to model potential underseepage flow through the foundation due to the design flood level. These analyses were performed using the finite element mesh software program SEEP/W and in the same general procedure used for the closure structure and levee embankments as discussed in Section 6.6. The design flood elevation was modeled as 42.7 feet, which is consistent with the Columbia River flood elevation for the West Setback Levee. The seepage through the foundations soils was calculated assuming saturated, steady-state conditions.

The exit gradients at the inboard toe of the levee were averaged over 2 mesh units (approx. 4 feet) and the volume was calculated using a ‘flux boundary’ near the landside toe.

For both analysis sections, the calculated exit gradients were lower than the maximum recommended value of 0.5 (USACE, 2000). Despite the relatively high permeability of the foundation soils the exit gradients for the analysis sections were low due to the embedment of footing and the height soil on the landside of the wall (relative to the flood level). Table 19 shows the results of the seepage analyses for each individual floodwall cross section.

Table 19: Summary of Steady-State Seepage Results

Centerline Station	Steady-State Seepage Exit Gradient
W 53+50	0.10
W 55+25	0.06

The seepage analyses show that the floodwall design meets the USACE guidelines for seepage control. On that basis, it should excess water pressures on landside toe of the wall that could cause sand boils or piping of materials.

The seepage analyses were also used to estimate the volume of water at that could pass through the foundation. These analyses were performed using a conservatively high permeability as shown in Table 18 to consider the granular nature of the foundation. SEEP/W analyses estimated that the seepage under the floodwall would be approximately 0.5 to 1 gallon per minute per foot of wall. The seepage should be collected in a lateral toe drain embedded at the landside toe of the wall with enough capacity to move the estimate volume of water to a surface collector.

10. BORROW MATERIALS

The project includes areas of significant grading and contouring in the interior of the site to create extended habitat areas, stream channels, and to generate borrow materials for the levee construction.

The test pit exploration program was performed to determine the subsurface conditions on the interior of the site. Test pits were excavated in a rough grid pattern and strategically placed at locations of extended habitat areas and stream channels. The grid extended from the East to West Setback Levees and were concentrated to the southern half of the site where most of the grading will be performed. The conditions encountered in the exploration program were used to determine the suitability of the onsite soils for levee embankment fill.

10.1 Subsurface conditions

The interior of the Refuge site is generally underlain by Columbia River Alluvium consisting of interbedded layers of slightly clayey silt and silty sand. The higher elevation areas tend to be drier with less clay content. The materials are generally consistent with the materials encountered in the boreholes along the setback levee alignments as discussed in Section 4.

10.2 Potential Borrow for Levee Fill

The materials encountered in the interior of the site are generally acceptable to use for levee embankment materials. However, as discussed in more detail below, the existing natural water content is significantly higher than the optimum water content for compaction. On that basis, some drying of the soils will likely be necessary during construction. Laboratory testing on the test pit samples show that the soils could be compacted to sufficient density with adequately low hydraulic conductivity to restrain flooding from protected areas. Onsite soils have relatively low amounts of organics, which generally consist of rootlets and grasses. The topsoil zone is relatively thin in most areas averaging 4 to 6 inches thick.

The natural water contents of the borrow soils was tested higher than the optimum water content to achieve the best compaction. The dry density of the two samples tested were 94.1 and 104.7 pcf with optimum water contents of 24% and 17.5%, respectively. The natural water content of these samples was approximately 55% and 29%, respectively. Compaction of the drier more granular materials created higher dry density. Soil characterized as sandy silt or silty sand are likely to have lower in-situ water and compacted to higher densities.

Placement of these soils in the levee embankment will require conditioning to dry the soil to achieve water contents that are within an acceptable range of optimum. The soil should be compacted to within 95 percent of maximum dry density as determined by a Standard Proctor Compaction Test. The preliminary range of water contents to achieve this specification is -3% to +3% of optimum based on CCI laboratory test results. Additional compaction testing will need to be performed to determine density curves for specific materials used in the levee embankments.

Soils characterized as sandy silt and silty sand with natural water contents of 30 percent or less could be used as levee embankment fill with less conditioning. These materials are typically encountered at shallower depths and toward the southern portion of the site near the existing levee.

With additional soil conditioning, consisting of aeration or blending with drier granular soils, clayey silts and silty clay soils could be used as levee borrow materials. Soils that are too wet to be suitable for levee embankments could be diverted to non-structural fill locations such as wavebreak overbuild and upland refugia.

Construction control and monitoring will be required to prevent the use of borrow materials that are unsuitable for levee embankment fill. The construction control should include frequent density testing to confirm target densities are achieved.

10.3 Existing Camas-Washougal Levee Materials

The West and East Setback Levees tie into the existing Camas-Washougal Levee at approximate station L’ 57+00 and L’ 172+00, respectively. The restoration project proposes to remove the section of existing levee between the setback levee and use the excavated soil as borrow for the setback levees.

The existing levee materials were previously investigated in 2011 during work for the Camas-Washougal Levee FEMA Certification Engineering Evaluations (Cornforth, 2012). The FEMA certification study covered the length of the Camas-Washougal levee, including the portion that will be removed during the Steigerwald Restoration project. Boreholes were drilled through the levee crest and at the landward and riverward toes. The boreholes were typically grouped in sets of 2 or 3 (e.g. a riverward, a crest, and a landward boring), and these sets were approximately 1,000 feet apart. A location map and site plans from the 2012 certification study showing the location of the boreholes are provided in Appendix F.

The study performed a total of 64 boreholes, with 31 of these borings within the current restoration project limits. Thirteen of the boreholes were drilled through the levee crest to perform SPTs and collect samples for testing. Soil samples from both the embankment and foundation materials were also collected for laboratory testing, which included water contents, gradations, Atterberg limits, unit weights, consolidation, and shear strength testing (both triaxial and direct shear). Tests conducted on samples from the embankment materials within the Steigerwald project area are summarized in Table 20 below.

Table 20: Laboratory Tests of Existing Levee Materials (Cornforth, 2012).

Borehole	Laboratory Test			
	Water Contents	Gradations	Unit Weights	Direct Shear
CC-29	X	X	X	X
CC-32	X			
CC-34	X			
CC-36	X			
CC-38	X			
CC-40	X	X	X	
CC-43	X			
CC-45	X			
CC-47	X			
CC-49	X			
CC-51	X	X		
CC-54	X			
CC-57	X			

Material properties from unit weight and direct shear testing are provided below in Table 21 and Table 22. Water content test results are shown on the Summary Boring Logs in Appendix F. Gradation test results are provided on plots in Appendix F.

Table 21: Summary of Unit Weight of Levee Embankment Materials (Cornforth, 2012)

Boring No.	Sample No.	Depth (ft)	Moist Unit Weight (pcf)	Dry Unit Weight (pcf)	Summary Log Classification
CC-29	S-2	8.0-8.5	109	97	slightly silty Sand (SM)
CC-29	S-2	8.5-9.0	105	95	slightly silty Sand (SM)
CC-29	S-2	9.9-9.5	104	94	slightly silty Sand (SM)
CC-40	S-2	8.0-8.5	106	95	silty Sand (SM)

Table 22: Summary of Direct Shear Testing of Levee Materials (Cornforth, 2012)

Boring No.	Sample No.	Depth (ft)	Friction Angle, φ' (degrees)	Cohesion Intercept c' (psf)	Summary Log Classification
CC-01*	S-3	13-15	47	37	Sand (SP)
CC-29	S-2	8-10	40	40	Sand (SP)

**Borehole outside of the project area,* In general, the 2012 study encountered levee materials that were consistent with dredged and compacted river alluvium. Samples collected from the levee (within and outside the project limits) were predominantly fine sand with traces of mica and silt. A summary of material properties of the existing levee embankment based on the laboratory testing program are summarized in Table 23.

Table 23: Summary of Soil Properties for Existing Levee Embankment Material

Material Description	Water Content Range	Dry Unit Weight, γ (pcf)	Friction Angle, φ' (degrees)	Cohesion Intercept, c' (psf)
Fine SAND, trace silt	5% to 29%* (Avg = 17%)	95	40	40

*Based on laboratory testing of 42 samples.

Based on the results from previous investigations and laboratory testing, the existing levee materials are suitable borrow material for the construction of the new setback levees.

Sincerely,

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11. REFERENCES

Cornforth Consultants, Inc (2012). "Camas-Washougal Levee FEMA Certification Engineering Evaluations." Report for Port of Camas-Washougal, May 2012.

Davis, E.H., and Poulos, H.G. (1972). "Rate of Settlement under Two- and Three-Dimensional Conditions." *Geotechnique*, 22 (1), pp. 95-114.

Duncan, J.M. 2000. "Factors of safety and reliability in geotechnical engineering." *Journal of Geotechnical and Geoenvironmental Engineering.* Volume 126, Pages 307-316.

Evarts, R.C., O'Conner, J.E., and Tolan, T.L. (2013). *Geologic Map of the Washougal Quadrangle, Clark County, Washington, and Multnomah County, Oregon, Scientific Investigations Map 3257*, U.S. Geological Survey.

Federal Emergency Management Agency (FEMA). (2012). *Flood Insurance Study (FIS) for Clark County and Unincorporated Areas*. September 5, 2012.

Fiksdal, A.J. (1975). *Sand and Gravel in Clark County, Open File 75-11*, Div. of Geology and Earth Resources, Washington State Dept. of Natural Resources.

Janbu, N. (1965). "Consolidation of clay layers based on non-linear stress-strain." *Proceedings of the 6th International Conference on Soil Mechanics and Foundation Engineering*, (2), Montreal, pp. 83-87.

Phillips, W.M. (1987). *Geologic Map of the Vancouver Quadrangle, Washington and Oregon, Open File Report 87-10*, Div. of Geology and Earth Resources, Washington State Dept. of Natural Resources.

United States Department of the Army, Corps of Engineers (USACE) (1989). *Engineering and Design – Retaining and Flood Walls* (EM 1110-2-2502), September 29, 1989.

United States Department of the Army, Corps of Engineers (USACE) (2000). *Engineering and Design – Design and Construction of Levees* (EM 1110-2-1913), April 30, 2000.

United States Department of the Army, Corps of Engineers (USACE) (1990). *Engineering and Design – Settlement Analysis* (EM 1110-1-1904), September 30, 1990.

United States Department of the Army, Corps of Engineers (USACE) (2005). *Engineering and Design – Design Guidance for Levee Underseepage* (ETL 1110-2-569). May 1, 2005.

United States Department of the Army, Corps of Engineers (USACE) (2010). *Engineering and Design – USACE Process for the National Flood Insurance Program (NFIP) Levee System Evaluation* (EC 1110-2-6067). August 31, 2010.

United States Department of the Army, Corps of Engineers (USACE) (1989). *Lower Columbia River Flood Control Study, River Mile 0 to 145 Summary Report, Volumes 1 and 2; Columbia River and Tributaries Review Study CRT 69.* USACE, Portland District, Portland, Oregon, January 1989.

Trimble, D.E. (1963). *Geology of Portland, Oregon and Adjacent Areas*, Geological Survey Bulletin 1119, U.S. Government Printing Office, Washington, D.C.

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Limitations in the Use and Interpretation of this Geotechnical Report

Our professional services were performed, our findings obtained, and our recommendations prepared in accordance with generally accepted engineering principles and practices. This warranty is in lieu of all other warranties, either expressed or implied.

The geotechnical report was prepared for the use of the Owner in the design of the subject facility and should be made available to potential contractors and/or the Contractor for information on factual data only. This report should not be used for contractual purposes as a warranty of interpreted subsurface conditions such as those indicated by the interpretive boring and test pit logs, cross-sections, or discussion of subsurface conditions contained herein.

The analyses, conclusions and recommendations contained in the report are based on site conditions as they presently exist and assume that the exploratory borings, test pits, and/or probes are representative of the subsurface conditions of the site. If, during construction, subsurface conditions are found which are significantly different from those observed in the exploratory borings and test pits, or assumed to exist in the excavations, we should be advised at once so that we can review these conditions and reconsider our recommendations where necessary. If there is a substantial lapse of time between the submission of this report and the start of work at the site, or if conditions have changed due to natural causes or construction operations at or adjacent to the site, this report should be reviewed to determine the applicability of the conclusions and recommendations considering the changed conditions and time lapse.

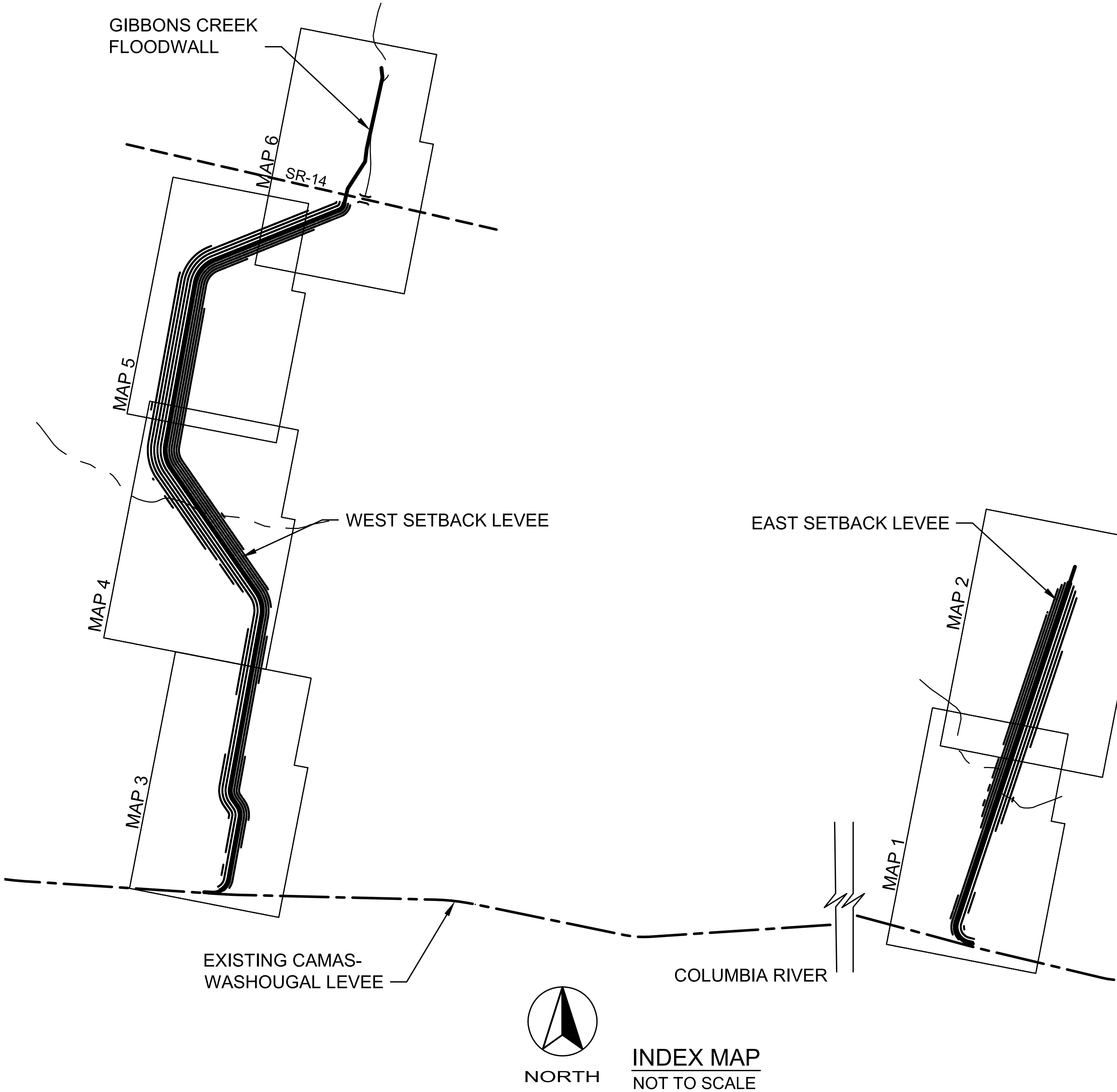
The Summary Boring Logs are our opinion of the subsurface conditions revealed by periodic sampling of the ground as the borings progressed. The soil descriptions and interfaces between strata are interpretive and actual changes may be gradual.

The boring logs and related information depict subsurface conditions only at these specific locations and at the particular time designated on the logs. Soil conditions at other locations may differ from conditions occurring at these boring locations. Also, the passage of time may result in a change in the soil conditions at these boring locations.

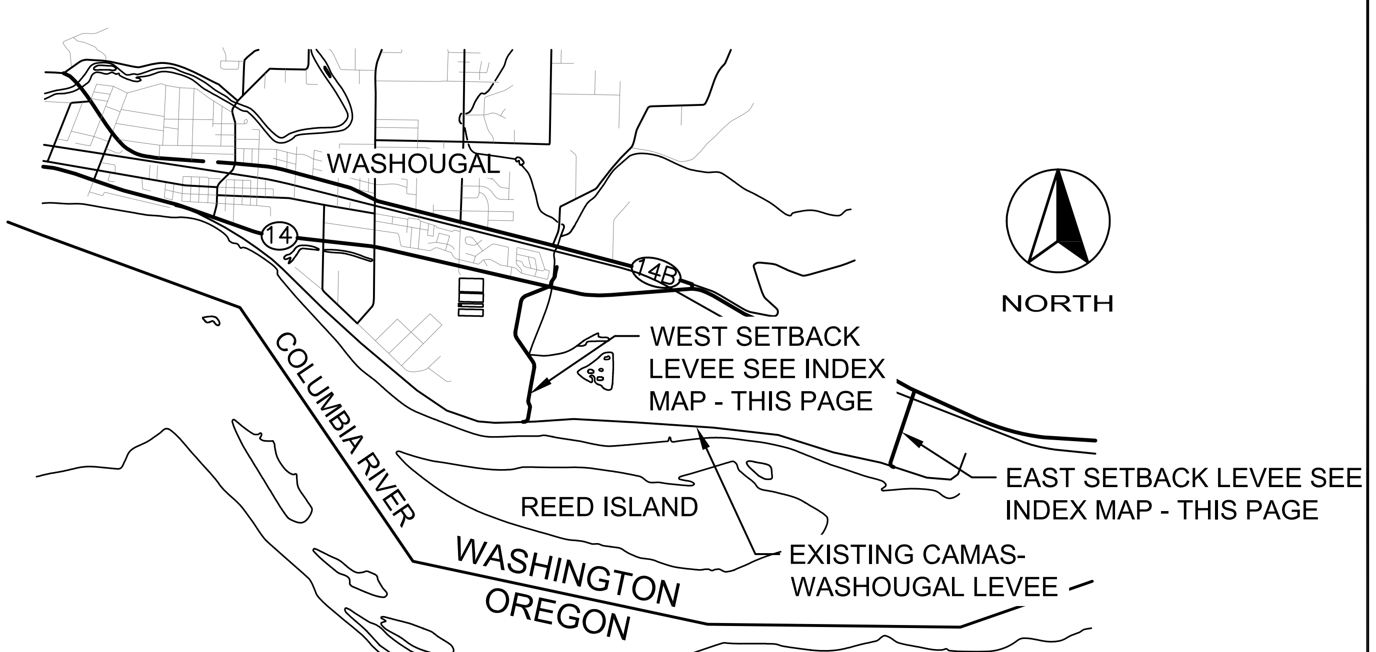
Groundwater levels often vary seasonally. Groundwater levels reported on the boring logs or in the body of the report are factual data only for the dates shown.

Unanticipated soil conditions are commonly encountered on construction sites and cannot be fully anticipated by merely taking soil samples, borings or test pits. Such unexpected conditions frequently require that additional expenditures be made to attain a properly constructed project. It is recommended that the Owner consider providing a contingency fund to accommodate such potential extra costs.

This firm cannot be responsible for any deviation from the intent of this report including, but not restricted to, any changes to the scheduled time of construction, the nature of the project or the specific construction methods or means indicated in this report; nor can our firm be responsible for any construction activity on sites other than the specific site referred to in this report.



INDEX MAP
NOT TO SCALE



VICINITY MAP
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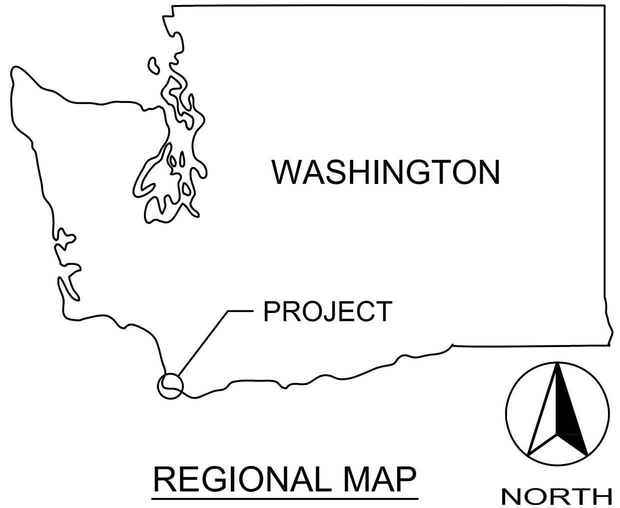

REGIONAL MAP
NOT TO SCALE

2567/Geologic Profiles.dwg NAU

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LOCATION MAP

STEIGERWALD LEVEE DESIGN
WASHOUGAL, WASHINGTON

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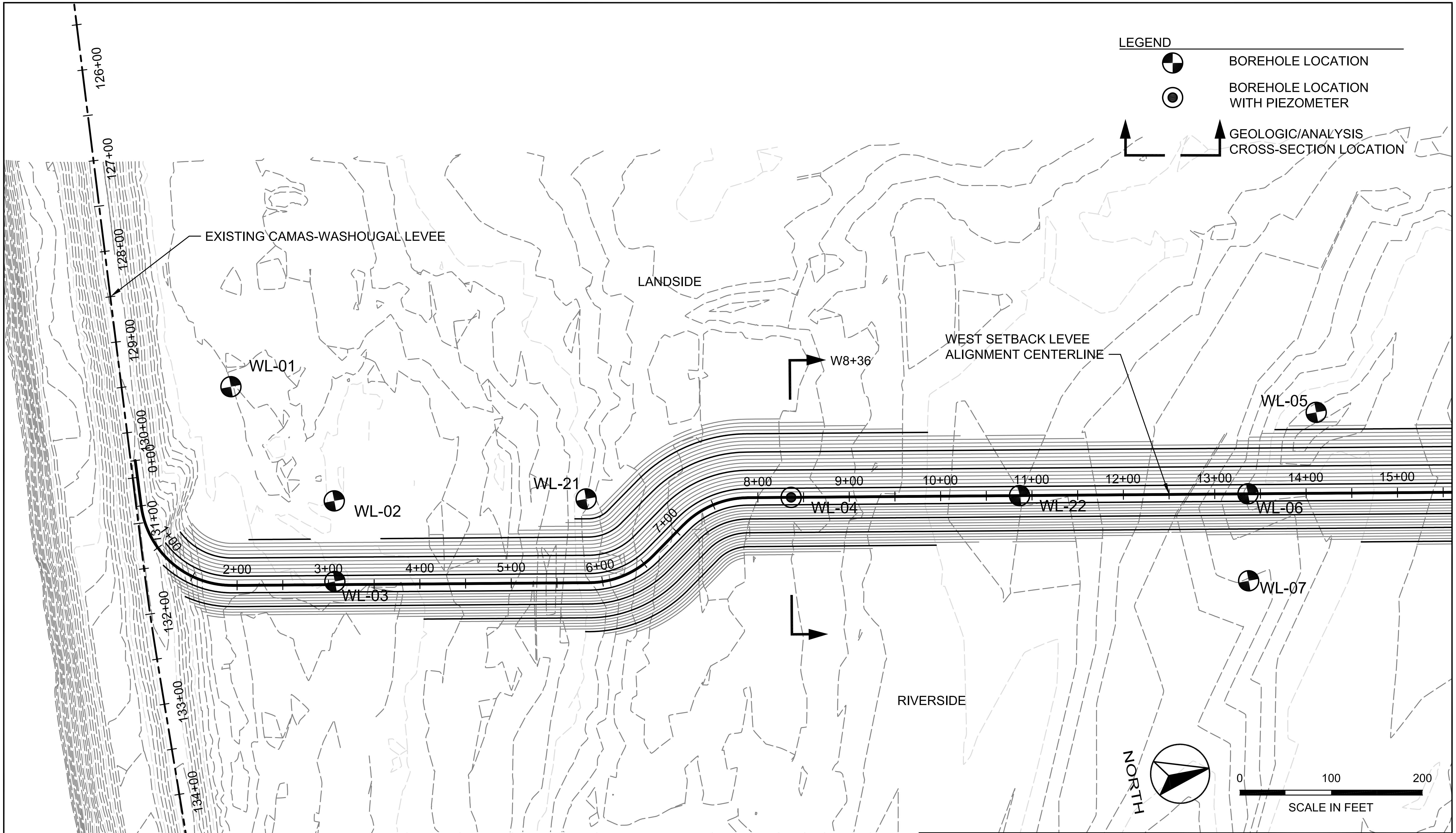
FIG. 1



NOTE: BASE MAP CREATED BY STATEWIDE LAND SURVEYING INC., ON 7/19/2015.

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SITE MAP 1

STEIGERWALD LEVEE DESIGN
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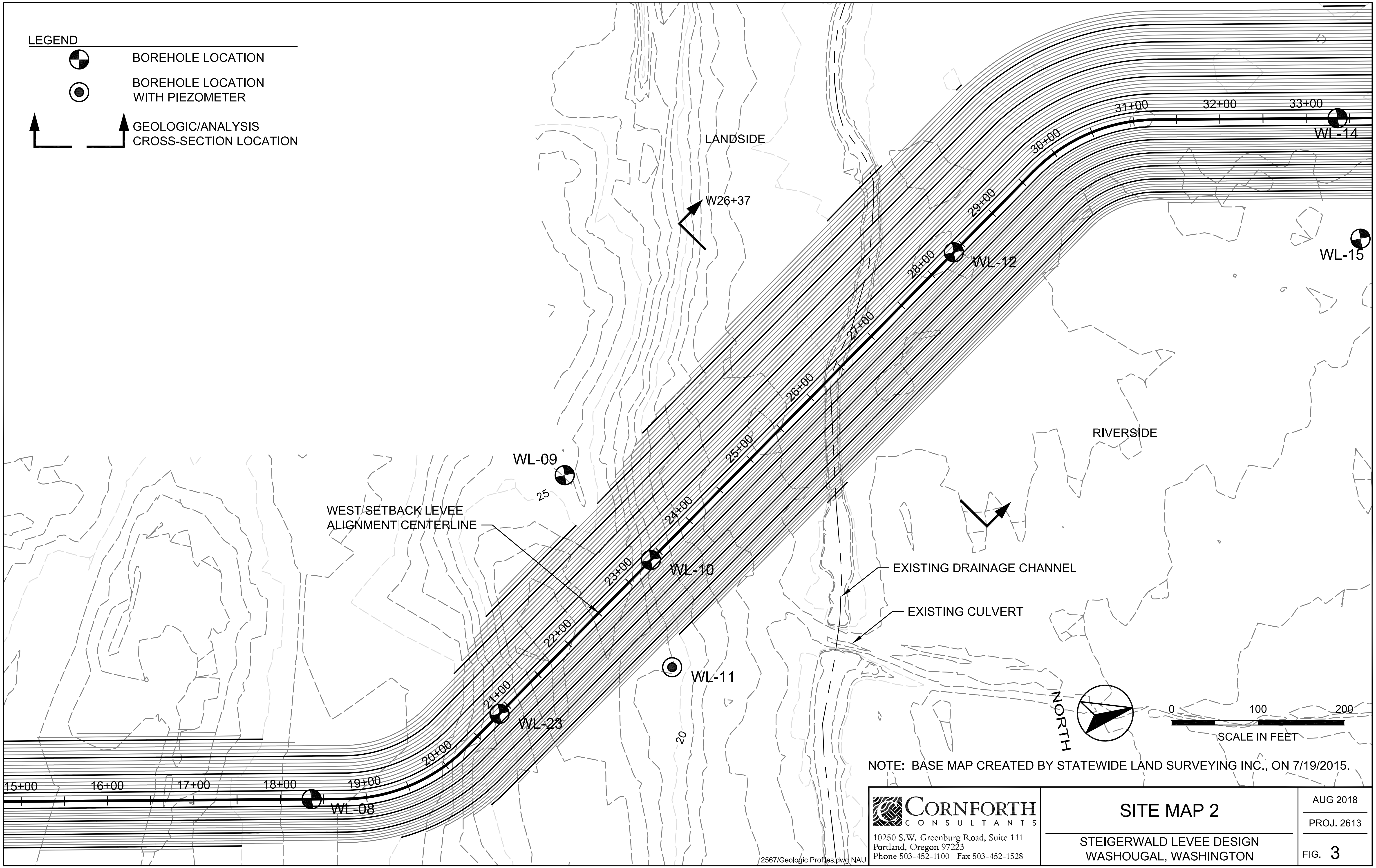
FIG. 2



NOTE: BASE MAP CREATED BY STATEWIDE LAND SURVEYING INC., ON 7/19/2015.

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SITE MAP 2

STEIGERWALD LEVEE DESIGN
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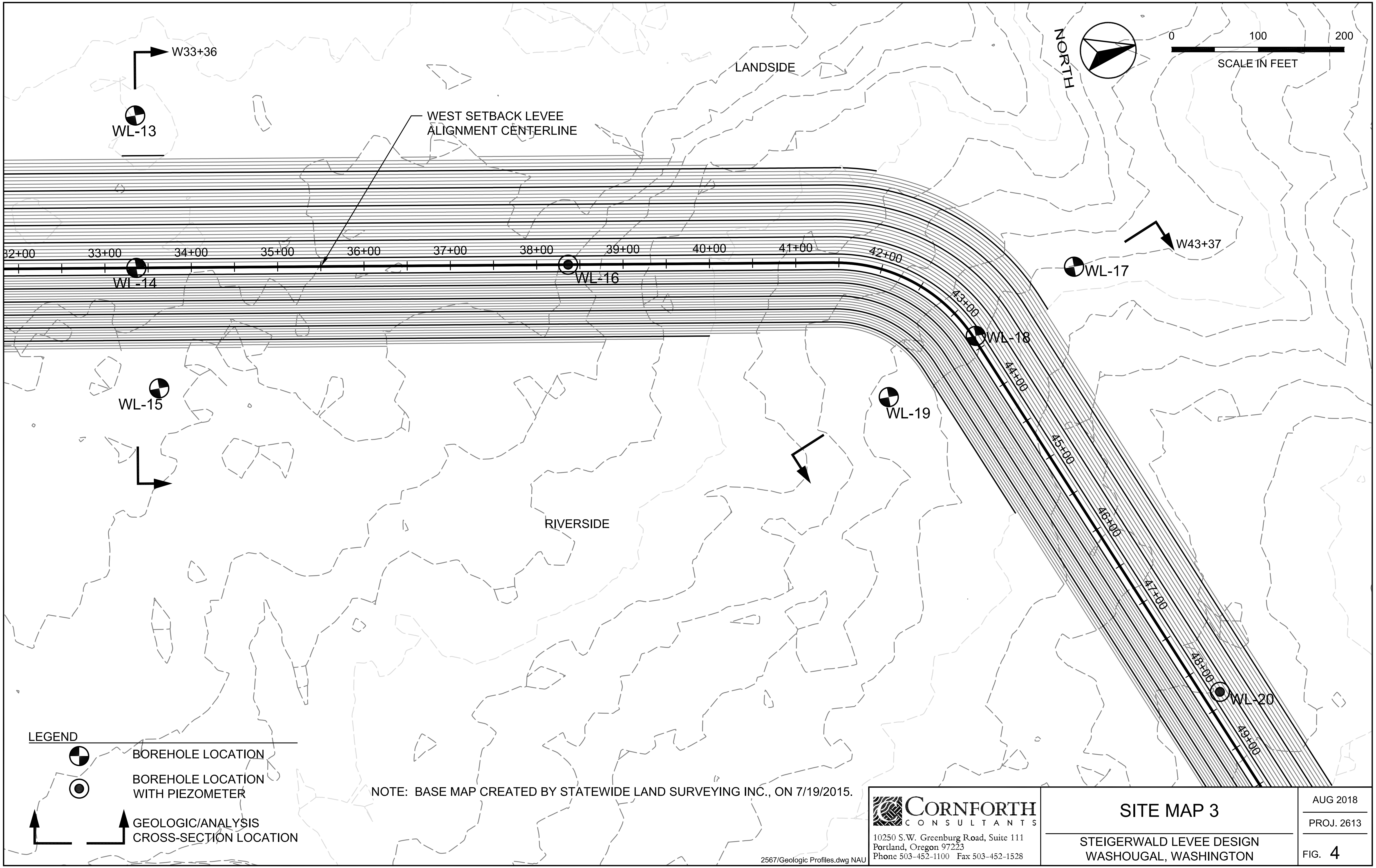
FIG. 3



NOTE: BASE MAP CREATED BY STATEWIDE LAND SURVEYING INC., ON 7/19/2015.

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SITE MAP 3

STEIGERWALD LEVEE DESIGN
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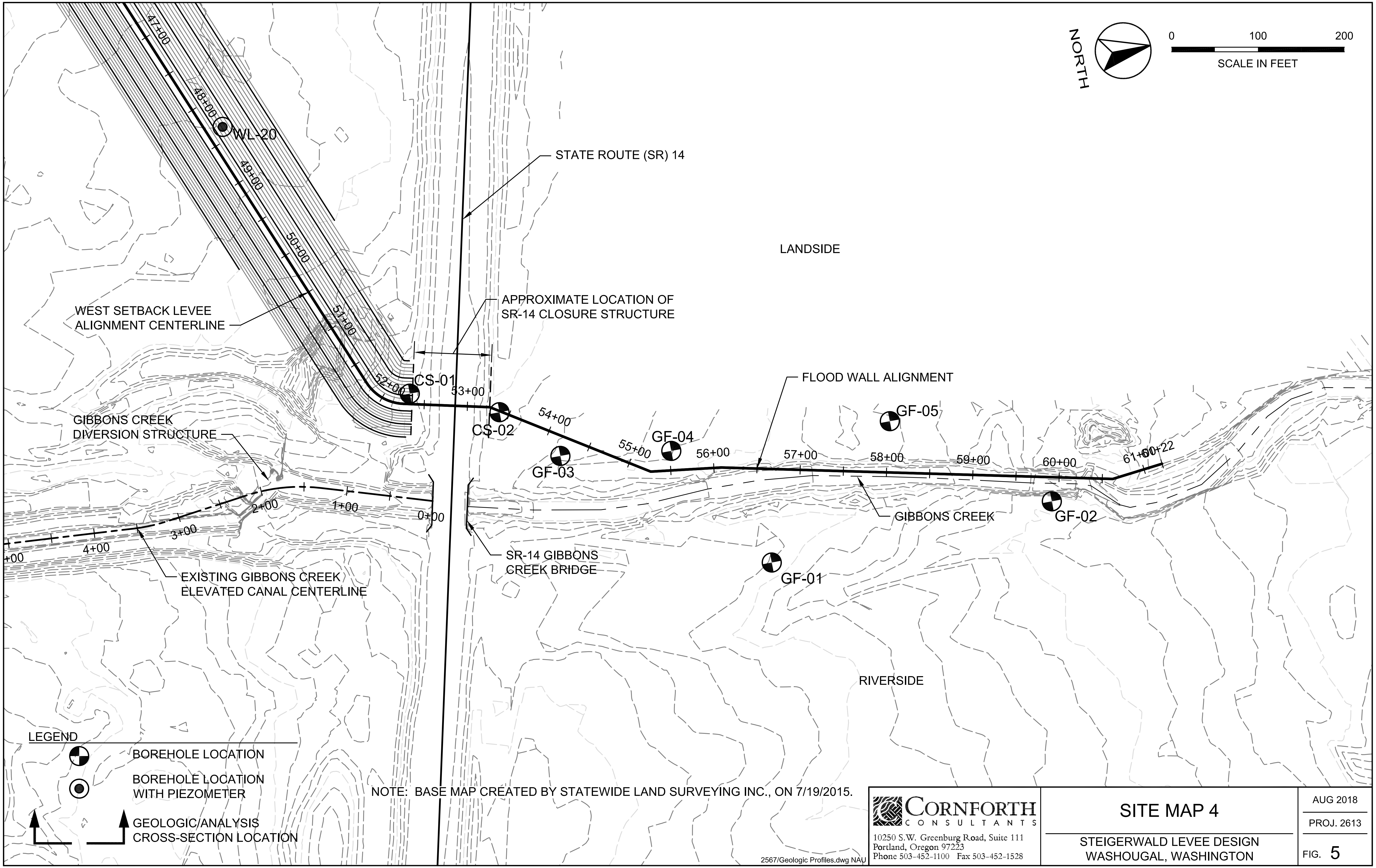
FIG. 4



NOTE: BASE MAP CREATED BY STATEWIDE LAND SURVEYING INC., ON 7/19/2015.

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SITE MAP 4

STEIGERWALD LEVEE DESIGN
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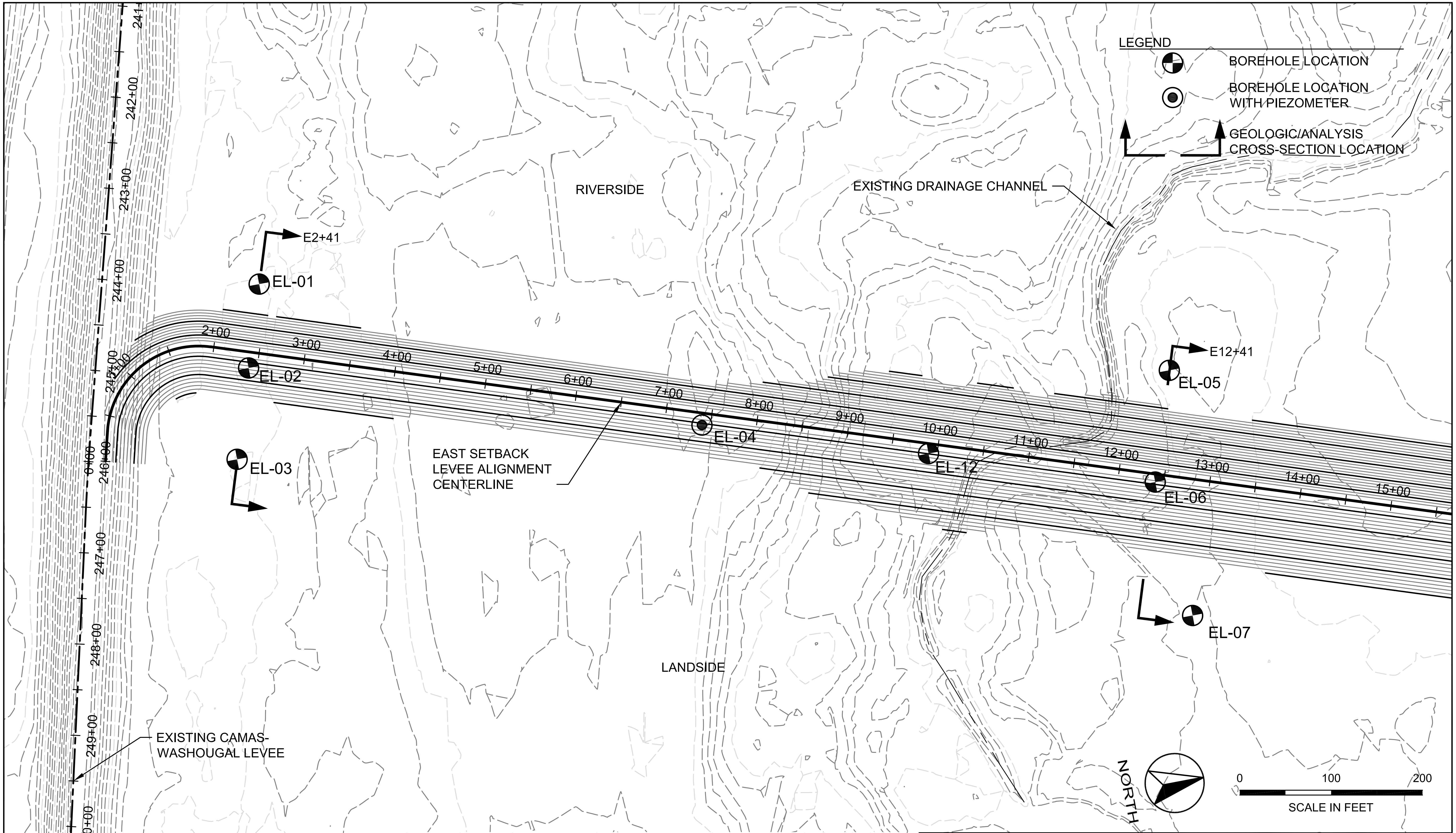
FIG. 5



NOTE: BASE MAP CREATED BY STATEWIDE LAND SURVEYING INC., ON 7/19/2015.

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SITE MAP 5

STEIGERWALD LEVEE DESIGN
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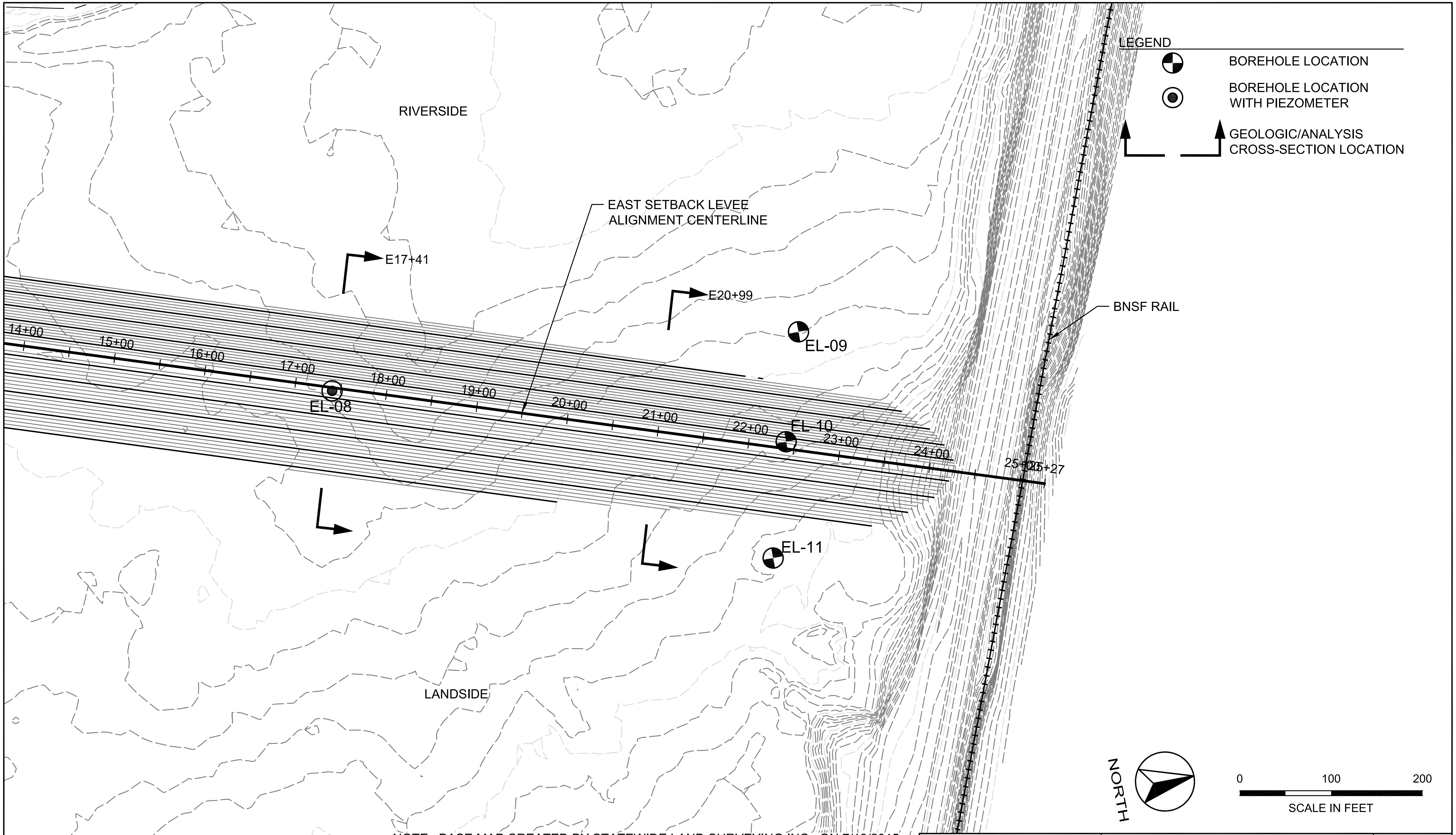
FIG. 6



NOTE: BASE MAP CREATED BY STATEWIDE LAND SURVEYING INC., ON 7/19/2015.

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SITE MAP 6

STEIGERWALD LEVEE DESIGN
WASHOUGAL, WASHINGTON

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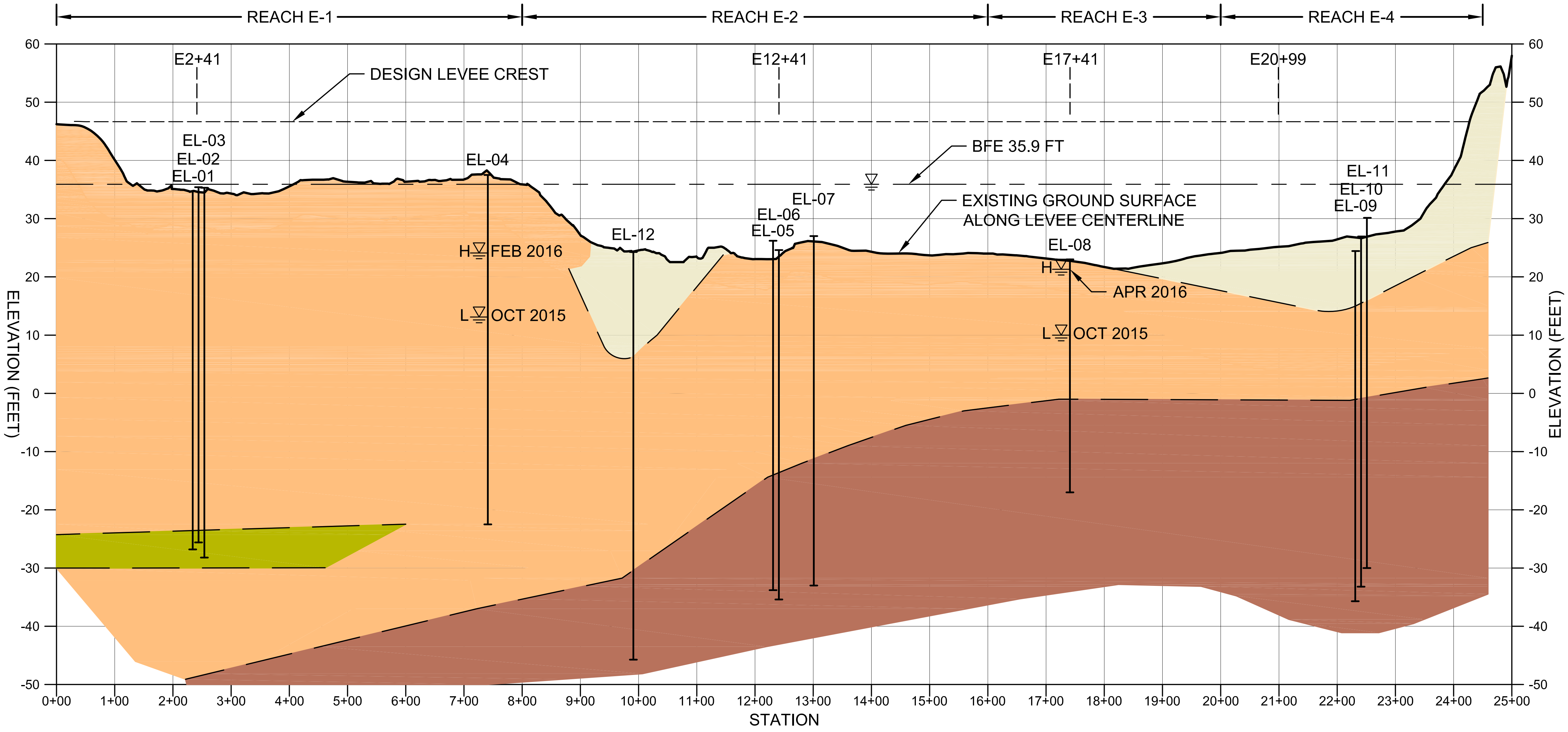
FIG. 7



SUBSURFACE CONDITIONS

⬜	MEDIUM DENSE, GRAVEL INTERMIXED WITH SILT AND SAND (LAWTON CREEK ALLUVIUM)
🟧	LOOSE, SANDY SILT TO SILTY SAND (COLUMBIA RIVER ALLUVIUM)
🟫	DENSE, GRAVEL AND COBBLES IN MATRIX OF SILTY SAND (CATACLYSMIC FLOOD DEPOSIT)
🟩	MEDIUM DENSE, FINE SAND TO SANDY SILT (ASH DEPOSIT)

NOTE: SOIL CONTACTS WERE INTERPRETED FROM BOREHOLE DATA AND ACTUAL CONDITIONS MAY VARY.

KEY

H/L ▽	SEASONAL HIGH/LOW GROUNDWATER AS MEASURED IN VIBRATING WIRE PIEZOMETERS
E2+41	GEOLOGIC/ANALYSIS CROSS-SECTIONS
EL-03	APPROX. BOREHOLE LOCATION

0 20 40
VERTICAL SCALE IN FEET

0 200 400
HORIZONTAL SCALE IN FEET

2567/Geologic Profiles.dwg NAU

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GEOLOGIC PROFILE
EAST SETBACK LEVEE

STEIGERWALD LEVEE DESIGN
WASHOUGAL, WASHINGTON

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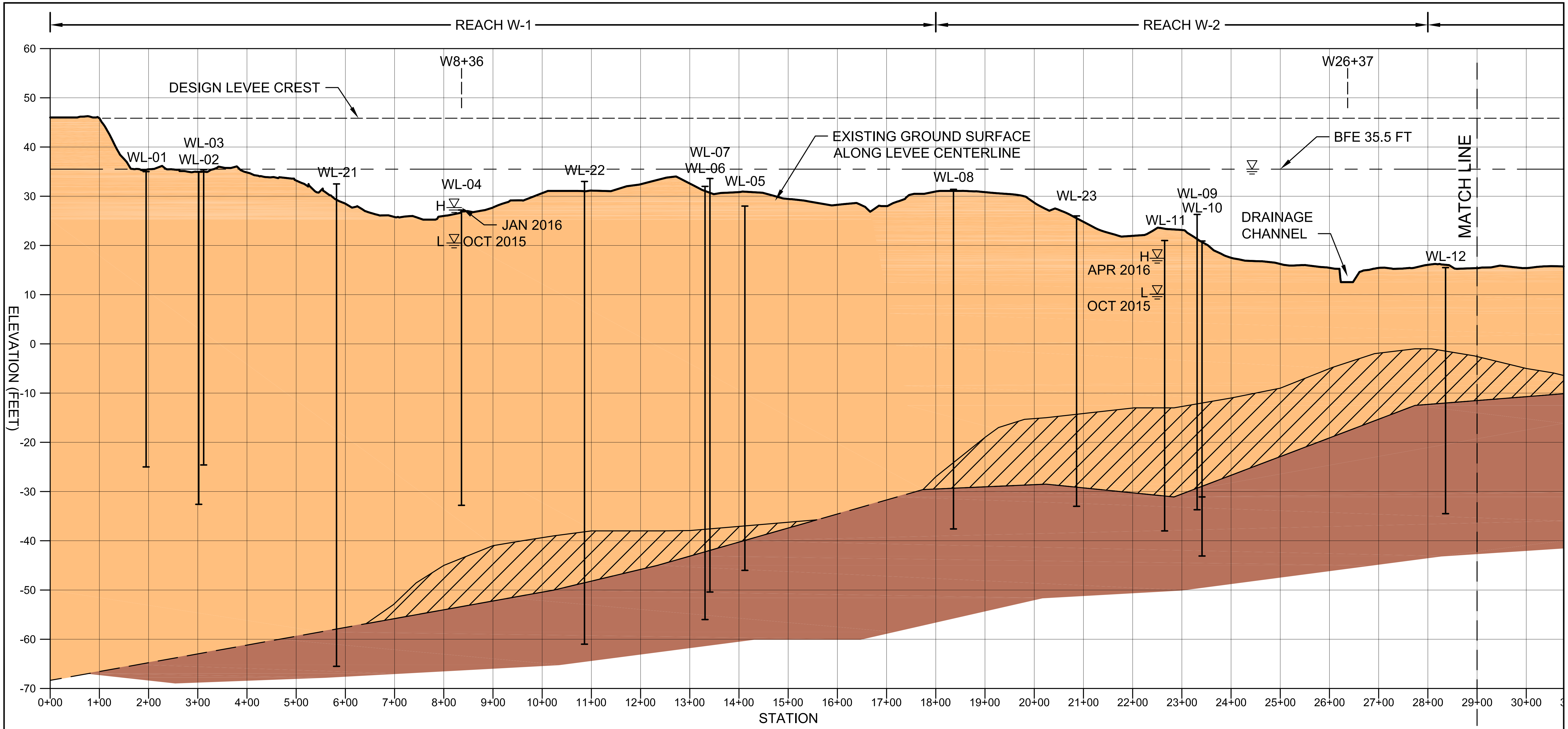
FIG. 8



0 20 40

VERTICAL SCALE IN FEET

0 200 400

HORIZONTAL SCALE IN FEET

SUBSURFACE CONDITIONS

⬜	MEDIUM DENSE, INTERMIXED SILT, SAND, GRAVEL AND COBBLES (GIBBONS CREEK FAN DEPOSIT)
🟧	LOOSE, SANDY SILT TO SILTY SAND (COLUMBIA RIVER ALLUVIUM)
▨	MEDIUM DENSE, SILTY SANDY GRAVEL (COLUMBIA RIVER ALLUVIUM)
🟫	DENSE, GRAVEL AND COBBLES IN MATRIX OF SILTY SAND (CATACLYSMIC FLOOD DEPOSIT)

NOTE: SOIL CONTACTS WERE INTERPRETED FROM BOREHOLE DATA AND ACTUAL CONDITIONS MAY VARY.

KEY

H/L ▽	SEASONAL HIGH/LOW GROUNDWATER AS MEASURED IN VIBRATING WIRE PIEZOMETERS
W8+36	GEOLOGIC/ANALYSIS CROSS-SECTIONS
WL-03	APPROX. BOREHOLE LOCATION

2567/Geologic Profiles.dwg NAU

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GEOLOGIC PROFILE
WEST SETBACK LEVEE (1/2)

STEIGERWALD LEVEE DESIGN
WASHOUGAL, WASHINGTON

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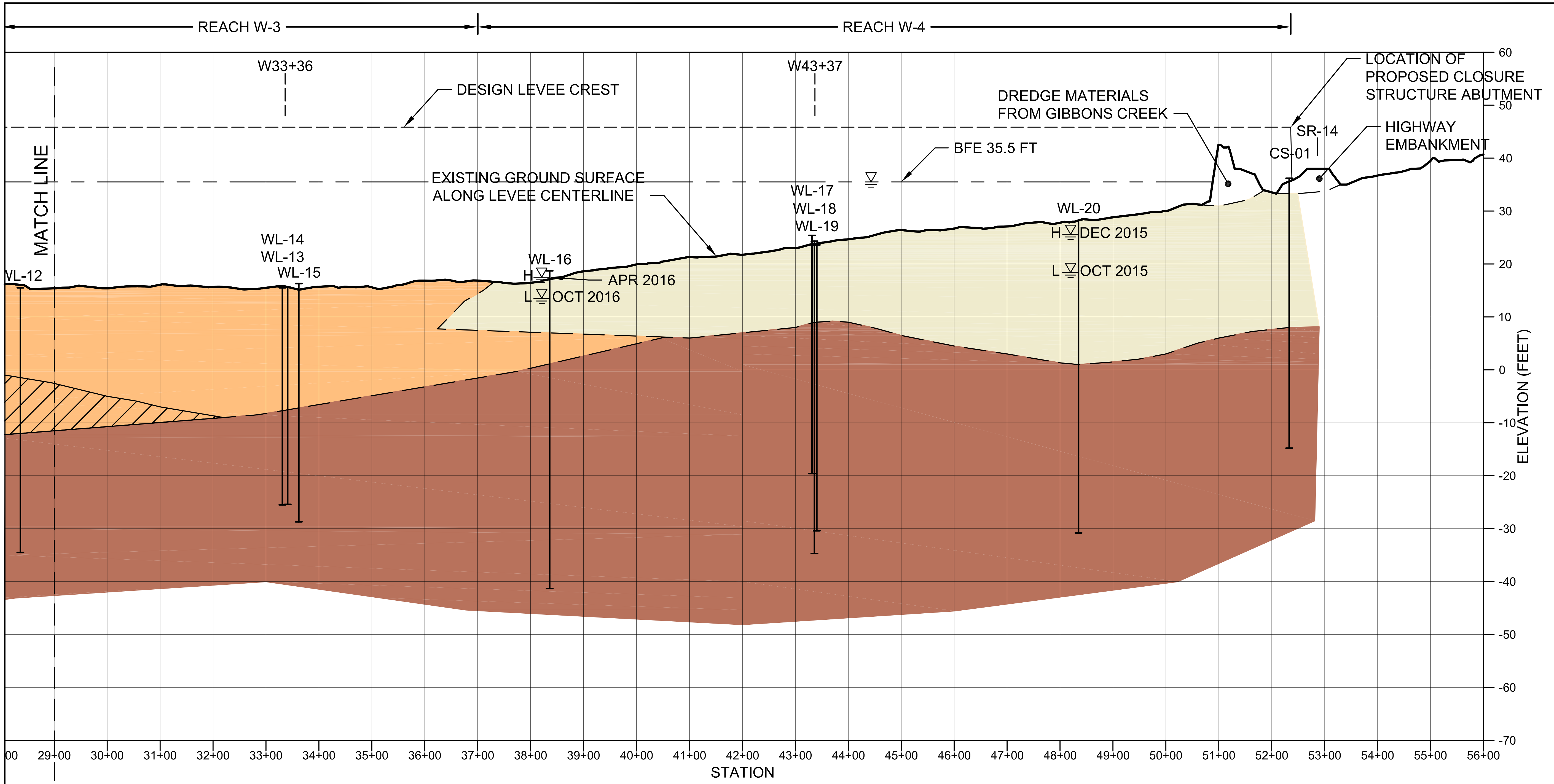
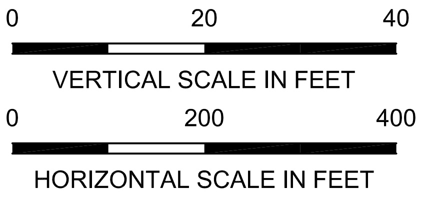
PROJ. 2613

FIG. 9





SUBSURFACE CONDITIONS

- ▭ MEDIUM DENSE, INTERMIXED SILT, SAND, GRAVEL AND COBBLES (GIBBONS CREEK FAN DEPOSIT)
- ▭ LOOSE, SANDY SILT TO SILTY SAND (COLUMBIA RIVER ALLUVIUM)
- ▨ MEDIUM DENSE, SILTY SANDY GRAVEL (COLUMBIA RIVER ALLUVIUM)
- ▭ DENSE, GRAVEL AND COBBLES IN MATRIX OF SILTY SAND (CATACLYSMIC FLOOD DEPOSIT)

NOTE: SOIL CONTACTS WERE INTERPRETED FROM BOREHOLE DATA AND ACTUAL CONDITIONS MAY VARY.

KEY

H/L ▽ SEASONAL HIGH/LOW GROUNDWATER AS MEASURED IN VIBRATING WIRE PIEZOMETERS

W8+36 | GEOLOGIC/ANALYSIS CROSS-SECTIONS

WL-03 APPROX. BOREHOLE LOCATION

2567/Geologic Profiles.dwg NAU

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GEOLOGIC PROFILE
WEST SETBACK LEVEE (2/2)

STEIGERWALD LEVEE DESIGN
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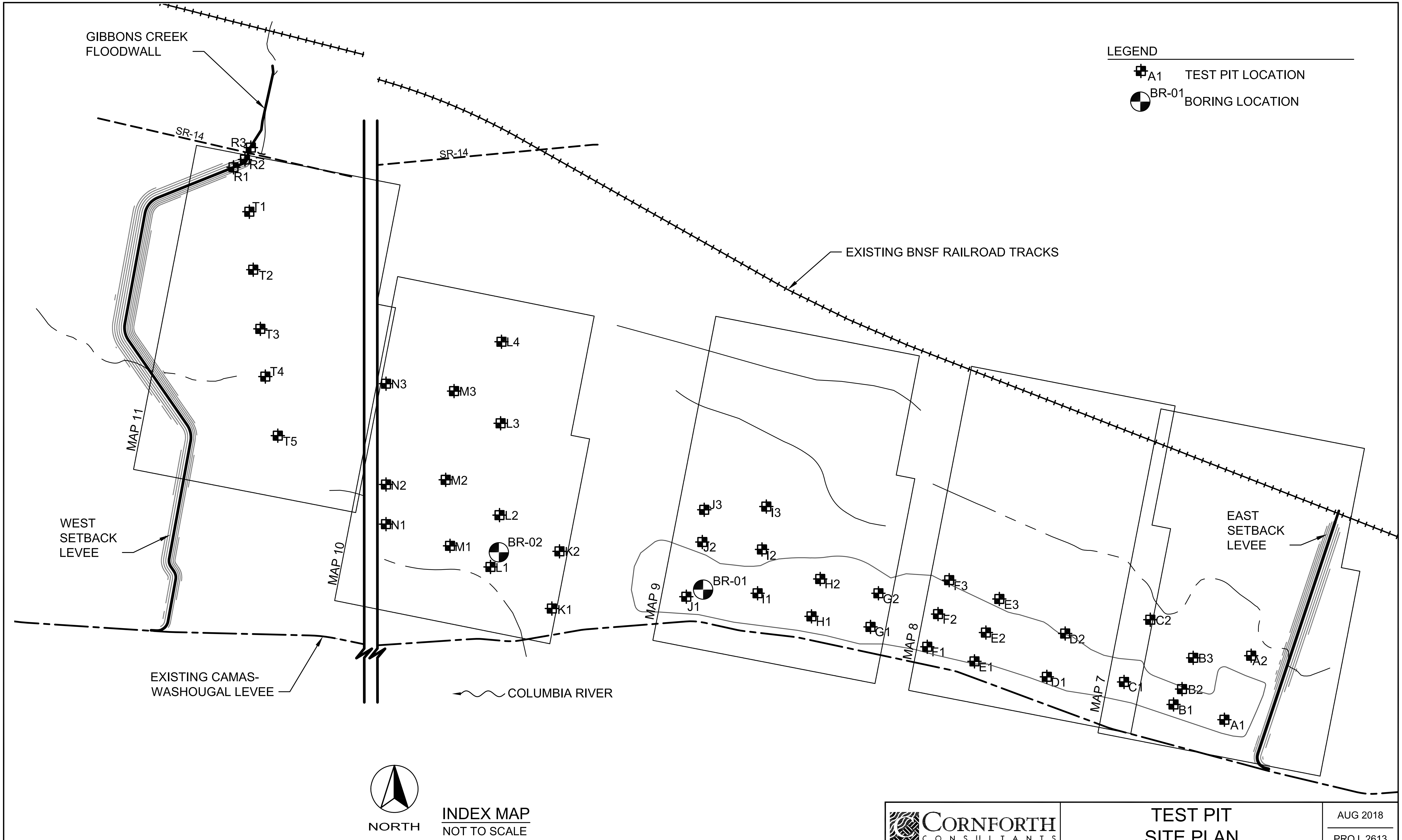
FIG. 10



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2613/Steigerwald Levee 60%.dwg NAU

TEST PIT
SITE PLAN

STEIGERWALD LEVEE DESIGN
WASHOUGAL, WASHINGTON

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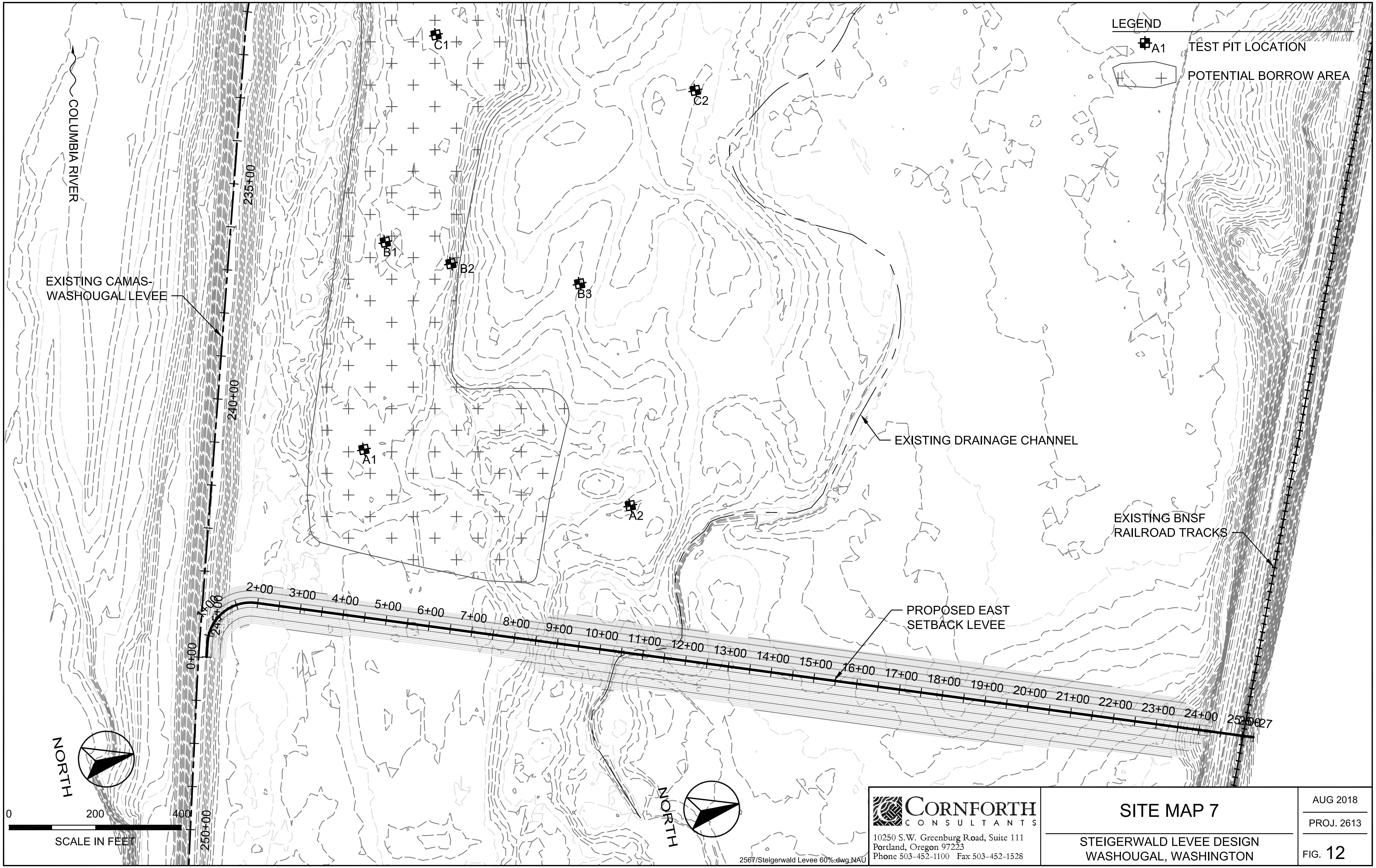
FIG. 11



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SITE MAP 7

STEIGERWALD LEVEE DESIGN
WASHOUGAL, WASHINGTON

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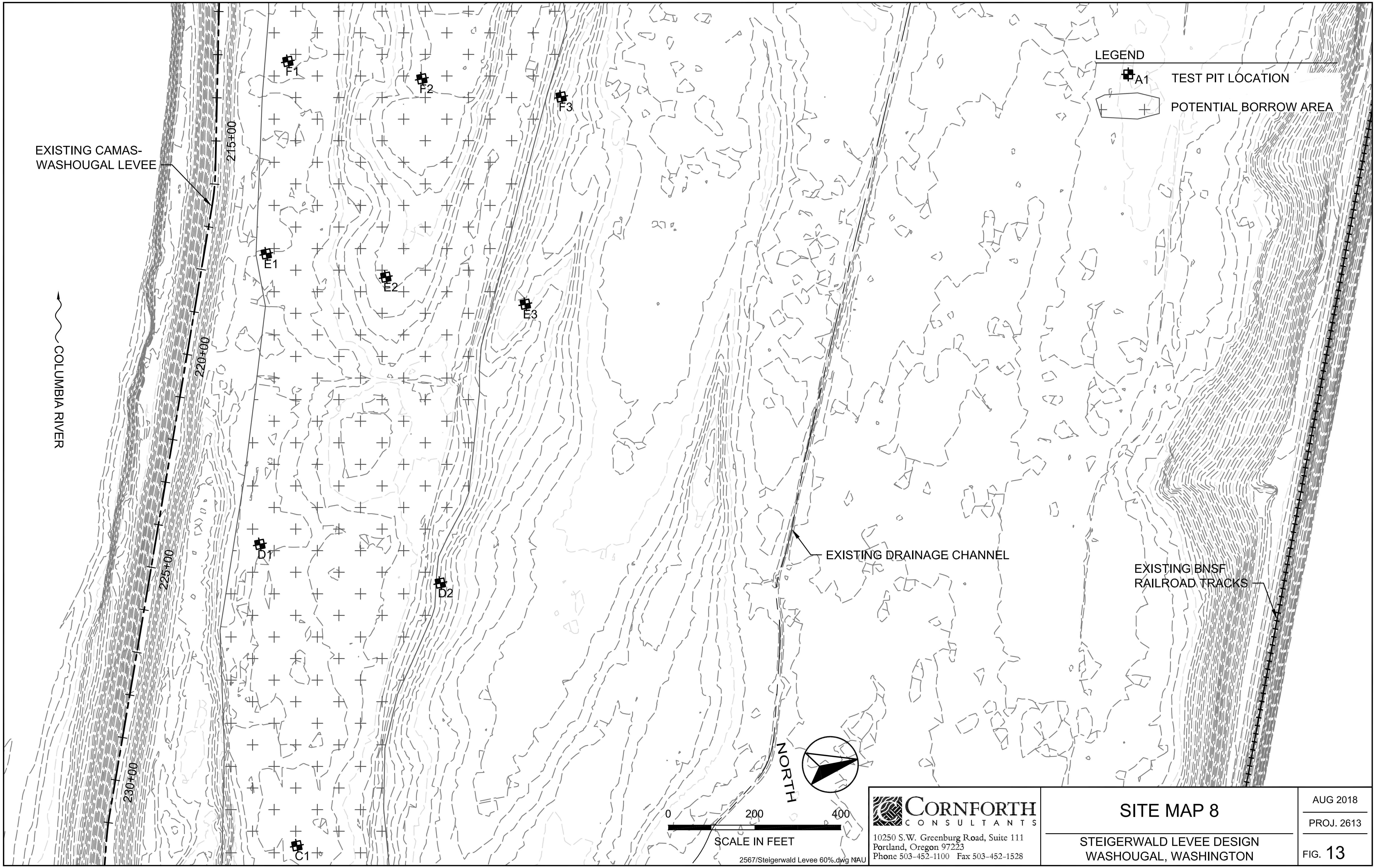
FIG. 12



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SITE MAP 8

STEIGERWALD LEVEE DESIGN
WASHOUGAL, WASHINGTON

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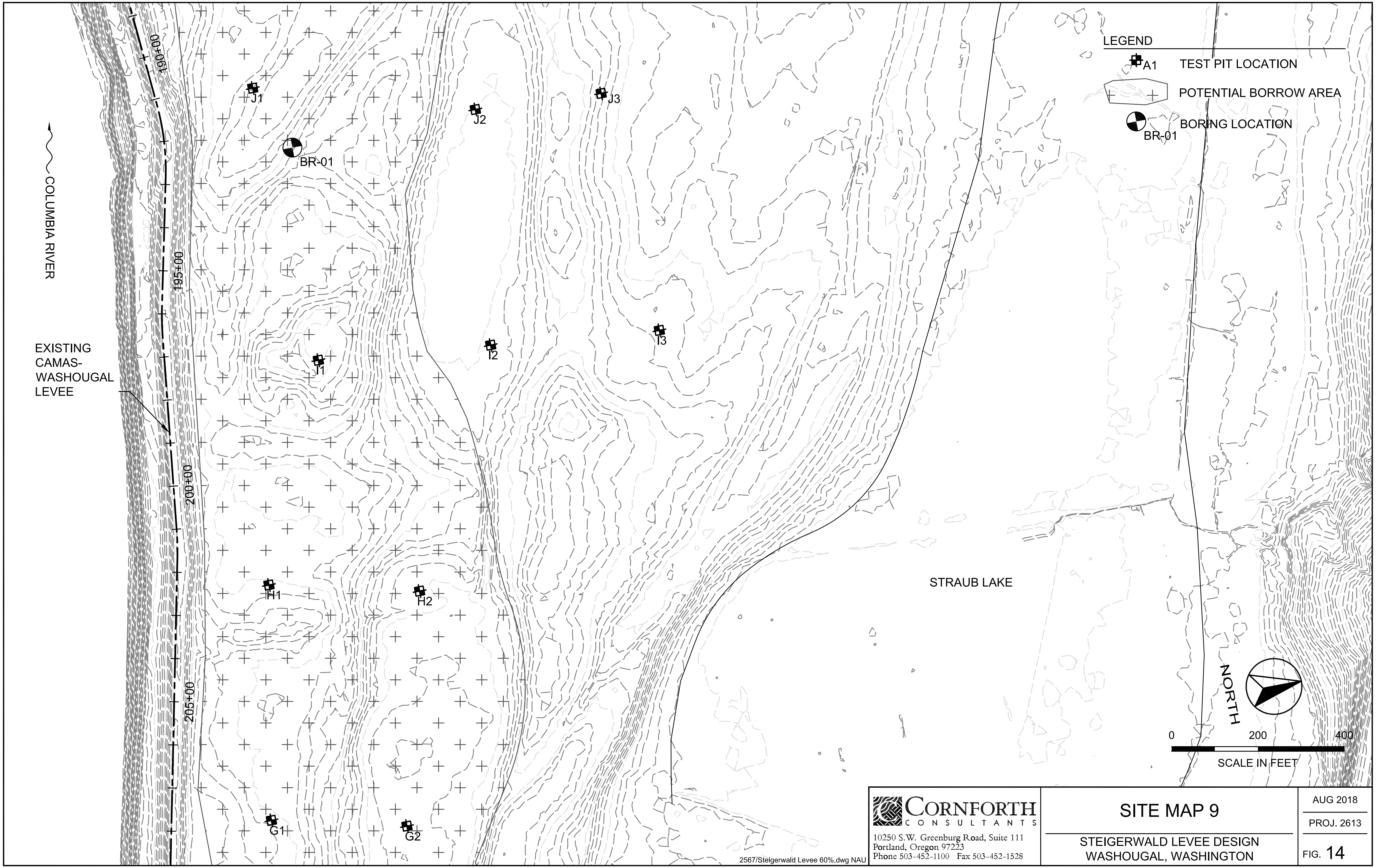
PROJ. 2613

FIG. 13



2567/Steigerwald Levee 60%.dwg NAU

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SITE MAP 9

STEIGERWALD LEVEE DESIGN
WASHOUGAL, WASHINGTON

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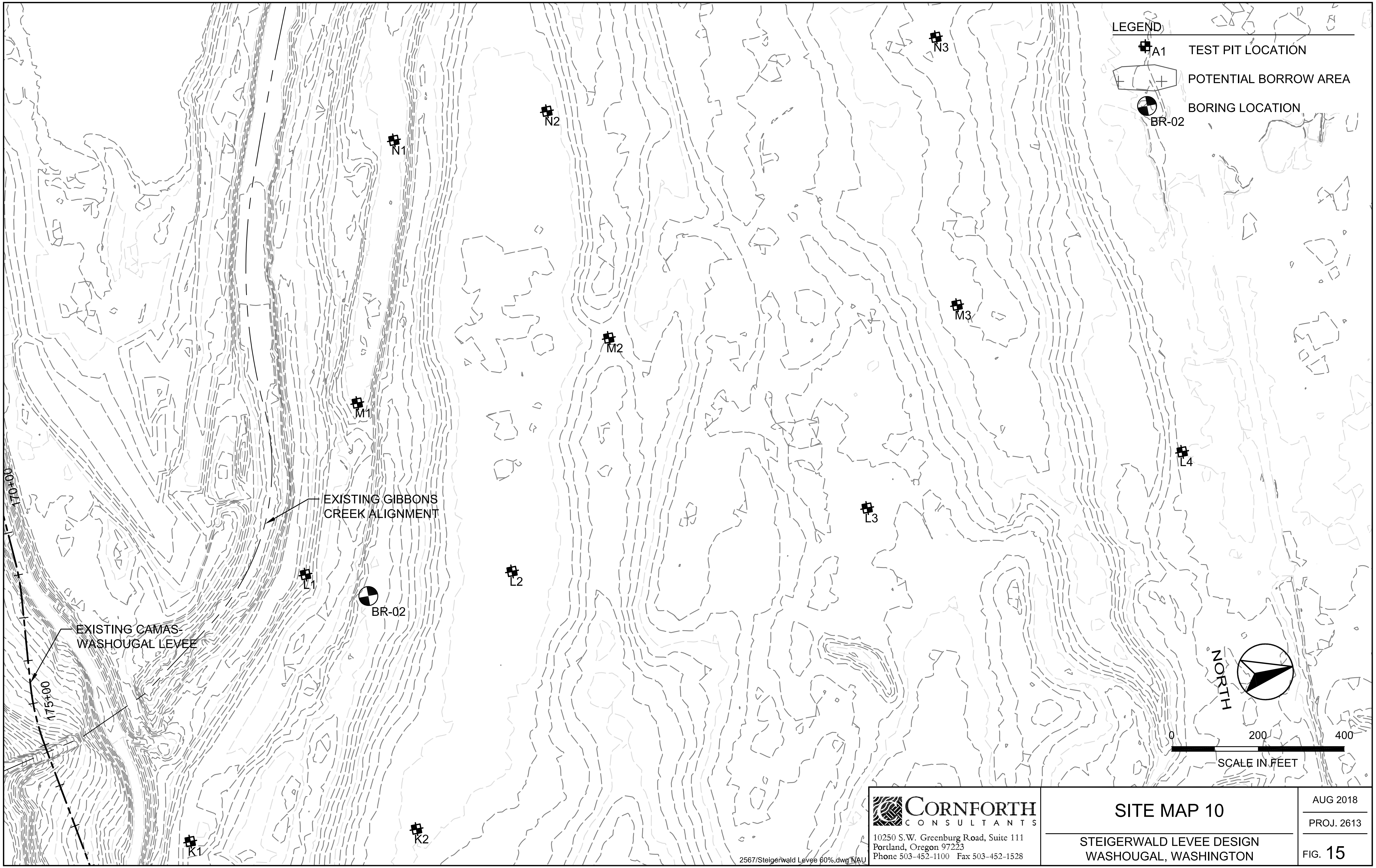
FIG. 14



2567/Steigerwald Levee 60%.dwg NAU

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SITE MAP 10

STEIGERWALD LEVEE DESIGN
WASHOUGAL, WASHINGTON

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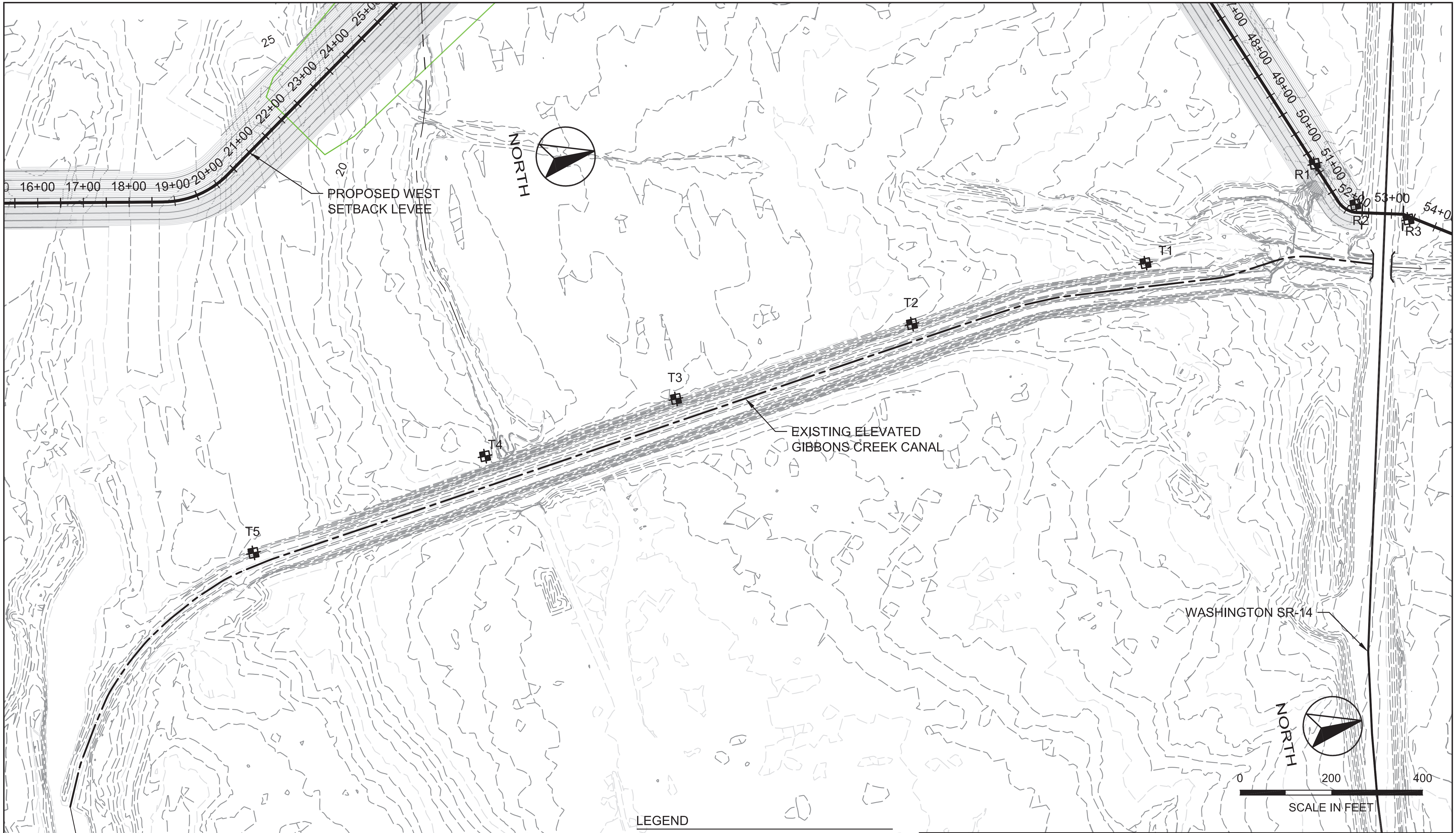
FIG. 15



LEGEND

⊞A1	TEST PIT LOCATION EXCAVATED IN NOV 2016
⊠K1	TEST PIT LOCATION TO BE EXCAVATED

2567/Steigerwald Levee 60%.dwg NAU

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SITE MAP 11

STEIGERWALD LEVEE DESIGN
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PROJ. 2613
FIG. 16

Appendix A – Summary Boring Logs

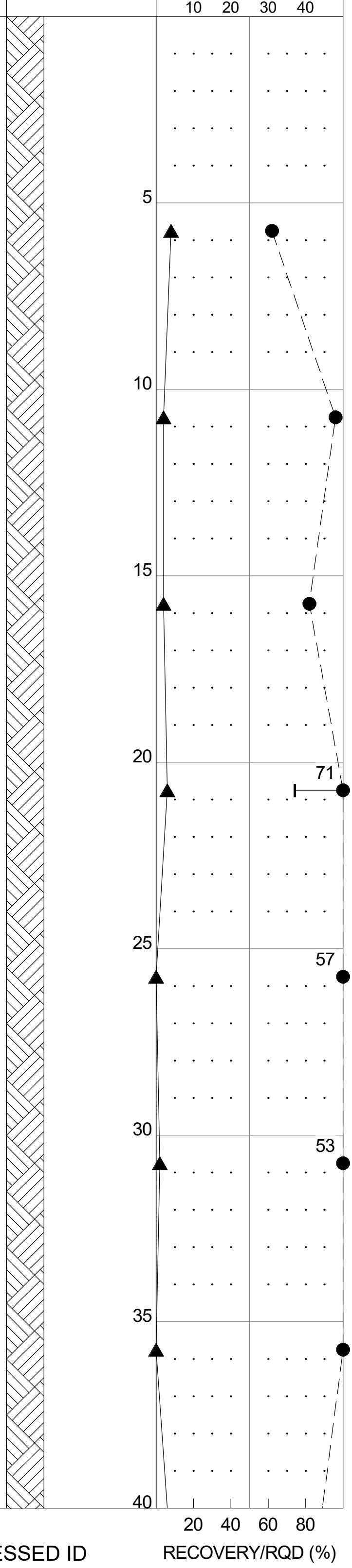
ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION SURFACE ELEVATION: 34.8 FT.
		SOFT, dark gray, fine-sandy SILT; some mica (COLUMBIA RIVER ALLUVIUM)
15.8	19	Interlayered: SOFT to MEDIUM STIFF, dark gray, fine-sandy SILT and VERY LOOSE to LOOSE, dark gray, silty fine SAND; some micas (COLUMBIA RIVER ALLUVIUM) … trace organics at 21 feet
-5.2	40	

SAMPLE NO.	PEN. DATA
S-1	1 2 2
S-2	0 1 1
S-3	0 0 2
S-4	0 1 2
S-5	
S-6	0 0 0
S-7	0 0 1
S-8	0 0 0

GROUND WATER/ INSTRUMENT INSTALLATION

PENETRATION TEST (BLOWS PER FOOT)

WATER CONTENT (%)



LEGEND

▨	2-INCH O.D. SPLIT SPOON
☒	3-INCH O.D. SPLIT SPOON
▯	3-INCH O.D. THIN WALL SAMPLER
▥	3-INCH O.D. PITCHER TUBE SAMPLER
*	NO SAMPLE RECOVERY
▼ MM/DD/YY	GROUND WATER LEVEL AND DATE OBSERVED
├─●─┤	LIQUID LIMIT WATER CONTENT PLASTIC LIMIT
▲	STANDARD PENETRATION TEST (BLOWS/FT.)
●	WATER CONTENT IN PERCENT
▨	CORE RECOVERY IN PERCENT
■	RQD IN PERCENT
PT-1	PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT USING A TREMIE TUBE FROM THE BOTTOM TO THE TOP OF THE HOLE.

HAMMER ASSEMBLY: AUTO TRIP

SPT SAMPLER: NO LINER - RECESSED ID

DRILL ROD USED: NWJ

BOREHOLE DIAM.: 4-7/8"

DRILLER: WESTERN STATES
DATE START: 8/3/2015 FINISH: 8/3/2015
DRILLING TECHNIQUE: MUD ROTARY

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SUMMARY BORING LOG WL-01 (1 of 2)

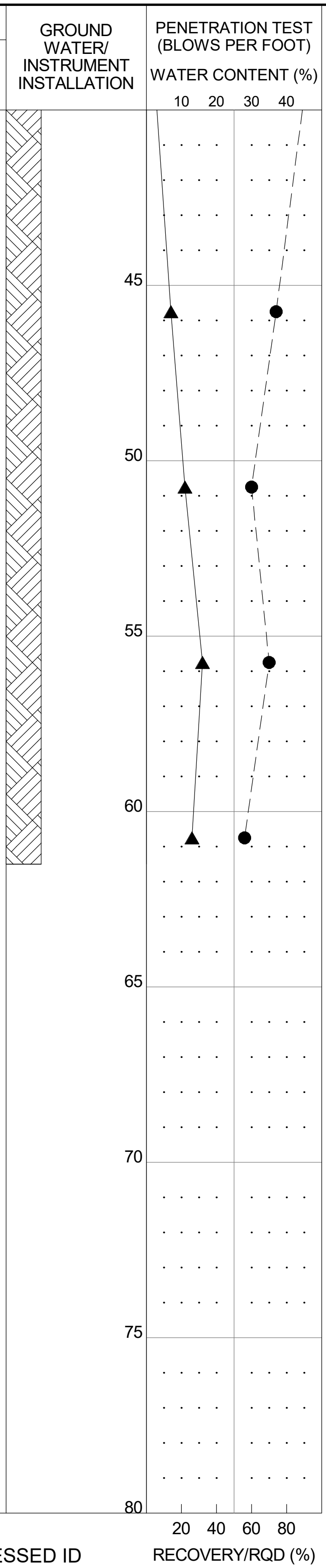
STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

AUG 2018

PROJ 2613

FIG. A-1

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION SURFACE ELEVATION: 34.8 FT.	SAMPLE NO.		SAMPLE PEN. DATA
		(continued from previous page)	S-9	▯	
			S-10	▨	1 4 3
-13.2	48	MEDIUM DENSE, dark gray, silty fine SAND; some micas (COLUMBIA RIVER ALLUVIUM)			
			S-11	▨	5 5 6
			S-12	▨	6 8 8
		… some organics at 56 feet			
			S-13	▨	7 9 4
-26.7	61.5	Bottom of Boring: 61.5 FT			



LEGEND

- ▨ 2-INCH O.D. SPLIT SPOON
- ☒ 3-INCH O.D. SPLIT SPOON
- ▯ 3-INCH O.D. THIN WALL SAMPLER
- ▥ 3-INCH O.D. PITCHER TUBE SAMPLER
- * NO SAMPLE RECOVERY
- ▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED
- ├─●─┤ LIQUID LIMIT, WATER CONTENT, PLASTIC LIMIT
- ▲ STANDARD PENETRATION TEST (BLOWS/FT.)
- ● WATER CONTENT IN PERCENT
- ▨ CORE RECOVERY IN PERCENT
- ■ RQD IN PERCENT
-] PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT USING A TREMIE TUBE FROM THE BOTTOM TO THE TOP OF THE HOLE.

HAMMER ASSEMBLY: AUTO TRIP

SPT SAMPLER: NO LINER - RECESSED ID

DRILL ROD USED: NWJ

BOREHOLE DIAM.: 4-7/8"

DRILLER: WESTERN STATES

DATE START: 8/3/2015 FINISH: 8/3/2015

DRILLING TECHNIQUE: MUD ROTARY

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SUMMARY BORING LOG WL-01 (2 of 2)

STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

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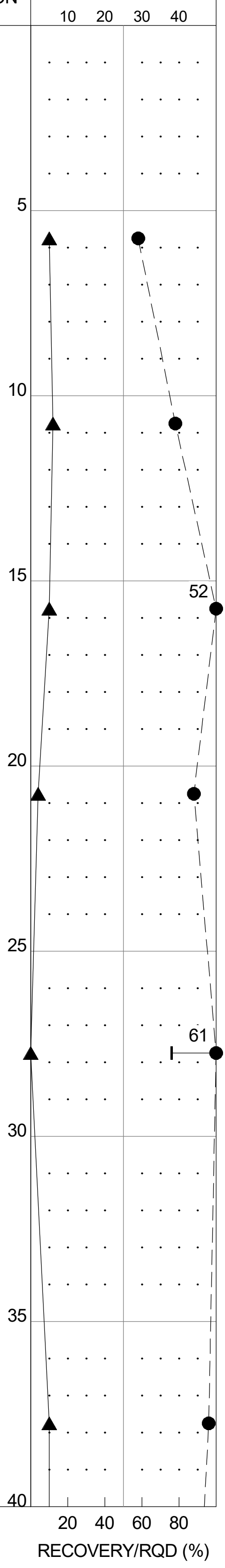
PROJ 2613

FIG. A-1

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION SURFACE ELEVATION: 34.9 FT.	SAMPLE NO.	SAMPLE PEN. DATA	GROUND WATER/ INSTRUMENT INSTALLATION
		VERY LOOSE to LOOSE, silty fine SAND; some micas (COLUMBIA RIVER ALLUVIUM)			
		… brown above 7 feet	S-1	1 3 2	
		… brown gray at 7 to 12 feet	S-2	1 3 3	
		… dark gray below 12 feet			
			S-3	1 1 4	
13.9	21	Interlayered: SOFT to MEDIUM STIFF, dark gray, clayey SILT to silty CLAY and VERY LOOSE to LOOSE, dark gray, silty fine SAND; some micas (COLUMBIA RIVER ALLUVIUM)	S-4	1 1 1	
			S-5		
			S-6	0 0 0	
			S-7		
			S-8	0 2 3	
-5.1	40				

PENETRATION TEST (BLOWS PER FOOT)

WATER CONTENT (%)



LEGEND

- ▨ 2-INCH O.D. SPLIT SPOON
- ☒ 3-INCH O.D. SPLIT SPOON
- ▯ 3-INCH O.D. THIN WALL SAMPLER
- ▥ 3-INCH O.D. PITCHER TUBE SAMPLER
- * NO SAMPLE RECOVERY
- ▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED
- ⊢●⊣ LIQUID LIMIT, WATER CONTENT, PLASTIC LIMIT
- ▲ STANDARD PENETRATION TEST (BLOWS/FT.)
- ● WATER CONTENT IN PERCENT
- ▨ CORE RECOVERY IN PERCENT
- ■ RQD IN PERCENT
-] PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT USING A TREMIE TUBE FROM THE BOTTOM TO THE TOP OF THE HOLE.

HAMMER ASSEMBLY: AUTO TRIP
SPT SAMPLER: NO LINER - RECESSED ID
DRILL ROD USED: NWJ
BOREHOLE DIAM.: 4-7/8"

DRILLER: WESTERN STATES
DATE START: 8/3/2015 FINISH: 8/3/2015
DRILLING TECHNIQUE: MUD ROTARY

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SUMMARY BORING LOG
WL-02 (1 of 2)

STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

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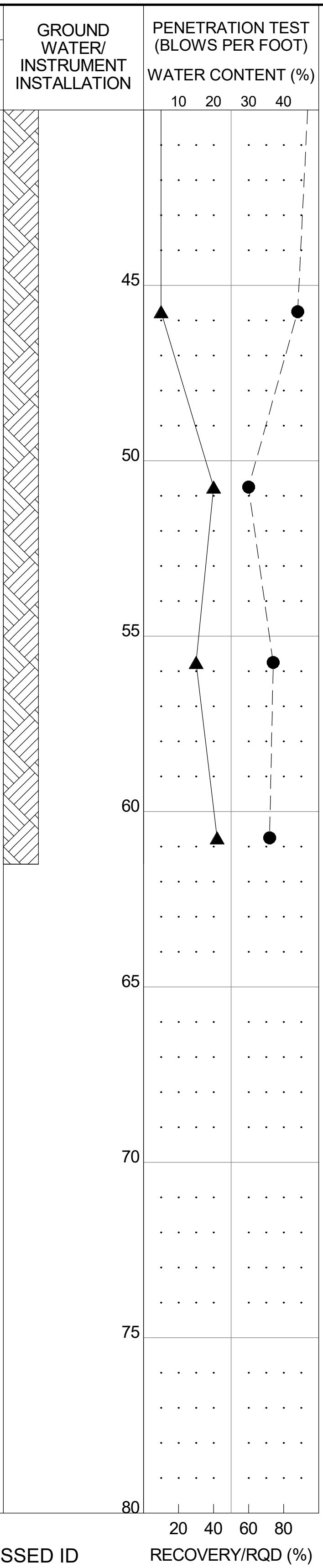
PROJ 2613

FIG. A-2

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION SURFACE ELEVATION: 34.9 FT.	SAMPLE NO.	SAMPLE PEN. DATA
		(continued from previous page)		
			S-9	6 3 2
-14.1	49	MEDIUM DENSE, dark gray, fine SAND; some micas (COLUMBIA RIVER ALLUVIUM)	S-10	7 10 10
		… seams of peat at 56 to 56.5 feet	S-11	4 7 8
-26.6	61.5	… peat seam (½-inch thick) at 61 feet	S-12	4 9 12
		Bottom of Boring: 61.5 FT		



LEGEND

- ▨ 2-INCH O.D. SPLIT SPOON
- ☒ 3-INCH O.D. SPLIT SPOON
- ▯ 3-INCH O.D. THIN WALL SAMPLER
- ▥ 3-INCH O.D. PITCHER TUBE SAMPLER
- * NO SAMPLE RECOVERY
- ▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED
- ├─●─┤ LIQUID LIMIT, WATER CONTENT, PLASTIC LIMIT
- ▲ STANDARD PENETRATION TEST (BLOWS/FT.)
- ● WATER CONTENT IN PERCENT
- ▨ CORE RECOVERY IN PERCENT
- ■ RQD IN PERCENT
-] PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT USING A TREMIE TUBE FROM THE BOTTOM TO THE TOP OF THE HOLE.

HAMMER ASSEMBLY: AUTO TRIP
SPT SAMPLER: NO LINER - RECESSED ID
DRILL ROD USED: NWJ
BOREHOLE DIAM.: 4-7/8"

DRILLER: WESTERN STATES
DATE START: 8/3/2015 FINISH: 8/3/2015
DRILLING TECHNIQUE: MUD ROTARY

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SUMMARY BORING LOG
WL-02 (2 of 2)

STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

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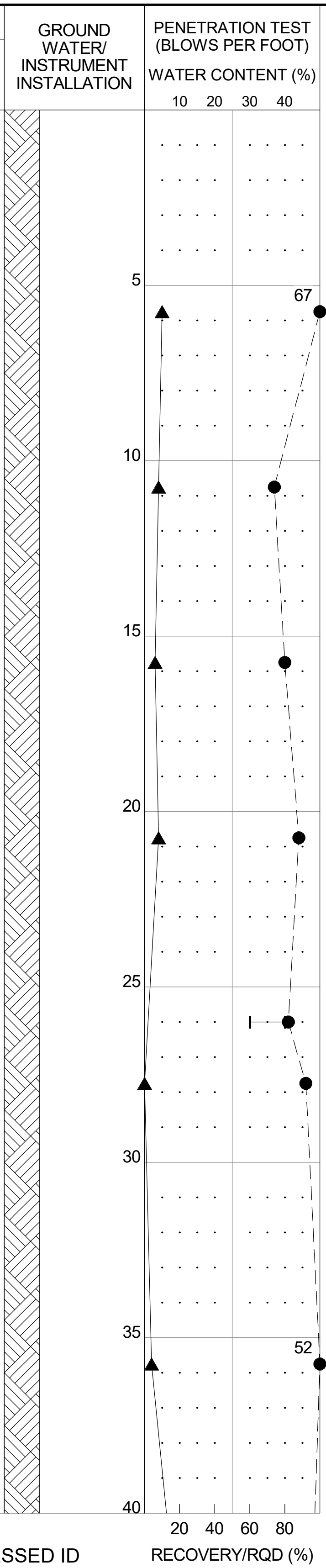
FIG. A-2

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION SURFACE ELEVATION: 35.4 FT.	SAMPLE NO.	PEN. DATA
		Interlayered: VERY LOOSE, silty fine SAND and SOFT, fine-sandy SILT; (COLUMBIA RIVER ALLUVIUM)		
		… soft, dark gray, sandy silt 0 to 8 feet, some fine gravel	S-1	1 3 2
		… brown, silty fine sand at 8 to 13 feet, some micas	S-2	2 2 2
		… dark gray, silty fine sand at 13 to 18 feet, some micas	S-3	1 1 2
		… soft to medium stiff, dark gray, fine-sandy silt at 18 to 25 feet, some micas	S-4	1 2 2
			S-5	
		… soft, gray-brown, clayey silt silt at 25 to 32 feet, some micas	S-6	0 0 0
		… layers of soft, gray-brown, fine-sandy silt and very loose, gray-brown, silty fine sand at 35 to 36.5 ft, each layer less than a foot thick, some micas	S-7	0 1 1
-4.6	40			



LEGEND

▨	2-INCH O.D. SPLIT SPOON
☒	3-INCH O.D. SPLIT SPOON
▯	3-INCH O.D. THIN WALL SAMPLER
▥	3-INCH O.D. PITCHER TUBE SAMPLER
*	NO SAMPLE RECOVERY
▼ MM/DD/YY	GROUND WATER LEVEL AND DATE OBSERVED
├─●─┤	LIQUID LIMIT WATER CONTENT PLASTIC LIMIT
▲	STANDARD PENETRATION TEST (BLOWS/FT.)
●	WATER CONTENT IN PERCENT
▨	CORE RECOVERY IN PERCENT
■	RQD IN PERCENT
PT-1	PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT USING A TREMIE TUBE FROM THE BOTTOM TO THE TOP OF THE HOLE.

HAMMER ASSEMBLY: AUTO TRIP
SPT SAMPLER: NO LINER - RECESSED ID
DRILL ROD USED: NWJ
BOREHOLE DIAM.: 4-7/8"

DRILLER: WESTERN STATES
DATE START: 8/4/2015 FINISH: 8/4/2015
DRILLING TECHNIQUE: MUD ROTARY

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Portland, Oregon 97223
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SUMMARY BORING LOG
WL-03 (1 of 2)

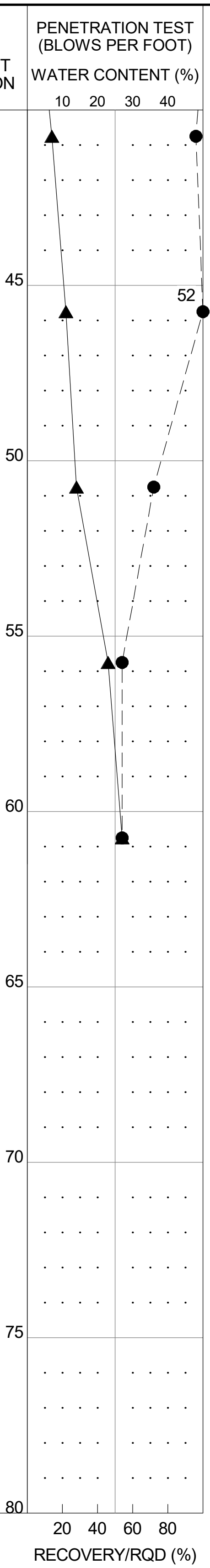
STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

AUG 2018
PROJ 2613
FIG. A-3

SURFACE ELEVATION: 35.4 FT.

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION	SAMPLE NO.	SAMPLE PEN. DATA
		Interlayered: LOOSE, dark gray, silty fine SAND and SOFT, dark gray, fine-sandy SILT; each layer less than a foot thick, some micas (COLUMBIA RIVER ALLUVIUM)	S-8	0 1 6
			S-9	0 4 7
-12.6	48	MEDIUM DENSE, dark gray, silty fine SAND; some micas (COLUMBIA RIVER ALLUVIUM)	S-10	4 7 7
			S-11	6 11 12
		… 1/8-inch thick peat at 56 feet		
		… sand at 60 to 61.5 feet has little fines	S-12	8 13 14
-26.1	61.5	Bottom of Boring: 61.5 FT		

GROUND WATER/ INSTRUMENT INSTALLATION



LEGEND

- ▨ 2-INCH O.D. SPLIT SPOON
- ☒ 3-INCH O.D. SPLIT SPOON
- ▯ 3-INCH O.D. THIN WALL SAMPLER
- ▥ 3-INCH O.D. PITCHER TUBE SAMPLER
- * NO SAMPLE RECOVERY
- ▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED
- LIQUID LIMIT, WATER CONTENT, PLASTIC LIMIT
- ▲ STANDARD PENETRATION TEST (BLOWS/FT.)
- ● WATER CONTENT IN PERCENT
- ▨ CORE RECOVERY IN PERCENT
- ■ RQD IN PERCENT
- PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT USING A TREMIE TUBE FROM THE BOTTOM TO THE TOP OF THE HOLE.

HAMMER ASSEMBLY: AUTO TRIP
SPT SAMPLER: NO LINER - RECESSED ID
DRILL ROD USED: NWJ
BOREHOLE DIAM.: 4-7/8"

DRILLER: WESTERN STATES
DATE START: 8/4/2015 FINISH: 8/4/2015
DRILLING TECHNIQUE: MUD ROTARY

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SUMMARY BORING LOG
WL-03 (2 of 2)

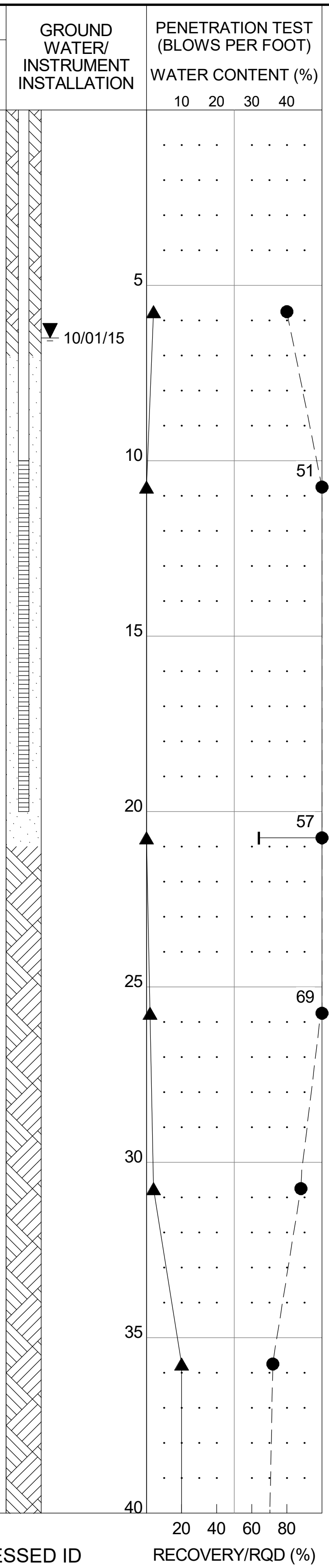
STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

AUG 2018

PROJ 2613

FIG. A-3

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION SURFACE ELEVATION: 27.2 FT.	SAMPLE NO.	PEN. DATA
		Interlayered: VERY LOOSE to LOOSE, silty fine SAND and SOFT, fine-sandy SILT; (COLUMBIA RIVER ALLUVIUM)		
			S-1	1 1 1
		… dark gray, silty fine sand, some micas, at 0 to 15 feet		
			S-2	0 0 0
		… soft, dark gray, fine-sandy silt, some micas, at 15 to 28 feet	S-3	0 0 0
			S-4	0 0 1
		… dark gray, silty fine sand at 28 to 33 feet	S-5	0 1 1
			S-6	3 3 7
		… dark gray, fine sand at 33 to 43 feet, little fines, some micas		
-12.8	40			



LEGEND

▨ 2-INCH O.D. SPLIT SPOON

☒ 3-INCH O.D. SPLIT SPOON

▯ 3-INCH O.D. THIN WALL SAMPLER

▥ 3-INCH O.D. PITCHER TUBE SAMPLER

* NO SAMPLE RECOVERY

MM/DD/YY ▼ GROUND WATER LEVEL AND DATE OBSERVED

LIQUID LIMIT

WATER CONTENT

PLASTIC LIMIT

▲ STANDARD PENETRATION TEST (BLOWS/FT.)

● WATER CONTENT IN PERCENT

▨ CORE RECOVERY IN PERCENT

■ RQD IN PERCENT

PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. STANDPIPE PIEZOMETER INSTALLED AT COMPLETION OF DRILLING, OF 1-INCH DIAMETER SCHEDULE 80, SLOTTED PVC PIPE BACKFILLED WITH 10-12 COLORADO SAND IN FILTER ZONE.
3. ABOVE GROUND MONUMENT AND BOLLARDS INSTALLED.

HAMMER ASSEMBLY: AUTO TRIP
SPT SAMPLER: NO LINER - RECESSED ID
DRILL ROD USED: NWJ
BOREHOLE DIAM.: 8-1/2" (0'-21'), 4-7/8" (21'-61.5)

DRILLER: WESTERN STATES
DATE START: 8/4/2015 FINISH: 8/4/2015
DRILLING TECHNIQUE: HOLLOW STEM AUGER/MUD ROTARY

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Portland, Oregon 97223
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SUMMARY BORING LOG WL-04 (1 of 2)

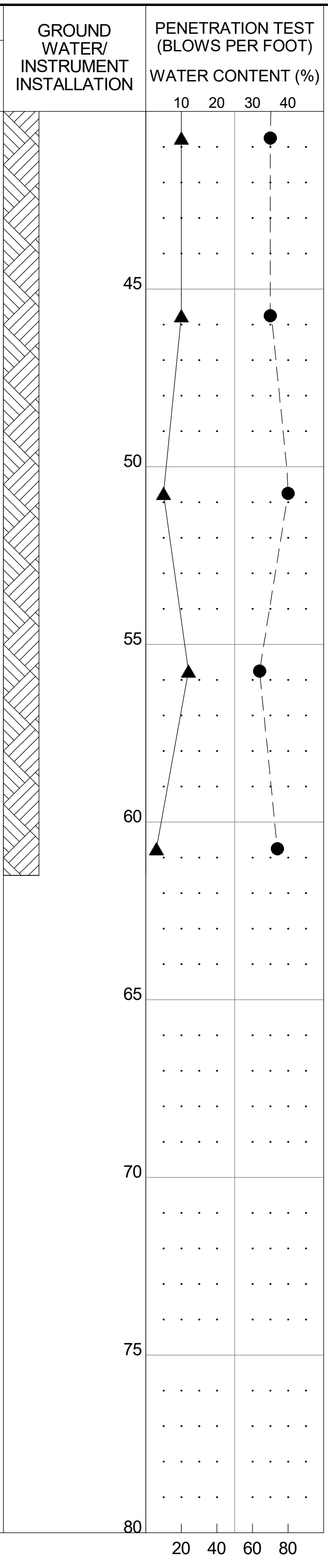
STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

AUG 2018

PROJ 2613

FIG. A-4

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION SURFACE ELEVATION: 27.2 FT.	SAMPLE NO.	SAMPLE PEN. DATA
		(continued form previous page)	S-7	4 4 6
			S-8	4 4 6
		… dark gray, silty fine sand at 43 to 59 feet, some micas	S-9	2 3 2
			S-10	7 7 5
-34.3	61.5	… soft, dark gray, fine-sandy silt, some micas, at 59 to 61.5 feet	S-11	0 0 3
		Bottom of Boring: 61.5 FT		



LEGEND

- ▨ 2-INCH O.D. SPLIT SPOON
- ☒ 3-INCH O.D. SPLIT SPOON
- ▯ 3-INCH O.D. THIN WALL SAMPLER
- ▥ 3-INCH O.D. PITCHER TUBE SAMPLER
- * NO SAMPLE RECOVERY
- ▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED
- ├●┤ LIQUID LIMIT, WATER CONTENT, PLASTIC LIMIT
- ▲ STANDARD PENETRATION TEST (BLOWS/FT.)
- ● WATER CONTENT IN PERCENT
- ▨ CORE RECOVERY IN PERCENT
- ■ RQD IN PERCENT
-] PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. STANDPIPE PIEZOMETER INSTALLED AT COMPLETION OF DRILLING, OF 1-INCH DIAMETER SCHEDULE 80, SLOTTED PVC PIPE BACKFILLED WITH 10-12 COLORADO SAND IN FILTER ZONE.
3. ABOVE GROUND MONUMENT AND BOLLARDS INSTALLED.

HAMMER ASSEMBLY: AUTO TRIP
SPT SAMPLER: NO LINER - RECESSED ID
DRILL ROD USED: NWJ
BOREHOLE DIAM.: 8-1/2" (0'-21'), 4-7/8" (21'-61.5)

DRILLER: WESTERN STATES
DATE START: 8/4/2015 FINISH: 8/4/2015
DRILLING TECHNIQUE: HOLLOW STEM AUGER/MUD ROTARY

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SUMMARY BORING LOG WL-04 (2 of 2)

STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

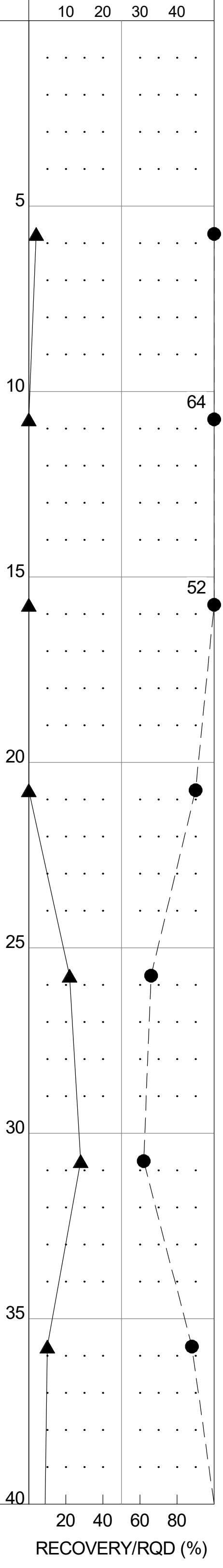
AUG 2018
PROJ 2613
FIG. A-4

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION SURFACE ELEVATION: 33.3 FT.	SAMPLE NO.	PEN. DATA
		Interlayered: VERY LOOSE to LOOSE, silty fine SAND and SOFT to MEDIUM STIFF, clayey SILT; (COLUMBIA RIVER ALLUVIUM)		
		… very loose, dark gray, silty fine sand at 0 to 8 feet, some micas	S-1	0 1 1
		… trace organics at 10 feet	S-2	0 0 0
		… very soft to soft, green gray, fine-sandy silt at 8 to 18 feet		
			S-3	0 0 0
			S-4	0 0 0
		… soft, green gray, fine-sandy silt at 18 to 28 feet, some micas		
			S-5	4 6 5
			S-6	4 7 7
		… loose, dark gray, silty fine sand at 28 to 38 feet, some micas		
			S-7	1 3 2
-6.7	40			

GROUND WATER/ INSTRUMENT INSTALLATION

PENETRATION TEST (BLOWS PER FOOT)

WATER CONTENT (%)



LEGEND

- ▨ 2-INCH O.D. SPLIT SPOON
- ☒ 3-INCH O.D. SPLIT SPOON
- ▯ 3-INCH O.D. THIN WALL SAMPLER
- ▥ 3-INCH O.D. PITCHER TUBE SAMPLER
- * NO SAMPLE RECOVERY
- ▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED
- LIQUID LIMIT, WATER CONTENT, PLASTIC LIMIT
- ▲ STANDARD PENETRATION TEST (BLOWS/FT.)
- ● WATER CONTENT IN PERCENT
- ▨ CORE RECOVERY IN PERCENT
- ■ RQD IN PERCENT
-] PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT USING A TREMIE TUBE FROM THE BOTTOM TO THE TOP OF THE HOLE.

HAMMER ASSEMBLY: AUTO TRIP SPT SAMPLER: NO LINER - RECESSED ID

DRILL ROD USED: NWJ BOREHOLE DIAM.: 4-7/8"

DRILLER: WESTERN STATES

DATE START: 8/7/2015 FINISH: 8/7/2015

DRILLING TECHNIQUE: MUD ROTARY

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SUMMARY BORING LOG WL-05 (1 of 2)

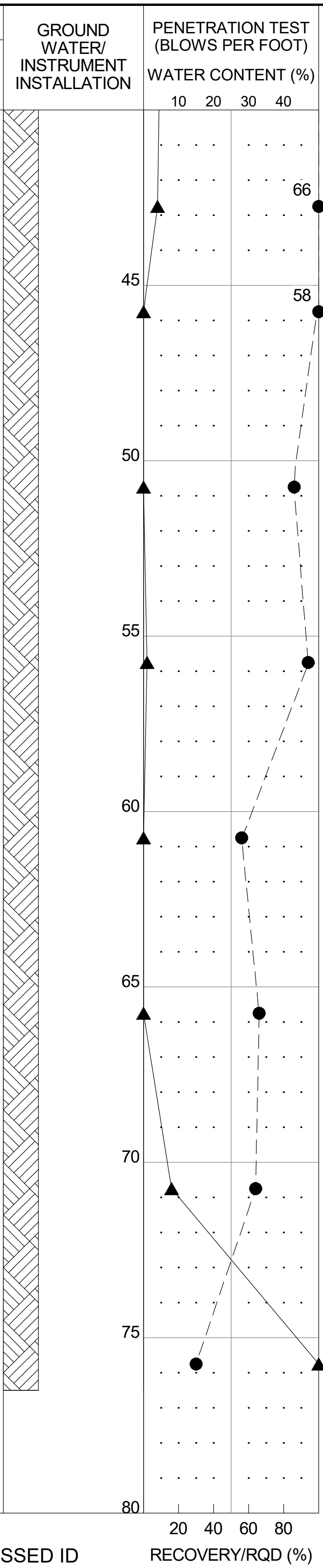
STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

AUG 2018

PROJ 2613

FIG. A-5

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION SURFACE ELEVATION: 33.3 FT.	SAMPLE NO.	PEN. DATA
		(continued from previous page)	S-8	
			S-9	0 0 4
		… soft, green gray, silt to fine-sandy silt at 38 to 50 feet, some micas		
			S-10	0 0 0
			S-11	0 0 0
		… very loose, green gray, silty fine sand, trace gravel, at 50 to 58 feet		
			S-12	0 0 1
			S-13	0 0 0
		… very loose, dark gray, silty fine sand, trace gravel, at 58 to 72 feet	S-14	0 0 0
		… increasing gravel at 68 feet		
			S-15	3 5 3
-38.7	72	DENSE, dark gray, GRAVEL in a matrix of silty sand (COLUMBIA RIVER ALLUVIUM)		
			S-16	25 20 32
-43.2	76.5	Bottom of Boring: 76.5 FT		



LEGEND

- ▨ 2-INCH O.D. SPLIT SPOON
- ☒ 3-INCH O.D. SPLIT SPOON
- ▯ 3-INCH O.D. THIN WALL SAMPLER
- ▥ 3-INCH O.D. PITCHER TUBE SAMPLER
- * NO SAMPLE RECOVERY
- ▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED
- LIQUID LIMIT
- WATER CONTENT
- PLASTIC LIMIT
- ▲ STANDARD PENETRATION TEST (BLOWS/FT.)
- ● WATER CONTENT IN PERCENT
- ▨ CORE RECOVERY IN PERCENT
- ■ RQD IN PERCENT
- PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT USING A TREMIE TUBE FROM THE BOTTOM TO THE TOP OF THE HOLE.

HAMMER ASSEMBLY: AUTO TRIP

SPT SAMPLER: NO LINER - RECESSED ID

DRILL ROD USED: NWJ

BOREHOLE DIAM.: 4-7/8"

DRILLER: WESTERN STATES
DATE START: 8/7/2015 FINISH: 8/7/2015
DRILLING TECHNIQUE: MUD ROTARY

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SUMMARY BORING LOG WL-05 (2 of 2)

STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

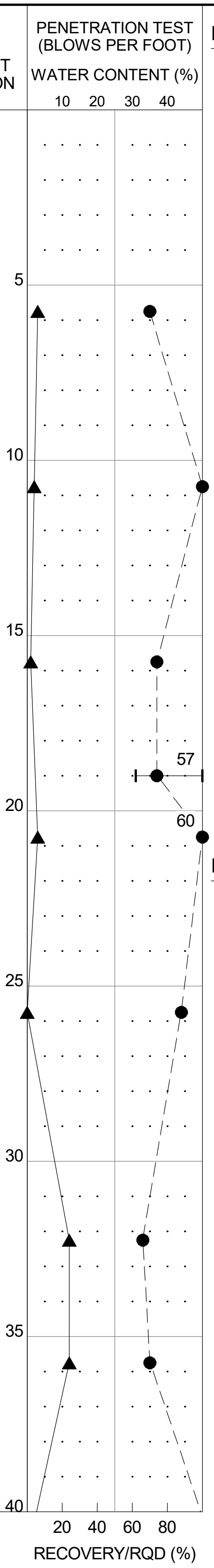
AUG 2018

PROJ 2613

FIG. A-5

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION SURFACE ELEVATION: 32.0 FT.	SAMPLE NO.	SAMPLE PEN. DATA
		Interlayered: VERY LOOSE to LOOSE, silty fine SAND and SOFT to MEDIUM STIFF, fine-sandy SILT; (COLUMBIA RIVER ALLUVIUM)		
		… brown, silty fine sand at 0 to 7 ft, micas	S-1	1 2 1
		… dark gray, silty fine sand at 7 to 13 feet, micas	S-2	1 1 1
		… dark gray, fine-sandy silt at 13 to 18 feet, micas	S-3	1 0 1
			S-4	
			S-5	1 1 2
		… soft, green gray, slightly clayey silt at 18 to 31 feet	S-6	0 0 0
			S-7	
			S-8	4 6 6
		… dark gray, silty fine sand at 31 to 38 feet, micas	S-9	4 7 5
-8.0	40			

GROUND WATER/ INSTRUMENT INSTALLATION



LEGEND

- ▨ 2-INCH O.D. SPLIT SPOON
- ☒ 3-INCH O.D. SPLIT SPOON
- ▯ 3-INCH O.D. THIN WALL SAMPLER
- ▥ 3-INCH O.D. PITCHER TUBE SAMPLER
- * NO SAMPLE RECOVERY
- ▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED
- LIQUID LIMIT
- WATER CONTENT
- PLASTIC LIMIT
- ▲ STANDARD PENETRATION TEST (BLOWS/FT.)
- ● WATER CONTENT IN PERCENT
- ▨ CORE RECOVERY IN PERCENT
- ■ RQD IN PERCENT
- PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT USING A TREMIE TUBE FROM THE BOTTOM TO THE TOP OF THE HOLE.

HAMMER ASSEMBLY: AUTO TRIP
SPT SAMPLER: NO LINER - RECESSED ID
DRILL ROD USED: NWJ
BOREHOLE DIAM.: 4-7/8"

DRILLER: WESTERN STATES
DATE START: 8/6/2015 FINISH: 8/6/2015
DRILLING TECHNIQUE: MUD ROTARY

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SUMMARY BORING LOG
WL-06 (1 of 3)

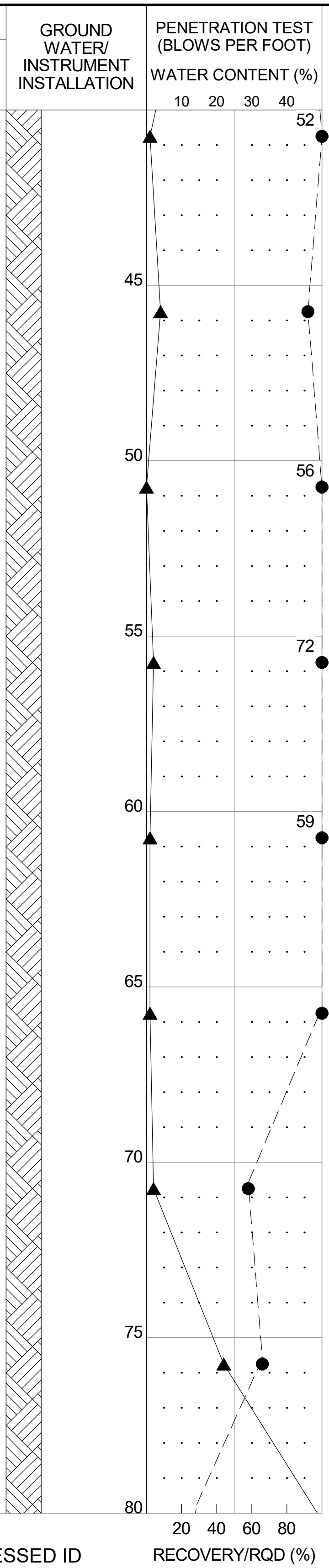
STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

AUG 2018

PROJ 2613

FIG. A-6

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION SURFACE ELEVATION: 32.0 FT.	SAMPLE NO.	PEN. DATA
		(continued from previous page) … dark gray, fine-sandy silt at 38 to 43 feet	S-10	0 0 1
		… green gray, fine-sandy silt at 43 to 48 feet	S-11	1 2 2
		… soft, green gray, silt at 48 to 53 feet	S-12	0 0 0
		… some gravel at 53.5 to 54.5 feet		
			S-13	0 0 2
		… green gray, fine-sandy silt at 53 to 68 feet, micas … trace peat fragments at 61 feet	S-14	0 0 1
			S-15	0 1 0
		... very loose, dark gray, silty fine sand at 68 to 72 feet, micas	S-16	1 1 1
-40.0	72	MEDIUM DENSE, dark gray, GRAVEL in a matrix of silty sand; some micas (COLUMBIA RIVER ALLUVIUM)		
			S-17	3 2 20
-47.0	79	DENSE, dark gray, GRAVEL and COBBLES in a		



LEGEND

▨ 2-INCH O.D. SPLIT SPOON

☒ 3-INCH O.D. SPLIT SPOON

▯ 3-INCH O.D. THIN WALL SAMPLER

▥ 3-INCH O.D. PITCHER TUBE SAMPLER

* NO SAMPLE RECOVERY

▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED

LIQUID LIMIT
WATER CONTENT
PLASTIC LIMIT

▲ STANDARD PENETRATION TEST (BLOWS/FT.)

● WATER CONTENT IN PERCENT

▨ CORE RECOVERY IN PERCENT

■ RQD IN PERCENT

PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT USING A TREMIE TUBE FROM THE BOTTOM TO THE TOP OF THE HOLE.

HAMMER ASSEMBLY: AUTO TRIP
DRILL ROD USED: NWJ

SPT SAMPLER: NO LINER - RECESSED ID
BOREHOLE DIAM.: 4-7/8"

DRILLER: WESTERN STATES
DATE START: 8/6/2015 FINISH: 8/6/2015
DRILLING TECHNIQUE: MUD ROTARY

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SUMMARY BORING LOG WL-06 (2 of 3)

STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

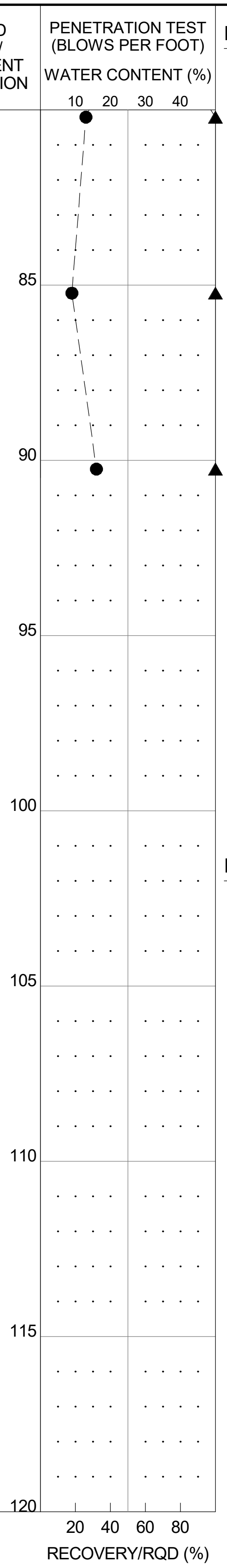
AUG 2018

PROJ 2613

FIG. A-6

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION SURFACE ELEVATION: 32.0 FT.	SAMPLE NO.	SAMPLE PEN. DATA
		(continued from previous page) matrix of silty sand (CATACLYSMIC-FLOOD DEPOSIT)	S-18	50/5"
			S-19	50/5.5"
		… circulation loss at 88 feet		
-58.5	90.5	… fine sand with micas at 90 feet	S-20	50/6"
		Bottom of Boring: 90.5 FT		

GROUND WATER/ INSTRUMENT INSTALLATION



LEGEND

▨	2-INCH O.D. SPLIT SPOON
☒	3-INCH O.D. SPLIT SPOON
▯	3-INCH O.D. THIN WALL SAMPLER
▥	3-INCH O.D. PITCHER TUBE SAMPLER
*	NO SAMPLE RECOVERY
▼ MM/DD/YY	GROUND WATER LEVEL AND DATE OBSERVED
├─●─┤	LIQUID LIMIT WATER CONTENT PLASTIC LIMIT
▲	STANDARD PENETRATION TEST (BLOWS/FT.)
●	WATER CONTENT IN PERCENT
▨	CORE RECOVERY IN PERCENT
■	RQD IN PERCENT
] PT-1	PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT USING A TREMIE TUBE FROM THE BOTTOM TO THE TOP OF THE HOLE.

HAMMER ASSEMBLY: AUTO TRIP
SPT SAMPLER: NO LINER - RECESSED ID
DRILL ROD USED: NWJ
BOREHOLE DIAM.: 4-7/8"

DRILLER: WESTERN STATES
DATE START: 8/6/2015 FINISH: 8/6/2015
DRILLING TECHNIQUE: MUD ROTARY

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SUMMARY BORING LOG
WL-06 (3 of 3)

STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

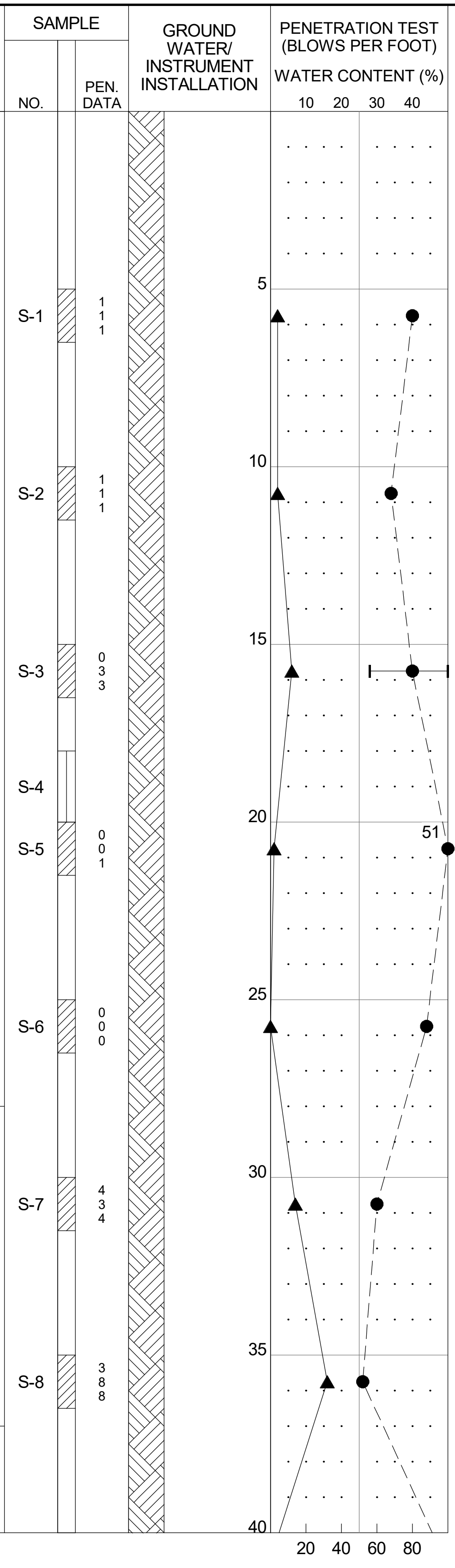
AUG 2018

PROJ 2613

FIG. A-6

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION SURFACE ELEVATION: 33.6 FT.
		Interlayered: VERY LOOSE to LOOSE, brown, silty fine SAND and SOFT to MEDIUM STIFF, brown, clayey SILT to silty CLAY; occasional organics, some mica (COLUMBIA RIVER ALLUVIUM) ...becomes gray to blue-gray at 8 feet
5.6	28	LOOSE, gray, slightly silty SAND, fine to medium sized sand, some mica (COLUMBIA RIVER ALLUVIUM)
-3.4	37	

SAMPLE NO.	PEN. DATA
S-1	1 1 1
S-2	1 1 1
S-3	0 3 3
S-4	
S-5	0 0 1
S-6	0 0 0
S-7	4 3 4
S-8	3 8 8



LEGEND

- ▨ 2-INCH O.D. SPLIT SPOON
- ☒ 3-INCH O.D. SPLIT SPOON
- ▯ 3-INCH O.D. THIN WALL SAMPLER
- ▥ 3-INCH O.D. PITCHER TUBE SAMPLER
- * NO SAMPLE RECOVERY
- ▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED
- LIQUID LIMIT / WATER CONTENT / PLASTIC LIMIT
- ▲ STANDARD PENETRATION TEST (BLOWS/FT.)
- ● WATER CONTENT IN PERCENT
- ▨ CORE RECOVERY IN PERCENT
- ▩ RQD IN PERCENT
- PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT USING A TREMIE TUBE FROM THE BOTTOM TO THE TOP OF THE HOLE.

HAMMER ASSEMBLY: AUTO TRIP
SPT SAMPLER: NO LINER - RECESSED ID
DRILL ROD USED: NWJ
BOREHOLE DIAM.: 4-7/8" (0'-10'), 3-7/8" (10'-85')

DRILLER: WESTERN STATES
DATE START: 8/5/2015 FINISH: 8/5/2015
DRILLING TECHNIQUE: MUD ROTARY

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10250 S.W. Greenburg Road, Suite 111
Portland, Oregon 97223
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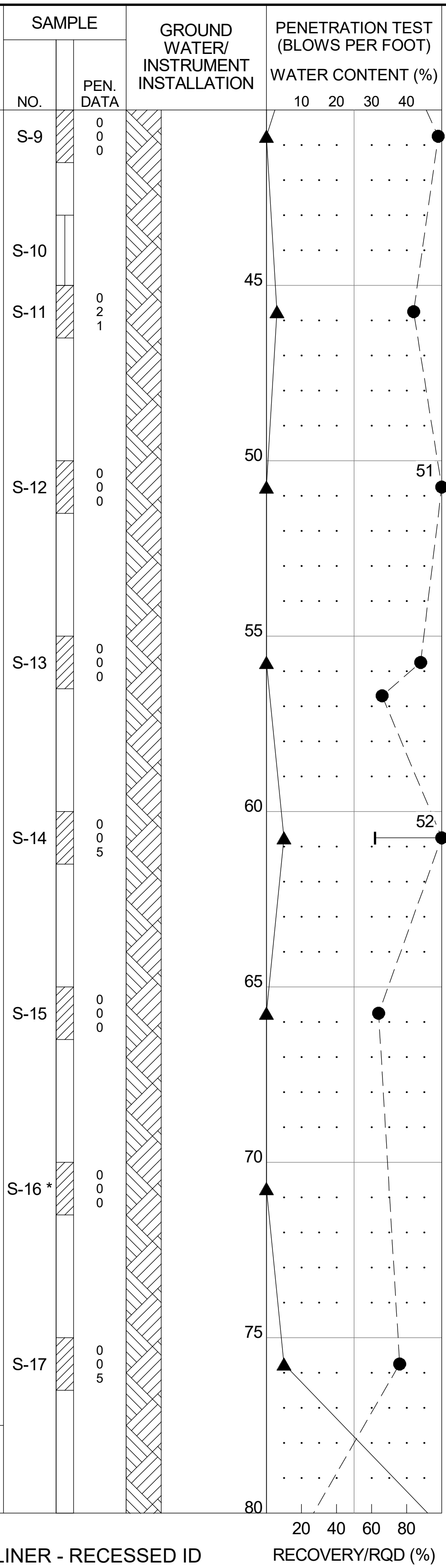
SUMMARY BORING LOG
WL-07 (1 of 3)

STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

AUG 2018
PROJ 2613
FIG. A-7

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION SURFACE ELEVATION: 33.6 FT.
		Interlayered: VERY LOOSE to LOOSE, gray to blue-gray, silty fine SAND and SOFT to MEDIUM STIFF, slightly clayey, fine-sandy SILT; occasional carbonized organics, some mica (COLUMBIA RIVER ALLUVIUM)
		...scattered gravel at 53 to 54 feet
-43.9	77.5	DENSE, dark gray, GRAVEL and COBBLES in a matrix of silty sand (CATACLYSMIC-FLOOD DEPOSIT)



LEGEND

- ▨ 2-INCH O.D. SPLIT SPOON
- ☒ 3-INCH O.D. SPLIT SPOON
- ▯ 3-INCH O.D. THIN WALL SAMPLER
- ▥ 3-INCH O.D. PITCHER TUBE SAMPLER
- * NO SAMPLE RECOVERY
- ▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED
- ├●┤ LIQUID LIMIT, WATER CONTENT, PLASTIC LIMIT
- ▲ STANDARD PENETRATION TEST (BLOWS/FT.)
- ● WATER CONTENT IN PERCENT
- ▨ CORE RECOVERY IN PERCENT
- ■ RQD IN PERCENT
-] PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT USING A TREMIE TUBE FROM THE BOTTOM TO THE TOP OF THE HOLE.

HAMMER ASSEMBLY: AUTO TRIP
SPT SAMPLER: NO LINER - RECESSED ID
DRILL ROD USED: NWJ
BOREHOLE DIAM.: 4-7/8" (0'-10'), 3-7/8" (10'-85')

DRILLER: WESTERN STATES
DATE START: 8/5/2015 FINISH: 8/5/2015
DRILLING TECHNIQUE: MUD ROTARY

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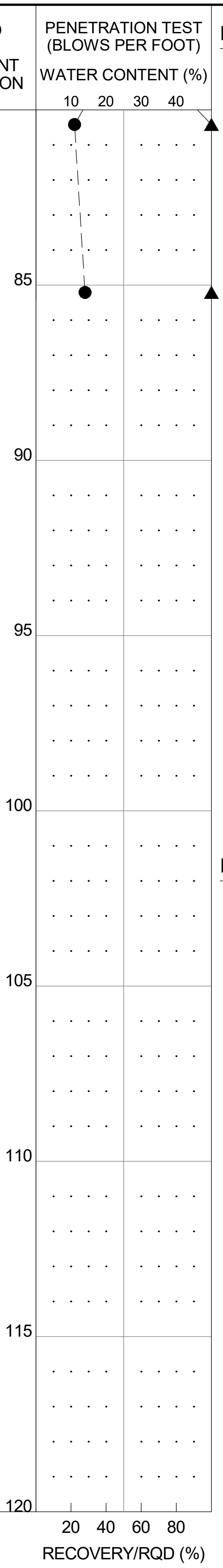
SUMMARY BORING LOG
WL-07 (2 of 3)

STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

AUG 2018
PROJ 2613
FIG. A-7

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION SURFACE ELEVATION: 33.6 FT.	SAMPLE NO.		SAMPLE PEN. DATA	GROUND WATER/ INSTRUMENT INSTALLATION
		DENSE, dark gray, GRAVEL and COBBLES in a matrix of silty sand (CATACLYSMIC-FLOOD DEPOSIT)	S-18	▨	29 50/4"	
-51.8	85.4		S-19	▨	50/5"	
		Bottom of Boring: 85.4 FT				



LEGEND

- ▨ 2-INCH O.D. SPLIT SPOON
- ☒ 3-INCH O.D. SPLIT SPOON
- ▯ 3-INCH O.D. THIN WALL SAMPLER
- ▥ 3-INCH O.D. PITCHER TUBE SAMPLER
- * NO SAMPLE RECOVERY
- ▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED
- ●— LIQUID LIMIT, WATER CONTENT, PLASTIC LIMIT
- ▲ STANDARD PENETRATION TEST (BLOWS/FT.)
- ● WATER CONTENT IN PERCENT
- ▨ CORE RECOVERY IN PERCENT
- ■ RQD IN PERCENT
-] PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT USING A TREMIE TUBE FROM THE BOTTOM TO THE TOP OF THE HOLE.

HAMMER ASSEMBLY: AUTO TRIP
SPT SAMPLER: NO LINER - RECESSED ID
DRILL ROD USED: NWJ
BOREHOLE DIAM.: 4-7/8" (0'-10'), 3-7/8" (10'-85')

DRILLER: WESTERN STATES
DATE START: 8/5/2015 FINISH: 8/5/2015
DRILLING TECHNIQUE: MUD ROTARY

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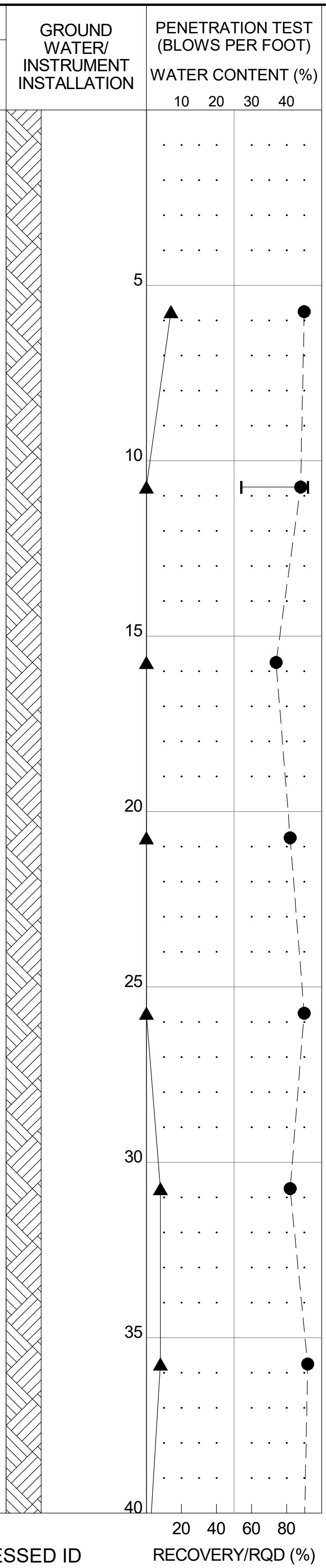
SUMMARY BORING LOG
WL-07 (3 of 3)

STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

AUG 2018
PROJ 2613
FIG. A-7

SURFACE ELEVATION: 31.4 FT.

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION	SAMPLE NO.	PEN. DATA
		Interlayered: VERY LOOSE to LOOSE, silty, fine SAND and sandy SILT and SOFT to MEDIUM STIFF, slightly clayey SILT (COLUMBIA RIVER ALLUVIUM)		
		… loose, mottled brown and orange, silty fine sand at 0 to 8 ft	S-1	2 3 4
		… soft, mottled brown and orange silty clay 8 to 13 ft	S-2	0 0 0
		… soft, brown, fine-sandy silt at 13 to 18 ft	S-3	0 0 0
		…very loose, dark gray, silty fine sand at 18 to 23 ft	S-4	0 0 0
			S-5	0 0 0
		… soft to medium stiff, green gray, fine-sandy silt from about 23 to 33 ft	S-6	1 2 2
			S-7	
		… interlayered, green gray, silty fine sand and sandy silt at 33 to 38 ft	S-8	0 2 2
-8.6	40			



HAMMER ASSEMBLY: AUTO TRIP
DRILL ROD USED: NWJ

SPT SAMPLER: NO LINER - RECESSED ID
BOREHOLE DIAM.: 4-7/8"

LEGEND

- ▨ 2-INCH O.D. SPLIT SPOON
- ☒ 3-INCH O.D. SPLIT SPOON
- ▯ 3-INCH O.D. THIN WALL SAMPLER
- ▥ 3-INCH O.D. PITCHER TUBE SAMPLER
- * NO SAMPLE RECOVERY
- ▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED
- ├─●─┤ LIQUID LIMIT, WATER CONTENT, PLASTIC LIMIT
- ▲ STANDARD PENETRATION TEST (BLOWS/FT.)
- ● WATER CONTENT IN PERCENT
- ▨ CORE RECOVERY IN PERCENT
- ■ RQD IN PERCENT
-] PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT USING A TREMIE TUBE FROM THE BOTTOM TO THE TOP OF THE HOLE.

DRILLER: WESTERN STATES
DATE START: 8/7/2015 FINISH: 8/10/2015
DRILLING TECHNIQUE: MUD ROTARY

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SUMMARY BORING LOG
WL-08 (1 of 2)

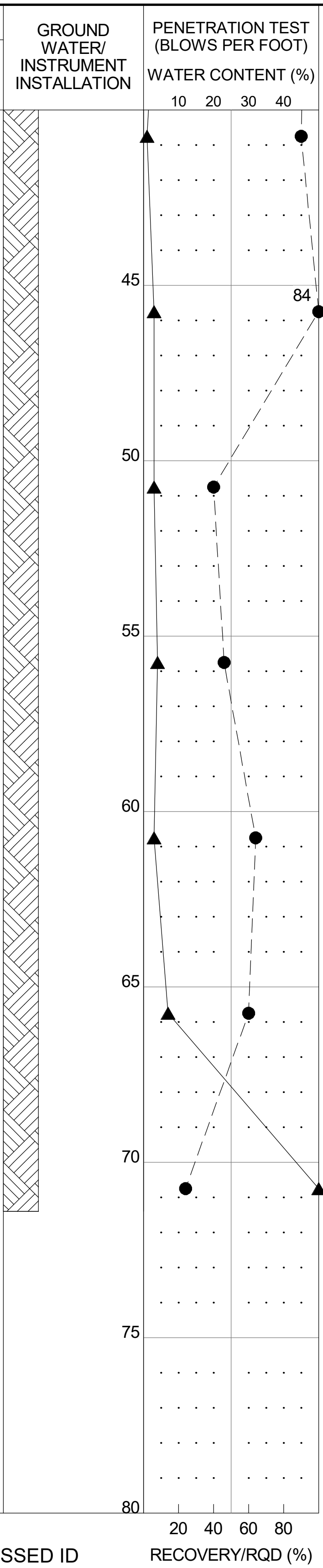
STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

AUG 2018

PROJ 2613

FIG. A-8

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION SURFACE ELEVATION: 31.4 FT.	SAMPLE NO.	PEN. DATA
		(continued from previous page)		
		… very loose, dark gray, silty fine sand, some micas, at 38 to 43 ft	S-9	0 1 0
		… interlayered, green gray, silty fine sand and fine sandy silt at 43 to 48 ft, some organics in silt	S-10	0 0 3
-16.6	48	VERY LOOSE to LOOSE, dark gray, silty fine SAND, trace gravel, some micas (COLUMBIA RIVER ALLUVIUM)	S-11	5 1 2
			S-12	2 2 2
			S-13	5 1 2
			S-14	7 4 3
-36.6	68	DENSE, dark gray, GRAVEL with silty sand; subrounded gravels (COLUMBIA RIVER ALLUVIUM)	S-15	25 20 50/5"
-40.0	71.4	Bottom of Boring: 71.4 FT		



LEGEND

- ▨ 2-INCH O.D. SPLIT SPOON
- ☒ 3-INCH O.D. SPLIT SPOON
- ▯ 3-INCH O.D. THIN WALL SAMPLER
- ▥ 3-INCH O.D. PITCHER TUBE SAMPLER
- * NO SAMPLE RECOVERY
- ▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED
- LIQUID LIMIT
- WATER CONTENT
- PLASTIC LIMIT
- ▲ STANDARD PENETRATION TEST (BLOWS/FT.)
- ● WATER CONTENT IN PERCENT
- ▨ CORE RECOVERY IN PERCENT
- ■ RQD IN PERCENT
- PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
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HAMMER ASSEMBLY: AUTO TRIP
SPT SAMPLER: NO LINER - RECESSED ID
DRILL ROD USED: NWJ
BOREHOLE DIAM.: 4-7/8"

DRILLER: WESTERN STATES
DATE START: 8/7/2015 FINISH: 8/10/2015
DRILLING TECHNIQUE: MUD ROTARY

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SUMMARY BORING LOG WL-08 (2 of 2)

STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

AUG 2018
PROJ 2613
FIG. A-8

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION
		SURFACE ELEVATION: 26.3 FT.
		SOFT to MEDIUM STIFF, mottled brown and orange, sandy SILT to slightly clayey SILT (COLUMBIA RIVER ALLUVIUM)
		… becomes gray at 16 feet
		… becomes dark gray at 35 ft
		… trace organics
-11.7	38	VERY LOOSE to LOOSE, dark gray, silty fine SAND with GRAVEL; subrounded gravel (COLUMBIA RIVER ALLUVIUM)

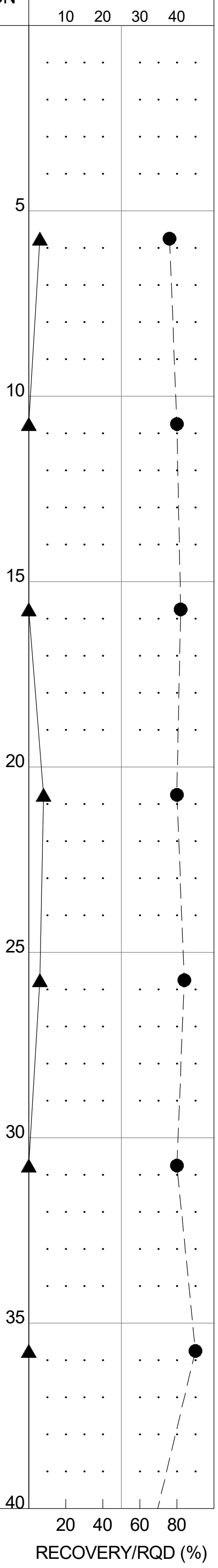
SAMPLE

NO.	PEN. DATA
S-1	1 2 1
S-2	0 0 0
S-3	0 0 0
S-4	1 2 2
S-5	1 1 2
S-6	
S-7	0 0 0
S-8	0 0 0

GROUND WATER/ INSTRUMENT INSTALLATION

PENETRATION TEST (BLOWS PER FOOT)

WATER CONTENT (%)



LEGEND

- ▨ 2-INCH O.D. SPLIT SPOON
- ☒ 3-INCH O.D. SPLIT SPOON
- ▯ 3-INCH O.D. THIN WALL SAMPLER
- ▥ 3-INCH O.D. PITCHER TUBE SAMPLER
- * NO SAMPLE RECOVERY
- ▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED
- ├●┤ LIQUID LIMIT, WATER CONTENT, PLASTIC LIMIT
- ▲ STANDARD PENETRATION TEST (BLOWS/FT.)
- ● WATER CONTENT IN PERCENT
- ▨ CORE RECOVERY IN PERCENT
- ▩ RQD IN PERCENT
-] PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT USING A TREMIE TUBE FROM THE BOTTOM TO THE TOP OF THE HOLE.

HAMMER ASSEMBLY: AUTO TRIP
SPT SAMPLER: NO LINER - RECESSED ID
DRILL ROD USED: NWJ
BOREHOLE DIAM.: 4-7/8" & 3-7/8"

DRILLER: WESTERN STATES
DATE START: 8/10/2015 FINISH: 8/10/2015
DRILLING TECHNIQUE: MUD ROTARY

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SUMMARY BORING LOG
WL-09 (1 of 2)

STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

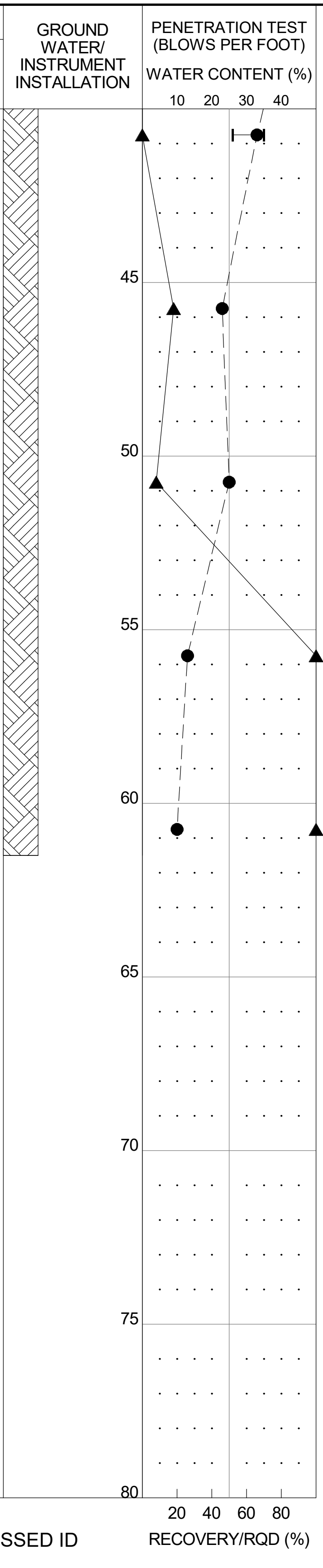
AUG 2018

PROJ 2613

FIG. A-9

SURFACE ELEVATION: 26.3 FT.

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION	SAMPLE NO.	PEN. DATA
		VERY LOOSE to LOOSE, dark gray, silty fine SAND with GRAVEL; subrounded gravel (COLUMBIA RIVER ALLUVIUM) … some micas	S-9	0 0 0
			S-10	11 7 2
			S-11	2 3 1
-26.7	53	DENSE, dark gray, GRAVEL with silty sand (COLUMBIA RIVER ALLUVIUM)	S-12	12 29 21
			S-13	20 29 36
-35.2	61.5	Bottom of Boring: 61.5 FT		



LEGEND

- ▨ 2-INCH O.D. SPLIT SPOON
- ☒ 3-INCH O.D. SPLIT SPOON
- ▯ 3-INCH O.D. THIN WALL SAMPLER
- ▥ 3-INCH O.D. PITCHER TUBE SAMPLER
- * NO SAMPLE RECOVERY
- ▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED
- ├●┤ LIQUID LIMIT, WATER CONTENT, PLASTIC LIMIT
- ▲ STANDARD PENETRATION TEST (BLOWS/FT.)
- ● WATER CONTENT IN PERCENT
- ▨ CORE RECOVERY IN PERCENT
- ■ RQD IN PERCENT
- PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT USING A TREMIE TUBE FROM THE BOTTOM TO THE TOP OF THE HOLE.

HAMMER ASSEMBLY: AUTO TRIP
SPT SAMPLER: NO LINER - RECESSED ID
DRILL ROD USED: NWJ
BOREHOLE DIAM.: 4-7/8" & 3-7/8"

DRILLER: WESTERN STATES
DATE START: 8/10/2015 FINISH: 8/10/2015
DRILLING TECHNIQUE: MUD ROTARY

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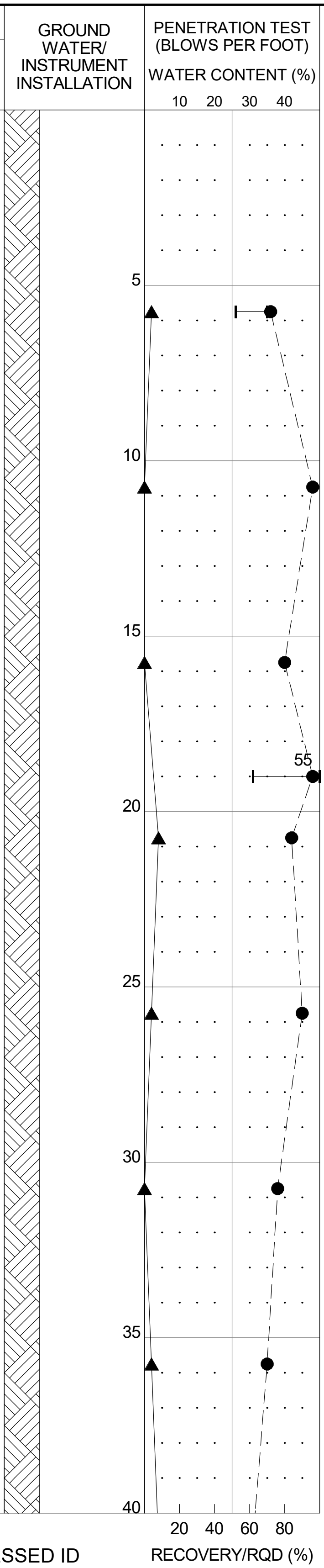
SUMMARY BORING LOG WL-09 (2 of 2)

STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

AUG 2018
PROJ 2613
FIG. A-9

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION	SAMPLE NO.	SAMPLE PEN. DATA
		SURFACE ELEVATION: 20.9 FT.		
		MEDIUM STIFF, brown, SILT to clayey SILT (COLUMBIA RIVER ALLUVIUM)		
		… mottled brown and orange at 5 feet	S-1	0 1 1
		… brown and gray at 10 feet	S-2	0 0 0
		… color change to gray at 13 feet		
			S-3	0 0 0
			S-4	
			S-5	0 2 2
			S-6	0 1 1
-7.1	28	VERY LOOSE, dark gray, silty fine SAND (COLUMBIA RIVER ALLUVIUM)		
			S-7	0 0 0
		… increasing gravel below 35 feet	S-8	4 1 1
-19.1	40			



LEGEND

- ▨ 2-INCH O.D. SPLIT SPOON
- ☒ 3-INCH O.D. SPLIT SPOON
- ▯ 3-INCH O.D. THIN WALL SAMPLER
- ▥ 3-INCH O.D. PITCHER TUBE SAMPLER
- * NO SAMPLE RECOVERY
- ▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED
- ⊢●⊣ LIQUID LIMIT, WATER CONTENT, PLASTIC LIMIT
- ▲ STANDARD PENETRATION TEST (BLOWS/FT.)
- ● WATER CONTENT IN PERCENT
- ▨ CORE RECOVERY IN PERCENT
- ■ RQD IN PERCENT
-] PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT USING A TREMIE TUBE FROM THE BOTTOM TO THE TOP OF THE HOLE.

HAMMER ASSEMBLY: AUTO TRIP
SPT SAMPLER: NO LINER - RECESSED ID
DRILL ROD USED: NWJ
BOREHOLE DIAM.: 4-7/8" & 3-7/8"

DRILLER: WESTERN STATES
DATE START: 8/10/2015 FINISH: 8/11/2015
DRILLING TECHNIQUE: MUD ROTARY

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SUMMARY BORING LOG
WL-10 (1 of 2)

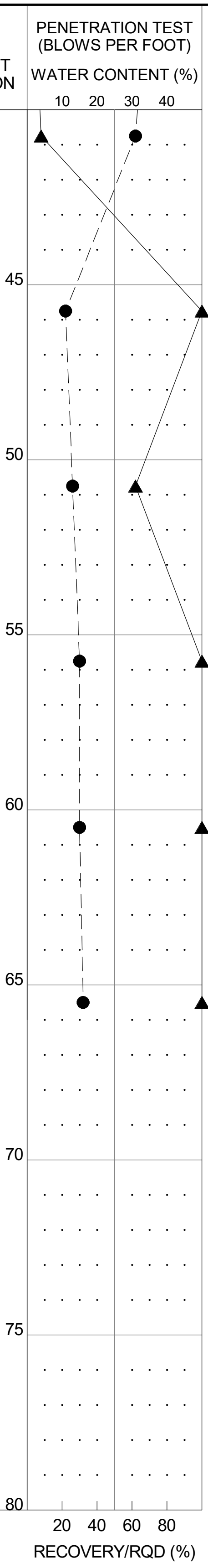
STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

AUG 2018
PROJ 2613
FIG. A-10

SURFACE ELEVATION: 20.9 FT.

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION	SAMPLE NO.	PEN. DATA
		VERY LOOSE, dark gray, silty fine SAND with some gravel (COLUMBIA RIVER ALLUVIUM)	S-9	1 1 3
-21.1	42	MEDIUM DENSE, brown and dark gray GRAVEL with silty sand (COLUMBIA RIVER ALLUVIUM)	S-10	15 32 37
			S-11	23 16 15
-32.1	53	DENSE, gray and brown, GRAVEL and COBBLES in a matrix of silty sand (CATACLYSMIC-FLOOD DEPOSIT) … circulation loss at 53 feet	S-12	18 35 41
			S-13	32 50/6"
			S-14	30 50/6"
-45.1	66	Bottom of Boring: 66 FT		

GROUND WATER/ INSTRUMENT INSTALLATION



LEGEND

- ▨ 2-INCH O.D. SPLIT SPOON
- ☒ 3-INCH O.D. SPLIT SPOON
- ▯ 3-INCH O.D. THIN WALL SAMPLER
- ▥ 3-INCH O.D. PITCHER TUBE SAMPLER
- * NO SAMPLE RECOVERY
- ▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED
- ├●┤ LIQUID LIMIT / WATER CONTENT / PLASTIC LIMIT
- ▲ STANDARD PENETRATION TEST (BLOWS/FT.)
- ● WATER CONTENT IN PERCENT
- ▨ CORE RECOVERY IN PERCENT
- ■ RQD IN PERCENT
-] PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT USING A TREMIE TUBE FROM THE BOTTOM TO THE TOP OF THE HOLE.

HAMMER ASSEMBLY: AUTO TRIP
SPT SAMPLER: NO LINER - RECESSED ID
DRILL ROD USED: NWJ
BOREHOLE DIAM.: 4-7/8" & 3-7/8"

DRILLER: WESTERN STATES
DATE START: 8/10/2015 FINISH: 8/11/2015
DRILLING TECHNIQUE: MUD ROTARY

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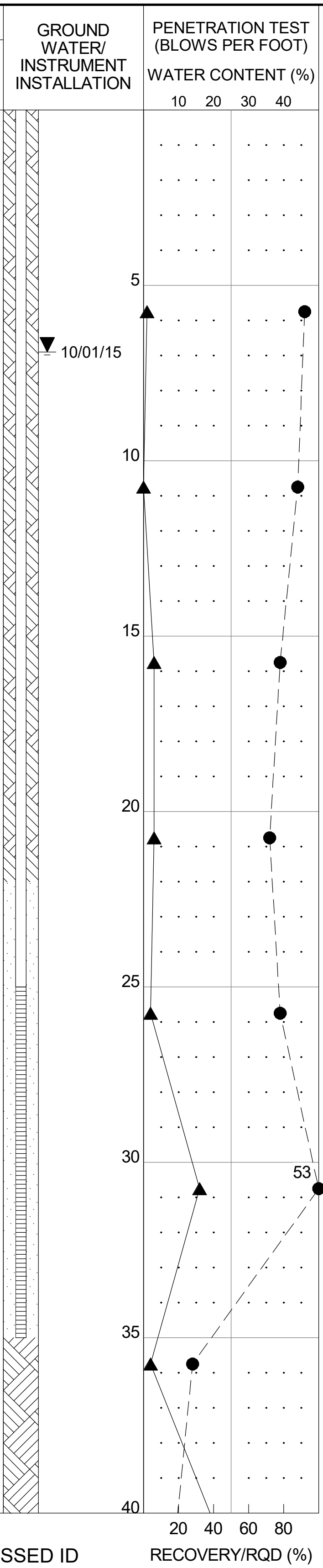
SUMMARY BORING LOG
WL-10 (2 of 2)

STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

AUG 2018
PROJ 2613
FIG. A-10

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION	SAMPLE NO.	SAMPLE PEN. DATA
		SURFACE ELEVATION: 17.7 FT.		
		MEDIUM STIFF, fine-sandy SILT (COLUMBIA RIVER ALLUVIUM)		
			S-1	0 0 1
		… mottled brown and orange above 12 feet	S-2	0 0 0
		… color change to gray at about 12 feet		
		… some micas at 15 feet	S-3	0 2 1
			S-4	
			S-5	1 2 1
-5.3	23	VERY LOOSE to LOOSE, gray, silty fine SAND (COLUMBIA RIVER ALLUVIUM)		
			S-6	0 1 1
		… increasing gravel below 30 feet	S-7	3 12 4
-16.3	34	MEDIUM DENSE, dark gray GRAVEL with silty sand; subrounded gravels (COLUMBIA RIVER ALLUVIUM)	S-8	8 1 1
-22.3	40			



LEGEND

- ▨ 2-INCH O.D. SPLIT SPOON
- ☒ 3-INCH O.D. SPLIT SPOON
- ▯ 3-INCH O.D. THIN WALL SAMPLER
- ▥ 3-INCH O.D. PITCHER TUBE SAMPLER
- * NO SAMPLE RECOVERY
- MM/DD/YY ▼ GROUND WATER LEVEL AND DATE OBSERVED
- LIQUID LIMIT, WATER CONTENT, PLASTIC LIMIT
- ▲ STANDARD PENETRATION TEST (BLOWS/FT.)
- ● WATER CONTENT IN PERCENT
- ▨ CORE RECOVERY IN PERCENT
- ■ RQD IN PERCENT
- PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. STANDPIPE PIEZOMETER INSTALLED AT COMPLETION OF DRILLING, OF 1-INCH DIAMETER SCHEDULE 80, SLOTTED PVC PIPE BACKFILLED WITH 10-12 COLORADO SAND IN FILTER ZONE.
3. ABOVE GROUND MONUMENT AND BOLLARDS INSTALLED.

HAMMER ASSEMBLY: AUTO TRIP

SPT SAMPLER: NO LINER - RECESSED ID

DRILL ROD USED: NWJ

BOREHOLE DIAM.: 4-7/8" & 3-7/8"

DRILLER: WESTERN STATES
DATE START: 8/11/2015 FINISH: 8/12/2015
DRILLING TECHNIQUE: MUD ROTARY

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SUMMARY BORING LOG WL-11 (1 of 2)

STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

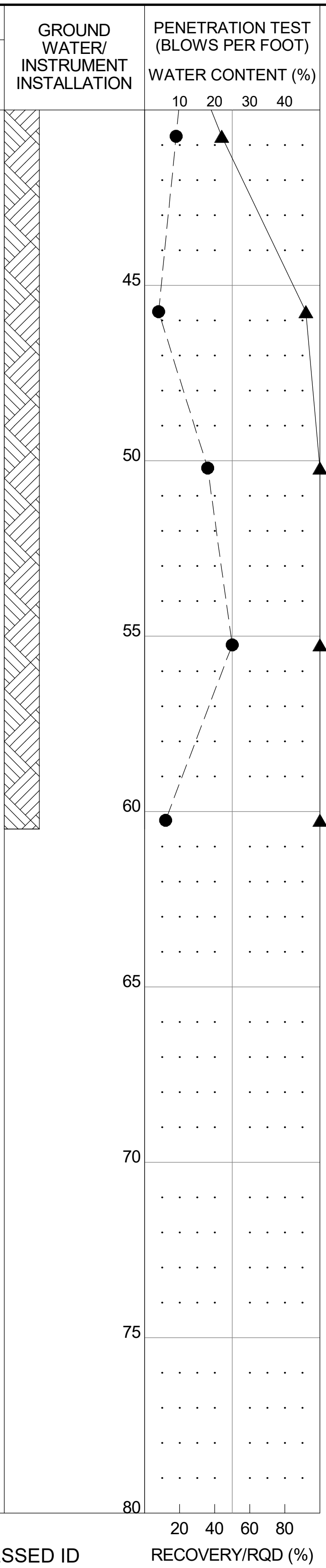
AUG 2018

PROJ 2613

FIG. A-11

SURFACE ELEVATION: 17.7 FT.

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION	SAMPLE NO.	PEN. DATA
		(continued from previous page)	S-9	8 9 13
			S-10	13 17 29
-29.3	47	DENSE, dark gray GRAVEL and COBBLES in a matrix of silty sand; (CATACLYSMIC-FLOOD DEPOSIT)	S-11	50/5"
		… brown-gray sandy matrix at 55 feet	S-12	50/6"
-42.8	60.5	… gray-green sandy matrix at 60 feet	S-13	50/6"
		Bottom of Boring: 60.5 FT		



LEGEND

- ▨ 2-INCH O.D. SPLIT SPOON
- ☒ 3-INCH O.D. SPLIT SPOON
- ▯ 3-INCH O.D. THIN WALL SAMPLER
- ▥ 3-INCH O.D. PITCHER TUBE SAMPLER
- * NO SAMPLE RECOVERY
- ▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED
- ├─●─┤ LIQUID LIMIT, WATER CONTENT, PLASTIC LIMIT
- ▲ STANDARD PENETRATION TEST (BLOWS/FT.)
- ● WATER CONTENT IN PERCENT
- ▨ CORE RECOVERY IN PERCENT
- ■ RQD IN PERCENT
-] PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. STANDPIPE PIEZOMETER INSTALLED AT COMPLETION OF DRILLING, OF 1-INCH DIAMETER SCHEDULE 80, SLOTTED PVC PIPE BACKFILLED WITH 10-12 COLORADO SAND IN FILTER ZONE.
3. ABOVE GROUND MONUMENT AND BOLLARDS INSTALLED.

HAMMER ASSEMBLY: AUTO TRIP
SPT SAMPLER: NO LINER - RECESSED ID
DRILL ROD USED: NWJ
BOREHOLE DIAM.: 4-7/8" & 3-7/8"

DRILLER: WESTERN STATES
DATE START: 8/11/2015 FINISH: 8/12/2015
DRILLING TECHNIQUE: MUD ROTARY

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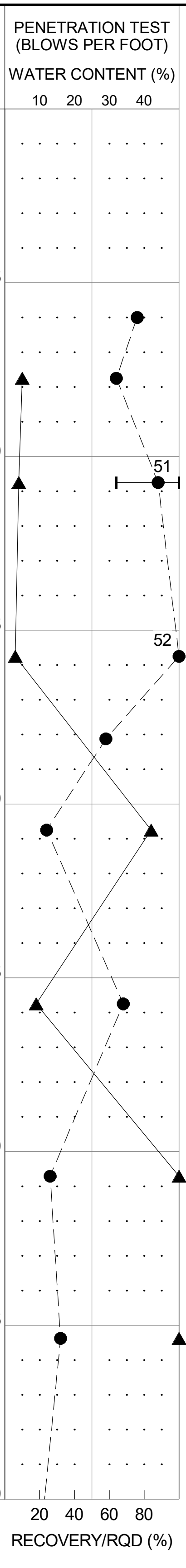
SUMMARY BORING LOG
WL-11 (2 of 2)

STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

AUG 2018
PROJ 2613
FIG. A-11

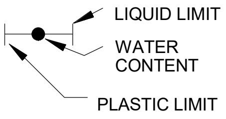
ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION SURFACE ELEVATION: 15.5 FT.	SAMPLE NO.	PEN. DATA
		Interlayered: VERY LOOSE to LOOSE, brown, silty fine SAND and SOFT, brown, fine-sandy SILT; occasional organics, some mica (COLUMBIA RIVER ALLUVIUM)		
			S-1 *	
		…some rounded fine to coarse gravel from 7 to 8 feet	S-2	0 1 4
			S-3	0 2 2
			S-4	0 1 2
-1.5	17	MEDIUM DENSE, gray, silty gravelly fine SAND to sandy GRAVEL; fine to coarse subrounded gravel (COLUMBIA RIVER ALLUVIUM)		
			S-5 *	
			S-6	20 34 8
			S-7	20 4 5
-13.5	29	DENSE, dark gray GRAVEL in a matrix of silty sand; fine to coarse subrounded gravel (CATACLYSMIC-FLOOD DEPOSIT)	S-8	2 3 50/5"
			S-9	45 50/3"
-24.5	40			

GROUND WATER/ INSTRUMENT INSTALLATION



LEGEND

- ▨ 2-INCH O.D. SPLIT SPOON
- ☒ 3-INCH O.D. SPLIT SPOON
- ▯ 3-INCH O.D. THIN WALL SAMPLER
- ▥ 3-INCH O.D. PITCHER TUBE SAMPLER
- * NO SAMPLE RECOVERY
- ▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED



- ▲ STANDARD PENETRATION TEST (BLOWS/FT.)
- ● WATER CONTENT IN PERCENT
- ▨ CORE RECOVERY IN PERCENT
- ■ RQD IN PERCENT
-] PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT USING A TREMIE TUBE FROM THE BOTTOM TO THE TOP OF THE HOLE.
3. SHELBY SAMPLE S-1 AND S-5 WERE COLLECTED IN SAMPLE JARS.

HAMMER ASSEMBLY: AUTO TRIP
SPT SAMPLER: NO LINER - RECESSED ID
DRILL ROD USED: NWJ
BOREHOLE DIAM.: 8-1/4" (0'-15'), 3-7/8" (15'-50')

DRILLER: WESTERN STATES
DATE START: 8/12/2015 FINISH: 8/13/2015
DRILLING TECHNIQUE: HOLLOW STEM AUGER/MUD ROTARY

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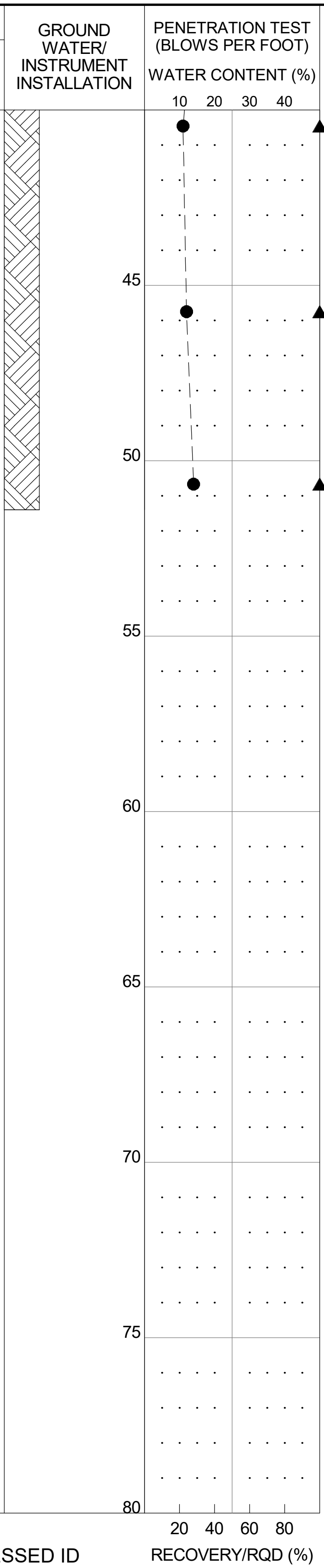
SUMMARY BORING LOG WL-12 (1 of 2)

STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

AUG 2018
PROJ 2613
FIG. A-12

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION SURFACE ELEVATION: 15.5 FT.	SAMPLE NO.	SAMPLE PEN. DATA
		(continued from previous page)	S-10	28 50/5"
			S-11	47 48 43
			S-12	30 37 50/4"
-35.9	51.4	Bottom of Boring: 51.4 FT		



LEGEND

- ▨ 2-INCH O.D. SPLIT SPOON
- ☒ 3-INCH O.D. SPLIT SPOON
- ▯ 3-INCH O.D. THIN WALL SAMPLER
- ▥ 3-INCH O.D. PITCHER TUBE SAMPLER
- * NO SAMPLE RECOVERY
- ▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED
- ├●┤ LIQUID LIMIT, WATER CONTENT, PLASTIC LIMIT
- ▲ STANDARD PENETRATION TEST (BLOWS/FT.)
- ● WATER CONTENT IN PERCENT
- ▨ CORE RECOVERY IN PERCENT
- ■ RQD IN PERCENT
-] PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT USING A TREMIE TUBE FROM THE BOTTOM TO THE TOP OF THE HOLE.
3. SHELBY SAMPLE S-1 AND S-5 WERE COLLECTED IN SAMPLE JARS.

HAMMER ASSEMBLY: AUTO TRIP

SPT SAMPLER: NO LINER - RECESSED ID

DRILL ROD USED: NWJ

BOREHOLE DIAM.: 8-1/4" (0'-15'), 3-7/8" (15'-50')

DRILLER: WESTERN STATES
DATE START: 8/12/2015 FINISH: 8/13/2015
DRILLING TECHNIQUE: HOLLOW STEM AUGER/MUD ROTARY

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SUMMARY BORING LOG
WL-12 (2 of 2)

STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

AUG 2018

PROJ 2613

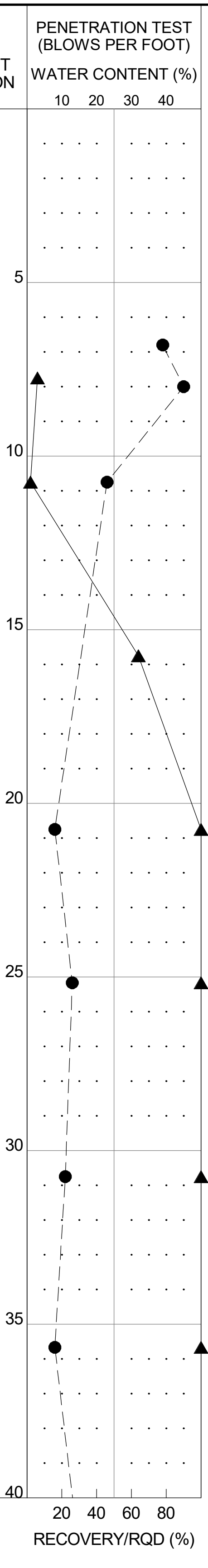
FIG. A-12

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION
		SURFACE ELEVATION: 15.5 FT.
		Interlayered: VERY LOOSE to LOOSE, gray, silty fine SAND and SOFT, gray, fine-sandy SILT; occasional organics, some mica (COLUMBIA RIVER ALLUVIUM)
4.5	11	Interlayered: LOOSE to MEDIUM DENSE, brown and gray, sandy GRAVEL and SOFT to MEDIUM STIFF, gray, slightly clayey, fine-sandy SILT; occasional organics, some mica (COLUMBIA RIVER ALLUVIUM)
-1.5	17	DENSE, dark gray GRAVEL in a matrix of silty sand; fine to coarse subrounded gravel (CATACLYSMIC-FLOOD DEPOSIT)

SAMPLE

NO.	PEN. DATA
S-1	
S-2	0 1 2
S-3	0 0 1
S-4 *	4 16 16
S-5	36 31 30
S-6	50/4"
S-7	26 29 29
S-8	21 32 50/4"

GROUND WATER/ INSTRUMENT INSTALLATION



LEGEND

- ▨ 2-INCH O.D. SPLIT SPOON
- ☒ 3-INCH O.D. SPLIT SPOON
- ▯ 3-INCH O.D. THIN WALL SAMPLER
- ▥ 3-INCH O.D. PITCHER TUBE SAMPLER
- * NO SAMPLE RECOVERY
- ▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED
- LIQUID LIMIT / WATER CONTENT / PLASTIC LIMIT
- ▲ STANDARD PENETRATION TEST (BLOWS/FT.)
- ● WATER CONTENT IN PERCENT
- ▨ CORE RECOVERY IN PERCENT
- ■ RQD IN PERCENT
- PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT USING A TREMIE TUBE FROM THE BOTTOM TO THE TOP OF THE HOLE.

HAMMER ASSEMBLY: AUTO TRIP
SPT SAMPLER: NO LINER - RECESSED ID
DRILL ROD USED: NWJ
BOREHOLE DIAM.: 3-7/8"

DRILLER: WESTERN STATES
DATE START: 8/13/2015 FINISH: 8/14/2015
DRILLING TECHNIQUE: MUD ROTARY

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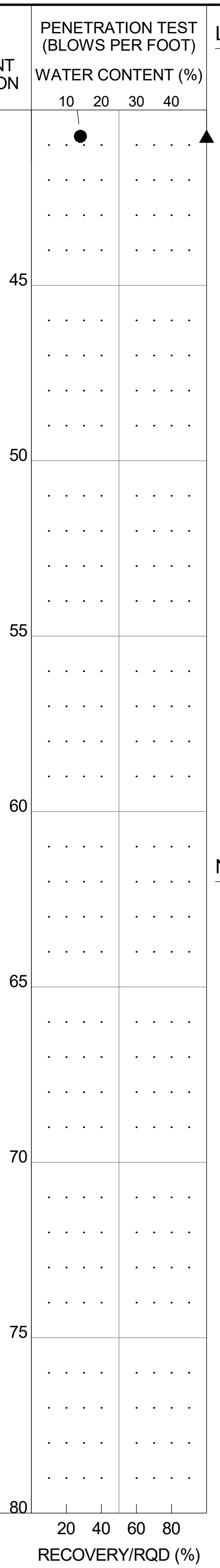
SUMMARY BORING LOG
WL-13 (1 of 2)

STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

AUG 2018
PROJ 2613
FIG. A-13

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION SURFACE ELEVATION: 15.5 FT.	SAMPLE NO.	SAMPLE	SAMPLE PEN. DATA	GROUND WATER/ INSTRUMENT INSTALLATION
			S-9	▨	33 31 49	☒
-26.0	41.5	Bottom of Boring: 41.5 FT				



LEGEND

▨ 2-INCH O.D. SPLIT SPOON

☒ 3-INCH O.D. SPLIT SPOON

▯ 3-INCH O.D. THIN WALL SAMPLER

▥ 3-INCH O.D. PITCHER TUBE SAMPLER

* NO SAMPLE RECOVERY

▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED

LIQUID LIMIT

WATER CONTENT

PLASTIC LIMIT

▲ STANDARD PENETRATION TEST (BLOWS/FT.)

● WATER CONTENT IN PERCENT

▨ CORE RECOVERY IN PERCENT

■ RQD IN PERCENT

PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT USING A TREMIE TUBE FROM THE BOTTOM TO THE TOP OF THE HOLE.

HAMMER ASSEMBLY: AUTO TRIP

SPT SAMPLER: NO LINER - RECESSED ID

DRILL ROD USED: NWJ

BOREHOLE DIAM.: 3-7/8"

DRILLER: WESTERN STATES

DATE START: 8/13/2015 FINISH: 8/14/2015

DRILLING TECHNIQUE: MUD ROTARY

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SUMMARY BORING LOG
WL-13 (2 of 2)

STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

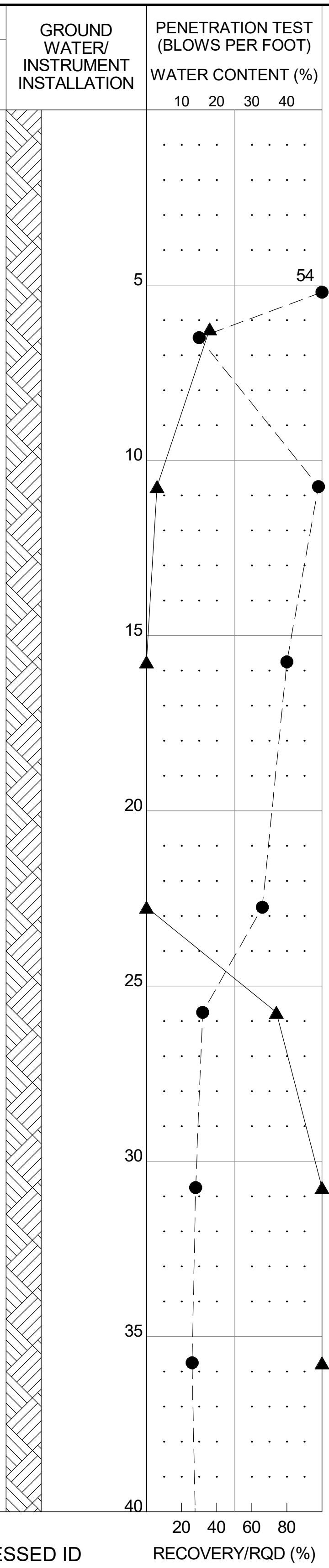
AUG 2018

PROJ 2613

FIG. A-13

SURFACE ELEVATION: 15.8 FT.

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION	SAMPLE NO.	PEN. DATA
		LOOSE to MEDIUM DENSE, gray, silty fine SAND to gravelly SAND; fine to coarse subrounded gravel, occasional organics, some mica (COLUMBIA RIVER ALLUVIUM)		
			S-1	
			S-2	8 11 7
6.8	9	Interlayered: VERY LOOSE to LOOSE, gray, gravelly SAND and SOFT, gray, slightly clayey, fine-sandy SILT; fine to coarse subrounded gravel, occasional organics, some mica (COLUMBIA RIVER ALLUVIUM)		
			S-3	1 2 1
			S-4	0 0 0
			S-5 *	
			S-6	0 0 0
-9.2	25	DENSE, dark gray GRAVEL in a matrix of silty sand; fine to coarse subrounded gravel (CATACLYSMIC-FLOOD DEPOSIT)		
			S-7	1 9 28
			S-8	31 23 30
			S-9	31 37 33
-24.2	40			



LEGEND

- ▨ 2-INCH O.D. SPLIT SPOON
- ☒ 3-INCH O.D. SPLIT SPOON
- ▯ 3-INCH O.D. THIN WALL SAMPLER
- ▯ 3-INCH O.D. PITCHER TUBE SAMPLER
- * NO SAMPLE RECOVERY
- ▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED
- LIQUID LIMIT, WATER CONTENT, PLASTIC LIMIT
- ▲ STANDARD PENETRATION TEST (BLOWS/FT.)
- ● WATER CONTENT IN PERCENT
- ▨ CORE RECOVERY IN PERCENT
- ■ RQD IN PERCENT
-] PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT USING A TREMIE TUBE FROM THE BOTTOM TO THE TOP OF THE HOLE.
3. SHELBY SAMPLE S-1 WAS COLLECTED IN A SAMPLE JAR.

HAMMER ASSEMBLY: AUTO TRIP
SPT SAMPLER: NO LINER - RECESSED ID
DRILL ROD USED: NWJ
BOREHOLE DIAM.: 3-7/8"

DRILLER: WESTERN STATES
DATE START: 8/14/2015 FINISH: 8/17/2015
DRILLING TECHNIQUE: MUD ROTARY

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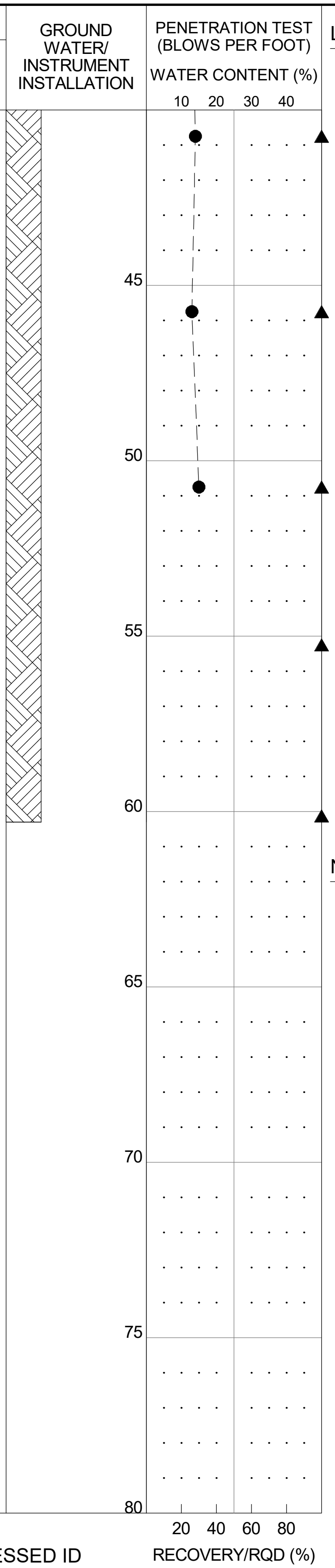
SUMMARY BORING LOG
WL-14 (1 of 2)

STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

AUG 2018
PROJ 2613
FIG. A-14

SURFACE ELEVATION: 15.8 FT.

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION	SAMPLE NO.	PEN. DATA
		(continued from previous page)	S-10	23 32 42
			S-11	25 27 31
			S-12	21 27 26
			S-13 *	50/6"
-44.5	60.3	Bottom of Boring: 60.3 FT	S-14 *	50/3"



LEGEND

- ▨ 2-INCH O.D. SPLIT SPOON
- ☒ 3-INCH O.D. SPLIT SPOON
- ▯ 3-INCH O.D. THIN WALL SAMPLER
- ▥ 3-INCH O.D. PITCHER TUBE SAMPLER
- * NO SAMPLE RECOVERY
- ▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED
- ├●┤ LIQUID LIMIT, WATER CONTENT, PLASTIC LIMIT
- ▲ STANDARD PENETRATION TEST (BLOWS/FT.)
- ● WATER CONTENT IN PERCENT
- ▨ CORE RECOVERY IN PERCENT
- ■ RQD IN PERCENT
-] PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT USING A TREMIE TUBE FROM THE BOTTOM TO THE TOP OF THE HOLE.
3. SHELBY SAMPLE S-1 WAS COLLECTED IN A SAMPLE JAR.

HAMMER ASSEMBLY: AUTO TRIP
SPT SAMPLER: NO LINER - RECESSED ID
DRILL ROD USED: NWJ
BOREHOLE DIAM.: 3-7/8"

DRILLER: WESTERN STATES
DATE START: 8/14/2015 FINISH: 8/17/2015
DRILLING TECHNIQUE: MUD ROTARY

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Phone 503-452-1100 Fax 503-452-1528

SUMMARY BORING LOG
WL-14 (2 of 2)

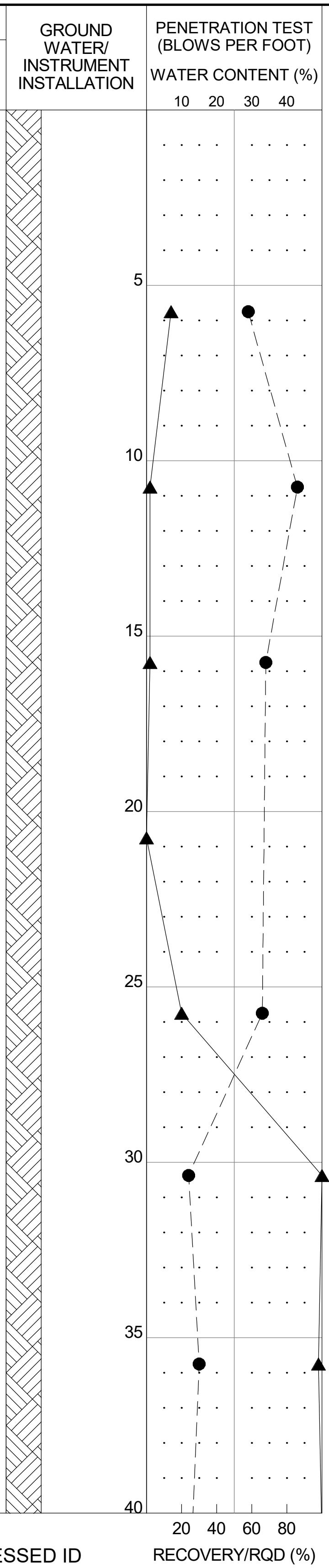
STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

AUG 2018

PROJ 2613

FIG. A-14

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION SURFACE ELEVATION: 16.5 FT.	SAMPLE NO.	PEN. DATA
		LOOSE to MEDIUM DENSE, gray, silty fine SAND to gravelly SAND; fine subrounded gravel, occasional organics, some mica (COLUMBIA RIVER ALLUVIUM)	S-1	9 6 1
9.5	7	Interlayered: VERY LOOSE to LOOSE, gray, gravelly SAND and SOFT, gray, slightly clayey, fine-sandy SILT; fine to coarse subrounded gravel, occasional organics, some mica (COLUMBIA RIVER ALLUVIUM)	S-2	1 0 1
			S-3	3 0 1
			S-4 *	0 0 0
			S-5	0 0 10
-11.5	28	DENSE, dark gray GRAVEL in a matrix of silty sand; fine to coarse subrounded gravel (CATACLYSMIC-FLOOD DEPOSIT)	S-6	38 50/3"
			S-7	40 24 25
-23.5	40			



LEGEND

- ▨ 2-INCH O.D. SPLIT SPOON
- ☒ 3-INCH O.D. SPLIT SPOON
- ▯ 3-INCH O.D. THIN WALL SAMPLER
- ▥ 3-INCH O.D. PITCHER TUBE SAMPLER
- * NO SAMPLE RECOVERY
- ▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED
- ├─●─┤ LIQUID LIMIT, WATER CONTENT, PLASTIC LIMIT
- ▲ STANDARD PENETRATION TEST (BLOWS/FT.)
- ● WATER CONTENT IN PERCENT
- ▨ CORE RECOVERY IN PERCENT
- ■ RQD IN PERCENT
-] PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT USING A TREMIE TUBE FROM THE BOTTOM TO THE TOP OF THE HOLE.

HAMMER ASSEMBLY: AUTO TRIP
SPT SAMPLER: NO LINER - RECESSED ID
DRILL ROD USED: NWJ
BOREHOLE DIAM.: 3-7/8"

DRILLER: WESTERN STATES
DATE START: 8/17/2015 FINISH: 8/17/2015
DRILLING TECHNIQUE: MUD ROTARY

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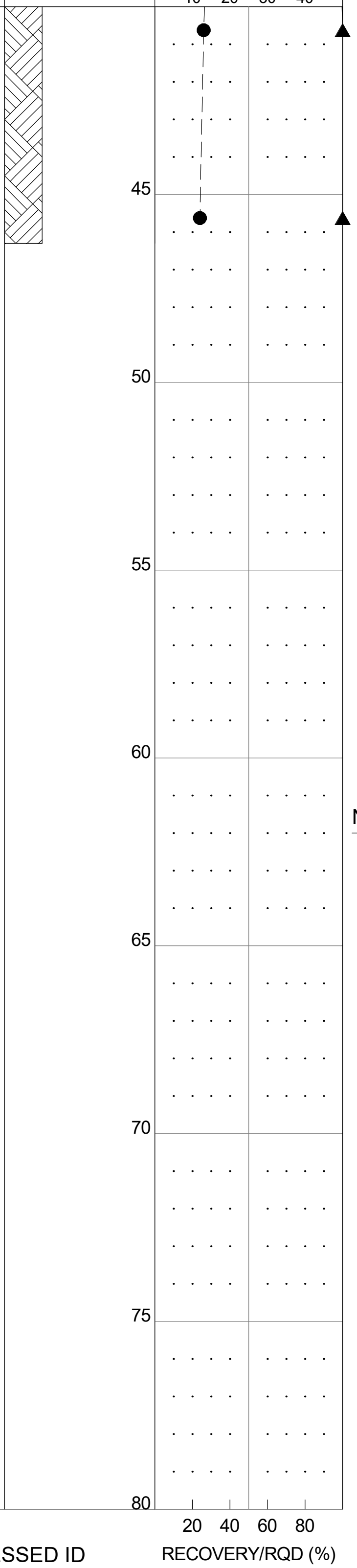
SUMMARY BORING LOG WL-15 (1 of 2)

STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

AUG 2018
PROJ 2613
FIG. A-15

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION SURFACE ELEVATION: 16.5 FT.	SAMPLE NO.	SAMPLE PEN. DATA	GROUND WATER/ INSTRUMENT INSTALLATION	PENETRATION TEST (BLOWS PER FOOT) WATER CONTENT (%)
		(continued from previous page)	S-8	27 40 50/3"		
			S-9	28 30 50/3"		
-29.8	46.3	Bottom of Boring: 46.3 FT				



LEGEND

- ▨ 2-INCH O.D. SPLIT SPOON
- ☒ 3-INCH O.D. SPLIT SPOON
- ▯ 3-INCH O.D. THIN WALL SAMPLER
- ▥ 3-INCH O.D. PITCHER TUBE SAMPLER
- * NO SAMPLE RECOVERY
- ▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED
- LIQUID LIMIT, WATER CONTENT, PLASTIC LIMIT
- ▲ STANDARD PENETRATION TEST (BLOWS/FT.)
- ● WATER CONTENT IN PERCENT
- ▨ CORE RECOVERY IN PERCENT
- ■ RQD IN PERCENT
-] PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT USING A TREMIE TUBE FROM THE BOTTOM TO THE TOP OF THE HOLE.

HAMMER ASSEMBLY: AUTO TRIP
SPT SAMPLER: NO LINER - RECESSED ID
DRILL ROD USED: NWJ
BOREHOLE DIAM.: 3-7/8"

DRILLER: WESTERN STATES
DATE START: 8/17/2015 FINISH: 8/17/2015
DRILLING TECHNIQUE: MUD ROTARY

CORNFORTH CONSULTANTS
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Phone 503-452-1100 Fax 503-452-1528

SUMMARY BORING LOG
WL-15 (2 of 2)

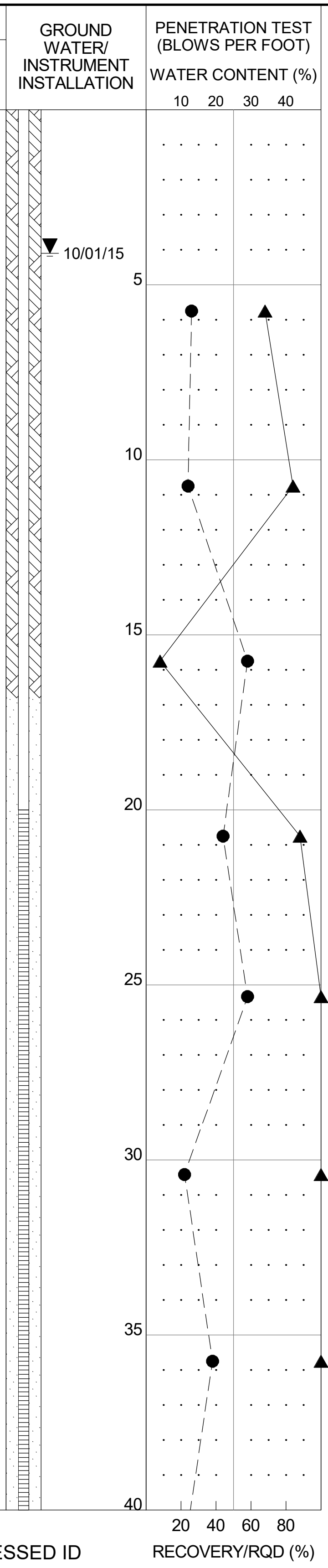
STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

AUG 2018

PROJ 2613

FIG. A-15

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION	SAMPLE NO.	SAMPLE PEN. DATA
		SURFACE ELEVATION: 18.7 FT.		
		MEDIUM DENSE, brown, silty SAND and dark gray GRAVEL and ROCK FRAGMENTS; rounded and angular particles, some quartz gravel (GIBBONS CREEK ALLUVIAL FAN DEPOSIT)		
			S-1	10 17 17
			S-2	17 18 24
6.7	12	LOOSE, brown, sandy SILT; some mica (COLUMBIA RIVER ALLUVIUM)		
			S-3	2 2 2
-0.3	19	DENSE, dark gray GRAVEL and COBBLES in a matrix of silty, fine sand; rounded gravel, some mica (CATACLYSMIC-FLOOD DEPOSIT)		
			S-4	11 19 25
			S-5	8 50/2"
			S-6	27 50/4"
			S-7	25 29 33
-21.3	40			



LEGEND

- ▨ 2-INCH O.D. SPLIT SPOON
- ☒ 3-INCH O.D. SPLIT SPOON
- ▯ 3-INCH O.D. THIN WALL SAMPLER
- ▥ 3-INCH O.D. PITCHER TUBE SAMPLER
- * NO SAMPLE RECOVERY
- ▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED
- ├●┤ LIQUID LIMIT, WATER CONTENT, PLASTIC LIMIT
- ▲ STANDARD PENETRATION TEST (BLOWS/FT.)
- ● WATER CONTENT IN PERCENT
- ▨ CORE RECOVERY IN PERCENT
- ■ RQD IN PERCENT
-] PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. STANDPIPE PIEZOMETER INSTALLED AT COMPLETION OF DRILLING, OF 1-INCH DIAMETER SCHEDULE 80, SLOTTED PVC PIPE BACKFILLED WITH 10-12 COLORADO SAND IN FILTER ZONE.
3. ABOVE GROUND MONUMENT AND BOLLARDS INSTALLED.

HAMMER ASSEMBLY: AUTO TRIP
SPT SAMPLER: NO LINER - RECESSED ID
DRILL ROD USED: NWJ
BOREHOLE DIAM.: 3-7/8"

DRILLER: WESTERN STATES
DATE START: 8/18/2015 FINISH: 8/19/2015
DRILLING TECHNIQUE: MUD ROTARY

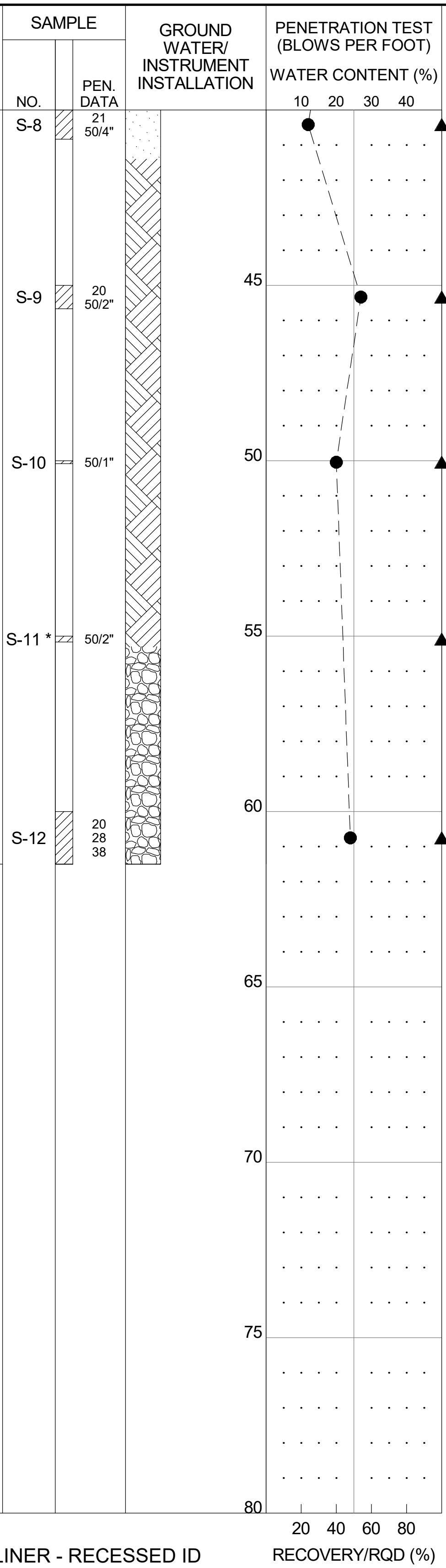
CORNFORTH CONSULTANTS
10250 S.W. Greenburg Road, Suite 111
Portland, Oregon 97223
Phone 503-452-1100 Fax 503-452-1528

SUMMARY BORING LOG WL-16 (1 of 2)

STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

AUG 2018
PROJ 2613
FIG. A-16

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION SURFACE ELEVATION: 18.7 FT.	SAMPLE NO.	PEN. DATA
		(continued from previous page)	S-8	21 50/4"
			S-9	20 50/2"
			S-10	50/1"
			S-11 *	50/2"
			S-12	20 28 38
-42.8	61.5	Bottom of Boring: 61.5 FT		



LEGEND

- ▨ 2-INCH O.D. SPLIT SPOON
- ☒ 3-INCH O.D. SPLIT SPOON
- ▯ 3-INCH O.D. THIN WALL SAMPLER
- ▥ 3-INCH O.D. PITCHER TUBE SAMPLER
- * NO SAMPLE RECOVERY
- ▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED
- ├●┤ LIQUID LIMIT, WATER CONTENT, PLASTIC LIMIT
- ▲ STANDARD PENETRATION TEST (BLOWS/FT.)
- ● WATER CONTENT IN PERCENT
- ▨ CORE RECOVERY IN PERCENT
- ■ RQD IN PERCENT
-] PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. STANDPIPE PIEZOMETER INSTALLED AT COMPLETION OF DRILLING, OF 1-INCH DIAMETER SCHEDULE 80, SLOTTED PVC PIPE BACKFILLED WITH 10-12 COLORADO SAND IN FILTER ZONE.
3. ABOVE GROUND MONUMENT AND BOLLARDS INSTALLED.

HAMMER ASSEMBLY: AUTO TRIP
SPT SAMPLER: NO LINER - RECESSED ID
DRILL ROD USED: NWJ
BOREHOLE DIAM.: 3-7/8"

DRILLER: WESTERN STATES
DATE START: 8/18/2015 FINISH: 8/19/2015
DRILLING TECHNIQUE: MUD ROTARY

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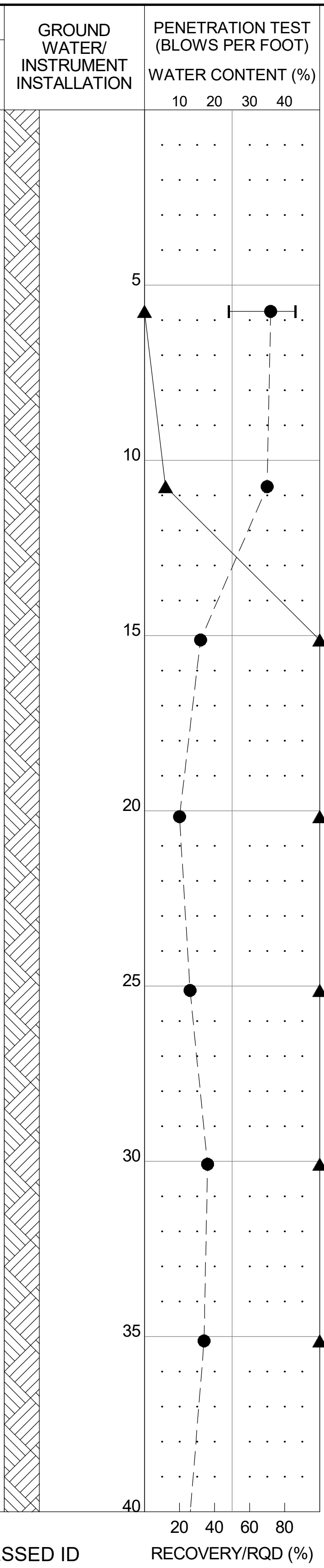
SUMMARY BORING LOG WL-16 (2 of 2)

STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

AUG 2018
PROJ 2613
FIG. A-16

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION	SAMPLE NO.	SAMPLE PEN. DATA
		SURFACE ELEVATION: 25.4 FT.		
		Interlayered: VERY SOFT, brown, clayey SILT to silty CLAY; scattered organics and LOOSE, brown, silty fine SAND; micas, trace gravel (GIBBONS CREEK ALLUVIAL FAN DEPOSIT)		
			S-1	0 0 0
			S-2	1 1 5
13.4	12	DENSE, dark gray GRAVEL and COBBLES in a matrix of silty sand; subrounded and angular particles (CATACLYSMIC-FLOOD DEPOSIT)		
			S-3	50/5"
		… some light-colored gravel	S-4	50/4"
		… color of sand matrix changes from brown to dark green-gray		
			S-5	50/3"
		… some micas	S-6	50/2"
			S-7	50/3"
-14.6	40			



LEGEND

- ▨ 2-INCH O.D. SPLIT SPOON
- ☒ 3-INCH O.D. SPLIT SPOON
- ▯ 3-INCH O.D. THIN WALL SAMPLER
- ▥ 3-INCH O.D. PITCHER TUBE SAMPLER
- * NO SAMPLE RECOVERY
- ▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED
- ├●┤ LIQUID LIMIT, WATER CONTENT, PLASTIC LIMIT
- ▲ STANDARD PENETRATION TEST (BLOWS/FT.)
- ● WATER CONTENT IN PERCENT
- ▨ CORE RECOVERY IN PERCENT
- ■ RQD IN PERCENT
-] PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT USING A TREMIE TUBE FROM THE BOTTOM TO THE TOP OF THE HOLE.

HAMMER ASSEMBLY: AUTO TRIP
SPT SAMPLER: NO LINER - RECESSED ID
DRILL ROD USED: NWJ
BOREHOLE DIAM.: 4-7/8"

DRILLER: WESTERN STATES
DATE START: 8/14/2015 FINISH: 8/14/2015
DRILLING TECHNIQUE: MUD ROTARY

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Phone 503-452-1100 Fax 503-452-1528

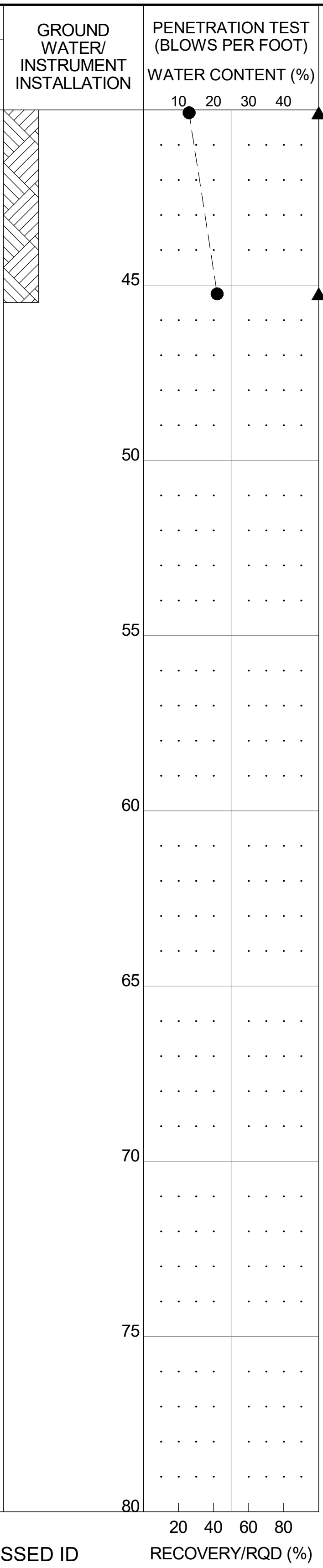
SUMMARY BORING LOG
WL-17 (1 of 2)

STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

AUG 2018
PROJ 2613
FIG. A-17

SURFACE ELEVATION: 25.4 FT.

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION	SAMPLE NO.	SAMPLE PEN. DATA
		DENSE, dark gray GRAVEL and COBBLES in a matrix of gray, silty sand; some quartz sand, subrounded particles (CATACLYSMIC-FLOOD DEPOSIT)	S-8	50/2"
-20.1	45.5	Bottom of Boring: 45.5 FT	S-9	50/6"



LEGEND

- ▨ 2-INCH O.D. SPLIT SPOON
- ☒ 3-INCH O.D. SPLIT SPOON
- ▯ 3-INCH O.D. THIN WALL SAMPLER
- ▥ 3-INCH O.D. PITCHER TUBE SAMPLER
- * NO SAMPLE RECOVERY
- ▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED
- LIQUID LIMIT, WATER CONTENT, PLASTIC LIMIT
- ▲ STANDARD PENETRATION TEST (BLOWS/FT.)
- ● WATER CONTENT IN PERCENT
- ▨ CORE RECOVERY IN PERCENT
- ■ RQD IN PERCENT
-] PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT USING A TREMIE TUBE FROM THE BOTTOM TO THE TOP OF THE HOLE.

HAMMER ASSEMBLY: AUTO TRIP
SPT SAMPLER: NO LINER - RECESSED ID
DRILL ROD USED: NWJ
BOREHOLE DIAM.: 4-7/8"

DRILLER: WESTERN STATES
DATE START: 8/14/2015 FINISH: 8/14/2015
DRILLING TECHNIQUE: MUD ROTARY

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SUMMARY BORING LOG
WL-17 (2 of 2)

STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

AUG 2018

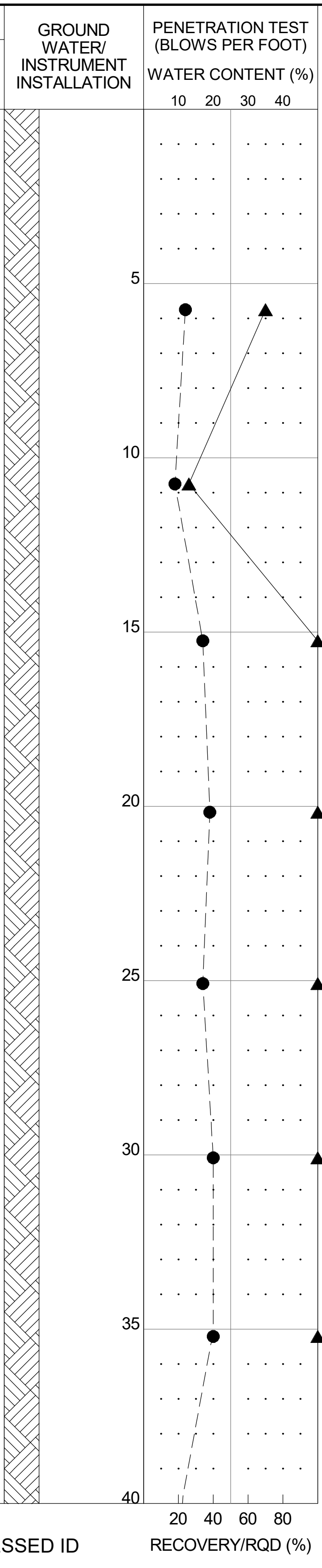
PROJ 2613

FIG. A-17

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION SURFACE ELEVATION: 24.3 FT.
		MEDIUM DENSE, dark gray ROCK FRAGMENTS and GRAVEL in a matrix of brown, silty sand; angular and subangular particles, ground surface had been graded in the past (GIBBONS CREEK ALLUVIAL FAN DEPOSIT)
11.3	13	DENSE, dark gray GRAVEL and COBBLES in a matrix of silty sand; subrounded and subangular particles (CATACLYSMIC-FLOOD DEPOSIT) … color of sand matrix changes from brown to dark green-gray
-15.7	40	

SAMPLE

NO.	PEN. DATA
S-1	12 16 19
S-2	15 9 4
S-3	50/6"
S-4	50/4"
S-5	50/2"
S-6	50/2"
S-7	50/5"



LEGEND

- ▨ 2-INCH O.D. SPLIT SPOON
- ☒ 3-INCH O.D. SPLIT SPOON
- ▯ 3-INCH O.D. THIN WALL SAMPLER
- ▥ 3-INCH O.D. PITCHER TUBE SAMPLER
- * NO SAMPLE RECOVERY
- ▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED
- LIQUID LIMIT, WATER CONTENT, PLASTIC LIMIT
- ▲ STANDARD PENETRATION TEST (BLOWS/FT.)
- ● WATER CONTENT IN PERCENT
- ▨ CORE RECOVERY IN PERCENT
- ■ RQD IN PERCENT
- PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT USING A TREMIE TUBE FROM THE BOTTOM TO THE TOP OF THE HOLE.

HAMMER ASSEMBLY: AUTO TRIP
SPT SAMPLER: NO LINER - RECESSED ID
DRILL ROD USED: NWJ
BOREHOLE DIAM.: 4-7/8"

DRILLER: WESTERN STATES
DATE START: 8/13/2015 FINISH: 8/14/2015
DRILLING TECHNIQUE: MUD ROTARY

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SUMMARY BORING LOG WL-18 (1 of 2)

STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

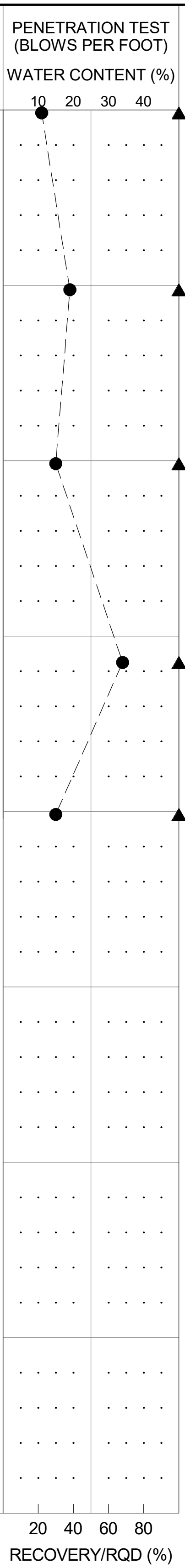
AUG 2018

PROJ 2613

FIG. A-18

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION SURFACE ELEVATION: 24.3 FT.	SAMPLE NO.	SAMPLE PEN. DATA
		DENSE, dark gray GRAVEL and COBBLES in a matrix of dark green-gray, silty sand; subrounded and subangular particles (CATACLYSMIC-FLOOD DEPOSIT)	S-8	50/2"
			S-9	50/3"
			S-10	50/2"
-27.7	52	Interlayered: VERY DENSE, gray, fine SAND; micas and STIFF, gray, fine-sandy SILT (CATACLYSMIC-FLOOD DEPOSIT)	S-11	23 28 32
-32.7	57	DENSE, dark gray GRAVEL and COBBLES in a matrix of dark green-gray, fine sand; micas (CATACLYSMIC-FLOOD DEPOSIT)		
-35.9	60.2	Bottom of Boring: 60.2 FT	S-12	50/2"

GROUND WATER/ INSTRUMENT INSTALLATION



LEGEND

- ▨ 2-INCH O.D. SPLIT SPOON
- ☒ 3-INCH O.D. SPLIT SPOON
- ▯ 3-INCH O.D. THIN WALL SAMPLER
- ▥ 3-INCH O.D. PITCHER TUBE SAMPLER
- * NO SAMPLE RECOVERY
- ▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED
- ● LIQUID LIMIT, WATER CONTENT, PLASTIC LIMIT
- ▲ STANDARD PENETRATION TEST (BLOWS/FT.)
- ● WATER CONTENT IN PERCENT
- ▨ CORE RECOVERY IN PERCENT
- ■ RQD IN PERCENT
- PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT USING A TREMIE TUBE FROM THE BOTTOM TO THE TOP OF THE HOLE.

HAMMER ASSEMBLY: AUTO TRIP

SPT SAMPLER: NO LINER - RECESSED ID

DRILL ROD USED: NWJ

BOREHOLE DIAM.: 4-7/8"

DRILLER: WESTERN STATES

DATE START: 8/13/2015 FINISH: 8/14/2015

DRILLING TECHNIQUE: MUD ROTARY

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SUMMARY BORING LOG
WL-18 (2 of 2)

STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

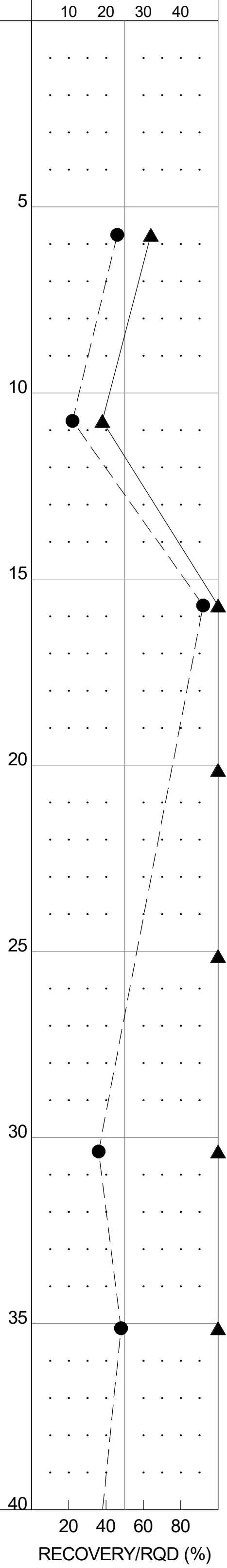
AUG 2018

PROJ 2613

FIG. A-18

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION SURFACE ELEVATION: 23.6 FT.	SAMPLE NO.	PEN. DATA	GROUND WATER/ INSTRUMENT INSTALLATION
		MEDIUM DENSE, brown, silty SAND and dark gray GRAVEL and ROCK FRAGMENTS; rounded and angular particles, some quartz gravel (GIBBONS CREEK ALLUVIAL FAN DEPOSIT)			
			S-1	3 15 17	
		… encountered groundwater at 10 feet … becomes gravelly at 10 feet	S-2	10 11 8	
			S-3	2 5 50/5"	
3.6	20	DENSE, dark gray GRAVEL and COBBLES in a matrix of silty sand; rounded unfractured faces (CATACLYSMIC-FLOOD DEPOSIT)	S-4	50/3"	
			S-5	50/3"	
		… dense, brown, silty sand at 30 to 31 feet	S-6	32 50/3"	
			S-7	50/3"	
-16.4	40				

PENETRATION TEST (BLOWS PER FOOT)
WATER CONTENT (%)



LEGEND

- ▨ 2-INCH O.D. SPLIT SPOON
- ☒ 3-INCH O.D. SPLIT SPOON
- ▯ 3-INCH O.D. THIN WALL SAMPLER
- ▥ 3-INCH O.D. PITCHER TUBE SAMPLER
- * NO SAMPLE RECOVERY
- ▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED
- ├─●─┤ LIQUID LIMIT, WATER CONTENT, PLASTIC LIMIT
- ▲ STANDARD PENETRATION TEST (BLOWS/FT.)
- ● WATER CONTENT IN PERCENT
- ▨ CORE RECOVERY IN PERCENT
- ■ RQD IN PERCENT
-] PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT USING A TREMIE TUBE FROM THE BOTTOM TO THE TOP OF THE HOLE.

HAMMER ASSEMBLY: AUTO TRIP
SPT SAMPLER: NO LINER - RECESSED ID
DRILL ROD USED: NWJ
BOREHOLE DIAM.: 8-1/4" (0'-20'), 3-7/8" (20'-55')

DRILLER: WESTERN STATES
DATE START: 8/17/2015 FINISH: 8/17/2015
DRILLING TECHNIQUE: HOLLOW STEM AUGER/MUD ROTARY

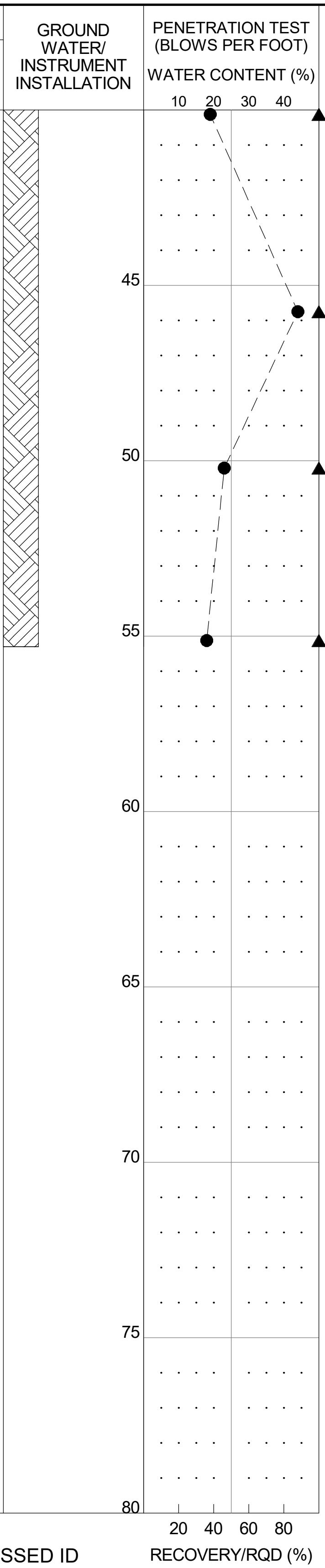
CORNFORTH CONSULTANTS
10250 S.W. Greenburg Road, Suite 111
Portland, Oregon 97223
Phone 503-452-1100 Fax 503-452-1528

SUMMARY BORING LOG
WL-19 (1 of 2)

STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

AUG 2018
PROJ 2613
FIG. A-19

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION	SAMPLE NO.	SAMPLE PEN. DATA
		SURFACE ELEVATION: 23.6 FT.		
		DENSE, dark gray GRAVEL and COBBLES in a matrix of silty, fine sand; rounded unfractured faces (CATACLYSMIC-FLOOD DEPOSIT)	S-8	50/3"
-20.4	44	DENSE, dark gray, silty, fine SAND; some micas, some brown mottles (CATACLYSMIC-FLOOD DEPOSIT)	S-9	16 22 29
-24.4	48	DENSE, dark gray GRAVEL and COBBLES in a matrix of silty, fine sand; rounded gravel (CATACLYSMIC-FLOOD DEPOSIT)	S-10 S-11	50/5" 50/3"
-31.7	55.3	Bottom of Boring: 55.3 FT		



LEGEND

- ▨ 2-INCH O.D. SPLIT SPOON
- ☒ 3-INCH O.D. SPLIT SPOON
- ▯ 3-INCH O.D. THIN WALL SAMPLER
- ▥ 3-INCH O.D. PITCHER TUBE SAMPLER
- * NO SAMPLE RECOVERY
- ▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED
- ├─●─┤ LIQUID LIMIT, WATER CONTENT, PLASTIC LIMIT
- ▲ STANDARD PENETRATION TEST (BLOWS/FT.)
- ● WATER CONTENT IN PERCENT
- ▨ CORE RECOVERY IN PERCENT
- ■ RQD IN PERCENT
-] PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT USING A TREMIE TUBE FROM THE BOTTOM TO THE TOP OF THE HOLE.

HAMMER ASSEMBLY: AUTO TRIP

SPT SAMPLER: NO LINER - RECESSED ID

DRILL ROD USED: NWJ

BOREHOLE DIAM.: 8-1/4" (0'-20'), 3-7/8" (20'-55')

DRILLER: WESTERN STATES
DATE START: 8/17/2015 FINISH: 8/17/2015
DRILLING TECHNIQUE: HOLLOW STEM AUGER/MUD ROTARY

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10250 S.W. Greenburg Road, Suite 111
Portland, Oregon 97223
Phone 503-452-1100 Fax 503-452-1528

SUMMARY BORING LOG
WL-19 (2 of 2)

STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

AUG 2018

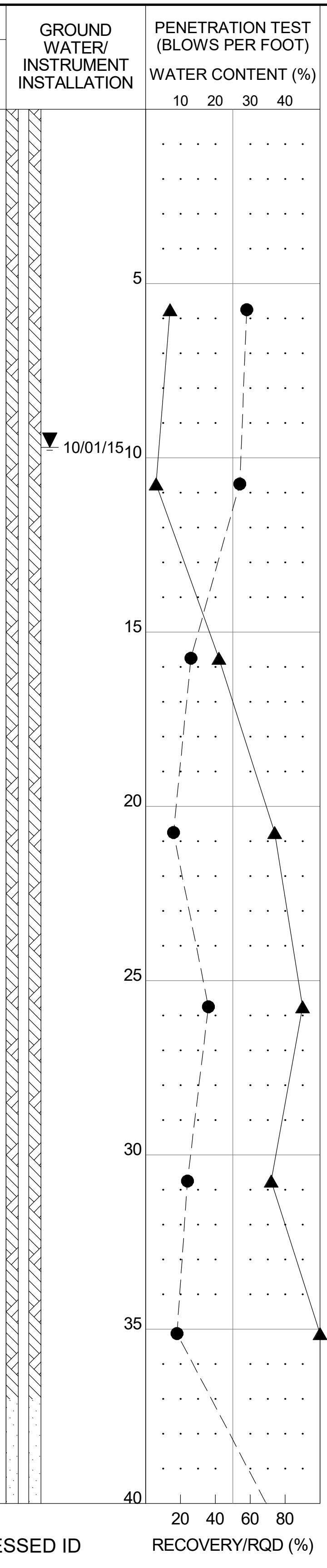
PROJ 2613

FIG. A-19

SURFACE ELEVATION: 28.2 FT.

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION
		LOOSE, brown, sandy SILT to silty fine SAND with some gravel; subrounded and angular gravel, ground surface had been graded in the past (GIBBONS CREEK ALLUVIAL FAN DEPOSIT)
		… becomes MEDIUM DENSE with increasing gravel
10.2	18	DENSE, dark gray, GRAVEL and ROCK FRAGMENTS in a matrix of brown silty sand; subrounded and angular particles (GIBBONS CREEK ALLUVIAL FAN DEPOSIT)
		… circulation loss at 27 feet
-3.8	32	DENSE, dark gray, GRAVEL and COBBLES in a matrix of brown, silty sand; subrounded and angular particles (CATACLYSMIC-FLOOD DEPOSIT) … lost circulation at 32 to 33 feet
-10.8	39	

SAMPLE NO.	PEN. DATA
S-1	5 3 4
S-2	1 1 2
S-3	10 8 13
S-4	15 18 19
S-5	25 21 24
S-6	21 21 15
S-7	50/3"



LEGEND

- ▨ 2-INCH O.D. SPLIT SPOON
- ☒ 3-INCH O.D. SPLIT SPOON
- ▯ 3-INCH O.D. THIN WALL SAMPLER
- ▥ 3-INCH O.D. PITCHER TUBE SAMPLER
- * NO SAMPLE RECOVERY
- ▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED
- ├─●─┤ LIQUID LIMIT, WATER CONTENT, PLASTIC LIMIT
- ▲ STANDARD PENETRATION TEST (BLOWS/FT.)
- ● WATER CONTENT IN PERCENT
- ▨ CORE RECOVERY IN PERCENT
- ■ RQD IN PERCENT
-] PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. STANDPIPE PIEZOMETER INSTALLED AT COMPLETION OF DRILLING, OF 1-INCH DIAMETER SCHEDULE 80, SLOTTED PVC PIPE BACKFILLED WITH 10-12 COLORADO SAND IN FILTER ZONE.
3. ABOVE GROUND MONUMENT AND BOLLARDS INSTALLED.

HAMMER ASSEMBLY: AUTO TRIP
SPT SAMPLER: NO LINER - RECESSED ID
DRILL ROD USED: NWJ
BOREHOLE DIAM.: 4-7/8"

DRILLER: WESTERN STATES
DATE START: 8/12/2015 FINISH: 8/13/2015
DRILLING TECHNIQUE: MUD ROTARY

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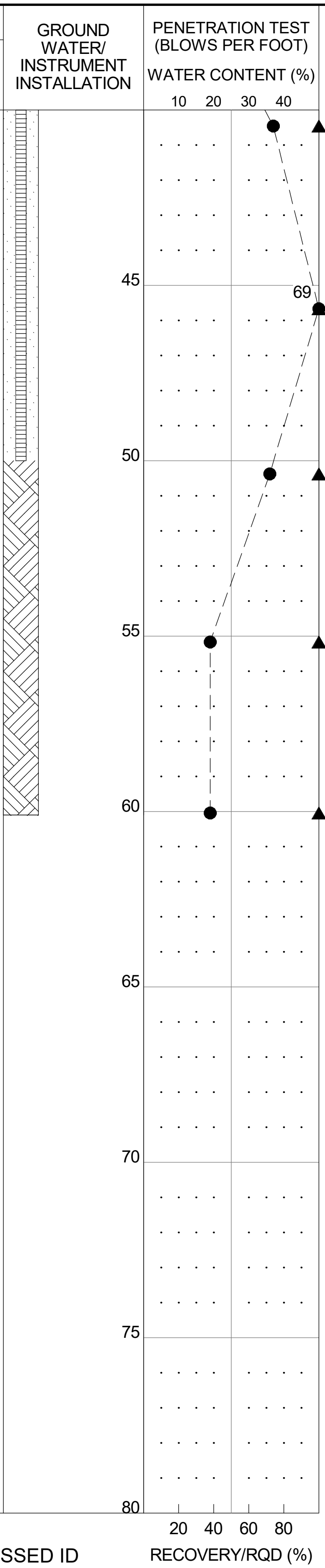
Phone 503-452-1100 Fax 503-452-1528

SUMMARY BORING LOG
WL-20 (1 of 2)

STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

AUG 2018
PROJ 2613
FIG. A-20

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION SURFACE ELEVATION: 28.2 FT.	SAMPLE NO.	SAMPLE PEN. DATA
		DENSE, dark green-gray, fine SAND; some micas, some gravel (CATACLYSMIC-FLOOD DEPOSIT)	S-8	25 50/5"
			S-9	15 21 50/4"
			S-10	21 50/3"
-26.8	55	DENSE, dark gray, GRAVEL and COBBLES in a matrix of silty sand (CATACLYSMIC-FLOOD DEPOSIT)	S-11	50/4"
-31.9	60.1	Bottom of Boring: 60.1 FT	S-12	50/1"



LEGEND

▨	2-INCH O.D. SPLIT SPOON
☒	3-INCH O.D. SPLIT SPOON
▯	3-INCH O.D. THIN WALL SAMPLER
▥	3-INCH O.D. PITCHER TUBE SAMPLER
*	NO SAMPLE RECOVERY
▼ MM/DD/YY	GROUND WATER LEVEL AND DATE OBSERVED
├●┤	LIQUID LIMIT / WATER CONTENT / PLASTIC LIMIT
▲	STANDARD PENETRATION TEST (BLOWS/FT.)
●	WATER CONTENT IN PERCENT
▨	CORE RECOVERY IN PERCENT
■	RQD IN PERCENT
] PT-1	PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. STANDPIPE PIEZOMETER INSTALLED AT COMPLETION OF DRILLING, OF 1-INCH DIAMETER SCHEDULE 80, SLOTTED PVC PIPE BACKFILLED WITH 10-12 COLORADO SAND IN FILTER ZONE.
3. ABOVE GROUND MONUMENT AND BOLLARDS INSTALLED.

HAMMER ASSEMBLY: AUTO TRIP
SPT SAMPLER: NO LINER - RECESSED ID
DRILL ROD USED: NWJ
BOREHOLE DIAM.: 4-7/8"

DRILLER: WESTERN STATES
DATE START: 8/12/2015 FINISH: 8/13/2015
DRILLING TECHNIQUE: MUD ROTARY

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SUMMARY BORING LOG
WL-20 (2 of 2)

STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

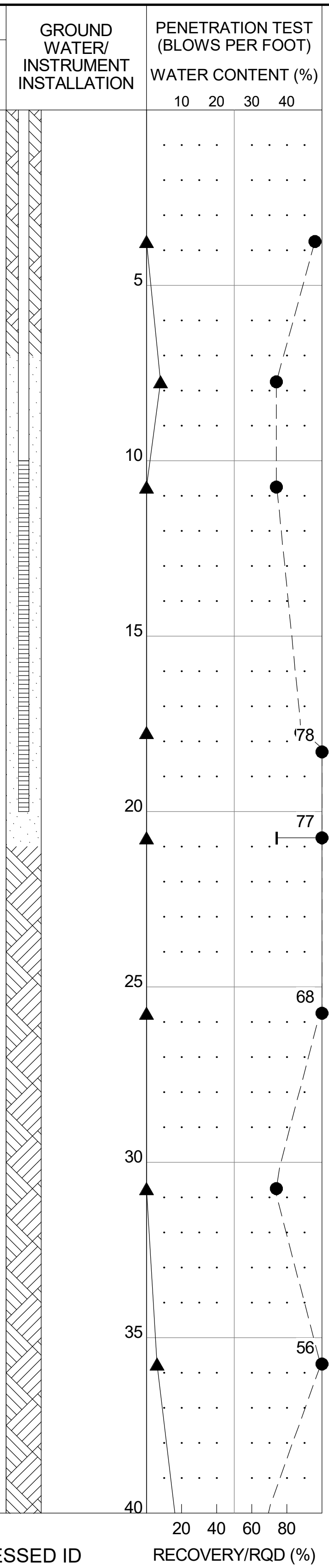
AUG 2018

PROJ 2613

FIG. A-20

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION SURFACE ELEVATION: 29.5 FT.
		Interlayered: VERY LOOSE to LOOSE, brown, silty fine SAND and SOFT, fine-sandy SILT; some mica, occasional organics (COLUMBIA RIVER ALLUVIUM)
		... becomes gray at 7 feet
-9.5	39	

SAMPLE NO.	PEN. DATA
S-1	0 0 0
S-2	
S-3	1 2 2
S-4	0 0 0
S-5	
S-6	0 0 0
S-7	0 0 0
S-8	0 0 0
S-9	0 0 0
S-10	0 0 3



LEGEND

- ▨ 2-INCH O.D. SPLIT SPOON
- ☒ 3-INCH O.D. SPLIT SPOON
- ▯ 3-INCH O.D. THIN WALL SAMPLER
- ▥ 3-INCH O.D. PITCHER TUBE SAMPLER
- * NO SAMPLE RECOVERY
- ▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED
- ├●┤ LIQUID LIMIT, WATER CONTENT, PLASTIC LIMIT
- ▲ STANDARD PENETRATION TEST (BLOWS/FT.)
- ● WATER CONTENT IN PERCENT
- ▨ CORE RECOVERY IN PERCENT
- ■ RQD IN PERCENT
-] PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT USING A TREMIE TUBE FROM THE BOTTOM TO THE TOP OF THE HOLE.

HAMMER ASSEMBLY: AUTO TRIP

SPT SAMPLER: NO LINER - RECESSED ID

DRILL ROD USED: NWJ

BOREHOLE DIAM.: 3-7/8"

DRILLER: WESTERN STATES
DATE START: 8/19/2015 FINISH: 8/20/2015
DRILLING TECHNIQUE: MUD ROTARY

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SUMMARY BORING LOG
WL-21 (1 of 3)

STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

AUG 2018

PROJ 2613

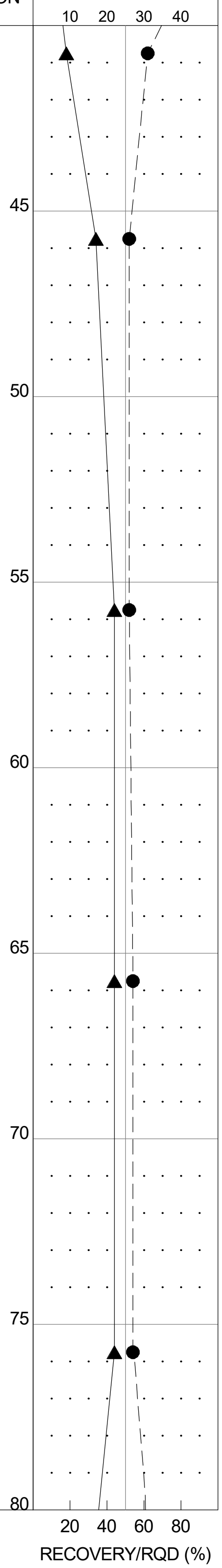
FIG. A-21

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION SURFACE ELEVATION: 29.5 FT.	SAMPLE NO.	SAMPLE PEN. DATA
		Interlayered: SOFT to MEDIUM STIFF, gray, fine-sandy SILT and LOOSE to MEDIUM DENSE, gray, silty fine SAND; some micas (COLUMBIA RIVER ALLUVIUM)	S-11	3 5 4
			S-12	11 10 7
			S-13	14 12 10
			S-14	12 11 11
			S-15	11 11 11

GROUND WATER/ INSTRUMENT INSTALLATION

PENETRATION TEST (BLOWS PER FOOT)

WATER CONTENT (%)



LEGEND

▨ 2-INCH O.D. SPLIT SPOON

☒ 3-INCH O.D. SPLIT SPOON

▯ 3-INCH O.D. THIN WALL SAMPLER

▥ 3-INCH O.D. PITCHER TUBE SAMPLER

* NO SAMPLE RECOVERY

▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED

LIQUID LIMIT

WATER CONTENT

PLASTIC LIMIT

▲ STANDARD PENETRATION TEST (BLOWS/FT.)

● WATER CONTENT IN PERCENT

▨ CORE RECOVERY IN PERCENT

■ RQD IN PERCENT

PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT USING A TREMIE TUBE FROM THE BOTTOM TO THE TOP OF THE HOLE.

HAMMER ASSEMBLY: AUTO TRIP
SPT SAMPLER: NO LINER - RECESSED ID
DRILL ROD USED: NWJ
BOREHOLE DIAM.: 3-7/8"

DRILLER: WESTERN STATES
DATE START: 8/19/2015 FINISH: 8/20/2015
DRILLING TECHNIQUE: MUD ROTARY

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SUMMARY BORING LOG
WL-21 (2 of 3)

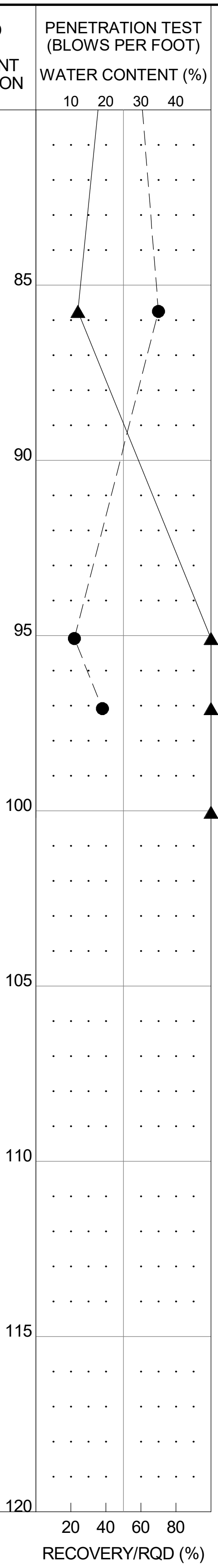
STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

AUG 2018

PROJ 2613

FIG. A-21

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION SURFACE ELEVATION: 29.5 FT.	SAMPLE NO.	SAMPLE PEN. DATA	GROUND WATER/ INSTRUMENT INSTALLATION
		Interlayered: SOFT to MEDIUM STIFF, gray, fine-sandy SILT and LOOSE to MEDIUM DENSE, gray, silty fine SAND; some micas (COLUMBIA RIVER ALLUVIUM)	S-16	11 6 6	
-63.5	93	DENSE, dark gray GRAVEL and COBBLES in a matrix of silty sand; subrounded and angular particles (CATACLYSMIC-FLOOD DEPOSIT)	S-17 S-18	50/3" 50/3"	
-70.7	100.2	Bottom of Boring: 100.2 FT	S-19 *	50/2"	



LEGEND

- ▨ 2-INCH O.D. SPLIT SPOON
- ☒ 3-INCH O.D. SPLIT SPOON
- ▯ 3-INCH O.D. THIN WALL SAMPLER
- ▥ 3-INCH O.D. PITCHER TUBE SAMPLER
- * NO SAMPLE RECOVERY
- ▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED
- LIQUID LIMIT
- WATER CONTENT
- PLASTIC LIMIT
- ▲ STANDARD PENETRATION TEST (BLOWS/FT.)
- ● WATER CONTENT IN PERCENT
- ▨ CORE RECOVERY IN PERCENT
- ■ RQD IN PERCENT
- PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT USING A TREMIE TUBE FROM THE BOTTOM TO THE TOP OF THE HOLE.

HAMMER ASSEMBLY: AUTO TRIP
SPT SAMPLER: NO LINER - RECESSED ID
DRILL ROD USED: NWJ
BOREHOLE DIAM.: 3-7/8"

DRILLER: WESTERN STATES
DATE START: 8/19/2015 FINISH: 8/20/2015
DRILLING TECHNIQUE: MUD ROTARY

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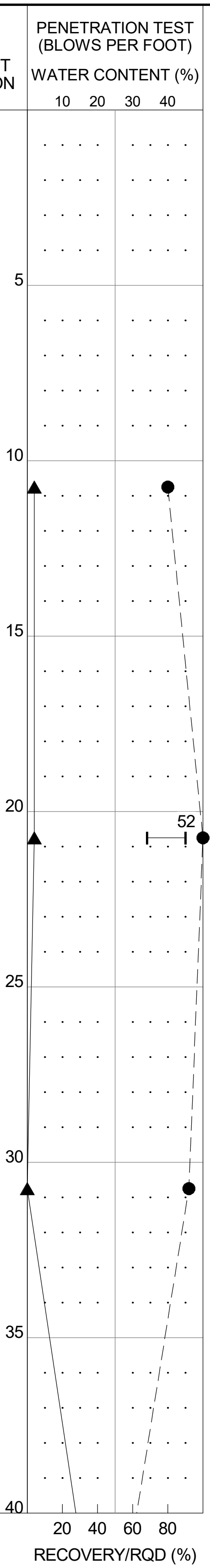
SUMMARY BORING LOG
WL-21 (3 of 3)

STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

AUG 2018
PROJ 2613
FIG. A-21

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION SURFACE ELEVATION: 33.0 FT.	SAMPLE NO.	SAMPLE PEN. DATA
		Interlayered: VERY LOOSE to LOOSE, silty fine SAND and SOFT, fine-sandy SILT; (COLUMBIA RIVER ALLUVIUM)		
			S-1	
		… dark gray, silty fine sand, some micas, at 0 to 15 feet	S-2	1 1 1
			S-3	0 1 1
		… soft, green gray, fine-sandy silt at 15 to 35 feet		
		… some micas	S-4	0 0 0
-7.0	40			

GROUND WATER/ INSTRUMENT INSTALLATION



LEGEND

- ▨ 2-INCH O.D. SPLIT SPOON
- ☒ 3-INCH O.D. SPLIT SPOON
- ▯ 3-INCH O.D. THIN WALL SAMPLER
- ▥ 3-INCH O.D. PITCHER TUBE SAMPLER
- * NO SAMPLE RECOVERY
- ▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED
- ├─●─┤ LIQUID LIMIT / WATER CONTENT / PLASTIC LIMIT
- ▲ STANDARD PENETRATION TEST (BLOWS/FT.)
- ● WATER CONTENT IN PERCENT
- ▨ CORE RECOVERY IN PERCENT
- ■ RQD IN PERCENT
-] PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT USING A TREMIE TUBE FROM THE BOTTOM TO THE TOP OF THE HOLE.

HAMMER ASSEMBLY: AUTO TRIP
SPT SAMPLER: NO LINER - RECESSED ID
DRILL ROD USED: NWJ
BOREHOLE DIAM.: 4-7/8" & 3-7/8"

DRILLER: WESTERN STATES
DATE START: 8/24/2015 FINISH: 8/24/2015
DRILLING TECHNIQUE: MUD ROTARY

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SUMMARY BORING LOG
WL-22 (1 of 3)

STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

AUG 2018

PROJ 2613

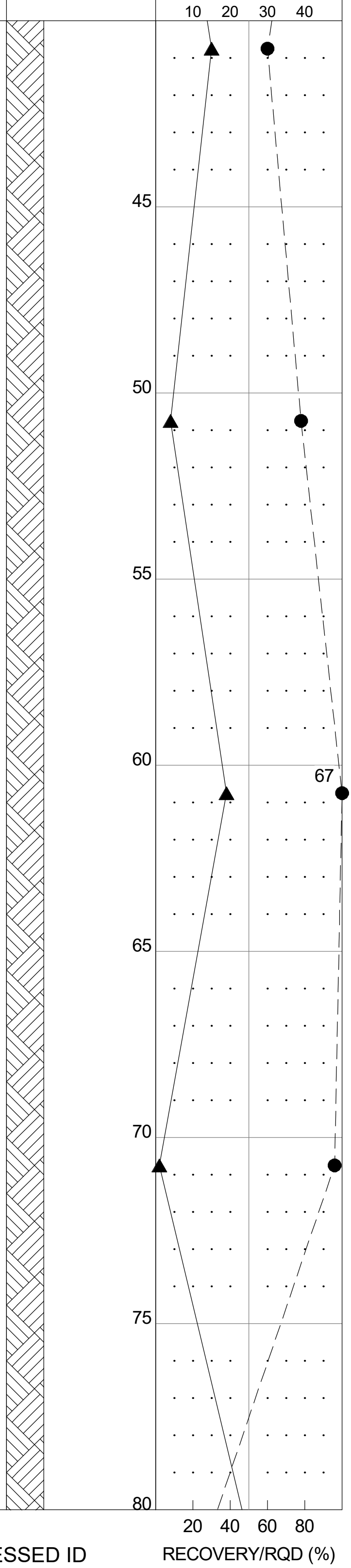
FIG. A-22

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION SURFACE ELEVATION: 33.0 FT.	SAMPLE NO.	SAMPLE PEN. DATA
		(continued from previous page)	S-5	4 7 8
		… dark gray, silty fine sand at 35 to 72 feet	S-6	0 2 2
		… gray and very silty at 60 feet	S-7	7 7 12
		… some micas at 70 feet	S-8	0 0 1
-39.0	72	… soft to medium stiff, dark gray, fine-sandy silt, some micas, at 71 feet		
		MEDIUM DENSE, dark gray, GRAVEL in a matrix of silty sand; trace quartzite gravel, subrounded gravels (COLUMBIA RIVER ALLUVIUM)		
-47.0	80			

GROUND WATER/ INSTRUMENT INSTALLATION

PENETRATION TEST (BLOWS PER FOOT)

WATER CONTENT (%)



LEGEND

- ▨ 2-INCH O.D. SPLIT SPOON
- ☒ 3-INCH O.D. SPLIT SPOON
- ▯ 3-INCH O.D. THIN WALL SAMPLER
- ▥ 3-INCH O.D. PITCHER TUBE SAMPLER
- * NO SAMPLE RECOVERY
- ▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED
- LIQUID LIMIT, WATER CONTENT, PLASTIC LIMIT
- ▲ STANDARD PENETRATION TEST (BLOWS/FT.)
- ● WATER CONTENT IN PERCENT
- ▨ CORE RECOVERY IN PERCENT
- ■ RQD IN PERCENT
- PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT USING A TREMIE TUBE FROM THE BOTTOM TO THE TOP OF THE HOLE.

HAMMER ASSEMBLY: AUTO TRIP

SPT SAMPLER: NO LINER - RECESSED ID

DRILL ROD USED: NWJ

BOREHOLE DIAM.: 4-7/8" & 3-7/8"

DRILLER: WESTERN STATES
DATE START: 8/24/2015 FINISH: 8/24/2015
DRILLING TECHNIQUE: MUD ROTARY

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SUMMARY BORING LOG
WL-22 (2 of 3)

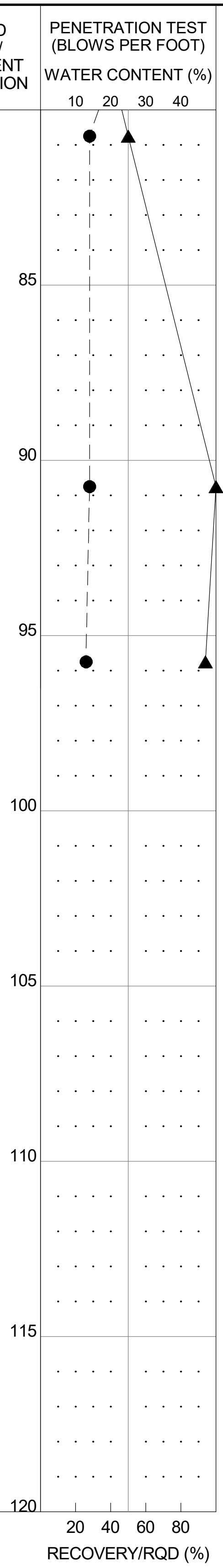
STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

AUG 2018

PROJ 2613

FIG. A-22

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION SURFACE ELEVATION: 33.0 FT.	SAMPLE NO.	PEN. DATA	GROUND WATER/ INSTRUMENT INSTALLATION
		(continued from previous page)	S-9	14 9 16	
-52.0	85	DENSE, dark gray, GRAVEL and COBBLES in a matrix of silty sand; trace light-colored quartzite gravels, rounded gravels (CATACLYSMIC-FLOOD DEPOSIT)			
			S-10	26 26 36	
		… trace orange sand at 91 feet			
		… circulation loss at 92.5 feet			
		… dark green-gray sand matrix at 95 feet	S-11	24 22 25	
-63.5	96.5	Bottom of Boring: 96.5 FT			



LEGEND

- ▨ 2-INCH O.D. SPLIT SPOON
- ☒ 3-INCH O.D. SPLIT SPOON
- ▯ 3-INCH O.D. THIN WALL SAMPLER
- ▥ 3-INCH O.D. PITCHER TUBE SAMPLER
- * NO SAMPLE RECOVERY
- ▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED
- LIQUID LIMIT
- WATER CONTENT
- PLASTIC LIMIT
- ▲ STANDARD PENETRATION TEST (BLOWS/FT.)
- ● WATER CONTENT IN PERCENT
- ▨ CORE RECOVERY IN PERCENT
- ■ RQD IN PERCENT
- PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT USING A TREMIE TUBE FROM THE BOTTOM TO THE TOP OF THE HOLE.

HAMMER ASSEMBLY: AUTO TRIP
DRILL ROD USED: NWJ
SPT SAMPLER: NO LINER - RECESSED ID
BOREHOLE DIAM.: 4-7/8" & 3-7/8"

DRILLER: WESTERN STATES
DATE START: 8/24/2015 FINISH: 8/24/2015
DRILLING TECHNIQUE: MUD ROTARY

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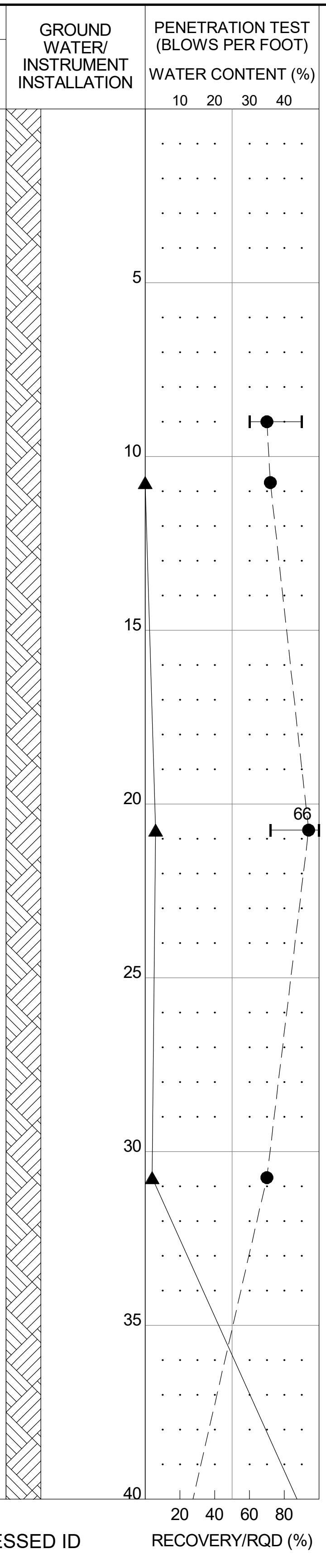
SUMMARY BORING LOG
WL-22 (3 of 3)

STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

AUG 2018
PROJ 2613
FIG. A-22

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION SURFACE ELEVATION: 25.0 FT.	SAMPLE NO.	PEN. DATA
		Interlayered: SOFT, brown, slightly sandy, clayey SILT and VERY LOOSE to LOOSE, silty fine SAND (COLUMBIA RIVER ALLUVIUM)		
			S-1	
		… brown with orange mottles at 10 to 11.5 feet … circulation loss at 10 feet	S-2	0 0 0
		… gray and slightly clayey at 20 - 21.5 feet	S-3	0 1 2
		… dark gray below 30 feet … very loose, silty, fine sand with trace micas at about 31 feet	S-4	0 1 1
-15.0	40			



LEGEND

▨ 2-INCH O.D. SPLIT SPOON

☒ 3-INCH O.D. SPLIT SPOON

▯ 3-INCH O.D. THIN WALL SAMPLER

▥ 3-INCH O.D. PITCHER TUBE SAMPLER

* NO SAMPLE RECOVERY

▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED

├●─┤ LIQUID LIMIT, WATER CONTENT, PLASTIC LIMIT

▲ STANDARD PENETRATION TEST (BLOWS/FT.)

● WATER CONTENT IN PERCENT

▨ CORE RECOVERY IN PERCENT

■ RQD IN PERCENT

] PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT USING A TREMIE TUBE FROM THE BOTTOM TO THE TOP OF THE HOLE.

HAMMER ASSEMBLY: AUTO TRIP
SPT SAMPLER: NO LINER - RECESSED ID
DRILL ROD USED: NWJ
BOREHOLE DIAM.: 4-7/8" & 3-7/8"

DRILLER: WESTERN STATES
DATE START: 8/25/2015 FINISH: 8/26/2015
DRILLING TECHNIQUE: MUD ROTARY

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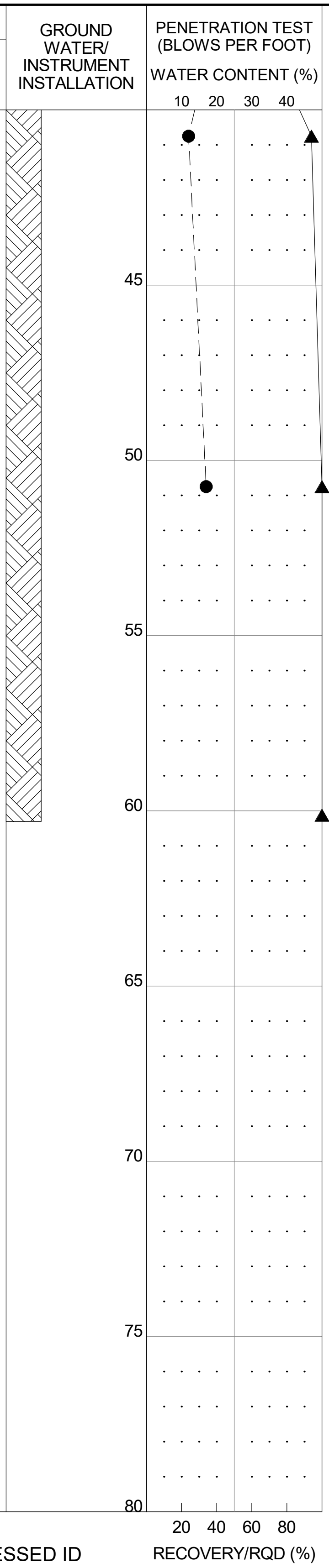
SUMMARY BORING LOG WL-23 (1 of 2)

STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

AUG 2018
PROJ 2613
FIG. A-23

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION	SAMPLE NO.	SAMPLE PEN. DATA
		SURFACE ELEVATION: 25.0 FT.		
		DENSE, dark gray GRAVEL in a matrix of silty sand; subrounded gravel (COLUMBIA RIVER ALLUVIUM) … trace light-colored quartz gravels	S-5	16 21 26
			S-6	17 30 36
-31.0	56	DENSE, dark gray, GRAVEL and COBBLES in a matrix of silty sand; trace light-colored quartzite gravels, rounded gravels (CATACLYSMIC-FLOOD DEPOSIT)		
-35.3	60.3	Bottom of Boring: 60.3 FT	S-6 *	50/3"



LEGEND

- ▨ 2-INCH O.D. SPLIT SPOON
- ☒ 3-INCH O.D. SPLIT SPOON
- ▯ 3-INCH O.D. THIN WALL SAMPLER
- ▥ 3-INCH O.D. PITCHER TUBE SAMPLER
- * NO SAMPLE RECOVERY
- ▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED
- ├─●─┤ LIQUID LIMIT, WATER CONTENT, PLASTIC LIMIT
- ▲ STANDARD PENETRATION TEST (BLOWS/FT.)
- ● WATER CONTENT IN PERCENT
- ▨ CORE RECOVERY IN PERCENT
- ■ RQD IN PERCENT
-] PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT USING A TREMIE TUBE FROM THE BOTTOM TO THE TOP OF THE HOLE.

HAMMER ASSEMBLY: AUTO TRIP
SPT SAMPLER: NO LINER - RECESSED ID
DRILL ROD USED: NWJ
BOREHOLE DIAM.: 4-7/8" & 3-7/8"

DRILLER: WESTERN STATES
DATE START: 8/25/2015 FINISH: 8/26/2015
DRILLING TECHNIQUE: MUD ROTARY

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SUMMARY BORING LOG
WL-23 (2 of 2)

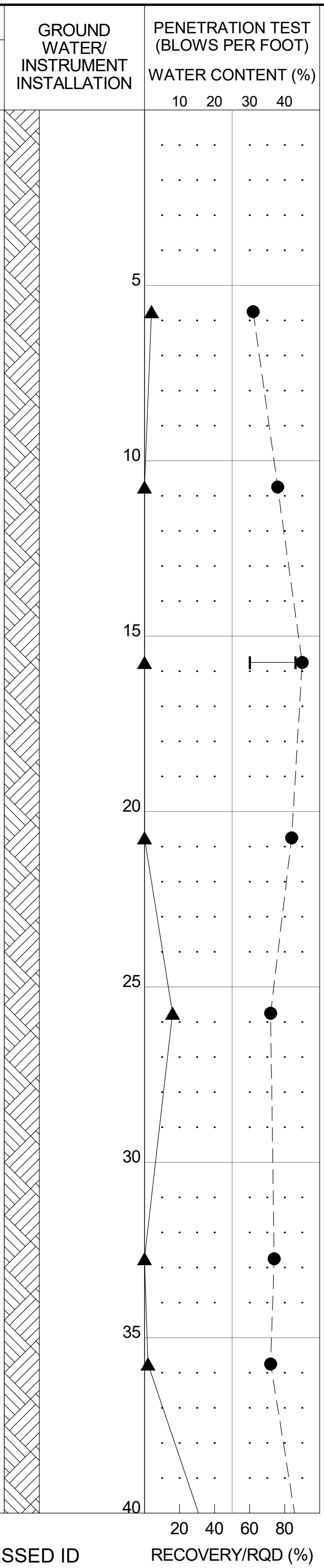
STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

AUG 2018

PROJ 2613

FIG. A-23

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION SURFACE ELEVATION: 34.7 FT.	SAMPLE NO.	PEN. DATA
		Interlayered: SOFT, brown, fine-sandy SILT and VERY LOOSE to LOOSE, brown, silty fine SAND; some mica (COLUMBIA RIVER ALLUVIUM)		
			S-1	1 1 1
			S-1b	
			S-2	0 0 0
			S-3	0 0 0
		…becomes gray at 20 feet	S-4	0 0 0
			S-5	0 4 4
			S-6	
			S-7	0 0 0
			S-8	0 0 1
-2.3	37			
		Interlayered: MEDIUM STIFF, gray, fine-sandy SILT and MEDIUM DENSE, gray, silty fine SAND; some mica, occasional organics (COLUMBIA RIVER ALLUVIUM)		
-5.3	40			



LEGEND

▨ 2-INCH O.D. SPLIT SPOON

☒ 3-INCH O.D. SPLIT SPOON

▯ 3-INCH O.D. THIN WALL SAMPLER

▥ 3-INCH O.D. PITCHER TUBE SAMPLER

* NO SAMPLE RECOVERY

▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED

LIQUID LIMIT

WATER CONTENT

PLASTIC LIMIT

▲ STANDARD PENETRATION TEST (BLOWS/FT.)

● WATER CONTENT IN PERCENT

▨ CORE RECOVERY IN PERCENT

■ RQD IN PERCENT

PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. STANDPIPE PIEZOMETER INSTALLED AT COMPLETION OF DRILLING, OF 1-INCH DIAMETER SCHEDULE 80, SLOTTED PVC PIPE BACKFILLED WITH 10-12 COLORADO SAND IN FILTER ZONE.
3. FLUSH MOUNT MONUMENT INSTALLED.

HAMMER ASSEMBLY: AUTO TRIP
SPT SAMPLER: NO LINER - RECESSED ID
DRILL ROD USED: NWJ
BOREHOLE DIAM.: 3-7/8"

DRILLER: WESTERN STATES
DATE START: 7/27/2015 FINISH: 7/27/2015
DRILLING TECHNIQUE: MUD ROTARY

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Phone 503-452-1100 Fax 503-452-1528

SUMMARY BORING LOG
EL-01 (1 of 2)

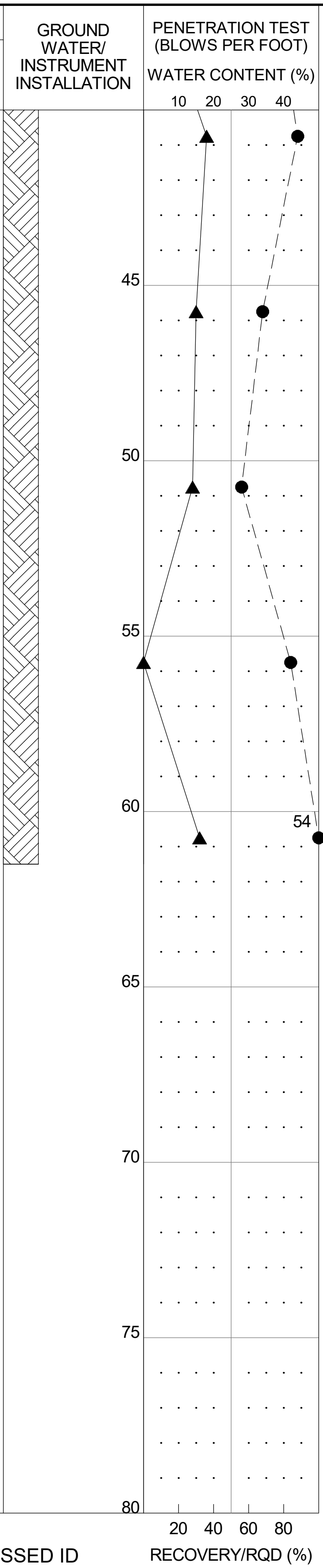
STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

AUG 2018

PROJ 2613

FIG. A-24

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION SURFACE ELEVATION: 34.7 FT.	SAMPLE NO.	PEN. DATA
		(continued from previous page)	S-9	1 10 8
		…encountered scattered fine to coarse subrounded gravel from 40 to 43 feet		
			S-10	3 7 8
			S-11	10 7 7
			S-12	1 0 0
-26.3 -26.8	61 61.5	MEDIUM DENSE, white to light gray, fine SAND; very poorly graded clean sand (ASH DEPOSIT/COLUMBIA RIVER ALLUVIUM?)	S-13	3 6 10
		Bottom of Boring: 61.5 FT		



LEGEND

▨ 2-INCH O.D. SPLIT SPOON

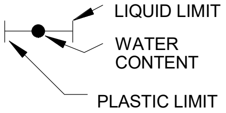
☒ 3-INCH O.D. SPLIT SPOON

▯ 3-INCH O.D. THIN WALL SAMPLER

▥ 3-INCH O.D. PITCHER TUBE SAMPLER

* NO SAMPLE RECOVERY

▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED



▲ STANDARD PENETRATION TEST (BLOWS/FT.)

● WATER CONTENT IN PERCENT

▨ CORE RECOVERY IN PERCENT

■ RQD IN PERCENT

] PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. STANDPIPE PIEZOMETER INSTALLED AT COMPLETION OF DRILLING, OF 1-INCH DIAMETER SCHEDULE 80, SLOTTED PVC PIPE BACKFILLED WITH 10-12 COLORADO SAND IN FILTER ZONE.
3. FLUSH MOUNT MONUMENT INSTALLED.

HAMMER ASSEMBLY: AUTO TRIP
SPT SAMPLER: NO LINER - RECESSED ID
DRILL ROD USED: NWJ
BOREHOLE DIAM.: 3-7/8"

DRILLER: WESTERN STATES
DATE START: 7/27/2015 FINISH: 7/27/2015
DRILLING TECHNIQUE: MUD ROTARY

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Portland, Oregon 97223
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SUMMARY BORING LOG
EL-01 (2 of 2)

STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

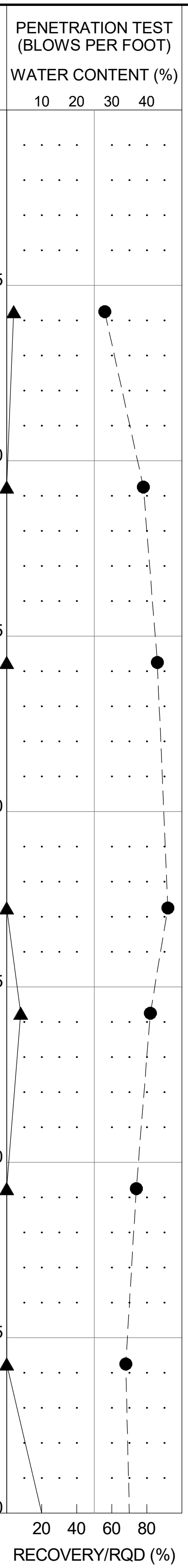
AUG 2018

PROJ 2613

FIG. A-24

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION SURFACE ELEVATION: 35.4 FT.	SAMPLE NO.	PEN. DATA
		Interlayered: SOFT, brown, fine-sandy SILT and VERY LOOSE to LOOSE, brown, silty fine SAND; some mica (COLUMBIA RIVER ALLUVIUM)		
			S-1	1 1 1
			S-2	0 0 0
			S-3	0 0 0
		…becomes gray at 18 feet		
			S-4	
			S-5	1 0 0
			S-6	2 0 4
			S-7	2 0 0
			S-8	0 0 0
-1.6	37	Interlayered: MEDIUM STIFF, gray, fine-sandy SILT and MEDIUM DENSE, gray, silty fine SAND; some mica, occasional organics (COLUMBIA RIVER ALLUVIUM)		
-4.6	40			

GROUND WATER/ INSTRUMENT INSTALLATION



LEGEND

- ▨ 2-INCH O.D. SPLIT SPOON
- ☒ 3-INCH O.D. SPLIT SPOON
- ▯ 3-INCH O.D. THIN WALL SAMPLER
- ▥ 3-INCH O.D. PITCHER TUBE SAMPLER
- * NO SAMPLE RECOVERY
- ▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED
- LIQUID LIMIT, WATER CONTENT, PLASTIC LIMIT
- ▲ STANDARD PENETRATION TEST (BLOWS/FT.)
- ● WATER CONTENT IN PERCENT
- ▨ CORE RECOVERY IN PERCENT
- ■ RQD IN PERCENT
- PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT USING A TREMIE TUBE FROM THE BOTTOM TO THE TOP OF THE HOLE.
3. SAMPLE S-9 CONSISTED OF A FAILED SHELBY TUBE SAMPLE ATTEMPT.

HAMMER ASSEMBLY: AUTO TRIP
SPT SAMPLER: NO LINER - RECESSED ID
DRILL ROD USED: NWJ
BOREHOLE DIAM.: 3-7/8"

DRILLER: WESTERN STATES
DATE START: 7/27/2015 FINISH: 7/27/2015
DRILLING TECHNIQUE: MUD ROTARY

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SUMMARY BORING LOG EL-02 (1 of 2)

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WASHOUGAL, WA

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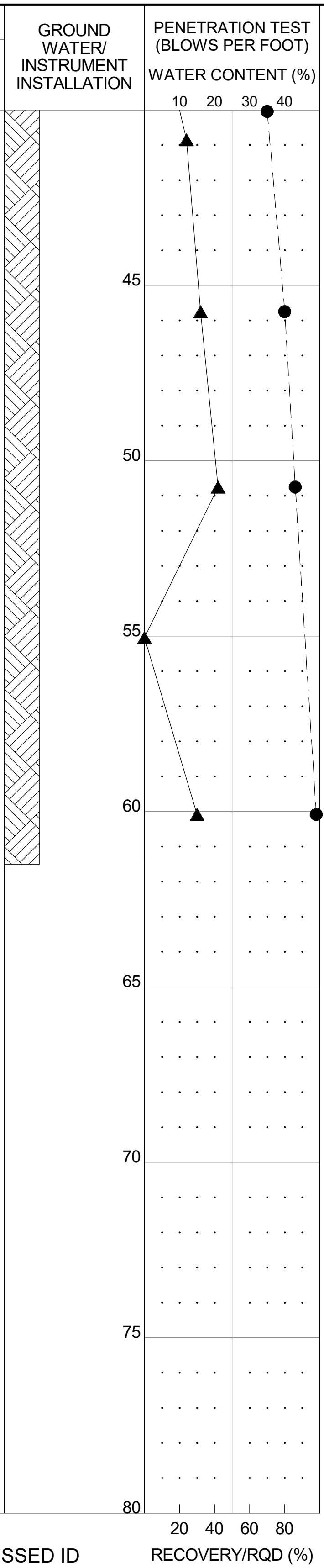
PROJ 2613
FIG. A-25

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION	SAMPLE NO.	SAMPLE PEN. DATA
		SURFACE ELEVATION: 35.4 FT.		
		(continued from previous page)	S-9 *	
			S-10	9 5 7
		…encountered scattered fine to coarse subrounded gravel from 39 to 47 feet		
			S-11	10 10 6
			S-12	4 10 11
			S-13 *	0 0 0
-23.6	59	MEDIUM DENSE, white to light gray, silty fine SAND; very poorly graded clean sand (ASH DEPOSIT/COLUMBIA RIVER ALLUVIUM?)	S-14	1 5 10
-26.1	61.5	Bottom of Boring: 61.5 FT		



LEGEND

▨ 2-INCH O.D. SPLIT SPOON

☒ 3-INCH O.D. SPLIT SPOON

▯ 3-INCH O.D. THIN WALL SAMPLER

▥ 3-INCH O.D. PITCHER TUBE SAMPLER

* NO SAMPLE RECOVERY

▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED

LIQUID LIMIT

WATER CONTENT

PLASTIC LIMIT

▲ STANDARD PENETRATION TEST (BLOWS/FT.)

● WATER CONTENT IN PERCENT

▨ CORE RECOVERY IN PERCENT

■ RQD IN PERCENT

PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT USING A TREMIE TUBE FROM THE BOTTOM TO THE TOP OF THE HOLE.
3. SAMPLE S-9 CONSISTED OF A FAILED SHELBY TUBE SAMPLE ATTEMPT.

HAMMER ASSEMBLY: AUTO TRIP
SPT SAMPLER: NO LINER - RECESSED ID
DRILL ROD USED: NWJ
BOREHOLE DIAM.: 3-7/8"

DRILLER: WESTERN STATES
DATE START: 7/27/2015 FINISH: 7/27/2015
DRILLING TECHNIQUE: MUD ROTARY

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SUMMARY BORING LOG
EL-02 (2 of 2)

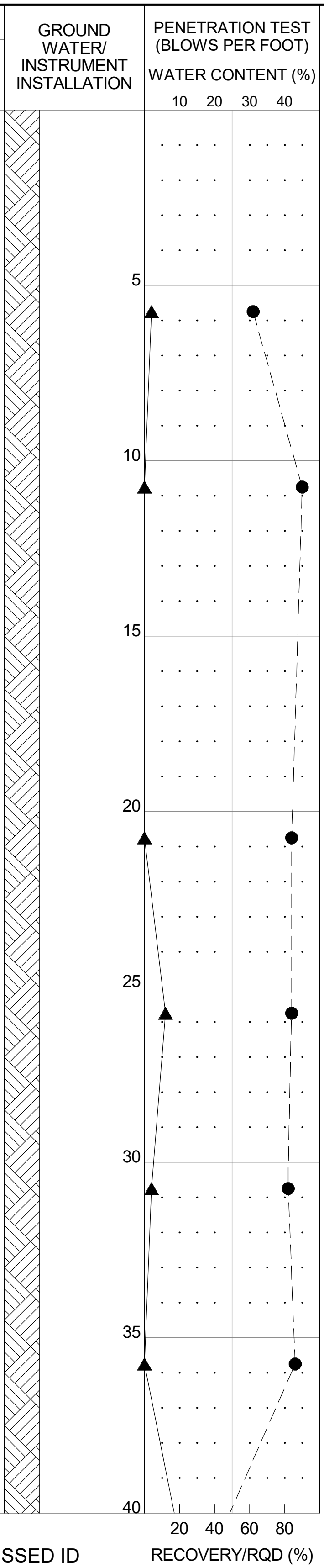
STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

AUG 2018

PROJ 2613

FIG. A-25

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION	SAMPLE NO.	SAMPLE PEN. DATA
		SURFACE ELEVATION: 35.3 FT.		
		Interlayered: SOFT, brown, fine-sandy SILT and VERY LOOSE to LOOSE, brown, silty fine SAND; some mica (COLUMBIA RIVER ALLUVIUM)		
			S-1	1 1 1
			S-2	0 0 0
			S-3	
		…becomes gray at 18 feet		
			S-4	0 0 0
			S-5	1 2 4
			S-6	2 1 1
			S-7	0 0 0
-1.7	37	Interlayered: MEDIUM STIFF, gray, fine-sandy SILT and MEDIUM DENSE, gray, silty fine SAND; some mica, occasional organics (COLUMBIA RIVER ALLUVIUM)		
-4.7	40			



LEGEND

- ▨ 2-INCH O.D. SPLIT SPOON
- ☒ 3-INCH O.D. SPLIT SPOON
- ▯ 3-INCH O.D. THIN WALL SAMPLER
- ▥ 3-INCH O.D. PITCHER TUBE SAMPLER
- * NO SAMPLE RECOVERY
- ▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED
- ├●┤ LIQUID LIMIT, WATER CONTENT, PLASTIC LIMIT
- ▲ STANDARD PENETRATION TEST (BLOWS/FT.)
- ● WATER CONTENT IN PERCENT
- ▨ CORE RECOVERY IN PERCENT
- ■ RQD IN PERCENT
-] PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT USING A TREMIE TUBE FROM THE BOTTOM TO THE TOP OF THE HOLE.

HAMMER ASSEMBLY: AUTO TRIP
SPT SAMPLER: NO LINER - RECESSED ID
DRILL ROD USED: NWJ
BOREHOLE DIAM.: 3-7/8"

DRILLER: WESTERN STATES
DATE START: 7/28/2015 FINISH: 7/28/2015
DRILLING TECHNIQUE: MUD ROTARY

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SUMMARY BORING LOG
EL-03 (1 of 2)

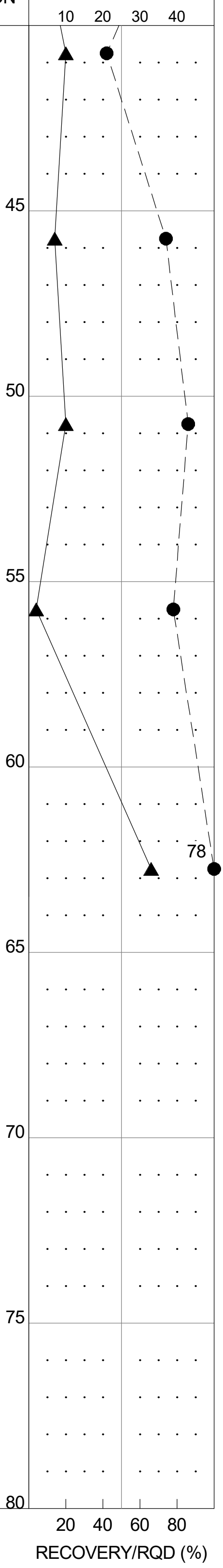
STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

AUG 2018
PROJ 2613
FIG. A-26

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION SURFACE ELEVATION: 35.3 FT.	SAMPLE NO.	SAMPLE PEN. DATA	GROUND WATER/ INSTRUMENT INSTALLATION
		(continued from previous page)	S-8	5 5 5	
		…encountered scattered fine to coarse subrounded gravel from 39 to 41.5 feet			
			S-9	8 4 3	
			S-10	1 2 8	
			S-11	1 1 1	
-23.7	59	MEDIUM DENSE, white to light gray, silty fine SAND; very poorly graded clean sand (ASH DEPOSIT/COLUMBIA RIVER ALLUVIUM?)	S-12		
			S-13	8 15 18	
-28.2	63.5	Bottom of Boring: 63.5 FT			

PENETRATION TEST (BLOWS PER FOOT)

WATER CONTENT (%)



LEGEND

▨	2-INCH O.D. SPLIT SPOON
☒	3-INCH O.D. SPLIT SPOON
▯	3-INCH O.D. THIN WALL SAMPLER
▥	3-INCH O.D. PITCHER TUBE SAMPLER
*	NO SAMPLE RECOVERY
▼ MM/DD/YY	GROUND WATER LEVEL AND DATE OBSERVED
●—┤	LIQUID LIMIT WATER CONTENT PLASTIC LIMIT
▲	STANDARD PENETRATION TEST (BLOWS/FT.)
●	WATER CONTENT IN PERCENT
▨	CORE RECOVERY IN PERCENT
■	RQD IN PERCENT
] PT-1	PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT USING A TREMIE TUBE FROM THE BOTTOM TO THE TOP OF THE HOLE.

HAMMER ASSEMBLY: AUTO TRIP

SPT SAMPLER: NO LINER - RECESSED ID

DRILL ROD USED: NWJ

BOREHOLE DIAM.: 3-7/8"

DRILLER: WESTERN STATES
DATE START: 7/28/2015 FINISH: 7/28/2015
DRILLING TECHNIQUE: MUD ROTARY

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SUMMARY BORING LOG EL-03 (2 of 2)

STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

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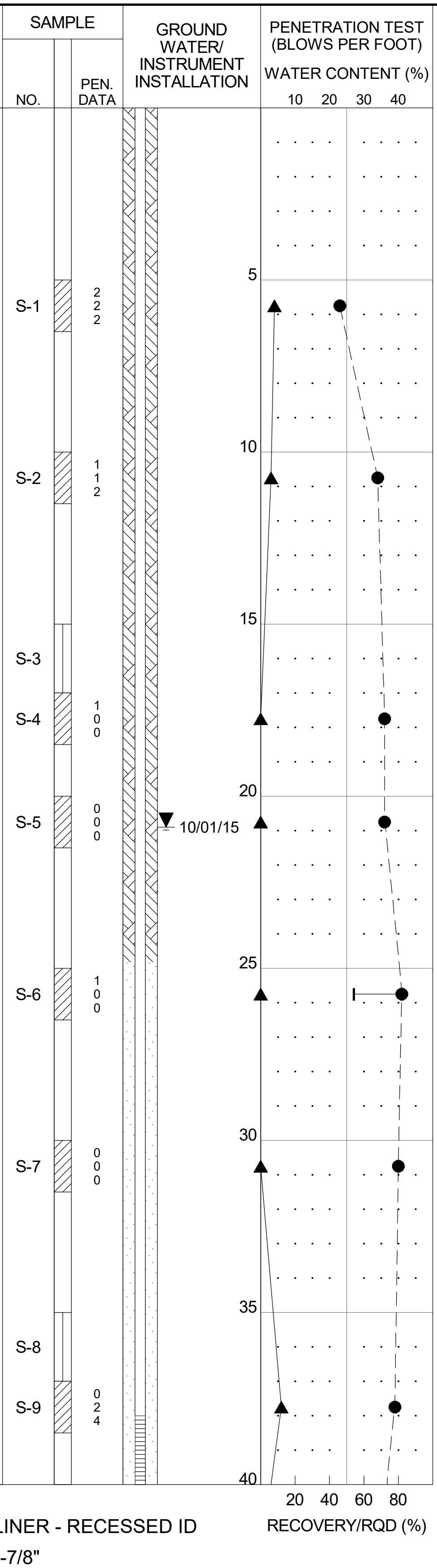
FIG. A-26

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION SURFACE ELEVATION: 37.5 FT.
		Interlayered: SOFT, brown, clayey SILT and VERY LOOSE to LOOSE, brown, silty fine SAND; some mica, occasional organics (COLUMBIA RIVER ALLUVIUM)
		…becomes gray at 34 feet
-2.5	40	



SAMPLE NO.	PEN. DATA
S-1	2 2 2
S-2	1 1 2
S-3	
S-4	1 0 0
S-5	0 0 0
S-6	1 0 0
S-7	0 0 0
S-8	
S-9	0 2 4

LEGEND

▨	2-INCH O.D. SPLIT SPOON
☒	3-INCH O.D. SPLIT SPOON
▯	3-INCH O.D. THIN WALL SAMPLER
▥	3-INCH O.D. PITCHER TUBE SAMPLER
*	NO SAMPLE RECOVERY
▼ MM/DD/YY	GROUND WATER LEVEL AND DATE OBSERVED
⊢●⊣	LIQUID LIMIT WATER CONTENT PLASTIC LIMIT
▲	STANDARD PENETRATION TEST (BLOWS/FT.)
●	WATER CONTENT IN PERCENT
▨	CORE RECOVERY IN PERCENT
■	RQD IN PERCENT
] PT-1	PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. STANDPIPE PIEZOMETER INSTALLED AT COMPLETION OF DRILLING. STANDPIPE CONSISTS OF 1-INCH DIAMETER SCHEDULE 80, SLOTTED PVC PIPE BACKFILLED WITH 10-20 COLORADO SAND IN FILTER ZONE.
3. FLUSH MOUNT MOVEMENT INSTALLED.

HAMMER ASSEMBLY: AUTO TRIP
SPT SAMPLER: NO LINER - RECESSED ID
DRILL ROD USED: NWJ
BOREHOLE DIAM.: 3-7/8"

DRILLER: WESTERN STATES
DATE START: 7/29/2015 FINISH: 7/29/2015
DRILLING TECHNIQUE: MUD ROTARY

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SUMMARY BORING LOG
EL-04 (1 of 2)

STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

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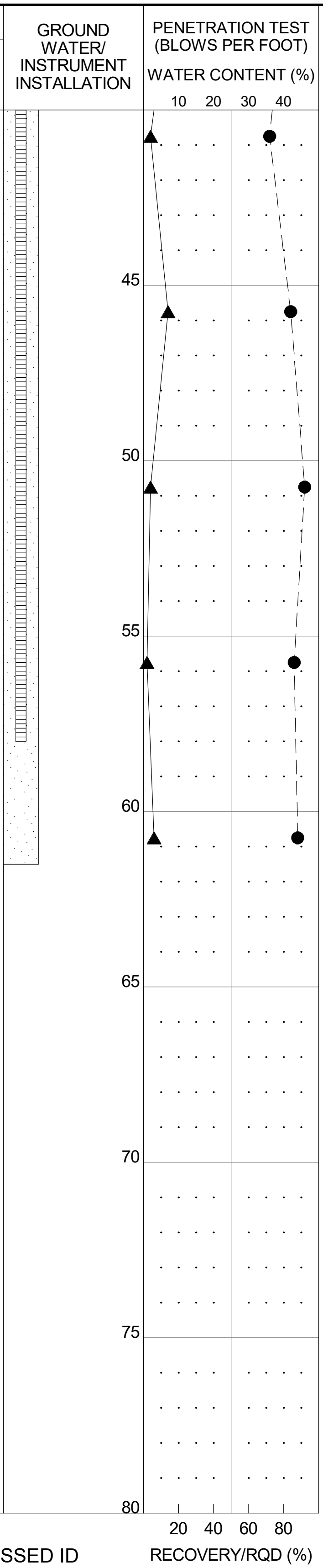
FIG. A-27

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION SURFACE ELEVATION: 37.5 FT.	SAMPLE NO.	SAMPLE PEN. DATA
		(continued from previous page)	S-10	0 1 1
			S-11	0 5 2
			S-12	1 1 1
			S-13	1 1 0
			S-14	0 1 2
-24.0	61.5	Bottom of Boring: 61.5 FT		



LEGEND

▨ 2-INCH O.D. SPLIT SPOON

☒ 3-INCH O.D. SPLIT SPOON

▯ 3-INCH O.D. THIN WALL SAMPLER

▥ 3-INCH O.D. PITCHER TUBE SAMPLER

* NO SAMPLE RECOVERY

▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED

├●┤ LIQUID LIMIT, WATER CONTENT, PLASTIC LIMIT

▲ STANDARD PENETRATION TEST (BLOWS/FT.)

● WATER CONTENT IN PERCENT

▨ CORE RECOVERY IN PERCENT

■ RQD IN PERCENT

] PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. STANDPIPE PIEZOMETER INSTALLED AT COMPLETION OF DRILLING. STANDPIPE CONSISTS OF 1-INCH DIAMETER SCHEDULE 80, SLOTTED PVC PIPE BACKFILLED WITH 10-20 COLORADO SAND IN FILTER ZONE.
3. FLUSH MOUNT MOVEMENT INSTALLED.

HAMMER ASSEMBLY: AUTO TRIP
SPT SAMPLER: NO LINER - RECESSED ID
DRILL ROD USED: NWJ
BOREHOLE DIAM.: 3-7/8"

DRILLER: WESTERN STATES
DATE START: 7/29/2015 FINISH: 7/29/2015
DRILLING TECHNIQUE: MUD ROTARY

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SUMMARY BORING LOG EL-04 (2 of 2)

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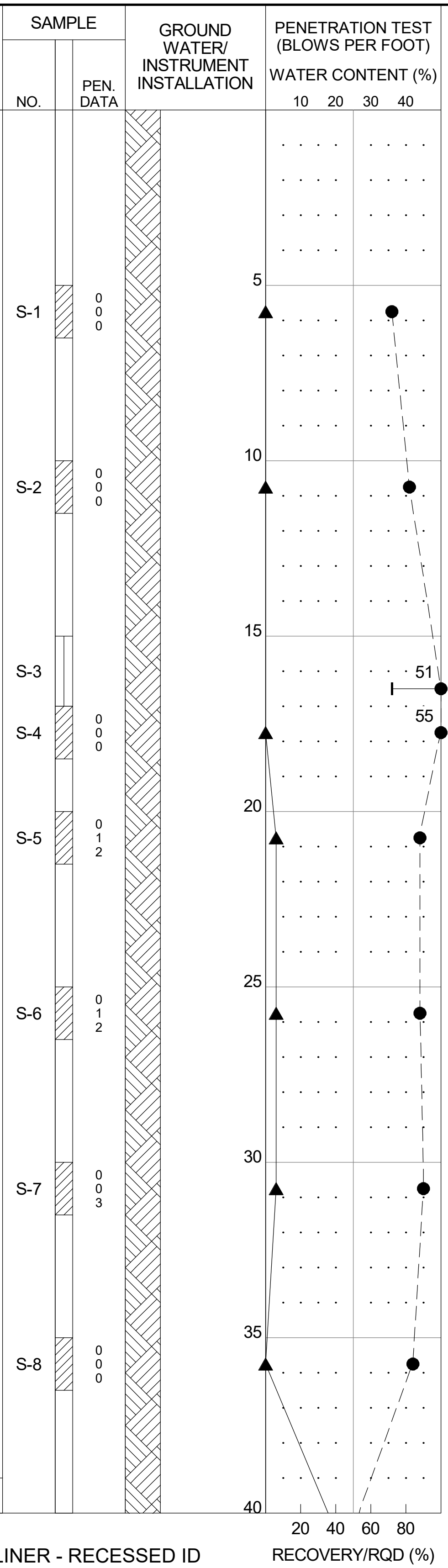
FIG. A-27

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION SURFACE ELEVATION: 26.2 FT.
		Interlayered: SOFT, brown, fine-sandy SILT and VERY LOOSE to LOOSE, brown, silty fine SAND; some mica, occasional organics (COLUMBIA RIVER ALLUVIUM)
		…becomes gray at 13 feet
-12.8	39	
-13.8	40	MEDIUM DENSE, dark gray, GRAVEL in a matrix of



LEGEND

- ▨ 2-INCH O.D. SPLIT SPOON
- ☒ 3-INCH O.D. SPLIT SPOON
- ▯ 3-INCH O.D. THIN WALL SAMPLER
- ▥ 3-INCH O.D. PITCHER TUBE SAMPLER
- * NO SAMPLE RECOVERY
- ▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED
- LIQUID LIMIT, WATER CONTENT, PLASTIC LIMIT
- ▲ STANDARD PENETRATION TEST (BLOWS/FT.)
- ● WATER CONTENT IN PERCENT
- ▨ CORE RECOVERY IN PERCENT
- ■ RQD IN PERCENT
- PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT USING A TREMIE TUBE FROM THE BOTTOM TO THE TOP OF THE HOLE.

HAMMER ASSEMBLY: AUTO TRIP

SPT SAMPLER: NO LINER - RECESSED ID

DRILL ROD USED: NWJ

BOREHOLE DIAM.: 3-7/8"

DRILLER: WESTERN STATES

DATE START: 7/31/2015 FINISH: 7/31/2015

DRILLING TECHNIQUE: MUD ROTARY

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SUMMARY BORING LOG
EL-05 (1 of 2)

STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

AUG 2018

PROJ 2613

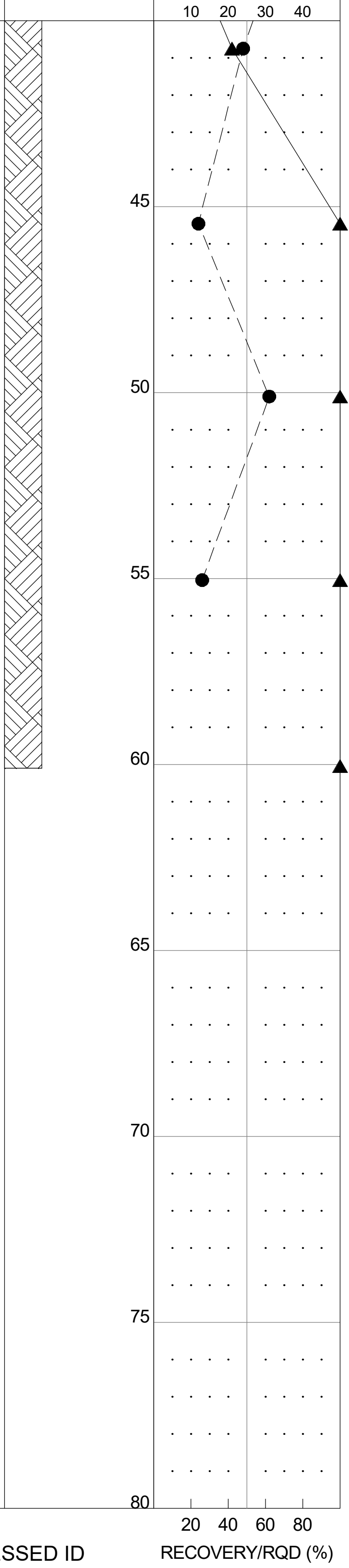
FIG. A-28

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION SURFACE ELEVATION: 26.2 FT.	SAMPLE NO.		SAMPLE PEN. DATA
		(continued from previous page) silty sand; some mica (COLUMBIA RIVER ALLUVIUM)	S-9	▨	4 12 9
-17.8	44	DENSE, dark gray, GRAVEL and COBBLES in a matrix of silty sand (CATACLYSMIC-FLOOD DEPOSIT)	S-10	▨	47 26 50/5"
			S-11	▨	50/3"
			S-12	▨	50/1"
-33.9	60.1	Bottom of Boring: 60.1 FT	S-13 *	▨	50/1"

GROUND WATER/ INSTRUMENT INSTALLATION

PENETRATION TEST (BLOWS PER FOOT)

WATER CONTENT (%)



LEGEND

- ▨ 2-INCH O.D. SPLIT SPOON
- ☒ 3-INCH O.D. SPLIT SPOON
- ▯ 3-INCH O.D. THIN WALL SAMPLER
- ▥ 3-INCH O.D. PITCHER TUBE SAMPLER
- * NO SAMPLE RECOVERY
- ▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED
- LIQUID LIMIT / WATER CONTENT / PLASTIC LIMIT
- ▲ STANDARD PENETRATION TEST (BLOWS/FT.)
- ● WATER CONTENT IN PERCENT
- ▨ CORE RECOVERY IN PERCENT
- ■ RQD IN PERCENT
-] PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT USING A TREMIE TUBE FROM THE BOTTOM TO THE TOP OF THE HOLE.

HAMMER ASSEMBLY: AUTO TRIP
SPT SAMPLER: NO LINER - RECESSED ID
DRILL ROD USED: NWJ
BOREHOLE DIAM.: 3-7/8"

DRILLER: WESTERN STATES
DATE START: 7/31/2015 FINISH: 7/31/2015
DRILLING TECHNIQUE: MUD ROTARY

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SUMMARY BORING LOG
EL-05 (2 of 2)

STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

AUG 2018

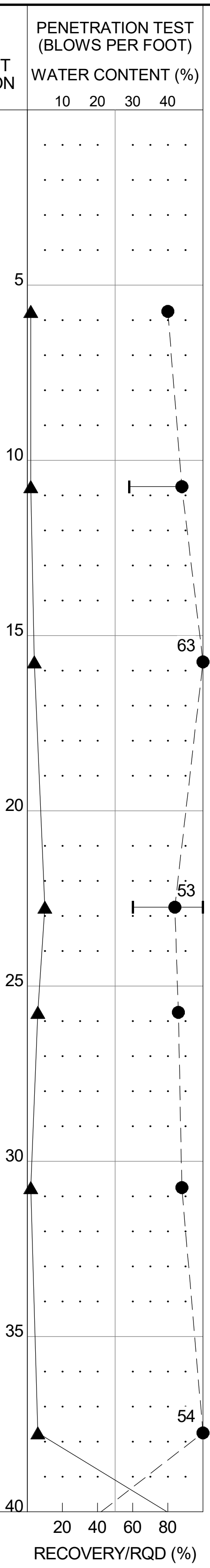
PROJ 2613

FIG. A-28

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION
		SURFACE ELEVATION: 24.6 FT.
		Interlayered: SOFT, brown, fine-sandy SILT to clayey SILT and VERY LOOSE to LOOSE, brown, silty fine SAND; some mica, occasional organics (COLUMBIA RIVER ALLUVIUM)
		…becomes gray at 13 feet
		…encountered zone of woody debris at 37 feet
-14.4	39	
-15.4	40	

SAMPLE NO.	PEN. DATA
S-1	0 1 0
S-2	0 1 0
S-3	0 0 2
S-4	
S-5	0 2 3
S-6	0 1 2
S-7	1 0 1
S-8	
S-9	0 1 2

GROUND WATER/ INSTRUMENT INSTALLATION



LEGEND

- ▨ 2-INCH O.D. SPLIT SPOON
- ☒ 3-INCH O.D. SPLIT SPOON
- ▯ 3-INCH O.D. THIN WALL SAMPLER
- ▥ 3-INCH O.D. PITCHER TUBE SAMPLER
- * NO SAMPLE RECOVERY
- ▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED
- ├●┤ LIQUID LIMIT, WATER CONTENT, PLASTIC LIMIT
- ▲ STANDARD PENETRATION TEST (BLOWS/FT.)
- ● WATER CONTENT IN PERCENT
- ▨ CORE RECOVERY IN PERCENT
- ■ RQD IN PERCENT
-] PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT USING A TREMIE TUBE FROM THE BOTTOM TO THE TOP OF THE HOLE.

HAMMER ASSEMBLY: AUTO TRIP
SPT SAMPLER: NO LINER - RECESSED ID
DRILL ROD USED: NWJ
BOREHOLE DIAM.: 8-1/4" (0'-25'), 3-7/8" (25'-80')

DRILLER: WESTERN STATES
DATE START: 7/30/2015 FINISH: 7/30/2015
DRILLING TECHNIQUE: HOLLOW STEM AUGER/MUD ROTARY

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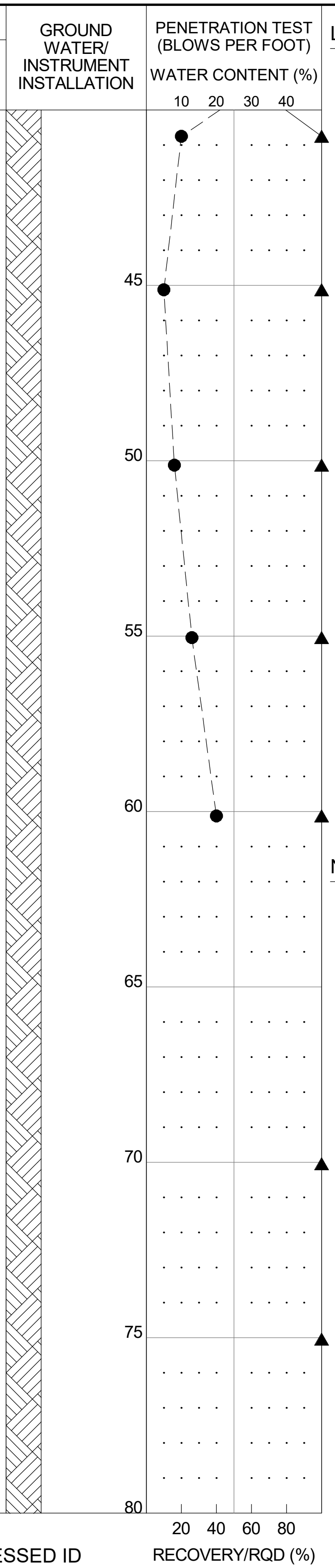
SUMMARY BORING LOG
EL-06 (1 of 3)

STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

AUG 2018
PROJ 2613
FIG. A-29

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION SURFACE ELEVATION: 24.6 FT.	SAMPLE NO.	SAMPLE PEN. DATA
		(continued from previous page) DENSE, dark gray, GRAVEL and COBBLES in a matrix of silty sand (CATACLYSMIC-FLOOD DEPOSIT)	S-10	12 28 24
			S-11	50/3"
			S-12	50/3"
			S-13	50/1"
			S-14	50/3"
			S-15 *	50/1"
			S-16 *	50/1"



LEGEND

- ▨ 2-INCH O.D. SPLIT SPOON
- ☒ 3-INCH O.D. SPLIT SPOON
- ▯ 3-INCH O.D. THIN WALL SAMPLER
- ▥ 3-INCH O.D. PITCHER TUBE SAMPLER
- * NO SAMPLE RECOVERY
- ▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED
- ├●┤ LIQUID LIMIT, WATER CONTENT, PLASTIC LIMIT
- ▲ STANDARD PENETRATION TEST (BLOWS/FT.)
- ● WATER CONTENT IN PERCENT
- ▨ CORE RECOVERY IN PERCENT
- ■ RQD IN PERCENT
-] PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT USING A TREMIE TUBE FROM THE BOTTOM TO THE TOP OF THE HOLE.

HAMMER ASSEMBLY: AUTO TRIP
SPT SAMPLER: NO LINER - RECESSED ID
DRILL ROD USED: NWJ
BOREHOLE DIAM.: 8-1/4" (0'-25'), 3-7/8" (25'-80')

DRILLER: WESTERN STATES
DATE START: 7/30/2015 FINISH: 7/30/2015
DRILLING TECHNIQUE: HOLLOW STEM AUGER/MUD ROTARY

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10250 S.W. Greenburg Road, Suite 111
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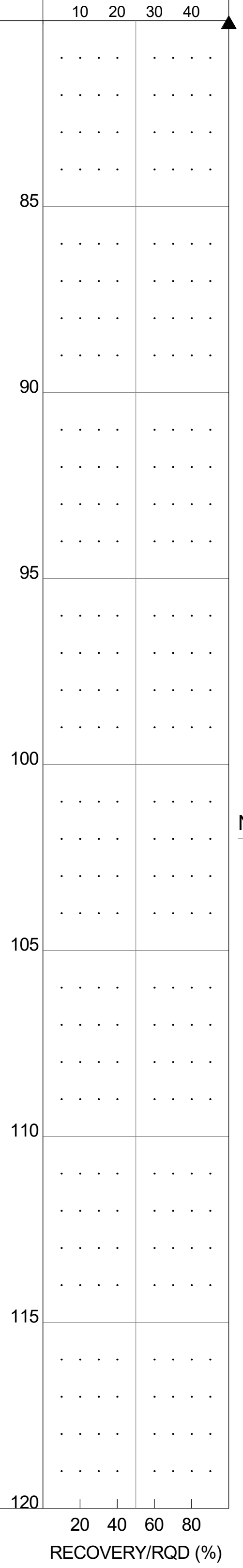
SUMMARY BORING LOG
EL-06 (2 of 3)

STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

AUG 2018
PROJ 2613
FIG. A-29

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION SURFACE ELEVATION: 24.6 FT.	SAMPLE NO.		SAMPLE PEN. DATA	GROUND WATER/ INSTRUMENT INSTALLATION	PENETRATION TEST (BLOWS PER FOOT) WATER CONTENT (%)
-55.5	80.1	Bottom of Boring: 80.1 FT	S-17	*	50/1"		▲



LEGEND

▨ 2-INCH O.D. SPLIT SPOON

☒ 3-INCH O.D. SPLIT SPOON

▯ 3-INCH O.D. THIN WALL SAMPLER

▥ 3-INCH O.D. PITCHER TUBE SAMPLER

* NO SAMPLE RECOVERY

▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED

LIQUID LIMIT

WATER CONTENT

PLASTIC LIMIT

▲ STANDARD PENETRATION TEST (BLOWS/FT.)

● WATER CONTENT IN PERCENT

▨ CORE RECOVERY IN PERCENT

■ RQD IN PERCENT

] PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT USING A TREMIE TUBE FROM THE BOTTOM TO THE TOP OF THE HOLE.

HAMMER ASSEMBLY: AUTO TRIP

SPT SAMPLER: NO LINER - RECESSED ID

DRILL ROD USED: NWJ

BOREHOLE DIAM.: 8-1/4" (0'-25'), 3-7/8" (25'-80')

DRILLER: WESTERN STATES
DATE START: 7/30/2015 FINISH: 7/30/2015
DRILLING TECHNIQUE: HOLLOW STEM AUGER/MUD ROTARY

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SUMMARY BORING LOG
EL-06 (3 of 3)

STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

AUG 2018

PROJ 2613

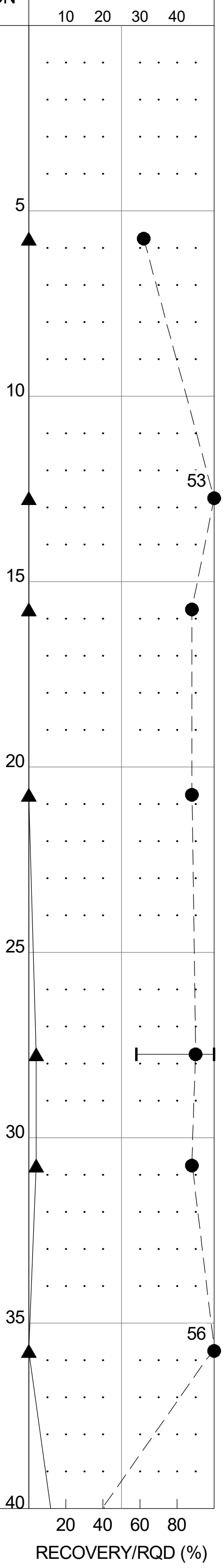
FIG. A-29

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION SURFACE ELEVATION: 27.9 FT.	SAMPLE NO.	PEN. DATA
		Interlayered: VERY LOOSE, brown and grey, sandy SILT to silty SAND to SOFT, clayey SILT to very silty CLAY; occasional mica and occasional local organics, moist (ALLUVIUM)		
			S-1	0 0 0
			S-2	
			S-3	0 0 0
			S-4	0 0 0
		… color switches from brown to grey		
			S-5	0 0 0
			S-6	
			S-7	0 0 2
			S-8	0 0 2
		… rounded fine gravels and coarse sand		
			S-9	0 0 0
-11.1	39			

GROUND WATER/ INSTRUMENT INSTALLATION

PENETRATION TEST (BLOWS PER FOOT)

WATER CONTENT (%)



LEGEND

- ▨ 2-INCH O.D. SPLIT SPOON
- ☒ 3-INCH O.D. SPLIT SPOON
- ▯ 3-INCH O.D. THIN WALL SAMPLER
- ▥ 3-INCH O.D. PITCHER TUBE SAMPLER
- * NO SAMPLE RECOVERY
- ▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED
- ⊢●⊣ LIQUID LIMIT, WATER CONTENT, PLASTIC LIMIT
- ▲ STANDARD PENETRATION TEST (BLOWS/FT.)
- ● WATER CONTENT IN PERCENT
- ▨ CORE RECOVERY IN PERCENT
- ■ RQD IN PERCENT
-] PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT USING A TREMIE TUBE FROM THE BOTTOM TO THE TOP OF THE HOLE.

HAMMER ASSEMBLY: AUTO TRIP
SPT SAMPLER: NO LINER - RECESSED ID
DRILL ROD USED: NWJ
BOREHOLE DIAM.: 3-7/8"

DRILLER: WESTERN STATES
DATE START: 8/3/2015 FINISH: 8/3/2015
DRILLING TECHNIQUE: MUD ROTARY

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SUMMARY BORING LOG
EL-07 (1 of 2)

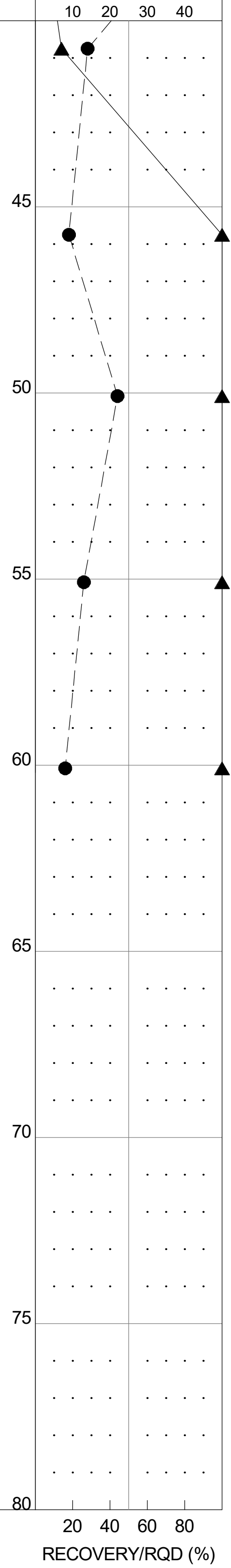
STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

AUG 2018

PROJ 2613

FIG. A-30

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION SURFACE ELEVATION: 27.9 FT.	SAMPLE NO.	SAMPLE PEN. DATA	GROUND WATER/ INSTRUMENT INSTALLATION	PENETRATION TEST (BLOWS PER FOOT) WATER CONTENT (%)
		VERY DENSE, grey, very sandy GRAVEL to very gravely SAND; occasional mica, rounded gravels and occasional cobbles in a matrix of coarse to medium sand, wet (ALLUVIUM) … LOOSE at 40 feet, becomes VERY DENSE at 45 feet	S-10	2 2 5		
			S-11	28 27 34		
			S-12	50/2"		
			S-13	50/2"		
-32.3	60.2	Bottom of Boring: 60.2 FT	S-14	50/2"		



LEGEND

- ▨ 2-INCH O.D. SPLIT SPOON
- ☒ 3-INCH O.D. SPLIT SPOON
- ▯ 3-INCH O.D. THIN WALL SAMPLER
- ▥ 3-INCH O.D. PITCHER TUBE SAMPLER
- * NO SAMPLE RECOVERY
- ▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED
- ├●┤ LIQUID LIMIT, WATER CONTENT, PLASTIC LIMIT
- ▲ STANDARD PENETRATION TEST (BLOWS/FT.)
- ● WATER CONTENT IN PERCENT
- ▨ CORE RECOVERY IN PERCENT
- ■ RQD IN PERCENT
-] PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT USING A TREMIE TUBE FROM THE BOTTOM TO THE TOP OF THE HOLE.

HAMMER ASSEMBLY: AUTO TRIP
SPT SAMPLER: NO LINER - RECESSED ID
DRILL ROD USED: NWJ
BOREHOLE DIAM.: 3-7/8"

DRILLER: WESTERN STATES
DATE START: 8/3/2015 FINISH: 8/3/2015
DRILLING TECHNIQUE: MUD ROTARY

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SUMMARY BORING LOG
EL-07 (2 of 2)

STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

AUG 2018

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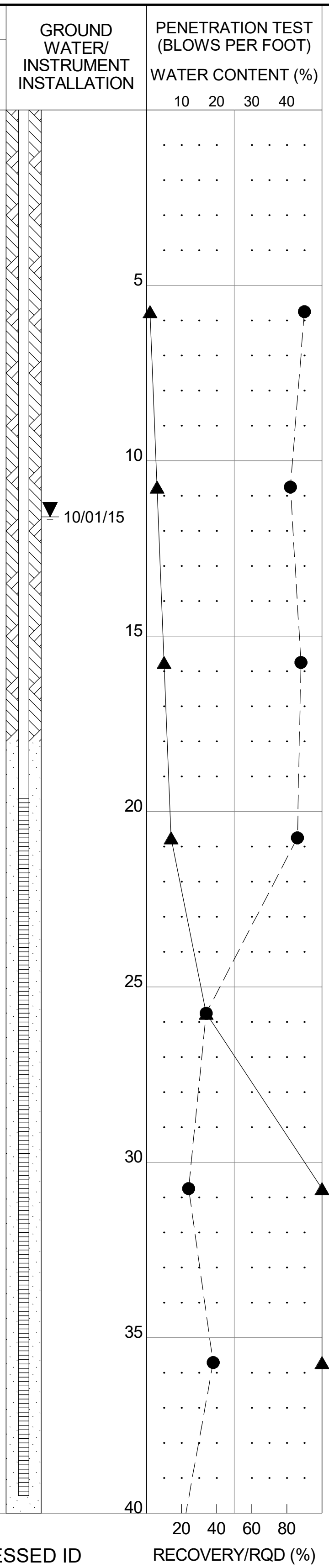
FIG. A-30

SURFACE ELEVATION: 23.0 FT.

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION	SAMPLE NO.	PEN. DATA
		Interlayered: SOFT, brown, fine-sandy SILT and VERY LOOSE to LOOSE, brown, silty fine SAND; some mica, occasional organics (COLUMBIA RIVER ALLUVIUM)		
			S-1	0 0 1
		...becomes gray at 8 feet		
			S-2	1 1 2
			S-3	1 2 3
			S-4	2 4 3
-1.0	24	MEDIUM DENSE, dark gray, GRAVEL and COBBLES in a matrix of silty sand; subrounded gravels (CATACLYSMIC-FLOOD DEPOSIT)		
			S-5	4 7 10
		....becomes dense at 29 feet		
			S-6	17 16 40
			S-7	19 33 50/5"



LEGEND

- ▨ 2-INCH O.D. SPLIT SPOON
- ☒ 3-INCH O.D. SPLIT SPOON
- ▯ 3-INCH O.D. THIN WALL SAMPLER
- ▥ 3-INCH O.D. PITCHER TUBE SAMPLER
- * NO SAMPLE RECOVERY
- ▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED
- ├─●─┤ LIQUID LIMIT, WATER CONTENT, PLASTIC LIMIT
- ▲ STANDARD PENETRATION TEST (BLOWS/FT.)
- ● WATER CONTENT IN PERCENT
- ▨ CORE RECOVERY IN PERCENT
- ■ RQD IN PERCENT
-] PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. STANDPIPE PIEZOMETER INSTALLED AT COMPLETION OF DRILLING. STANDPIPE CONSISTS OF 1-INCH DIAMETER SCHEDULE 80, SLOTTED PVC PIPE BACKFILLED WITH 10-20 COLORADO SAND IN FILTER ZONE.
3. FLUSH MOUNT MOVEMENT INSTALLED.

HAMMER ASSEMBLY: AUTO TRIP
SPT SAMPLER: NO LINER - RECESSED ID
DRILL ROD USED: NWJ
BOREHOLE DIAM.: 8-1/4"

DRILLER: WESTERN STATES
DATE START: 8/6/2015 FINISH: 8/6/2015
DRILLING TECHNIQUE: HOLLOW STEM AUGER

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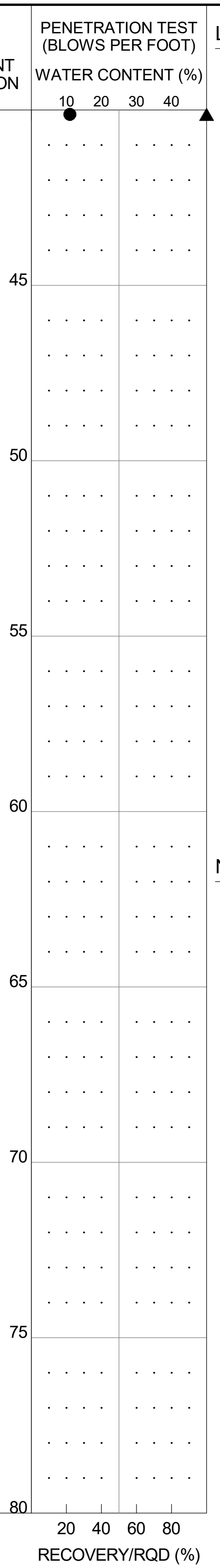
SUMMARY BORING LOG EL-08 (1 of 2)

STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

AUG 2018
PROJ 2613
FIG. A-31

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION SURFACE ELEVATION: 23.0 FT.	SAMPLE NO.		SAMPLE PEN. DATA	GROUND WATER/ INSTRUMENT INSTALLATION
-17.3	40.3	Bottom of Boring: 40.3 FT	S-8	▨	50/3"	



LEGEND

- ▨ 2-INCH O.D. SPLIT SPOON
- ☒ 3-INCH O.D. SPLIT SPOON
- ▯ 3-INCH O.D. THIN WALL SAMPLER
- ▥ 3-INCH O.D. PITCHER TUBE SAMPLER
- * NO SAMPLE RECOVERY
- ▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED
- LIQUID LIMIT, WATER CONTENT, PLASTIC LIMIT
- ▲ STANDARD PENETRATION TEST (BLOWS/FT.)
- ● WATER CONTENT IN PERCENT
- ▨ CORE RECOVERY IN PERCENT
- ■ RQD IN PERCENT
-] PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. STANDPIPE PIEZOMETER INSTALLED AT COMPLETION OF DRILLING. STANDPIPE CONSISTS OF 1-INCH DIAMETER SCHEDULE 80, SLOTTED PVC PIPE BACKFILLED WITH 10-20 COLORADO SAND IN FILTER ZONE.
3. FLUSH MOUNT MOVEMENT INSTALLED.

HAMMER ASSEMBLY: AUTO TRIP
SPT SAMPLER: NO LINER - RECESSED ID
DRILL ROD USED: NWJ
BOREHOLE DIAM.: 8-1/4"

DRILLER: WESTERN STATES
DATE START: 8/6/2015 FINISH: 8/6/2015
DRILLING TECHNIQUE: HOLLOW STEM AUGER

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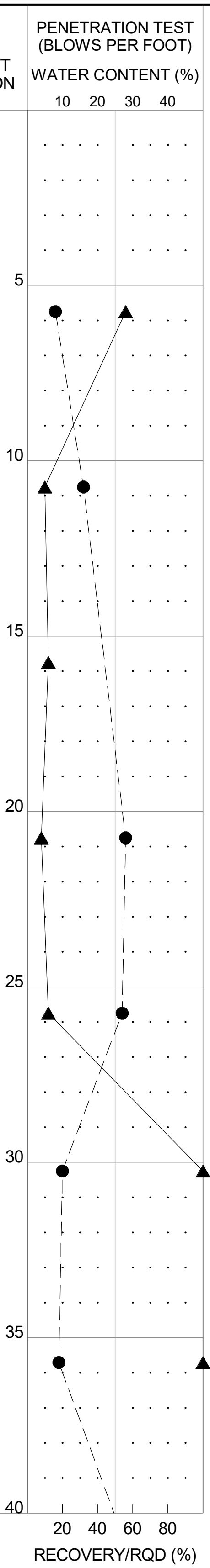
SUMMARY BORING LOG
EL-08 (2 of 2)

STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

AUG 2018
PROJ 2613
FIG. A-31

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION SURFACE ELEVATION: 24.3 FT.	SAMPLE NO.	SAMPLE PEN. DATA	GROUND WATER/ INSTRUMENT INSTALLATION
		MEDIUM DENSE, brown and gray, GRAVEL in a matrix of silty sand; subrounded gravels (COLUMBIA RIVER ALLUVIUM OR LAWTON CREEK ALLUVIAL FAN)			
			S-1	15 15 13	
			S-2	4 3 2	
11.3	13	LOOSE to MEDIUM DENSE, brown, gravelly SAND; occasional mica, rounded fine gravel (COLUMBIA RIVER ALLUVIUM)			
			S-3	4 3 3	
			S-4	3 2 2	
			S-5	3 3 3	
-3.7	28	DENSE, dark gray, GRAVEL and COBBLES in a matrix of silty sand; subrounded gravels (CATACLYSMIC-FLOOD DEPOSIT)			
			S-6	50/6"	
			S-7	19 17 50/5"	



LEGEND

▨ 2-INCH O.D. SPLIT SPOON

☒ 3-INCH O.D. SPLIT SPOON

▯ 3-INCH O.D. THIN WALL SAMPLER

▥ 3-INCH O.D. PITCHER TUBE SAMPLER

* NO SAMPLE RECOVERY

▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED

LIQUID LIMIT / WATER CONTENT / PLASTIC LIMIT

▲ STANDARD PENETRATION TEST (BLOWS/FT.)

● WATER CONTENT IN PERCENT

▨ CORE RECOVERY IN PERCENT

■ RQD IN PERCENT

PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT USING A TREMIE TUBE FROM THE BOTTOM TO THE TOP OF THE HOLE.

HAMMER ASSEMBLY: AUTO TRIP
SPT SAMPLER: NO LINER - RECESSED ID
DRILL ROD USED: NWJ
BOREHOLE DIAM.: 3-7/8"

DRILLER: WESTERN STATES
DATE START: 8/4/2015 FINISH: 8/4/2015
DRILLING TECHNIQUE: MUD ROTARY

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SUMMARY BORING LOG EL-09 (1 of 2)

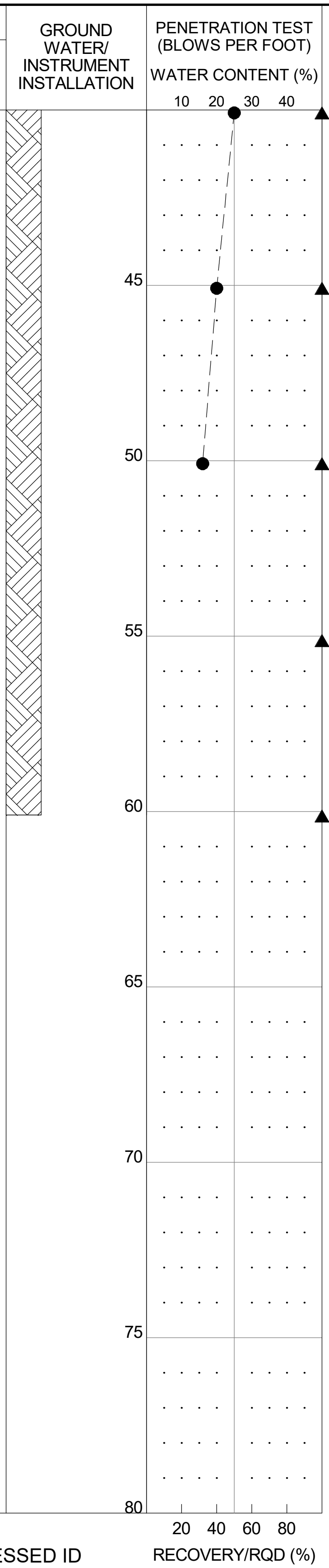
STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

AUG 2018

PROJ 2613

FIG. A-32

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION SURFACE ELEVATION: 24.3 FT.	SAMPLE NO.	SAMPLE PEN. DATA
		DENSE, dark gray, GRAVEL and COBBLES in a matrix of silty sand; subrounded gravels (CATACLYSMIC-FLOOD DEPOSIT)	S-8	50/2"
			S-9	50/2"
			S-10	50/2"
			S-11 *	50/3"
-35.8	60.1	Bottom of Boring: 60.1 FT	S-12 *	50/3"



LEGEND

▨	2-INCH O.D. SPLIT SPOON
☒	3-INCH O.D. SPLIT SPOON
▯	3-INCH O.D. THIN WALL SAMPLER
▥	3-INCH O.D. PITCHER TUBE SAMPLER
*	NO SAMPLE RECOVERY
▼ MM/DD/YY	GROUND WATER LEVEL AND DATE OBSERVED
├─●─┤	LIQUID LIMIT WATER CONTENT PLASTIC LIMIT
▲	STANDARD PENETRATION TEST (BLOWS/FT.)
●	WATER CONTENT IN PERCENT
▨	CORE RECOVERY IN PERCENT
■	RQD IN PERCENT
] PT-1	PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT USING A TREMIE TUBE FROM THE BOTTOM TO THE TOP OF THE HOLE.

HAMMER ASSEMBLY: AUTO TRIP

SPT SAMPLER: NO LINER - RECESSED ID

DRILL ROD USED: NWJ

BOREHOLE DIAM.: 3-7/8"

DRILLER: WESTERN STATES

DATE START: 8/4/2015 FINISH: 8/4/2015

DRILLING TECHNIQUE: MUD ROTARY

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SUMMARY BORING LOG
EL-09 (2 of 2)

STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

AUG 2018

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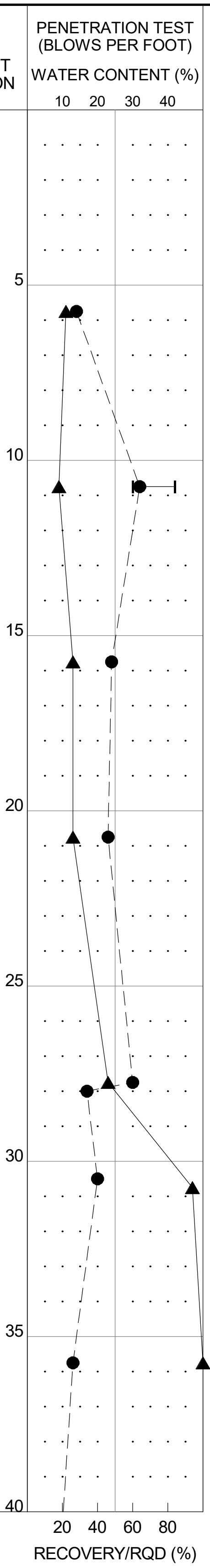
FIG. A-32

SURFACE ELEVATION: 26.8 FT.

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION	SAMPLE NO.	SAMPLE PEN. DATA	GROUND WATER/ INSTRUMENT INSTALLATION
		MEDIUM DENSE, brown and gray, GRAVEL in a matrix of silty sand; subrounded gravels (COLUMBIA RIVER ALLUVIUM OR LAWTON CREEK ALLUVIAL FAN)			
			S-1	5 6 5	
			S-2	5 5 4	
			S-3	6 8 5	
			S-4	5 6 7	
			S-5		
			S-6	4 4 19	
-2.2	29	DENSE, dark gray, GRAVEL and COBBLES in a matrix of silty sand; subrounded gravels (CATACLYSMIC-FLOOD DEPOSIT)			
			S-7	12 12 35	
			S-8	40 42 30	



LEGEND

- ▨ 2-INCH O.D. SPLIT SPOON
- ☒ 3-INCH O.D. SPLIT SPOON
- ▯ 3-INCH O.D. THIN WALL SAMPLER
- ▥ 3-INCH O.D. PITCHER TUBE SAMPLER
- * NO SAMPLE RECOVERY
- ▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED
- LIQUID LIMIT, WATER CONTENT, PLASTIC LIMIT
- ▲ STANDARD PENETRATION TEST (BLOWS/FT.)
- ● WATER CONTENT IN PERCENT
- ▨ CORE RECOVERY IN PERCENT
- ■ RQD IN PERCENT
- PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT USING A TREMIE TUBE FROM THE BOTTOM TO THE TOP OF THE HOLE.

HAMMER ASSEMBLY: AUTO TRIP
SPT SAMPLER: NO LINER - RECESSED ID
DRILL ROD USED: NWJ
BOREHOLE DIAM.: 4-7/8" (0'-20'), 3-7/8" (20'-60')

DRILLER: WESTERN STATES
DATE START: 8/4/2015 FINISH: 8/5/2015
DRILLING TECHNIQUE: MUD ROTARY

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SUMMARY BORING LOG
EL-10 (1 of 2)

STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

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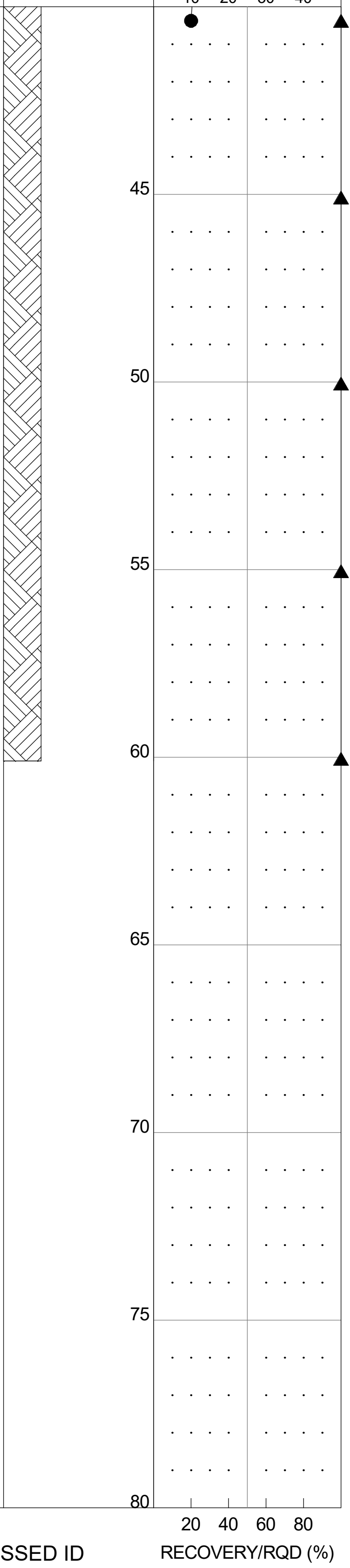
PROJ 2613
FIG. A-33

SURFACE ELEVATION: 26.8 FT.

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION	SAMPLE NO.	PEN. DATA
		DENSE, dark gray, GRAVEL and COBBLES in a matrix of silty sand; subrounded gravels (CATACLYSMIC-FLOOD DEPOSIT)	S-9	26 50/3"
			S-10 *	50/2"
			S-11 *	50/1"
			S-12 *	50/1"
-33.3	60.1	Bottom of Boring: 60.1 FT	S-13 *	50/1"



LEGEND

▨ 2-INCH O.D. SPLIT SPOON

☒ 3-INCH O.D. SPLIT SPOON

▯ 3-INCH O.D. THIN WALL SAMPLER

▥ 3-INCH O.D. PITCHER TUBE SAMPLER

* NO SAMPLE RECOVERY

▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED

├●┤ LIQUID LIMIT, WATER CONTENT, PLASTIC LIMIT

▲ STANDARD PENETRATION TEST (BLOWS/FT.)

● WATER CONTENT IN PERCENT

▨ CORE RECOVERY IN PERCENT

■ RQD IN PERCENT

] PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT USING A TREMIE TUBE FROM THE BOTTOM TO THE TOP OF THE HOLE.

HAMMER ASSEMBLY: AUTO TRIP
SPT SAMPLER: NO LINER - RECESSED ID
DRILL ROD USED: NWJ
BOREHOLE DIAM.: 4-7/8" (0'-20'), 3-7/8" (20'-60')

DRILLER: WESTERN STATES
DATE START: 8/4/2015 FINISH: 8/5/2015
DRILLING TECHNIQUE: MUD ROTARY

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SUMMARY BORING LOG
EL-10 (2 of 2)

STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

AUG 2018

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FIG. A-33

SURFACE ELEVATION: 30.0 FT.

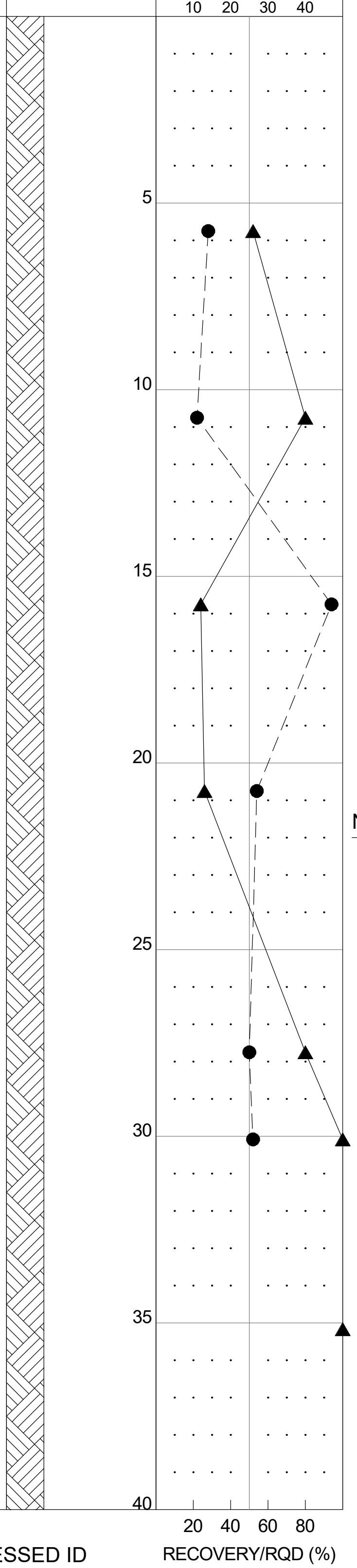
ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION
		MEDIUM DENSE, brown and gray, GRAVEL in a matrix of silty sand; subrounded gravels (COLUMBIA RIVER ALLUVIUM OR LAWTON CREEK ALLUVIAL FAN)
17.0	13	LOOSE to MEDIUM DENSE, brown, slightly gravelly SAND; occasional mica, rounded fine gravel (COLUMBIA RIVER ALLUVIUM)
1.0	29	DENSE, dark gray, GRAVEL and COBBLES in a matrix of silty sand; subrounded gravels (CATACLYSMIC-FLOOD DEPOSIT)

SAMPLE NO.		PEN. DATA
S-1	▨	12 14 12
S-2	☒	10 23 17
S-3	☒	14 7 5
S-4	☒	9 6 7
S-5	▯	
S-6	☒	10 14 26
S-7 *	☒	50/2"
S-8 *	☒	50/4"

GROUND WATER/ INSTRUMENT INSTALLATION

PENETRATION TEST (BLOWS PER FOOT)

WATER CONTENT (%)



LEGEND

▨ 2-INCH O.D. SPLIT SPOON

☒ 3-INCH O.D. SPLIT SPOON

▯ 3-INCH O.D. THIN WALL SAMPLER

▥ 3-INCH O.D. PITCHER TUBE SAMPLER

* NO SAMPLE RECOVERY

▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED

LIQUID LIMIT

WATER CONTENT

PLASTIC LIMIT

▲ STANDARD PENETRATION TEST (BLOWS/FT.)

● WATER CONTENT IN PERCENT

▨ CORE RECOVERY IN PERCENT

■ RQD IN PERCENT

] PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT USING A TREMIE TUBE FROM THE BOTTOM TO THE TOP OF THE HOLE.

HAMMER ASSEMBLY: AUTO TRIP

SPT SAMPLER: NO LINER - RECESSED ID

DRILL ROD USED: NWJ

BOREHOLE DIAM.: 4-7/8"

DRILLER: WESTERN STATES

DATE START: 8/5/2015 FINISH: 8/6/2015

DRILLING TECHNIQUE: MUD ROTARY

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10250 S.W. Greenburg Road, Suite 111
Portland, Oregon 97223
Phone 503-452-1100 Fax 503-452-1528

SUMMARY BORING LOG
EL-11 (1 of 2)

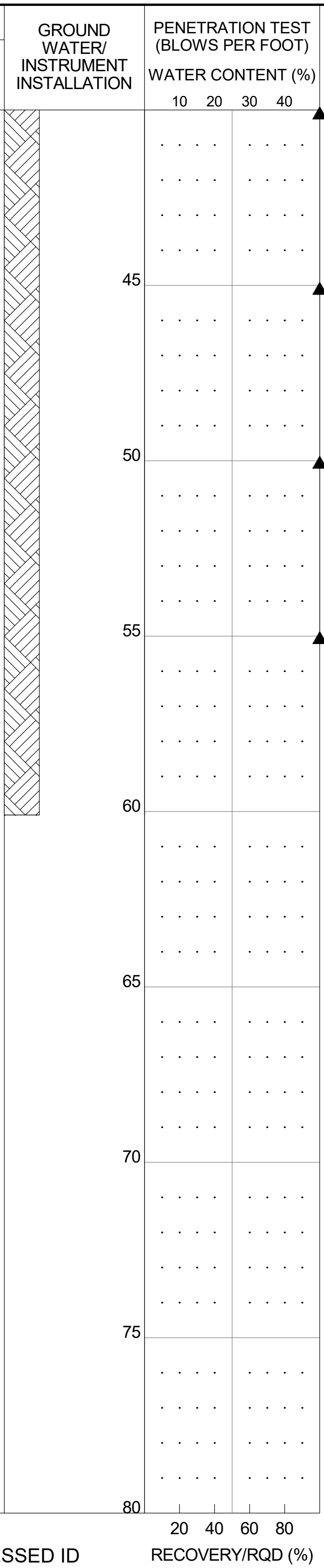
STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

AUG 2018

PROJ 2613

FIG. A-34

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION SURFACE ELEVATION: 30.0 FT.	SAMPLE NO.	SAMPLE PEN. DATA
		DENSE, dark gray, GRAVEL and COBBLES in a matrix of silty sand; subrounded gravels (CATACLYSMIC-FLOOD DEPOSIT)	S-9 *	50/2"
			S-10 *	50/2"
			S-11 *	50/1"
			S-12 *	50/1"
-30.1	60.1	Bottom of Boring: 60.1 FT		



LEGEND

- ▨ 2-INCH O.D. SPLIT SPOON
- ☒ 3-INCH O.D. SPLIT SPOON
- ▯ 3-INCH O.D. THIN WALL SAMPLER
- ▥ 3-INCH O.D. PITCHER TUBE SAMPLER
- * NO SAMPLE RECOVERY
- ▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED
- ├●┤ LIQUID LIMIT, WATER CONTENT, PLASTIC LIMIT
- ▲ STANDARD PENETRATION TEST (BLOWS/FT.)
- ● WATER CONTENT IN PERCENT
- ▨ CORE RECOVERY IN PERCENT
- ■ RQD IN PERCENT
-] PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT USING A TREMIE TUBE FROM THE BOTTOM TO THE TOP OF THE HOLE.

HAMMER ASSEMBLY: AUTO TRIP
SPT SAMPLER: NO LINER - RECESSED ID
DRILL ROD USED: NWJ
BOREHOLE DIAM.: 4-7/8"

DRILLER: WESTERN STATES
DATE START: 8/5/2015 FINISH: 8/6/2015
DRILLING TECHNIQUE: MUD ROTARY

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SUMMARY BORING LOG
EL-11 (2 of 2)

STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

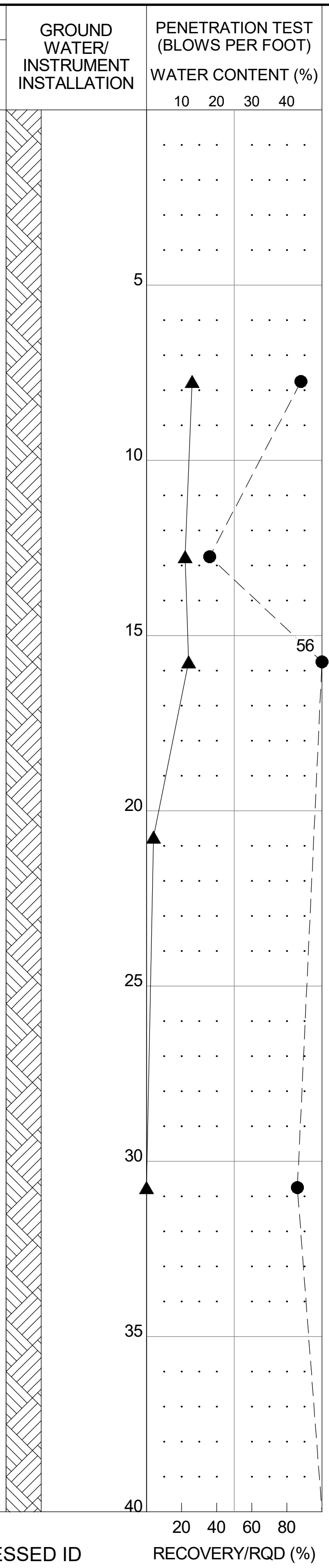
AUG 2018

PROJ 2613

FIG. A-34

DEPTH IN FEET	MATERIAL DESCRIPTION
	MEDIUM DENSE, mottled gray and brown, silty gravelly SAND; some mica, scattered organics (COLUMBIA RIVER ALLUVIUM)
	...encountered layer of organics at 13 feet
18	Interlayered: SOFT, gray, fine-sandy SILT and VERY LOOSE, gray, silty fine SAND; some mica, occasional organics (COLUMBIA RIVER ALLUVIUM)

SAMPLE NO.	PEN. DATA
S-1	
S-2	8 6 7
S-3	
S-4	1 4 7
S-5	4 8 4
S-6	1 1 1
S-7	0 0 0



LEGEND

- ▨ 2-INCH O.D. SPLIT SPOON
- ☒ 3-INCH O.D. SPLIT SPOON
- ▯ 3-INCH O.D. THIN WALL SAMPLER
- ▥ 3-INCH O.D. PITCHER TUBE SAMPLER
- * NO SAMPLE RECOVERY
- ▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED
- ●—— LIQUID LIMIT, WATER CONTENT, PLASTIC LIMIT
- ▲ STANDARD PENETRATION TEST (BLOWS/FT.)
- ● WATER CONTENT IN PERCENT
- ▨ CORE RECOVERY IN PERCENT
- ■ RQD IN PERCENT
- PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT USING A TREMIE TUBE FROM THE BOTTOM TO THE TOP OF THE HOLE.

HAMMER ASSEMBLY: AUTO TRIP

SPT SAMPLER: NO LINER - RECESSED ID

DRILL ROD USED: NWJ

BOREHOLE DIAM.: 3-7/8"

DRILLER: WESTERN STATES
DATE START: 8/27/2015 FINISH: 8/27/2015
DRILLING TECHNIQUE: MUD ROTARY

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SUMMARY BORING LOG
EL-12 (1 of 2)

STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

AUG 2018

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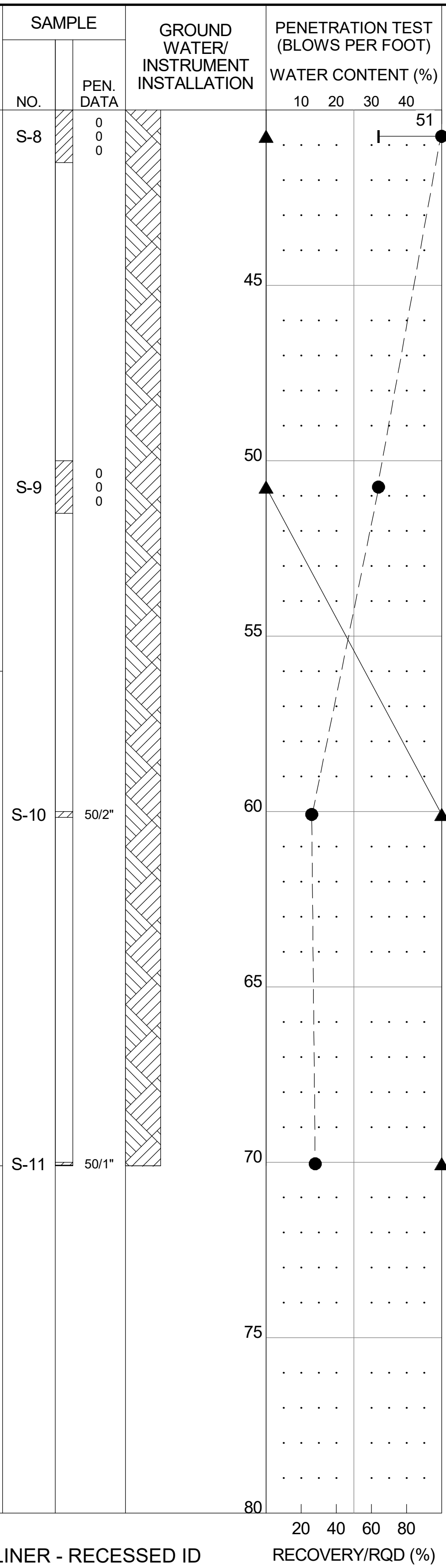
FIG. A-35

DEPTH IN FEET	MATERIAL DESCRIPTION
	Interlayered: SOFT, gray, fine-sandy SILT and VERY LOOSE, gray, silty fine SAND; some mica, occasional organics (COLUMBIA RIVER ALLUVIUM)
56	DENSE, gray, sandy GRAVEL in a matrix of brown silty sand, fine to coarse rounded gravel (CATACLYSMIC-FLOOD DEPOSIT)
70.1	Bottom of Boring: 70.1 FT



LEGEND

- ▨ 2-INCH O.D. SPLIT SPOON
- ☒ 3-INCH O.D. SPLIT SPOON
- ▯ 3-INCH O.D. THIN WALL SAMPLER
- ▥ 3-INCH O.D. PITCHER TUBE SAMPLER
- * NO SAMPLE RECOVERY
- ▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED
- ├●┤ LIQUID LIMIT, WATER CONTENT, PLASTIC LIMIT
- ▲ STANDARD PENETRATION TEST (BLOWS/FT.)
- ● WATER CONTENT IN PERCENT
- ▨ CORE RECOVERY IN PERCENT
- ■ RQD IN PERCENT
-] PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT USING A TREMIE TUBE FROM THE BOTTOM TO THE TOP OF THE HOLE.

HAMMER ASSEMBLY: AUTO TRIP
SPT SAMPLER: NO LINER - RECESSED ID
DRILL ROD USED: NWJ
BOREHOLE DIAM.: 3-7/8"

DRILLER: WESTERN STATES
DATE START: 8/27/2015 FINISH: 8/27/2015
DRILLING TECHNIQUE: MUD ROTARY

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SUMMARY BORING LOG
EL-12 (2 of 2)

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WASHOUGAL, WA

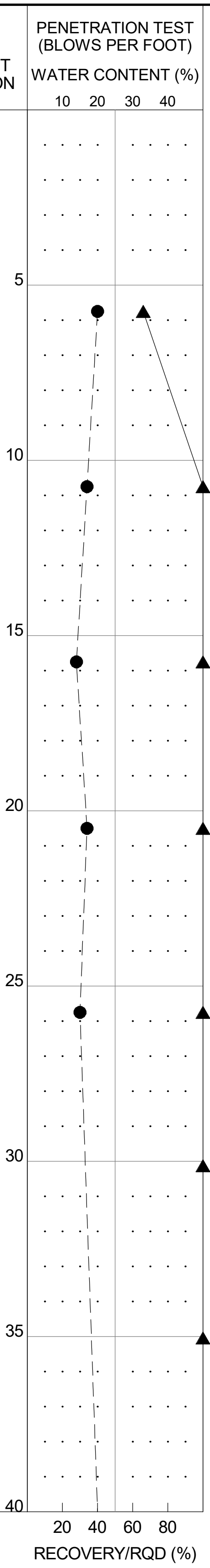
AUG 2018
PROJ 2613
FIG. A-35

SURFACE ELEVATION: 36.0 FT.

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION
		MEDIUM DENSE, dark gray and brown, GRAVEL and ROCK FRAGMENTS in a matrix of brown silty sand (FILL or GRADED GIBBONS CREEK ALLUVIAL FAN DEPOSIT)
29.0	7	DENSE, dark gray and brown, GRAVEL and ROCK FRAGMENTS in a matrix of brown silty sand; numerous light-colored quartz gravel, subrounded and angular particles (GIBBONS CREEK ALLUVIAL FAN DEPOSIT)
8.0	28	DENSE, dark gray, GRAVEL and COBBLES in a matrix of dark gray-green silty sand; rounded particles (CATACLYSMIC-FLOOD DEPOSIT)
-4.0	40	

SAMPLE NO.	PEN. DATA
S-1	9 12 21
S-2	23 28 35
S-3	33 44 38
S-4	20 50/6"
S-5	19 27 36
S-6 *	50/3"
S-7 *	50/1"

GROUND WATER/ INSTRUMENT INSTALLATION



LEGEND

▨	2-INCH O.D. SPLIT SPOON
☒	3-INCH O.D. SPLIT SPOON
▯	3-INCH O.D. THIN WALL SAMPLER
▥	3-INCH O.D. PITCHER TUBE SAMPLER
*	NO SAMPLE RECOVERY
▼ MM/DD/YY	GROUND WATER LEVEL AND DATE OBSERVED
├●┤	LIQUID LIMIT WATER CONTENT PLASTIC LIMIT
▲	STANDARD PENETRATION TEST (BLOWS/FT.)
●	WATER CONTENT IN PERCENT
▨	CORE RECOVERY IN PERCENT
■	RQD IN PERCENT
] PT-1	PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT USING A TREMIE TUBE FROM THE BOTTOM TO THE TOP OF THE HOLE.

HAMMER ASSEMBLY: AUTO TRIP
SPT SAMPLER: NO LINER - RECESSED ID
DRILL ROD USED: NWJ
BOREHOLE DIAM.: 4-7/8" (0'-30'), 3-7/8" (30'-50')

DRILLER: WESTERN STATES
DATE START: 8/25/2015 FINISH: 8/26/2015
DRILLING TECHNIQUE: MUD ROTARY

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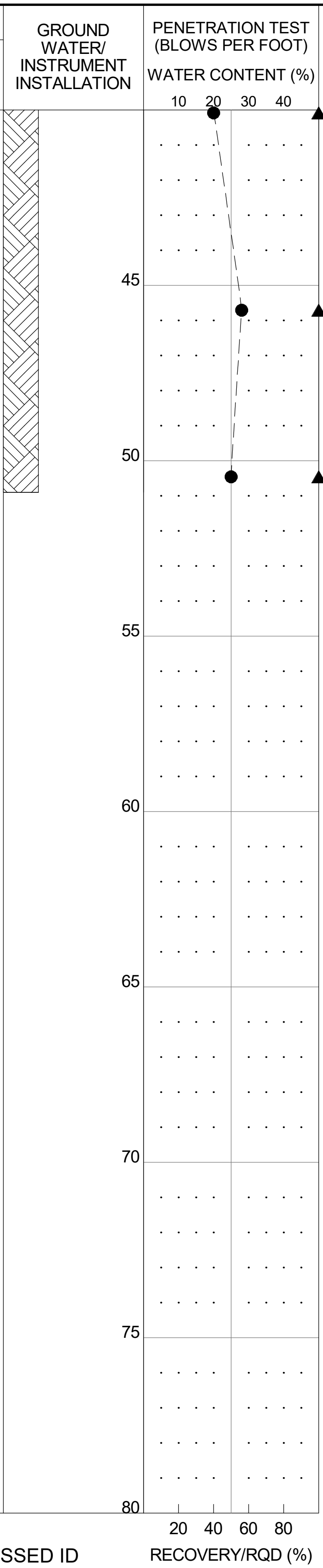
SUMMARY BORING LOG
CS-01 (1 of 2)

STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

AUG 2018
PROJ 2613
FIG. A-36

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION SURFACE ELEVATION: 36.0 FT.	SAMPLE NO.	PEN. DATA
		(continued from previous page)	S-8 *	50/2"
-6.0	42	VERY DENSE, dark gray, fine to medium SAND; clean, numerous quartz sand, trace micas, trace fine gravel (CATACLYSMIC-FLOOD DEPOSIT)		
			S-9	21 31 50/5"
-14.9	50.9	… trace wood fragments	S-10	27 50/5"
		Bottom of Boring: 50.9 FT		



LEGEND

▨ 2-INCH O.D. SPLIT SPOON

☒ 3-INCH O.D. SPLIT SPOON

▯ 3-INCH O.D. THIN WALL SAMPLER

▥ 3-INCH O.D. PITCHER TUBE SAMPLER

* NO SAMPLE RECOVERY

▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED

├─●─┤ LIQUID LIMIT, WATER CONTENT, PLASTIC LIMIT

▲ STANDARD PENETRATION TEST (BLOWS/FT.)

● WATER CONTENT IN PERCENT

▨ CORE RECOVERY IN PERCENT

■ RQD IN PERCENT

] PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT USING A TREMIE TUBE FROM THE BOTTOM TO THE TOP OF THE HOLE.

HAMMER ASSEMBLY: AUTO TRIP
SPT SAMPLER: NO LINER - RECESSED ID
DRILL ROD USED: NWJ
BOREHOLE DIAM.: 4-7/8" (0'-30'), 3-7/8" (30'-50')

DRILLER: WESTERN STATES
DATE START: 8/25/2015 FINISH: 8/26/2015
DRILLING TECHNIQUE: MUD ROTARY

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SUMMARY BORING LOG
CS-01 (2 of 2)

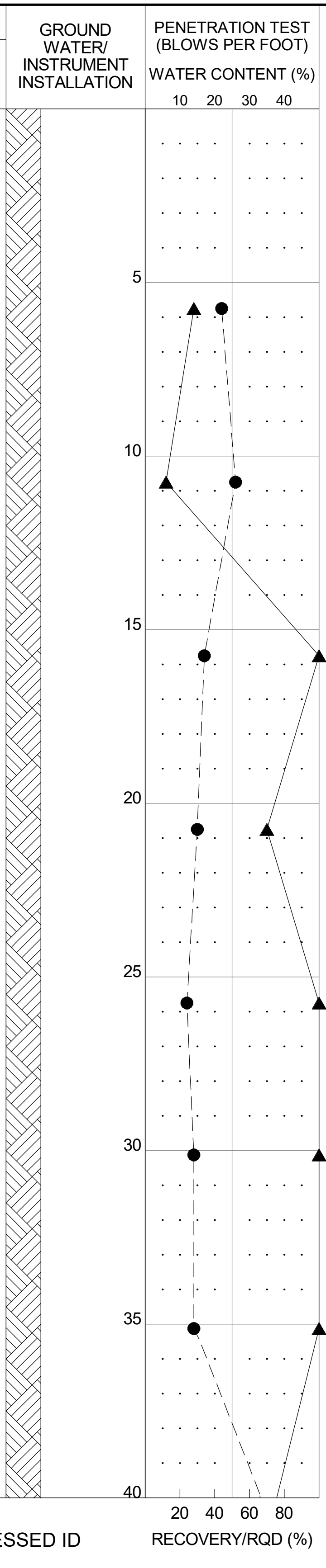
STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

AUG 2018

PROJ 2613

FIG. A-36

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION SURFACE ELEVATION: 35.0 FT.	SAMPLE NO.	PEN. DATA
		MEDIUM DENSE, brown, fine to medium SAND, and SOFT TO MEDIUM STIFF, fine-sandy SILT; some sand and gravel of quartz (GIBBONS CREEK ALLUVIAL FAN DEPOSIT)		
			S-1	5 6 8
			S-2	2 3 3
22.0	13	DENSE, dark gray and brown, GRAVEL and ROCK FRAGMENTS in a matrix of brown silty sand; numerous light-colored quartz gravel, subrounded and angular particles (GIBBONS CREEK ALLUVIAL FAN DEPOSIT)		
			S-3	23 32 26
			S-4	12 16 19
			S-5	17 25 50/6"
8.0	27	DENSE, dark gray and brown, GRAVEL and COBBLES in a matrix of brown sand; rounded particles (CATACLYSMIC-FLOOD DEPOSIT)		
			S-6	50/3"
			S-7	50/3"
-2.0	37	DENSE, brown and gray, silty fine to medium SAND; some micas (CATACLYSMIC-FLOOD DEPOSIT)		
-5.0	40			



LEGEND

- ▨ 2-INCH O.D. SPLIT SPOON
- ☒ 3-INCH O.D. SPLIT SPOON
- ▯ 3-INCH O.D. THIN WALL SAMPLER
- ▥ 3-INCH O.D. PITCHER TUBE SAMPLER
- * NO SAMPLE RECOVERY
- ▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED
- ├●┤ LIQUID LIMIT / WATER CONTENT / PLASTIC LIMIT
- ▲ STANDARD PENETRATION TEST (BLOWS/FT.)
- ● WATER CONTENT IN PERCENT
- ▨ CORE RECOVERY IN PERCENT
- ■ RQD IN PERCENT
-] PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT USING A TREMIE TUBE FROM THE BOTTOM TO THE TOP OF THE HOLE.

HAMMER ASSEMBLY: AUTO TRIP
SPT SAMPLER: NO LINER - RECESSED ID
DRILL ROD USED: NWJ
BOREHOLE DIAM.: 3-7/8"

DRILLER: WESTERN STATES
DATE START: 8/26/2015 FINISH: 8/26/2015
DRILLING TECHNIQUE: MUD ROTARY

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SUMMARY BORING LOG
CS-02 (1 of 2)

STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

AUG 2018

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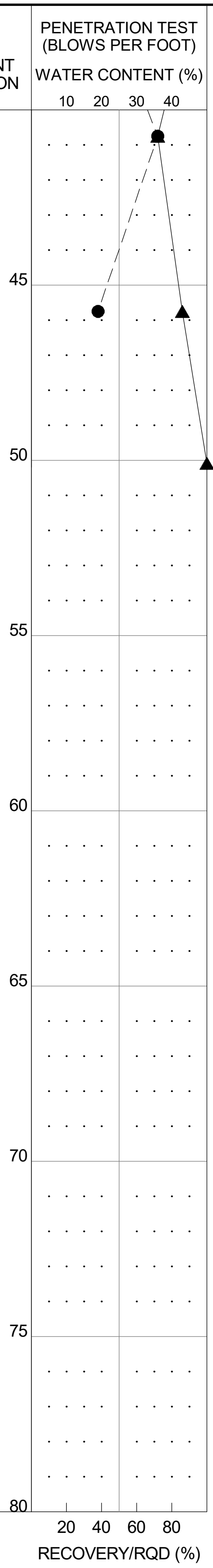
FIG. A-37

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION SURFACE ELEVATION: 35.0 FT.	SAMPLE NO.	PEN. DATA	GROUND WATER/ INSTRUMENT INSTALLATION
		(continued from previous page) … hole caves in at 40 ft at first SPT attempt	S-8	20 17 19	
-7.0	42	DENSE, dark gray, GRAVEL and COBBLES in a matrix of dark gray, silty sand; rounded particles (CATACLYSMIC-FLOOD DEPOSIT)	S-9	12 10 33	
			S-10 *	50/2"	
-15.2	50.2	Bottom of Boring: 50.2 FT			



LEGEND

- ▨ 2-INCH O.D. SPLIT SPOON
- ☒ 3-INCH O.D. SPLIT SPOON
- ▯ 3-INCH O.D. THIN WALL SAMPLER
- ▥ 3-INCH O.D. PITCHER TUBE SAMPLER
- * NO SAMPLE RECOVERY
- ▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED
- LIQUID LIMIT, WATER CONTENT, PLASTIC LIMIT
- ▲ STANDARD PENETRATION TEST (BLOWS/FT.)
- ● WATER CONTENT IN PERCENT
- ▨ CORE RECOVERY IN PERCENT
- ■ RQD IN PERCENT
- PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT USING A TREMIE TUBE FROM THE BOTTOM TO THE TOP OF THE HOLE.

HAMMER ASSEMBLY: AUTO TRIP
SPT SAMPLER: NO LINER - RECESSED ID
DRILL ROD USED: NWJ
BOREHOLE DIAM.: 3-7/8"

DRILLER: WESTERN STATES
DATE START: 8/26/2015 FINISH: 8/26/2015
DRILLING TECHNIQUE: MUD ROTARY

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SUMMARY BORING LOG
CS-02 (2 of 2)

STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

AUG 2018

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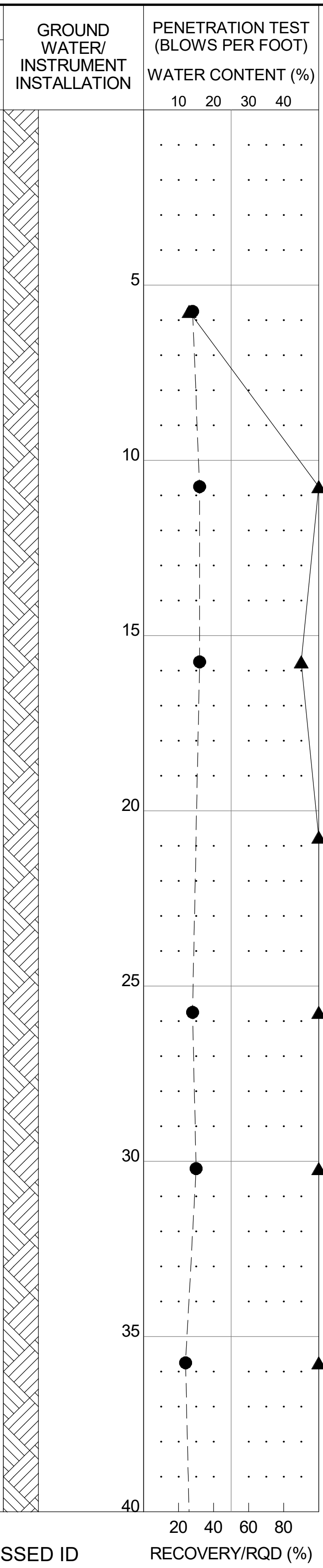
FIG. A-37

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION SURFACE ELEVATION: 40.0 FT.	SAMPLE NO.	PEN. DATA
		MEDIUM DENSE, dark gray and brown, gravelly SAND to sandy GRAVEL (GIBBONS CREEK ALLUVIAL FAN DEPOSIT)	S-1	5 7 6
32.0	8	DENSE, dark gray and brown, GRAVEL in a matrix of brown silty sand; numerous light-colored quartz gravel, subrounded to subangular particles (GIBBONS CREEK ALLUVIAL FAN DEPOSIT)	S-2	8 28 28
			S-3	24 22 23
			S-4 *	50/2"
			S-5	25 34 23
12.0	28	DENSE, dark gray, GRAVEL and COBBLES in a matrix of dark gray-green silty sand; rounded particles (CATACLYSMIC FLOOD DEPOSIT)	S-6	50/5"
			S-7	41 38 34
0.0	40			



LEGEND

▨	2-INCH O.D. SPLIT SPOON
☒	3-INCH O.D. SPLIT SPOON
▯	3-INCH O.D. THIN WALL SAMPLER
▥	3-INCH O.D. PITCHER TUBE SAMPLER
*	NO SAMPLE RECOVERY
▼ MM/DD/YY	GROUND WATER LEVEL AND DATE OBSERVED
├─●─┤	LIQUID LIMIT WATER CONTENT PLASTIC LIMIT
▲	STANDARD PENETRATION TEST (BLOWS/FT.)
●	WATER CONTENT IN PERCENT
▨	CORE RECOVERY IN PERCENT
■	RQD IN PERCENT
] PT-1	PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT USING A TREMIE TUBE FROM THE BOTTOM TO THE TOP OF THE HOLE.

HAMMER ASSEMBLY: AUTO TRIP
SPT SAMPLER: NO LINER - RECESSED ID
DRILL ROD USED: NWJ
BOREHOLE DIAM.: 3-7/8"

DRILLER: WESTERN STATES
DATE START: 8/25/2015 FINISH: 8/25/2015
DRILLING TECHNIQUE: MUD ROTARY

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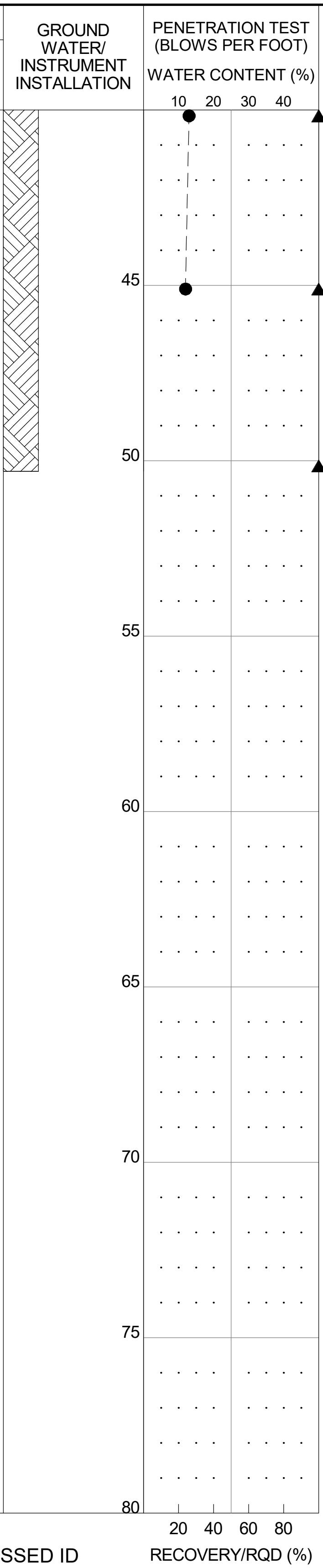
SUMMARY BORING LOG
GF-01 (1 of 2)

STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

AUG 2018
PROJ 2613
FIG. A-38

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION SURFACE ELEVATION: 40.0 FT.	SAMPLE NO.	SAMPLE PEN. DATA
		(continued from previous page)	S-8	50/4"
			S-9	50/3"
-10.3	50.3	Bottom of Boring: 50.3 FT	S-10 *	50/3"



LEGEND

- ▨ 2-INCH O.D. SPLIT SPOON
- ☒ 3-INCH O.D. SPLIT SPOON
- ▯ 3-INCH O.D. THIN WALL SAMPLER
- ▥ 3-INCH O.D. PITCHER TUBE SAMPLER
- * NO SAMPLE RECOVERY
- ▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED
- ├●┤ LIQUID LIMIT, WATER CONTENT, PLASTIC LIMIT
- ▲ STANDARD PENETRATION TEST (BLOWS/FT.)
- ● WATER CONTENT IN PERCENT
- ▨ CORE RECOVERY IN PERCENT
- ■ RQD IN PERCENT
-] PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT USING A TREMIE TUBE FROM THE BOTTOM TO THE TOP OF THE HOLE.

HAMMER ASSEMBLY: AUTO TRIP
SPT SAMPLER: NO LINER - RECESSED ID
DRILL ROD USED: NWJ
BOREHOLE DIAM.: 3-7/8"

DRILLER: WESTERN STATES
DATE START: 8/25/2015 FINISH: 8/25/2015
DRILLING TECHNIQUE: MUD ROTARY

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SUMMARY BORING LOG
GF-01 (2 of 2)

STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

AUG 2018

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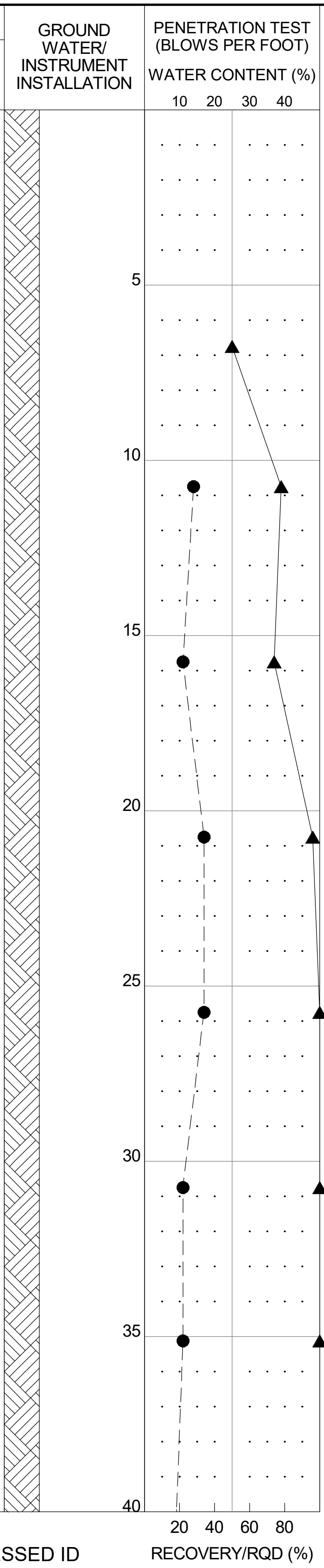
FIG. A-38

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION SURFACE ELEVATION: 45.0 FT.	SAMPLE NO.	SAMPLE PEN. DATA
		MEDIUM DENSE, dark gray and brown, gravelly SAND to sandy GRAVEL; gravel in a matrix of brown silty sand (GIBBONS CREEK ALLUVIAL FAN DEPOSIT)		
			S-1	
			S-2 *	16 13 12
36.0	9	DENSE, dark gray and brown, GRAVEL in a matrix of brown silty sand; numerous light-colored quartz gravel, subrounded to subangular particles (GIBBONS CREEK ALLUVIAL FAN DEPOSIT)		
			S-3	12 11 28
			S-4	18 19 18
			S-5	16 23 25
			S-6	37 31 32
			S-7	23 28 40
12.0	33	DENSE, dark gray, GRAVEL and COBBLES in a matrix of dark gray-green silty sand; rounded particles (CATACLYSMIC FLOOD DEPOSIT)		
			S-8	50/3"
5.0	40			



LEGEND

- ▨ 2-INCH O.D. SPLIT SPOON
- ☒ 3-INCH O.D. SPLIT SPOON
- ▯ 3-INCH O.D. THIN WALL SAMPLER
- ▥ 3-INCH O.D. PITCHER TUBE SAMPLER
- * NO SAMPLE RECOVERY
- ▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED
- LIQUID LIMIT
- WATER CONTENT
- PLASTIC LIMIT
- ▲ STANDARD PENETRATION TEST (BLOWS/FT.)
- ● WATER CONTENT IN PERCENT
- ▨ CORE RECOVERY IN PERCENT
- ■ RQD IN PERCENT
- PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT USING A TREMIE TUBE FROM THE BOTTOM TO THE TOP OF THE HOLE.

HAMMER ASSEMBLY: AUTO TRIP
SPT SAMPLER: NO LINER - RECESSED ID
DRILL ROD USED: NWJ
BOREHOLE DIAM.: 4-7/8"

DRILLER: WESTERN STATES
DATE START: 8/26/2015 FINISH: 8/26/2015
DRILLING TECHNIQUE: MUD ROTARY

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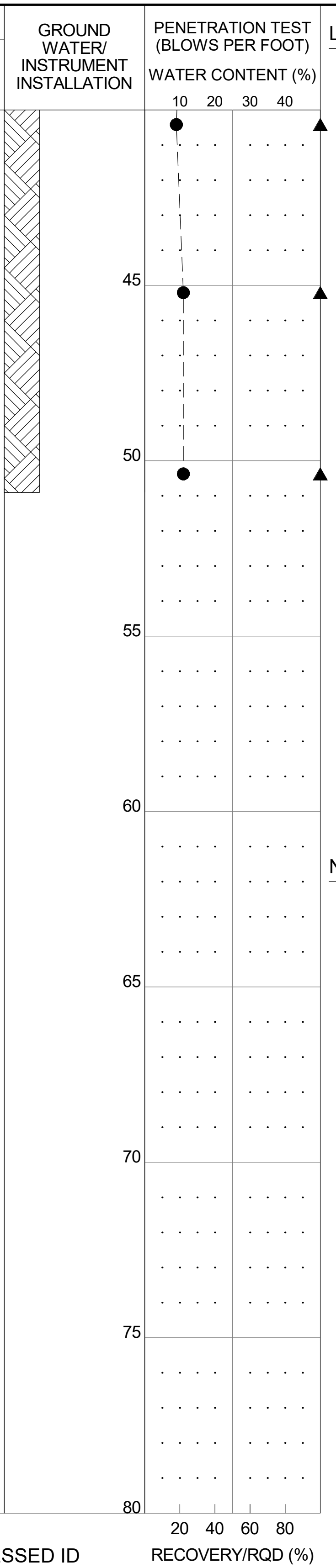
10250 S.W. Greenburg Road, Suite 111
Portland, Oregon 97223
Phone 503-452-1100 Fax 503-452-1528

SUMMARY BORING LOG GF-02 (1 of 2)

STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

AUG 2018
PROJ 2613
FIG. A-39

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION SURFACE ELEVATION: 45.0 FT.	SAMPLE NO.	SAMPLE PEN. DATA
		(continued from previous page)	S-9	39 50/4"
			S-10	50/5"
			S-11	41 50/4"
-5.9	50.9	Bottom of Boring: 50.9 FT		



LEGEND

- ▨ 2-INCH O.D. SPLIT SPOON
- ☒ 3-INCH O.D. SPLIT SPOON
- ▯ 3-INCH O.D. THIN WALL SAMPLER
- ▥ 3-INCH O.D. PITCHER TUBE SAMPLER
- * NO SAMPLE RECOVERY
- ▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED
- LIQUID LIMIT / WATER CONTENT / PLASTIC LIMIT
- ▲ STANDARD PENETRATION TEST (BLOWS/FT.)
- ● WATER CONTENT IN PERCENT
- ▨ CORE RECOVERY IN PERCENT
- ■ RQD IN PERCENT
- PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT USING A TREMIE TUBE FROM THE BOTTOM TO THE TOP OF THE HOLE.

HAMMER ASSEMBLY: AUTO TRIP
SPT SAMPLER: NO LINER - RECESSED ID
DRILL ROD USED: NWJ
BOREHOLE DIAM.: 4-7/8"

DRILLER: WESTERN STATES
DATE START: 8/26/2015 FINISH: 8/26/2015
DRILLING TECHNIQUE: MUD ROTARY

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SUMMARY BORING LOG
GF-02 (2 of 2)

STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

AUG 2018

PROJ 2613

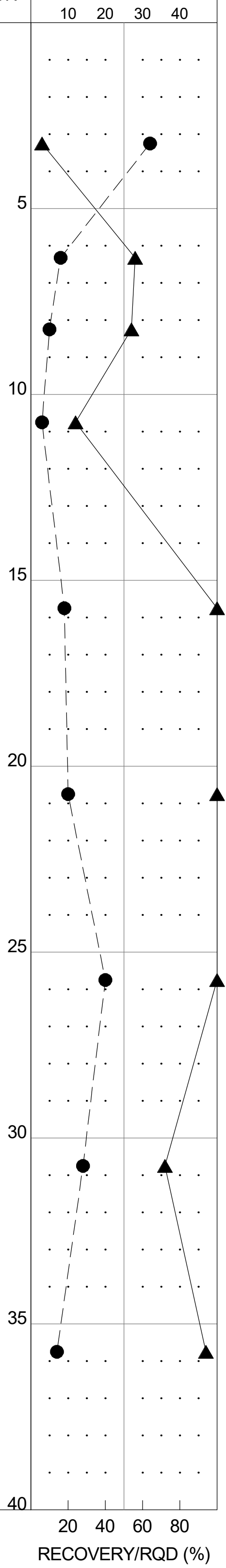
FIG. A-39

DEPTH IN FEET	MATERIAL DESCRIPTION	SAMPLE NO.		SAMPLE PEN. DATA	GROUND WATER/ INSTRUMENT INSTALLATION
	VERY LOOSE, brown, SAND; trace mica, scattered woody organics, (GIBBONS CREEK ALLUVIAL FAN DEPOSIT)	S-1	▨	2 1 2	
		S-2	▯		
5.5	MEDIUM DENSE to VERY DENSE, grey, sandy GRAVEL and ROCK FRAGMENTS in a matrix of brown silty sand, intact gravels are subrounded to rounded, scattered silt locally present in sand matrix, occasional cobbles and boulders are inferred from drill action (GIBBONS CREEK ALLUVIAL FAN DEPOSIT)	S-3	▨	8 14 14	
		S-4	▨	6 17 10	
		S-5	▨	5 7 5	
		S-6	▨	14 24 36	
		S-7	▨	20 49 50	
		S-8	▨	12 20 38	
		S-9	▨	6 19 17	
		S-10	▨	17 22 25	
36.5					

PENETRATION TEST (BLOWS PER FOOT)

WATER CONTENT (%)

10 20 30 40



Bottom of Boring: 40 FT

HAMMER ASSEMBLY: AUTO TRIP

SPT SAMPLER: NO LINER - RECESSED ID

DRILL ROD USED: NWJ

BOREHOLE DIAM.: 4-7/8" (0'-10'), 3-7/8" (10'-35')

LEGEND

▨	2-INCH O.D. SPLIT SPOON
☒	3-INCH O.D. SPLIT SPOON
▯	3-INCH O.D. THIN WALL SAMPLER
▥	3-INCH O.D. PITCHER TUBE SAMPLER
*	NO SAMPLE RECOVERY
▼ MM/DD/YY	GROUND WATER LEVEL AND DATE OBSERVED
├●┤	LIQUID LIMIT WATER CONTENT PLASTIC LIMIT
▲	STANDARD PENETRATION TEST (BLOWS/FT.)
●	WATER CONTENT IN PERCENT
▨	CORE RECOVERY IN PERCENT
■	RQD IN PERCENT
] PT-1	PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT USING A TREMIE TUBE FROM THE BOTTOM TO THE TOP OF THE HOLE.

DRILLER: WESTERN STATES

DATE START: 1/11/2016 FINISH: 1/12/2016

DRILLING TECHNIQUE: MUD ROTARY

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SUMMARY BORING LOG
GF-03

STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

AUG 2018

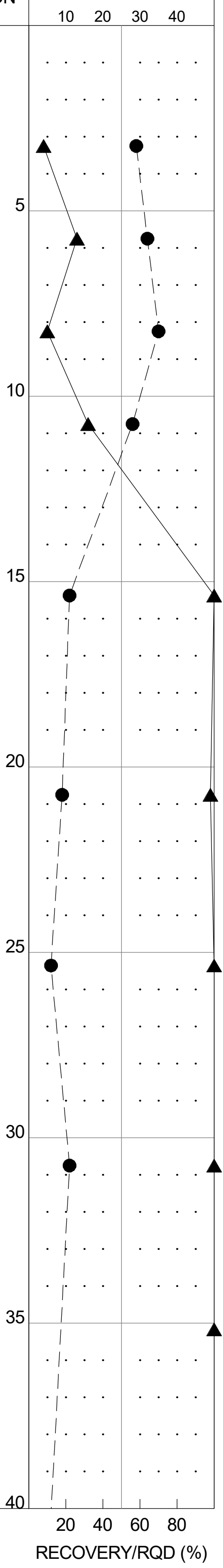
PROJ 2613

FIG. A-40

DEPTH IN FEET	MATERIAL DESCRIPTION	SAMPLE NO.	PEN. DATA	GROUND WATER/ INSTRUMENT INSTALLATION
	VERY LOOSE, brown, silty SAND to very silty SAND; scattered mica flakes, scattered rootlets and organics, fine to medium sand (GIBBON CREEK ALLUVIAL FAN DEPOSIT)			
		S-1	1 1 3	
	… occasional fine rounded gravel	S-2	0 7 6	
		S-3	2 3 2	
	… occasional coarse gravel	S-4	2 4 12	
14	DENSE to VERY DENSE, grey, sandy GRAVEL to very sandy GRAVEL; subrounded to rounded gravel, scattered silt, occasional cobbles are inferred from drill action (GIBBONS CREEK ALLUVIAL FAN DEPOSIT)	S-5	42 50/3"	
		S-6	16 26 23	
		S-7	26 50/3"	
		S-8	9 44 30	
		S-9	50/4"	
40				

PENETRATION TEST (BLOWS PER FOOT)

WATER CONTENT (%)



LEGEND

- ▨ 2-INCH O.D. SPLIT SPOON
- ☒ 3-INCH O.D. SPLIT SPOON
- ▯ 3-INCH O.D. THIN WALL SAMPLER
- ▥ 3-INCH O.D. PITCHER TUBE SAMPLER
- * NO SAMPLE RECOVERY
- ▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED
- LIQUID LIMIT / WATER CONTENT / PLASTIC LIMIT
- ▲ STANDARD PENETRATION TEST (BLOWS/FT.)
- ● WATER CONTENT IN PERCENT
- ▨ CORE RECOVERY IN PERCENT
- ■ RQD IN PERCENT
-] PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT USING A TREMIE TUBE FROM THE BOTTOM TO THE TOP OF THE HOLE.

HAMMER ASSEMBLY: AUTO TRIP

SPT SAMPLER: NO LINER - RECESSED ID

DRILL ROD USED: NWJ

BOREHOLE DIAM.: 3 7/8"

DRILLER: WESTERN STATES

DATE START: 1/13/2016 FINISH: 1/14/2016

DRILLING TECHNIQUE: MUD ROTARY

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SUMMARY BORING LOG GF-04 (1 of 2)

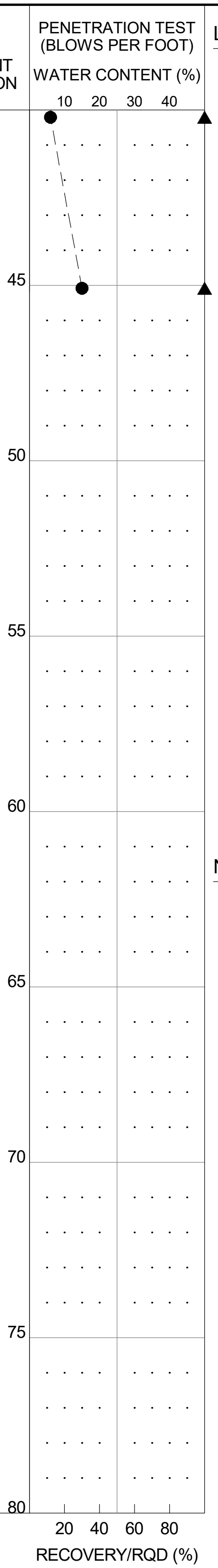
STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

AUG 2018

PROJ 2613

FIG. A-41

DEPTH IN FEET	MATERIAL DESCRIPTION	SAMPLE NO.	SAMPLE	PEN. DATA	GROUND WATER/ INSTRUMENT INSTALLATION
	(continued from previous page)	S-10	▨	50/5"	
45.2	Bottom of Boring: 45.2 FT	S-11	▨	50/2"	



LEGEND

▨	2-INCH O.D. SPLIT SPOON
☒	3-INCH O.D. SPLIT SPOON
▯	3-INCH O.D. THIN WALL SAMPLER
▥	3-INCH O.D. PITCHER TUBE SAMPLER
*	NO SAMPLE RECOVERY
▼ MM/DD/YY	GROUND WATER LEVEL AND DATE OBSERVED
├●┤	LIQUID LIMIT WATER CONTENT PLASTIC LIMIT
▲	STANDARD PENETRATION TEST (BLOWS/FT.)
●	WATER CONTENT IN PERCENT
▨	CORE RECOVERY IN PERCENT
■	RQD IN PERCENT
] PT-1	PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT USING A TREMIE TUBE FROM THE BOTTOM TO THE TOP OF THE HOLE.

HAMMER ASSEMBLY: AUTO TRIP
SPT SAMPLER: NO LINER - RECESSED ID
DRILL ROD USED: NWJ
BOREHOLE DIAM.: 3 7/8"

DRILLER: WESTERN STATES
DATE START: 1/13/2016 FINISH: 1/14/2016
DRILLING TECHNIQUE: MUD ROTARY

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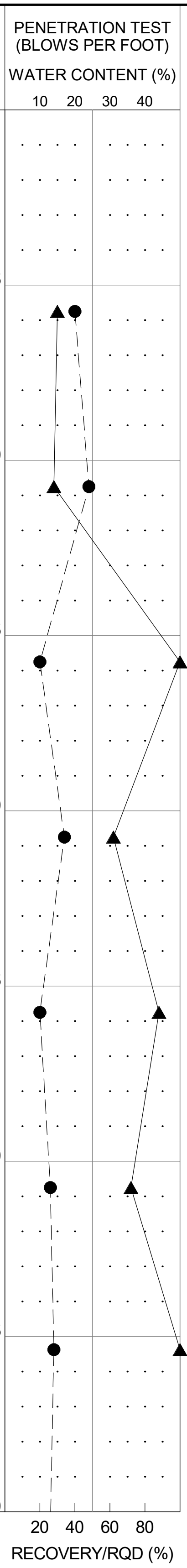
SUMMARY BORING LOG
GF-04 (2 of 2)

STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

AUG 2018
PROJ 2613
FIG. A-41

DEPTH IN FEET	MATERIAL DESCRIPTION	SAMPLE NO.	PEN. DATA	GROUND WATER/ INSTRUMENT INSTALLATION
	MEDIUM DENSE, brown, interbedded very sandy GRAVEL and silty SAND; occasional mica flakes, scattered rootlets and organics, sand size is fine to coarse (GIBBONS CREEK ALLUVIAL FAN DEPOSIT)			
		S-1	7 11 4	
	… occasional coarse gravel			
	… interbedded layers of sand and sandy gravel	S-2	10 4 10	
13	DENSE to VERY DENSE, brown and dark grey, sandy GRAVEL; intact gravels are sub rounded to rounded, scattered silt locally present in sand matrix, occasional cobbles are inferred from drill action (GIBBONS CREEK ALLUVIAL FAN DEPOSIT)			
		S-3	22 43 50/5"	
		S-4	10 16 15	
		S-5	22 23 21	
		S-6	21 18 18	
		S-7	30 50/4"	
40				



LEGEND

- ▨ 2-INCH O.D. SPLIT SPOON
- ☒ 3-INCH O.D. SPLIT SPOON
- ▯ 3-INCH O.D. THIN WALL SAMPLER
- ▥ 3-INCH O.D. PITCHER TUBE SAMPLER
- * NO SAMPLE RECOVERY
- ▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED
- LIQUID LIMIT, WATER CONTENT, PLASTIC LIMIT
- ▲ STANDARD PENETRATION TEST (BLOWS/FT.)
- ● WATER CONTENT IN PERCENT
- ▨ CORE RECOVERY IN PERCENT
- ■ RQD IN PERCENT
-] PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT USING A TREMIE TUBE FROM THE BOTTOM TO THE TOP OF THE HOLE.

HAMMER ASSEMBLY: AUTO TRIP
SPT SAMPLER: NO LINER - RECESSED ID
DRILL ROD USED: NWJ
BOREHOLE DIAM.: 4 7/8"

DRILLER: WESTERN STATES
DATE START: 1/15/2016 FINISH: 1/15/2016
DRILLING TECHNIQUE: MUD ROTARY

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10250 S.W. Greenburg Road, Suite 111
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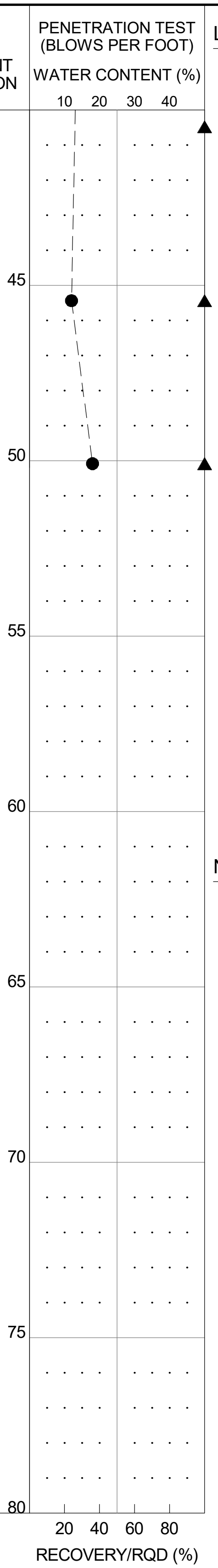
SUMMARY BORING LOG
GF-05 (1 of 2)

STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

AUG 2018
PROJ 2613
FIG. A-42

DEPTH IN FEET	MATERIAL DESCRIPTION	SAMPLE NO.	SAMPLE PEN. DATA
	(continued from the previous page)	S-8 ▨	46 50/5"
		S-9 ▨	49 50/5"
50.2		S-10 ▨	50/2"
	Bottom of Boring: 50.2 FT		

GROUND WATER/ INSTRUMENT INSTALLATION



LEGEND

- ▨ 2-INCH O.D. SPLIT SPOON
- ☒ 3-INCH O.D. SPLIT SPOON
- ▯ 3-INCH O.D. THIN WALL SAMPLER
- ▥ 3-INCH O.D. PITCHER TUBE SAMPLER
- * NO SAMPLE RECOVERY
- ▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED
- ├●┤ LIQUID LIMIT, WATER CONTENT, PLASTIC LIMIT
- ▲ STANDARD PENETRATION TEST (BLOWS/FT.)
- ● WATER CONTENT IN PERCENT
- ▨ CORE RECOVERY IN PERCENT
- ■ RQD IN PERCENT
-] PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT USING A TREMIE TUBE FROM THE BOTTOM TO THE TOP OF THE HOLE.

HAMMER ASSEMBLY: AUTO TRIP

SPT SAMPLER: NO LINER - RECESSED ID

DRILL ROD USED: NWJ

BOREHOLE DIAM.: 4 7/8"

DRILLER: WESTERN STATES

DATE START: 1/15/2016 FINISH: 1/15/2016

DRILLING TECHNIQUE: MUD ROTARY

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SUMMARY BORING LOG
GF-05 (2 of 2)

STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

AUG 2018

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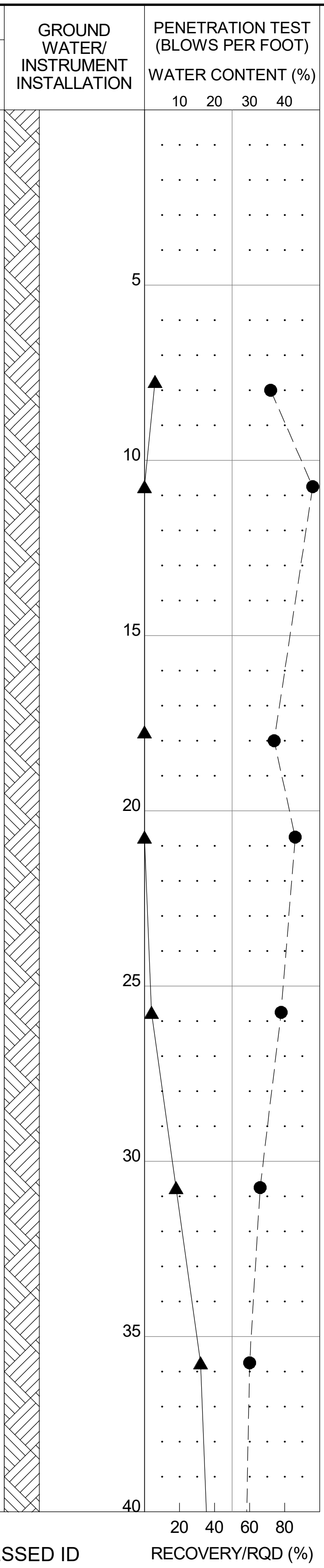
FIG. A-42

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION	SAMPLE NO.	PEN. DATA
		SURFACE ELEVATION: 30.0 FT.		
		VERY LOOSE, brown, silty SAND; fine to medium sand, occasional mica (COLUMBIA RIVER ALLUVIUM)		
			S-1	
			S-2	2 1 2
21.0	9	Interlayered: SOFT, brown, fine-sandy SILT and VERY LOOSE to LOOSE, brown, silty fine SAND; some mica (COLUMBIA RIVER ALLUVIUM)		
			S-3	0 0 0
			S-4	
			S-5	0 0 0
		…becomes gray at 19 feet		
			S-6	0 0 0
8.0	22	VERY LOOSE, gray, slightly silty SAND; some mica (COLUMBIA RIVER ALLUVIUM)		
			S-7	1 0 2
		…becomes MEDIUM DENSE from 29 to 43 feet		
			S-8	3 4 5
			S-9	7 7 9
-10.0	40			



LEGEND

- ▨ 2-INCH O.D. SPLIT SPOON
- ☒ 3-INCH O.D. SPLIT SPOON
- ▯ 3-INCH O.D. THIN WALL SAMPLER
- ▥ 3-INCH O.D. PITCHER TUBE SAMPLER
- * NO SAMPLE RECOVERY
- ▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED
- ├─●─┤ LIQUID LIMIT, WATER CONTENT, PLASTIC LIMIT
- ▲ STANDARD PENETRATION TEST (BLOWS/FT.)
- ● WATER CONTENT IN PERCENT
- ▨ CORE RECOVERY IN PERCENT
- ■ RQD IN PERCENT
-] PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT USING A TREMIE TUBE FROM THE BOTTOM TO THE TOP OF THE HOLE.

HAMMER ASSEMBLY: AUTO TRIP
SPT SAMPLER: NO LINER - RECESSED ID
DRILL ROD USED: NWJ
BOREHOLE DIAM.: 3-7/8"

DRILLER: WESTERN STATES
DATE START: 8/21/2015 FINISH: 8/21/2015
DRILLING TECHNIQUE: MUD ROTARY

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SUMMARY BORING LOG
BR-01 (1 of 3)

STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

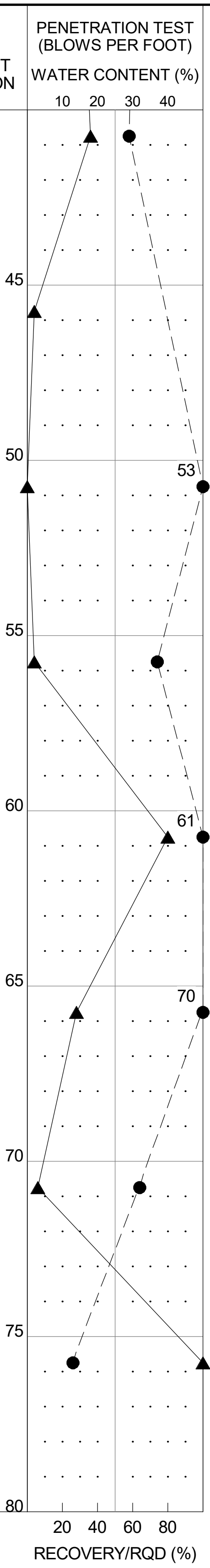
AUG 2018

PROJ 2613

FIG. A-43

SURFACE ELEVATION: 30.0 FT.

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION	SAMPLE NO.	SAMPLE PEN. DATA	GROUND WATER/ INSTRUMENT INSTALLATION
		(continued from previous page)	S-10	8 9 9	
			S-11 *	3 1 1	
-17.0	47	VERY LOOSE to LOOSE, gray, slightly fine sandy SILT; some mica, scattered organics (COLUMBIA RIVER ALLUVIUM)	S-12 S-13	0 0 0 3 1 1	
-28.0	58	MEDIUM DENSE, light gray, slightly clayey SILT (ASH DEPOSIT?)	S-14 S-15	16 22 18 11 8 6	
-39.0	69	VERY LOOSE to LOOSE, gray, slightly fine sandy SILT; some mica, scattered organics (COLUMBIA RIVER ALLUVIUM)	S-16	1 0 3	
-43.5	73.5	DENSE, dark gray, GRAVEL and COBBLES in a matrix of dark gray-green silty sand; rounded particles (CATACLYSMIC-FLOOD DEPOSIT)	S-17	25 40 34	
-50.0	80				



LEGEND

- ▨ 2-INCH O.D. SPLIT SPOON
- ☒ 3-INCH O.D. SPLIT SPOON
- ▯ 3-INCH O.D. THIN WALL SAMPLER
- ▥ 3-INCH O.D. PITCHER TUBE SAMPLER
- * NO SAMPLE RECOVERY
- ▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED
- ├─●─┤ LIQUID LIMIT, WATER CONTENT, PLASTIC LIMIT
- ▲ STANDARD PENETRATION TEST (BLOWS/FT.)
- ● WATER CONTENT IN PERCENT
- ▨ CORE RECOVERY IN PERCENT
- ■ RQD IN PERCENT
-] PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT USING A TREMIE TUBE FROM THE BOTTOM TO THE TOP OF THE HOLE.

HAMMER ASSEMBLY: AUTO TRIP

SPT SAMPLER: NO LINER - RECESSED ID

DRILL ROD USED: NWJ

BOREHOLE DIAM.: 3-7/8"

DRILLER: WESTERN STATES
DATE START: 8/21/2015 FINISH: 8/21/2015
DRILLING TECHNIQUE: MUD ROTARY

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SUMMARY BORING LOG BR-01 (2 of 3)

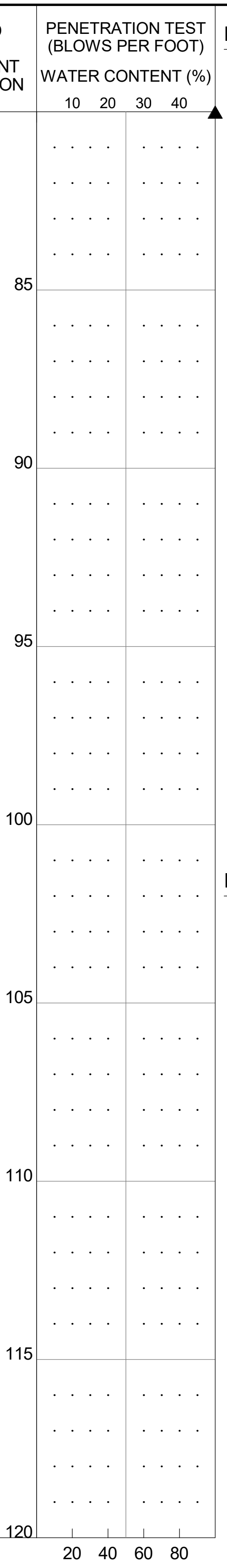
STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

AUG 2018

PROJ 2613

FIG. A-43

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION SURFACE ELEVATION: 30.0 FT.	SAMPLE NO.		SAMPLE PEN. DATA	GROUND WATER/ INSTRUMENT INSTALLATION
-50.3	80.3	(continued from previous page) Bottom of Boring: 80.3 FT	S-18 *	☐	50/3"	▨



LEGEND

- ▨ 2-INCH O.D. SPLIT SPOON
- ☒ 3-INCH O.D. SPLIT SPOON
- ▯ 3-INCH O.D. THIN WALL SAMPLER
- ▥ 3-INCH O.D. PITCHER TUBE SAMPLER
- * NO SAMPLE RECOVERY
- ▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED
- ├●┤ LIQUID LIMIT, WATER CONTENT, PLASTIC LIMIT
- ▲ STANDARD PENETRATION TEST (BLOWS/FT.)
- ● WATER CONTENT IN PERCENT
- ▨ CORE RECOVERY IN PERCENT
- ■ RQD IN PERCENT
-] PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT USING A TREMIE TUBE FROM THE BOTTOM TO THE TOP OF THE HOLE.

HAMMER ASSEMBLY: AUTO TRIP
SPT SAMPLER: NO LINER - RECESSED ID
DRILL ROD USED: NWJ
BOREHOLE DIAM.: 3-7/8"

DRILLER: WESTERN STATES
DATE START: 8/21/2015 FINISH: 8/21/2015
DRILLING TECHNIQUE: MUD ROTARY

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SUMMARY BORING LOG
BR-01 (3 of 3)

STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

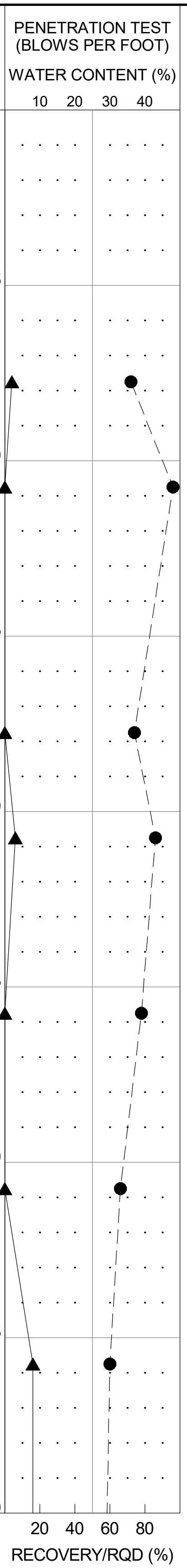
AUG 2018
PROJ 2613
FIG. A-43

SURFACE ELEVATION: 35.0 FT.

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION
		Interlayered: SOFT, brown, fine-sandy SILT and VERY LOOSE to LOOSE, brown, silty fine SAND; some mica, scattered organics (COLUMBIA RIVER ALLUVIUM)
4.0	31	LOOSE to MEDIUM DENSE, gray, slightly silty to silty SAND; some mica, occasional organics (COLUMBIA RIVER ALLUVIUM)
-5.0	40	

SAMPLE NO.	PEN. DATA
S-1 *	
S-2	0 1 1
S-3	0 0 0
S-4	
S-5	0 0 0
S-6	0 2 1
S-7	1 0 0
S-8	1 0 0
S-9	4 4 4

GROUND WATER/ INSTRUMENT INSTALLATION



LEGEND

- ▨ 2-INCH O.D. SPLIT SPOON
- ☒ 3-INCH O.D. SPLIT SPOON
- ▯ 3-INCH O.D. THIN WALL SAMPLER
- ▥ 3-INCH O.D. PITCHER TUBE SAMPLER
- * NO SAMPLE RECOVERY
- ▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED
- LIQUID LIMIT, WATER CONTENT, PLASTIC LIMIT
- ▲ STANDARD PENETRATION TEST (BLOWS/FT.)
- ● WATER CONTENT IN PERCENT
- ▨ CORE RECOVERY IN PERCENT
- ■ RQD IN PERCENT
- PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT USING A TREMIE TUBE FROM THE BOTTOM TO THE TOP OF THE HOLE.

HAMMER ASSEMBLY: AUTO TRIP
SPT SAMPLER: NO LINER - RECESSED ID
DRILL ROD USED: NWJ
BOREHOLE DIAM.: 3-7/8"

DRILLER: WESTERN STATES
DATE START: 8/24/2015 FINISH: 8/24/2015
DRILLING TECHNIQUE: MUD ROTARY

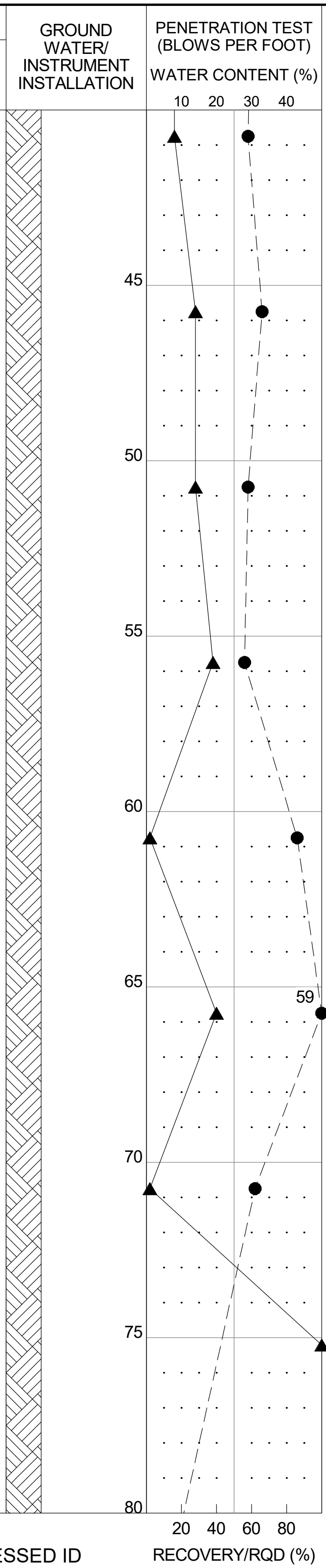
CORNFORTH CONSULTANTS
10250 S.W. Greenburg Road, Suite 111
Portland, Oregon 97223
Phone 503-452-1100 Fax 503-452-1528

SUMMARY BORING LOG BR-02 (1 of 3)

STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

AUG 2018
PROJ 2613
FIG. A-44

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION SURFACE ELEVATION: 35.0 FT.	SAMPLE NO.	PEN. DATA
		(continued from previous page)	S-10	4 3 5
			S-11	4 7 7
			S-12	8 6 8
			S-13	10 9 10
		…becomes VERY LOOSE from 59 to 63 feet	S-14	0 1 0
-29.0	64	MEDIUM DENSE, light gray, slightly clayey SILT (ASH DEPOSIT?)	S-15	2 8 12
-32.0	67	LOOSE, gray, slightly silty to silty SAND; some mica, occasional organics (COLUMBIA RIVER ALLUVIUM)	S-16	3 0 1
-37.5	72.5	DENSE, dark gray, GRAVEL and COBBLES in a matrix of dark gray-green silty sand; rounded particles (CATACLYSMIC-FLOOD DEPOSIT)	S-17 *	50/5"
-45.0	80			



LEGEND

- ▨ 2-INCH O.D. SPLIT SPOON
- ☒ 3-INCH O.D. SPLIT SPOON
- ▯ 3-INCH O.D. THIN WALL SAMPLER
- ▥ 3-INCH O.D. PITCHER TUBE SAMPLER
- * NO SAMPLE RECOVERY
- ▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED
- LIQUID LIMIT / WATER CONTENT / PLASTIC LIMIT
- ▲ STANDARD PENETRATION TEST (BLOWS/FT.)
- ● WATER CONTENT IN PERCENT
- ▨ CORE RECOVERY IN PERCENT
- ■ RQD IN PERCENT
- PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT USING A TREMIE TUBE FROM THE BOTTOM TO THE TOP OF THE HOLE.

HAMMER ASSEMBLY: AUTO TRIP
SPT SAMPLER: NO LINER - RECESSED ID
DRILL ROD USED: NWJ
BOREHOLE DIAM.: 3-7/8"

DRILLER: WESTERN STATES
DATE START: 8/24/2015 FINISH: 8/24/2015
DRILLING TECHNIQUE: MUD ROTARY

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Portland, Oregon 97223
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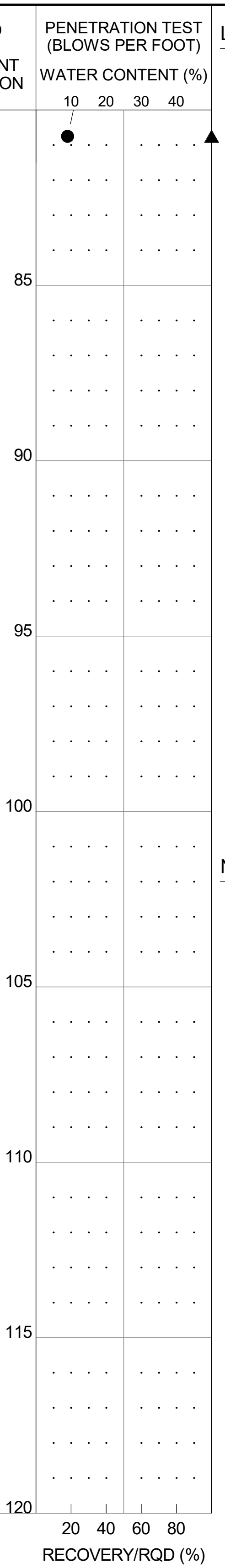
SUMMARY BORING LOG BR-02 (2 of 3)

STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

AUG 2018
PROJ 2613
FIG. A-44

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION SURFACE ELEVATION: 35.0 FT.	SAMPLE NO.	SAMPLE PEN. DATA	GROUND WATER/ INSTRUMENT INSTALLATION
		(continued from previous page)	S-18	36 47 50/3"	
-46.5	81.5	Bottom of Boring: 81.5 FT			



LEGEND

- ▨ 2-INCH O.D. SPLIT SPOON
- ☒ 3-INCH O.D. SPLIT SPOON
- ▯ 3-INCH O.D. THIN WALL SAMPLER
- ▥ 3-INCH O.D. PITCHER TUBE SAMPLER
- * NO SAMPLE RECOVERY
- ▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED
- ├─●─┤ LIQUID LIMIT, WATER CONTENT, PLASTIC LIMIT
- ▲ STANDARD PENETRATION TEST (BLOWS/FT.)
- ● WATER CONTENT IN PERCENT
- ▨ CORE RECOVERY IN PERCENT
- ■ RQD IN PERCENT
-] PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT USING A TREMIE TUBE FROM THE BOTTOM TO THE TOP OF THE HOLE.

HAMMER ASSEMBLY: AUTO TRIP
SPT SAMPLER: NO LINER - RECESSED ID
DRILL ROD USED: NWJ
BOREHOLE DIAM.: 3-7/8"

DRILLER: WESTERN STATES
DATE START: 8/24/2015 FINISH: 8/24/2015
DRILLING TECHNIQUE: MUD ROTARY

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SUMMARY BORING LOG
BR-02 (3 of 3)

STEIGERWALD LEVEE DESIGN
WASHOUGAL, WA

AUG 2018
PROJ 2613
FIG. A-44

Appendix B – Test Pit Logs

Project Location: Steigerwald National Wildlife Refuge
Date: 11/21/2016
Equipment: Hitachi ZX135

TP-A1

Depth (feet)	Soil Description
0 - 1	LOOSE, brown, silty SAND; trace clay, trace mica, numerous organics, moist
1 - 10	LOOSE, brown, silty SAND; mica, occasional organics, moist wc = 29% at 5 feet wc = 28% at 10 feet

Date: 9/19/2017
Equipment: CAT 305E

TP-A2

Depth (feet)	Soil Description
0 - 7	LOOSE, light brown, silty FINE SAND, trace mica, moist wc = 17% at 4 feet
7 - 9.5	LOOSE, mottled red-brown to gray, slightly clayey SILT; wc = 46% at 8 feet

Project Location: Steigerwald National Wildlife Refuge
Date: 11/21/2016
Equipment: Hitachi ZX135

TP-B1

Depth (feet)	Soil Description
0 - 1	LOOSE, dark brown, silty SAND; trace clay, trace mica, numerous organics, moist
1 - 10	LOOSE, dark brown, silty SAND; trace clay, mica, trace organics, moist wc = 28% at 5 feet wc = 30% at 10 feet

TP-B2

Depth (feet)	Soil Description
0 - 2	LOOSE, dark brown, sandy SILT; trace clay, trace mica, numerous organics, moist wc = 12% at 2 feet
2 - 3	LOOSE, dark brown, silty SAND; mica, trace organics, moist
3 - 10	LOOSE, dark brown, sandy SILT; trace clay, trace mica, occasional organics, moist wc = 28% at 5 feet wc = 33% at 10 feet

Date: 9/19/2017
Equipment: CAT 305E

TP-B3

Depth (feet)	Soil Description
0 - 3	LOOSE, light brown, fine sandy SILT, scattered organics, iron staining, moist wc = 14% at 1 feet
3 - 7	LOOSE, dark brown, slightly sandy SILT; trace clay, occasional organics, moist wc = 30% at 7 feet
7 - 10	LOOSE, brown, slightly clayey SILT; occasional organics, moist. wc = 37% at 10 feet

Project Location: Steigerwald National Wildlife Refuge
Date: 11/21/2016
Equipment: Hitachi ZX135

TP-C1

Depth (feet)	Soil Description
0 - 1	LOOSE, brown, sandy SILT; trace clay, trace mica, numerous organics, moist
1 - 9	LOOSE, brown, sandy SILT; trace clay, trace mica, occasional organics, moist wc = 28% at 5 feet
9 - 11	LOOSE, dark brown, fine sandy SILT; trace organics, wet wc = 28% at 11 feet

TP-C2

Depth (feet)	Soil Description
0 - 3	LOOSE, light brown, fine sandy SILT; scattered organics, moist wc = 13% at 2 feet
3 - 8	LOOSE, mottled brown and gray, slightly clayey SILT; scattered organics, moist wc = 29% at 4 feet wc = 37% at 7 feet
8 - 9	LOOSE, gray, slightly clayey SILT; scattered organics, moist wc = 34% at 8.5 feet
9 - 10	LOOSE, mottled brown and gray, slightly clayey SILT; scattered organics, moist

Project Location:	Steigerwald National Wildlife Refuge
Date:	11/21/2016 - 11/22/2016
Equipment:	Hitachi ZX135

TP-D1

Depth (feet)	Soil Description
0 - 3	LOOSE, brown, fine sandy SILT; trace clay, numerous organics, moist. wc = 20% at 1 feet
3 - 10	LOOSE, dark brown, fine sandy SILT; occasional organics, moist. wc = 29% at 5 feet wc = 27% at 10 feet

TP-D2

Depth (feet)	Soil Description
0 - 3	LOOSE, brown, fine sandy SILT; trace clay, scattered organics, moist. wc = 32% at 2 feet
3 - 5	LOOSE, gray-brown, SILT; trace clay, scattered rust mottling, scattered organics. wc = 35% at 5 feet
5 - 10	LOOSE, light brown, slightly clayey SILT; scattered rust mottling, wet. Light seepage encountered at 9.5 feet. wc = 38% at 10 feet

Project Location: Steigerwald National Wildlife Refuge
Date: 11/21/2016
Equipment: Hitachi ZX135

TP-E1

Depth (feet)	Soil Description
0 - 2	LOOSE, brown, fine sandy SILT; trace clay, numerous organics, moist.
2 - 9	LOOSE, brown, slightly sandy SILT; trace clay, occasional organics, moist. wc = 29% at 5 feet
9 - 10	LOOSE, brown, slightly clayey SILT; occasional organics, moist. wc = 29% at 10 feet

TP-E2

Depth (feet)	Soil Description
0 - 3	LOOSE, brown, SILT; trace mica, numerous organics, moist. wc = 34% at 1 feet
3 - 5	LOOSE, light brown, fine sandy SILT; scattered rust mottling, moist. wc = 39% at 4.5 feet
5 - 10	LOOSE, dark brown, slightly clayey SILT; scattered rust mottling from 9 to 10 feet, scattered organics. wc = 41% at 7 feet wc = 36% at 10 feet

TP-E3

Depth (feet)	Soil Description
0 - 5	LOOSE, mottled gray and brown, slightly clayey SILT; trace organics. wc = 36% at 4 feet
5 - 7	LOOSE, brown, SILT; trace clay, occasional organics, moist. Light seepage at 6.5 feet. wc = 40% at 5.5 feet

Project Location: Steigerwald National Wildlife Refuge
Date: 11/22/2016
Equipment: Hitachi ZX135

TP-F1

Depth (feet)	Soil Description
0 - 3.5	LOOSE, brown, fine sandy SILT; trace mica, scattered organics, moist. wc = 29% at 3 feet
3.5 - 10	LOOSE, brown, slightly clayey SILT; trace organics, moist. wc = 34% at 6 feet wc = 39% at 10 feet

TP-F2

Depth (feet)	Soil Description
0 - 4.5	LOOSE, brown, fine sandy SILT; trace mica, occasional organics, moist. wc = 30% at 4 feet
4.5 - 10	LOOSE, mottled gray and brown, slightly SILT; scattered iron staining, moist. Light seepage at 9 feet. wc = 35% at 8 feet

TP-F3

Depth (feet)	Soil Description
0 - 4	LOOSE, brown, slightly clayey SILT; scattered organics, moist.
4 - 10	LOOSE, mottled gray and brown, slightly clayey SILT; occasional organics, moist. wc = 43% at 5.5 feet wc = 41% at 9 feet

Project Location: Steigerwald National Wildlife Refuge
Date: 11/22/2016
Equipment: Hitachi ZX135

TP-G1

Depth (feet)	Soil Description
0 - 5	LOOSE, brown, fine sandy SILT; trace mica, scattered organics, moist. wc = 37% at 4 feet
5 - 10	LOOSE, dark brown, slightly clayey SILT; trace organics, moist. wc = 32% at 8 feet

TP-G2

Depth (feet)	Soil Description
0 - 4	LOOSE, brown, fine sandy SILT; trace mica, occasional organics, moist. wc = 35% at 3.5 feet
4 - 7	LOOSE, mottled gray and brown, slightly clayey to clayey SILT; trace organics, scattered iron staining, moist. Moderate seepage at 6 feet. wc = 65% at 5.5 feet

Project Location:	Steigerwald National Wildlife Refuge
Date:	11/22/2016
Equipment:	Hitachi ZX135

TP-H1

Depth (feet)	Soil Description
0 - 10	LOOSE, brown, silty fine SAND; scattered organics, moist. wc = 14% at 3 feet
10 - 11	LOOSE, brown, slightly clayey SILT; trace organics, moist. wc = 39% at 10 feet

TP-H2

Depth (feet)	Soil Description
0 - 6	LOOSE, brown, fine sandy SILT; trace mica, occasional organics, moist. wc = 33% at 3 feet
6 - 7	LOOSE, mottled gray and brown, slightly clayey SILT; trace organics, scattered iron staining, moist. Moderate seepage at 6.5 feet. wc = 37% at 7 feet

Project Location: Steigerwald National Wildlife Refuge
Date: 11/22/2016 - 11/23/2016
Equipment: Hitachi ZX135

TP-I1

Depth (feet)	Soil Description
0 - 10	LOOSE, brown, silty fine SAND; scattered organics, moist. wc = 9% at 4 feet wc = 10% at 10 feet

TP-I2

Depth (feet)	Soil Description
0 - 6	LOOSE, dark brown, slightly clayey SILT; occasional organics, moist to wet. Moderate to heavy seepage at 5.5 feet. wc = 34% at 1.5 feet wc = 39% at 6 feet
6 - 7	LOOSE, gray, clayey SILT; wet. wc = 53% at 7 feet

TP-I3

Depth (feet)	Soil Description
0 - 10	LOOSE, brown, slightly clayey SILT; occasional organics, moist. Light seepage at 10 feet. wc = 38% at 3 feet wc = 39% at 7 feet

Project Location:	Steigerwald National Wildlife Refuge
Date:	11/23/2016
Equipment:	Hitachi ZX135

TP-J1

Depth (feet)	Soil Description
0 - 8	LOOSE, brown, silty fine SAND to sandy SILT; trace mica, scattered organics, moist. wc = 24% at 3 feet wc = 34% at 6.5 feet
8 - 10	LOOSE, brown, slightly clayey SILT; wet. Interbedded layers of black clayey SILT at 8 feet. Light seepage at 9.5 feet. wc = 53% at 8.5 feet

TP-J2

Depth (feet)	Soil Description
0 - 5	LOOSE, brown, fine sandy SILT to silty FINE SAND; trace organics, moist. wc = 37% at 4 feet
5 - 7.5	LOOSE, mottled gray and brown, slightly clayey to clayey SILT; wet. Moderate seepage at 6 feet. wc = 53% at 7 feet

TP-J3

Depth (feet)	Soil Description
0 - 5	LOOSE, brown, slightly clayey SILT; trace mica, trace organics, moist. wc = 41% at 3 feet
5 - 10	LOOSE, mottled light brown and gray, clayey SILT; moist. wc = 50% at 6 feet

Project Location: Steigerwald National Wildlife Refuge
Date: 9/19/2017
Equipment: CAT 305E

TP-K1

Depth (feet)	Soil Description
0 - 3	LOOSE, brown, sandy SILT; mica, scattered organics wc = 15% at 2.5 feet
3 - 7	LOOSE, light brown, sandy SILT; occassional organics, trace mica wc = 15% at 4 feet
7 - 8	LOOSE, light brown, silty SAND; trace mica
8 - 10	LOOSE, mottled gray and brown, slightly clayey SILT, trace organics wc = 41% at 8.5 feet

TP-K2

Depth (feet)	Soil Description
0 - 2.5	LOOSE, mottled light gray and brown, sandy SILT; occasional iron staining wc = 12% at 2 feet
2.5 - 6.5	LOOSE, mottled light gray and brown, slightly clayey SILT; Light seepage at 6 feet. wc = 36% at 4 feet

Project Location: Steigerwald National Wildlife Refuge
Date: 9/19/2017
Equipment: CAT 305E

TP-L1

Depth (feet)	Soil Description
0 - 4	LOOSE, brown, fine SAND; occasional organics wc = 11% at 3 feet
4 - 9	LOOSE, dark brown, SILT; trace clay wc = 27% at 5 feet wc = 31% at 9 feet

TP-L2

Depth (feet)	Soil Description
0 - 2.5	LOOSE, light brown, slightly silty, FINE SAND; occasional organics, moist wc = 14% at 2 feet
2.5 - 6	LOOSE, dark brown, slightly clayey SILT; occasional organics, wet. Moderate seepage at 6 feet.

TP-L3

Depth (feet)	Soil Description
0 - 4	LOOSE, mottled light brown and gray, silty FINE SAND; occasional organics, dry to moist. wc = 19% at 2 feet
4 - 7	LOOSE, gray, slightly sandy SILT; trace clay, moist wc = 37% at 5 feet
7 - 10	LOOSE, gray, clayey SILT; wet. wc = 74% at 8 feet

TP-L4

Depth (feet)	Soil Description
0 - 8.5	SOFT, mottled dark brown and gray, clayey SILT, scattered organics. Light seepage at 2.5 feet. wc = 41% at 2 feet

Project Location: Steigerwald National Wildlife Refuge
Date: 9/21/2017
Equipment: CAT 305E

TP-M1

Depth (feet)	Soil Description
0 - 2.5	LOOSE, mottled brown and gray, slightly clayey SILT; scattered organics (rootlets), moist. wc = 36% at 2 feet
2.5 - 4	LOOSE, brown, silty SAND; trace mica, moist wc = 19% at 4 feet
4 - 6	LOOSE, mottled gray and brown, clayey SILT; interbedded zones of black organics wc = 38% at 5 feet wc = 62% at 6 feet

TP-M2

Depth (feet)	Soil Description
0 - 3.5	LOOSE, light brown, slighty silt fine SAND; trace organics (rootlets), dry to moist wc = 14% at 2 feet
3.5 - 6	LOOSE, mottled light gray and brown, SILT; trace clay, moist wc = 28% at 4.5 feet
6 - 7	SOFT, gray and brown, clayey SILT; trace organics wc = 55% at 6.5 feet

TP-M3

Depth (feet)	Soil Description
0 - 2.5	LOOSE, light brown, slightly silty fine SAND; trace organics (rootlets), dry to moist wc = 8% at 1.5 feet
2.5 - 5	LOOSE, mottled gray and brown, slightly clayey SILT; moist wc = 31% at 4 feet
5 - 10	LOOSE, brown, slightly clayey SILT; trace mica, moist. Light seepage at 9.5 feet. wc = 37% at 8.5 feet

Project Location: Steigerwald National Wildlife Refuge
Date: 9/20/2017
Equipment: CAT 305E

TP-N1

Depth (feet)	Soil Description
0 - 4.5	LOOSE, mottled gray and brown, slightly clayey SILT, scattered organics (rootlets), wet. Heavy seepage at 2 feet. wc = 44% at 2 feet

TP-N2

Depth (feet)	Soil Description
0 - 3	LOOSE, mottled brown and red-brown, slightly clayey, SILT; trace organics (rootlets), moist wc = 46% at 2 feet
3 - 4	LOOSE, mottled gray and brown, clayey SILT; trace organics (rootlets), wet. Heavy seepage at 3 feet. wc = 56% at 4 feet

TP-N3

Depth (feet)	Soil Description
0 - 2	LOOSE, light brown, silty fine SAND; scattered organics (rootlets), moist wc = 13% at 1.5 feet
2 - 5	LOOSE, mottled gray and brown, slightly sandy SILT; trace clay, trace organics, moist wc = 30% at 4 feet
5 - 10	LOOSE, brown, slightly clayey SILT; moist to wet. Light seepage at 9.5 feet. wc = 30% at 7 feet

Project Location: Steigerwald National Wildlife Refuge
Date: 11/29/2016
Equipment: Komatsu PC40

TP-R1

Depth (feet)	Soil Description
0 - 3	LOOSE, gray and brown, sandy GRAVEL; rounded gravel. (DREDGE SPOILS) wc = 27% at 3.5 feet
3 - 5.5	LOOSE, brown, SILT with rounded gravel; trace clay, scattered organics. (DREDGE SPOILS)
5.5 - 8	LOOSE, light brown, sandy GRAVEL; rounded gravel. (DREDGE SPOILS) wc = 7% at 6 feet

TP-R2

Depth (feet)	Soil Description
0 - 4.5	LOOSE, brown, sandy GRAVEL; subrounded gravel, scattered cobbles up to 5-inches maximum dimension; trace organics, moist. wc = 8% at 1 feet
4.5 - 6	LOOSE, brown, gravelly sandy SILT; trace organics, moist. wc = 13% at 5 feet
6 - 9	LOOSE, brown, gravelly SAND; scattered silt lenses, trace organics, moist. wc = 13% at 8 feet
9 - 9.5	LOOSE, brown, sandy GRAVEL; subrounded gravel, moist. wc = 7% at 9.5 feet

TP-R3

Depth (feet)	Soil Description
0 - 4.5	LOOSE, brown, sandy SILT; scattered subrounded gravel and cobbles up to 4-inches maximum dimension, trace organics, moist. wc = 18% at 1 feet wc = 33% at 3 feet
4.5 - 6.5	LOOSE, brown, sandy SILT; trace clay, moist. wc = 27% at 6 feet

Project Location: Steigerwald National Wildlife Refuge
Date: 11/23/2016 - 11/29/2016
Equipment: Komatsu PC40

TP-T1

Depth (feet)	Soil Description
0 - 3.5	LOOSE, brown, slightly clayey SILT; trace organics, wet. Moderate to heavy seepage at 3 feet. (EMBANKMENT FILL) wc = 35% at 1.5 feet wc = 37% at 3.5 feet

TP-T2

Depth (feet)	Soil Description
0 - 5	LOOSE, mottled brown and gray, slightly clayey SILT; scattered organics, scattered iron staining, moist. Moderate seepage at 2 feet. wc = 40% at 1 feet wc = 61% at 3 feet
5 - 5.5	LOOSE, gray, sandy GRAVEL; subrounded gravel, wet. wc = 20% at 5.5 feet

TP-T3

Depth (feet)	Soil Description
0 - 4	LOOSE, mottled gray and brown, slightly clayey SILT; trace organics, moist. Moderate seepage at 4 feet. wc = 31% at 1 feet wc = 53% at 3 feet
4 - 5.5	LOOSE, gray, slightly clayey sandy SILT; trace organics, wet to saturated wc = 55% at 4.5 feet

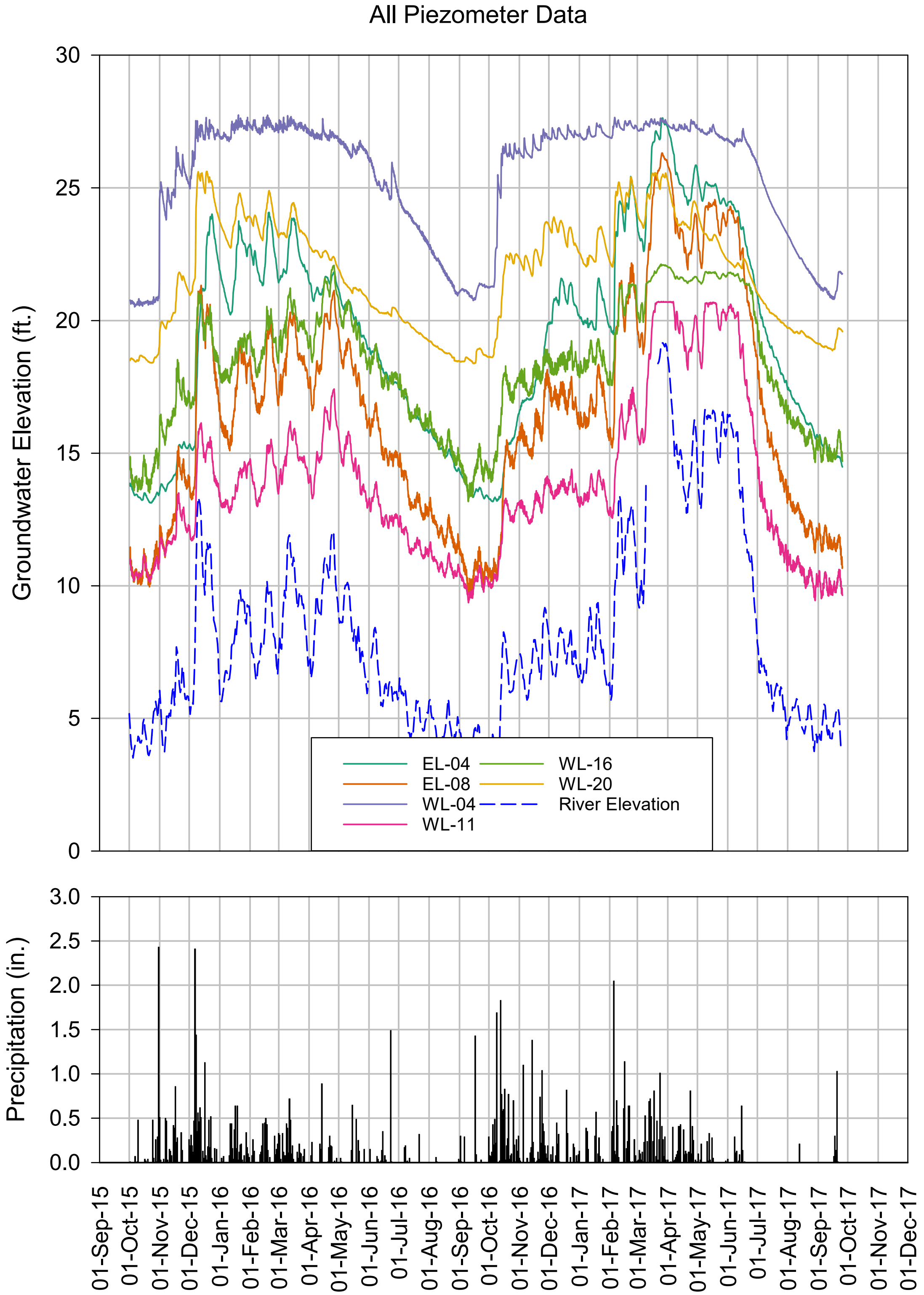
TP-T4

Depth (feet)	Soil Description
0 - 3.5	LOOSE, mottled gray and brown, slightly clayey SILT; trace organics, moist. Light seepage at 3 feet. wc = 34% at 1.5 feet wc = 46% at 3 feet
3.5 - 6.5	LOOSE, gray, slightly clayey sandy SILT; trace organics, wet. wc = 35% at 4 feet
6.5 - 8	LOOSE, mottled brown and gray, clayey SILT; wet. wc = 41% at 8 feet

TP-T5

Depth (feet)	Soil Description
0 - 5	LOOSE, mottled gray and brown, slightly clayey SILT; trace organics, moist to wet. Light seepage at 4.5 feet. wc = 35% at 2 feet wc = 38% at 4 feet

Appendix C – Groundwater Monitoring Plots



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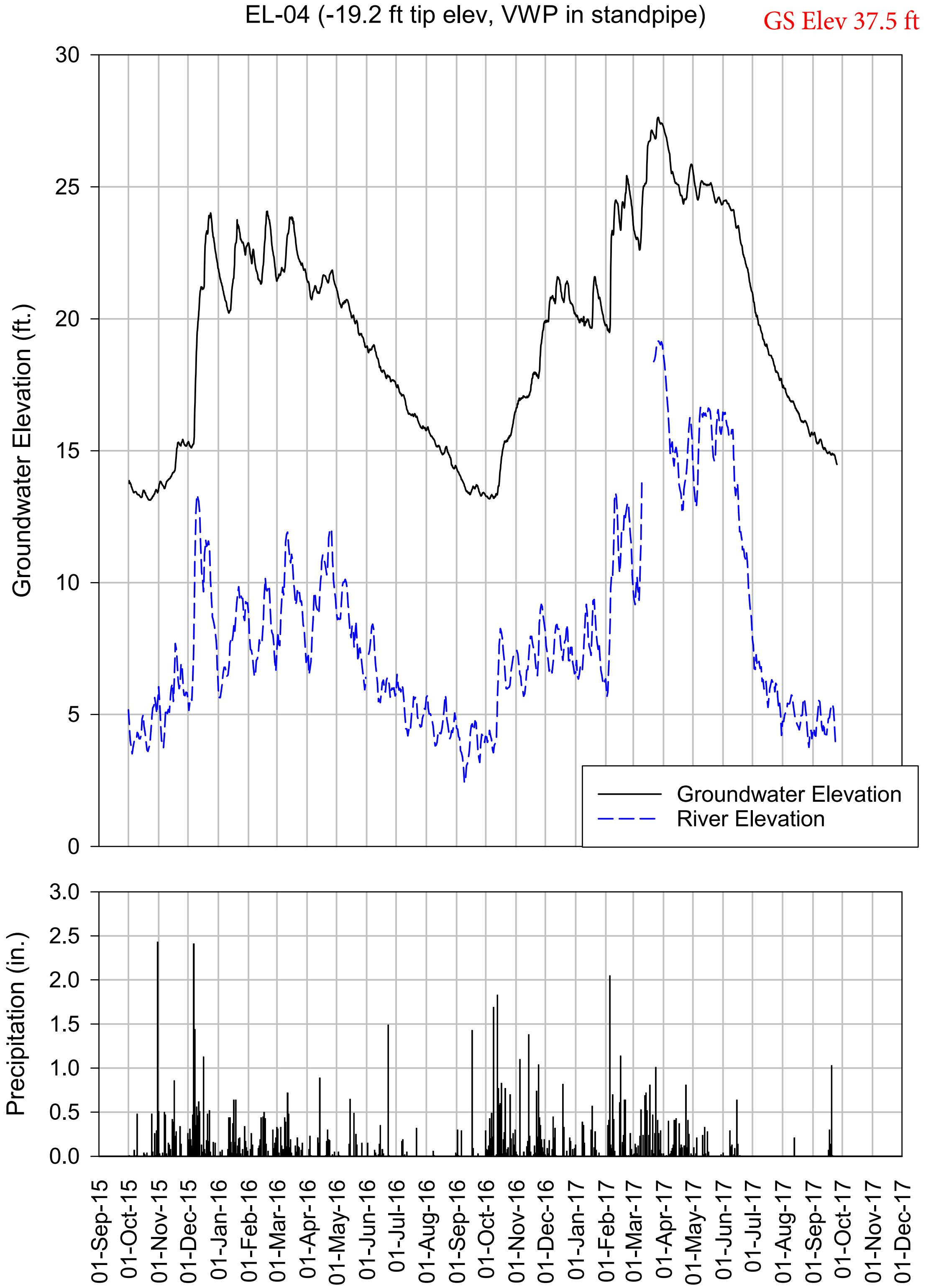
Groundwater Monitoring

STEIGERWALD LEVEE DESIGN - PH2
WASHOUGAL, WASHINGTON

AUG 2018

PROJ. 2613

FIG. C-1



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EL-04 HYDROGRAPH

STEIGERWALD LEVEE DESIGN - PH2
WASHOUGAL, WASHINGTON

AUG 2018

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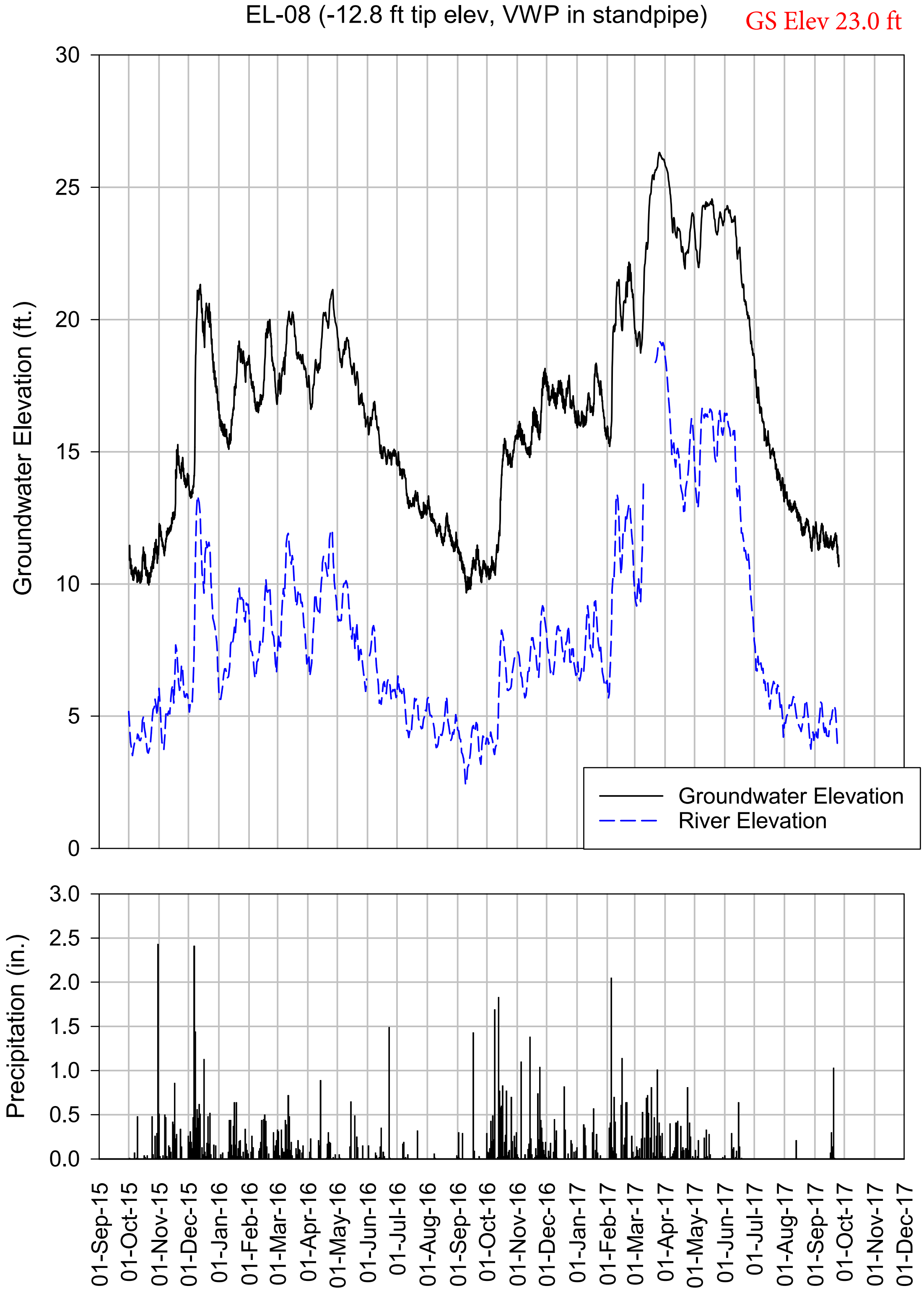
FIG. C-2



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EL-08 HYDROGRAPH

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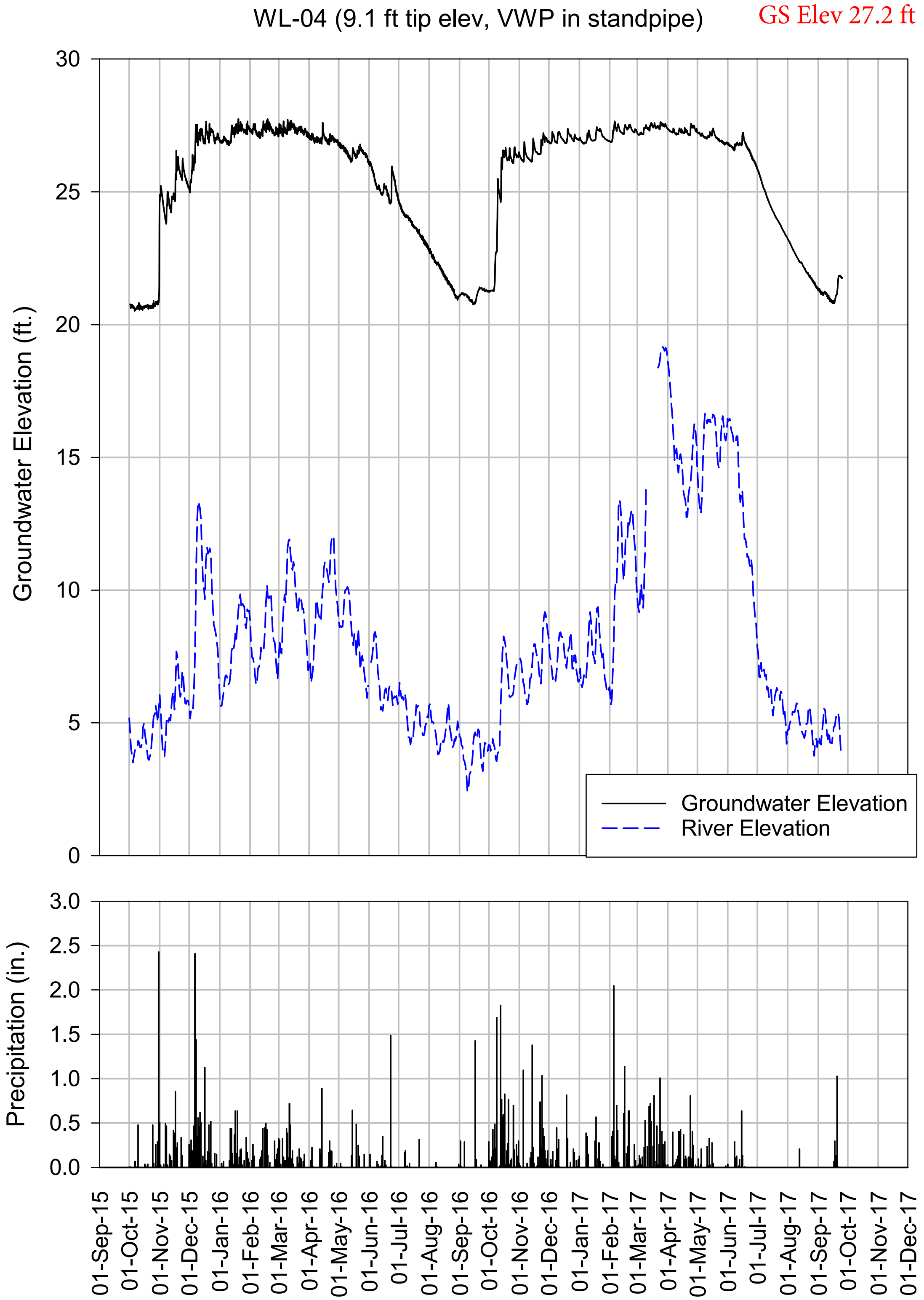
FIG. C-3



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WL-04 HYDROGRAPH

STEIGERWALD LEVEE DESIGN - PH2
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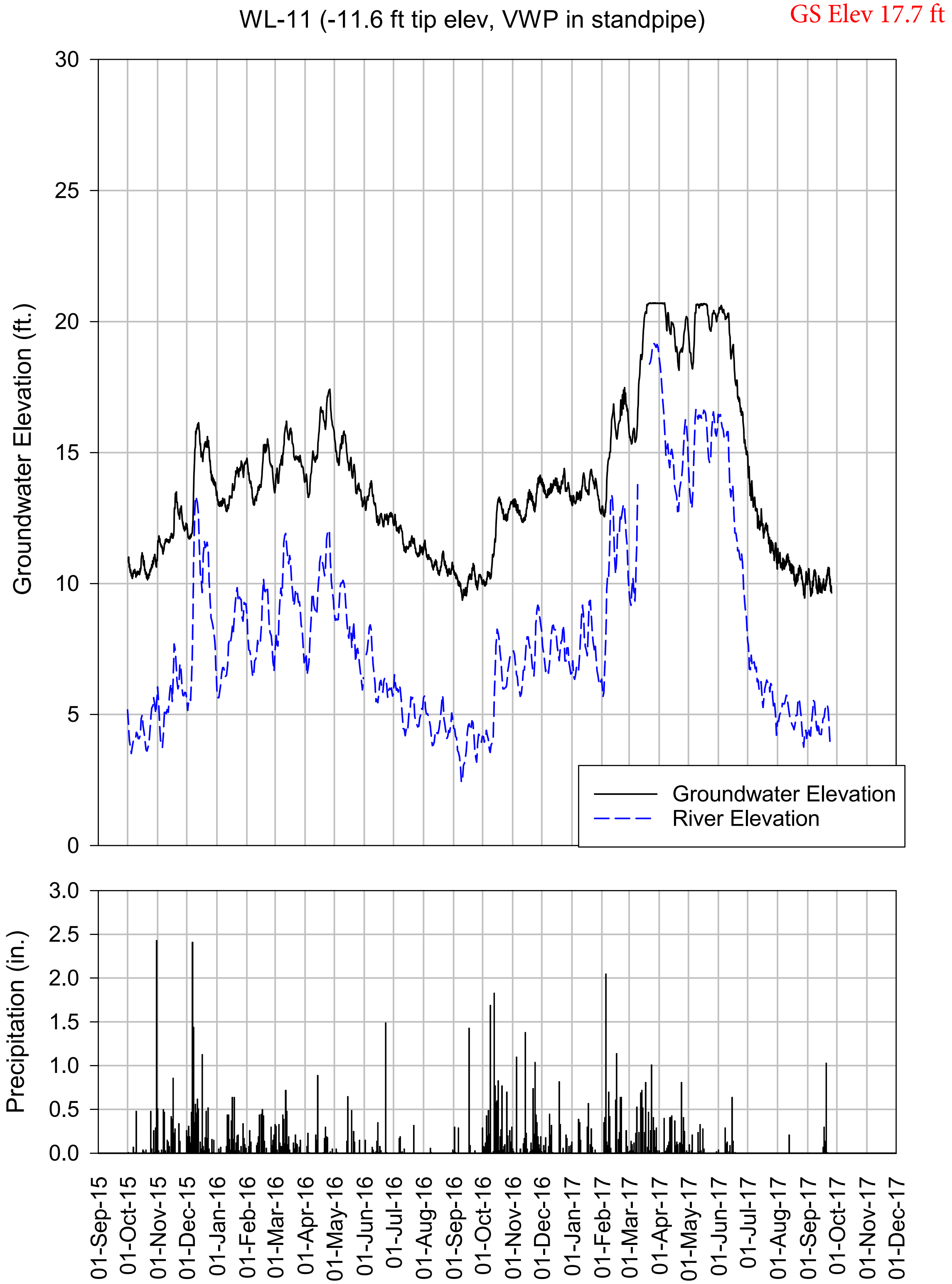
FIG. C-4



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WL-11 HYDROGRAPH

STEIGERWALD LEVEE DESIGN - PH2
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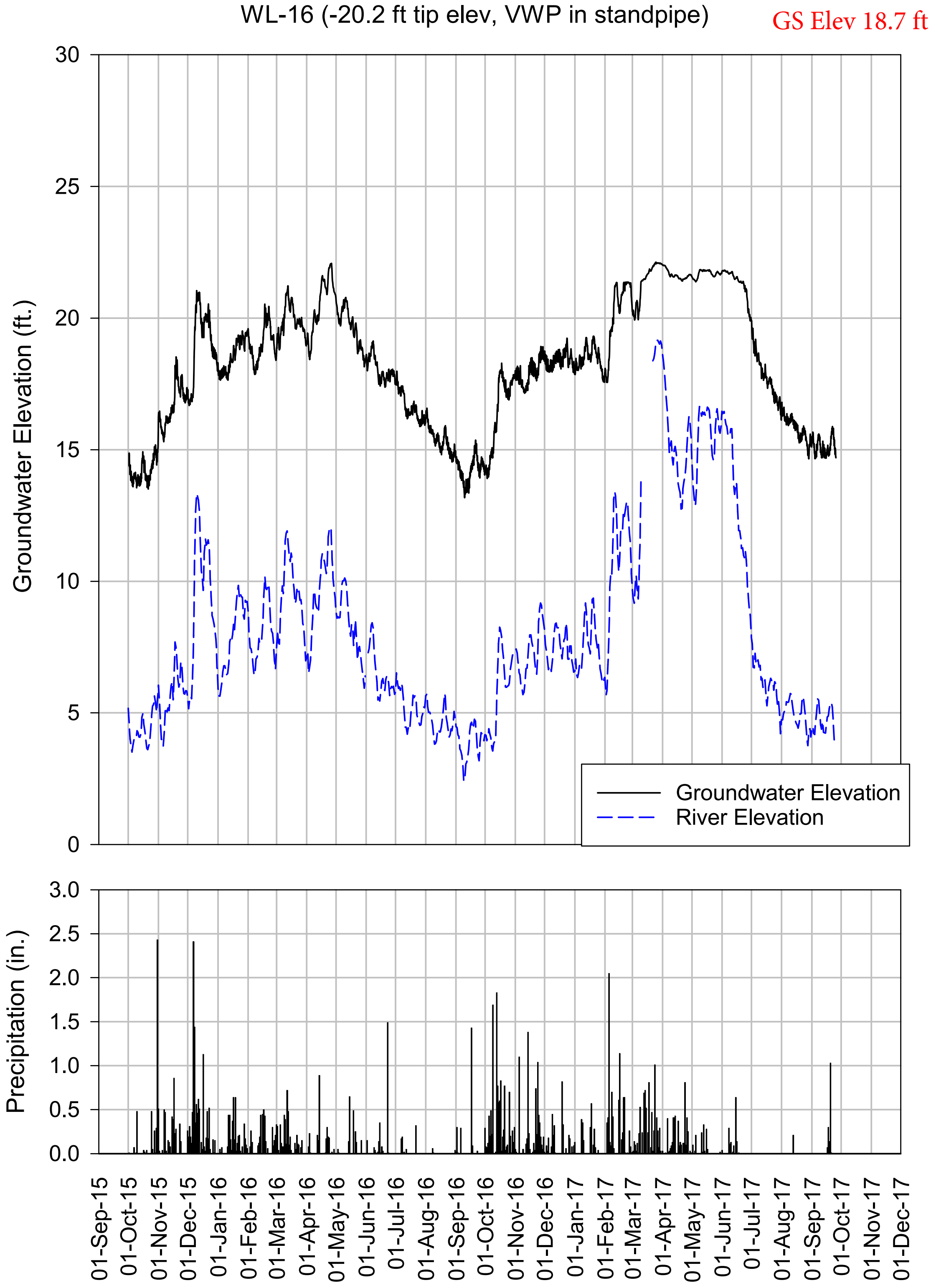
FIG. C-5



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WL-16 HYDROGRAPH

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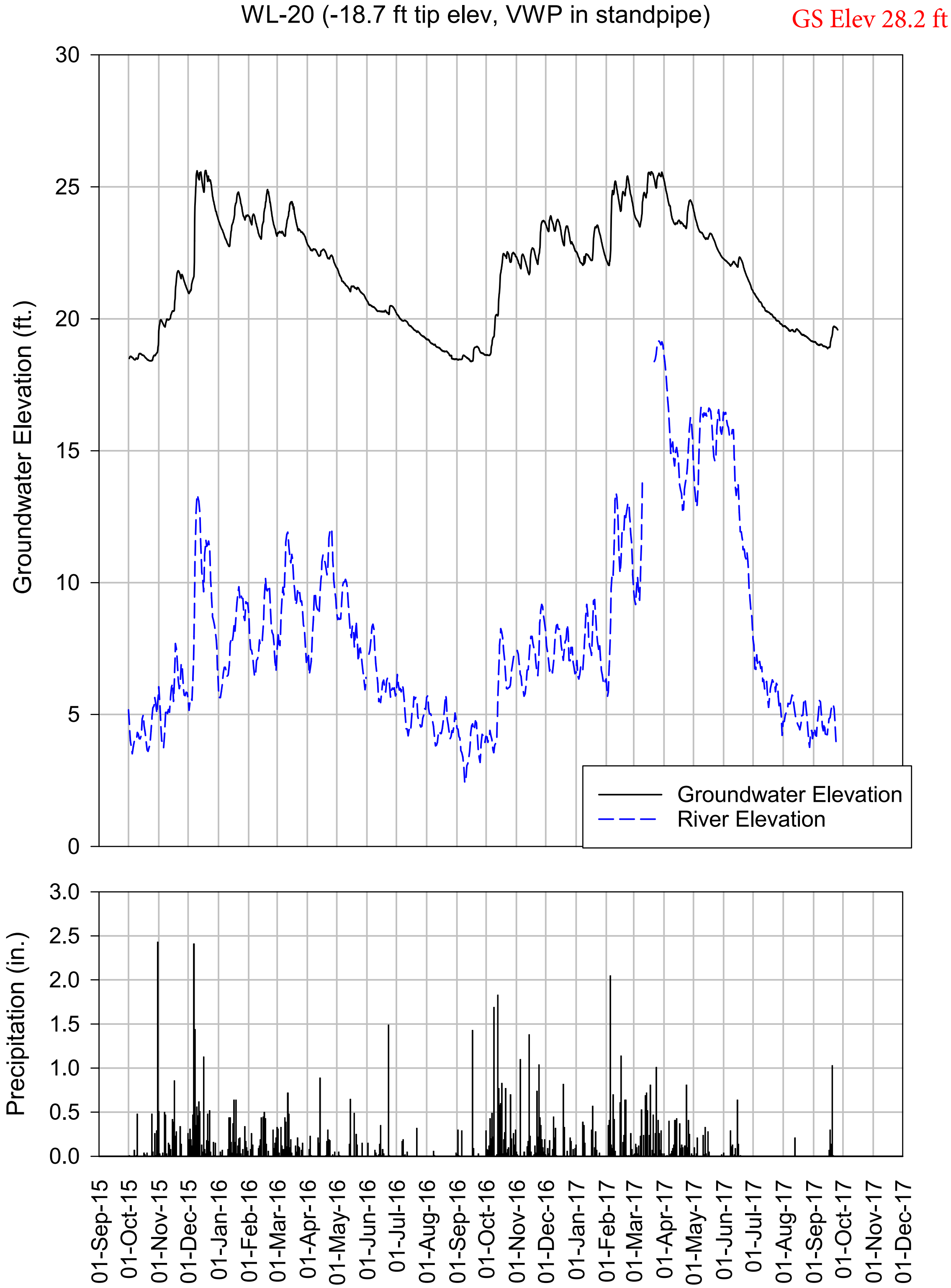
FIG. C-6



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WL-20 HYDROGRAPH

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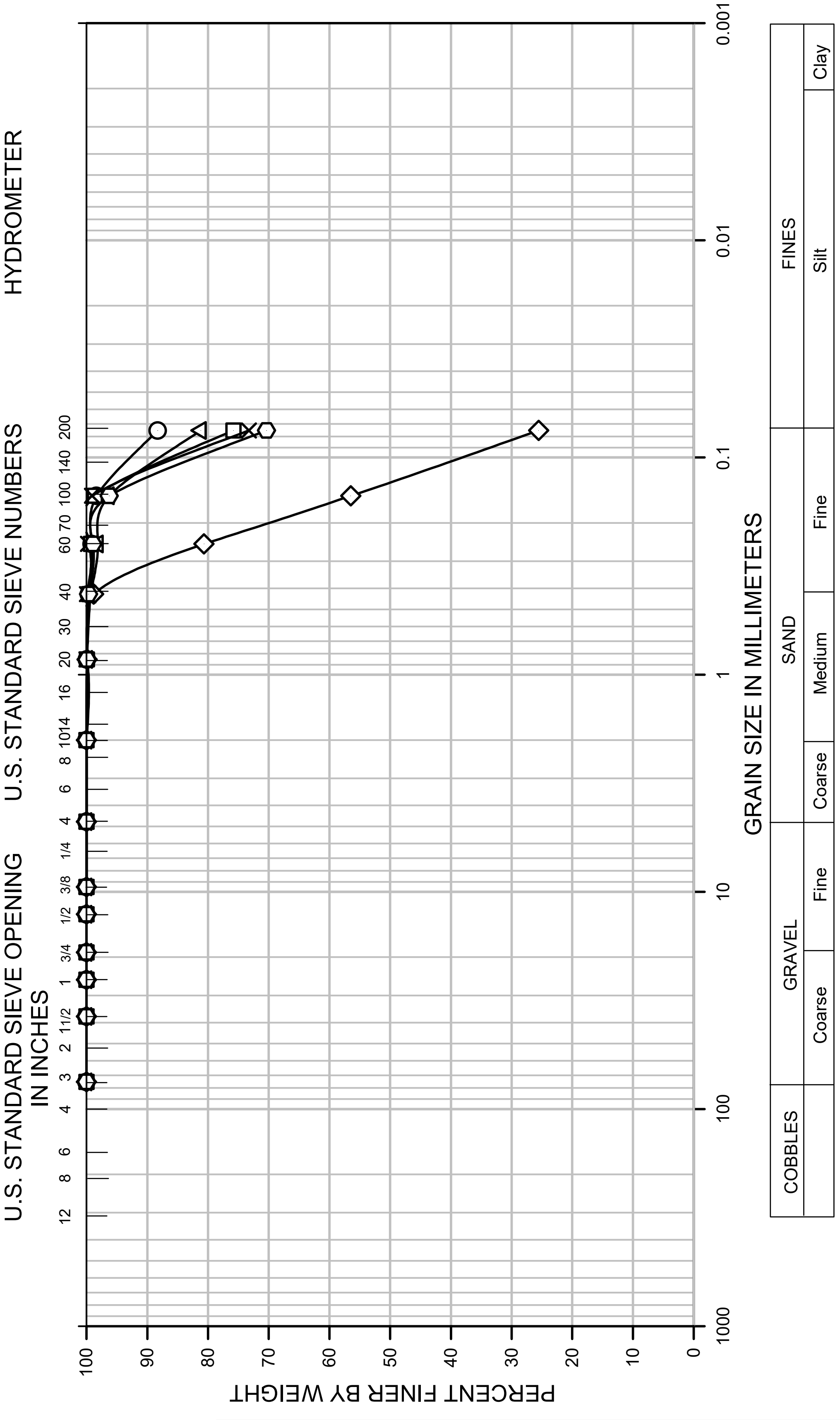
FIG. C-7

Appendix D – Laboratory Testing Results



	Boring No.	Sample No.	Depth	Classification	Nat W%	LL	PL	PI
○	WL-01	S-2	10 ft	Fine sandy SILT	48	--	--	--
◁	WL-04	S-2	10 ft	Fine sandy SILT	51	--	--	--
□	WL-05	S-4	20 ft	Fine sandy SILT	45	--	--	--
◇	WL-07	S-8	35 ft	Silty, fine to medium SAND	26	--	--	--
✕	WL-08	S-3	15 ft	Fine sandy SILT	37	--	--	--
⬡	WL-09	S-8	35 ft	Fine sandy SILT	45	--	--	--

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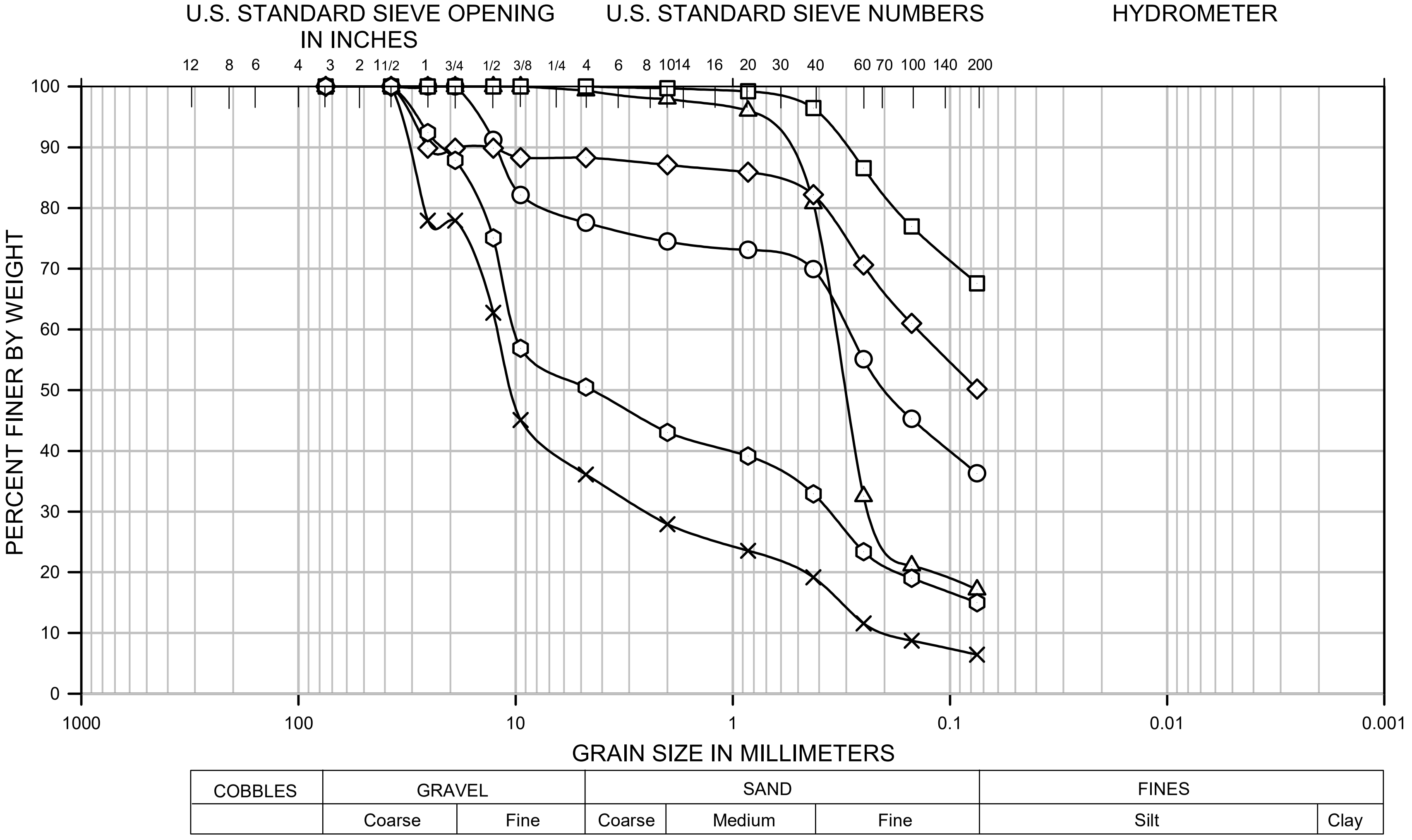
FIG. D-1



Boring No.	Sample No.	Depth	Classification	Nat W%	LL	PL	PI
─○─ WL-12	S-7	25 ft	Silty SAND with gravel	34	--	--	--
─△─ WL-14	S-1	5.5 ft	Silty SAND	54	--	--	--
─□─ WL-16	S-3	15 ft	Fine sandy SILT	29	--	--	--
─◇─ WL-17	S-2	10 ft	Fine sandy SILT	35	--	--	--
─×─ WL-18	S-1	5 ft	Well-graded GRAVEL with sand and silt	12	--	--	--
─⬡─ WL-19	S-1	5 ft	Silty GRAVEL with sand	23	--	--	--

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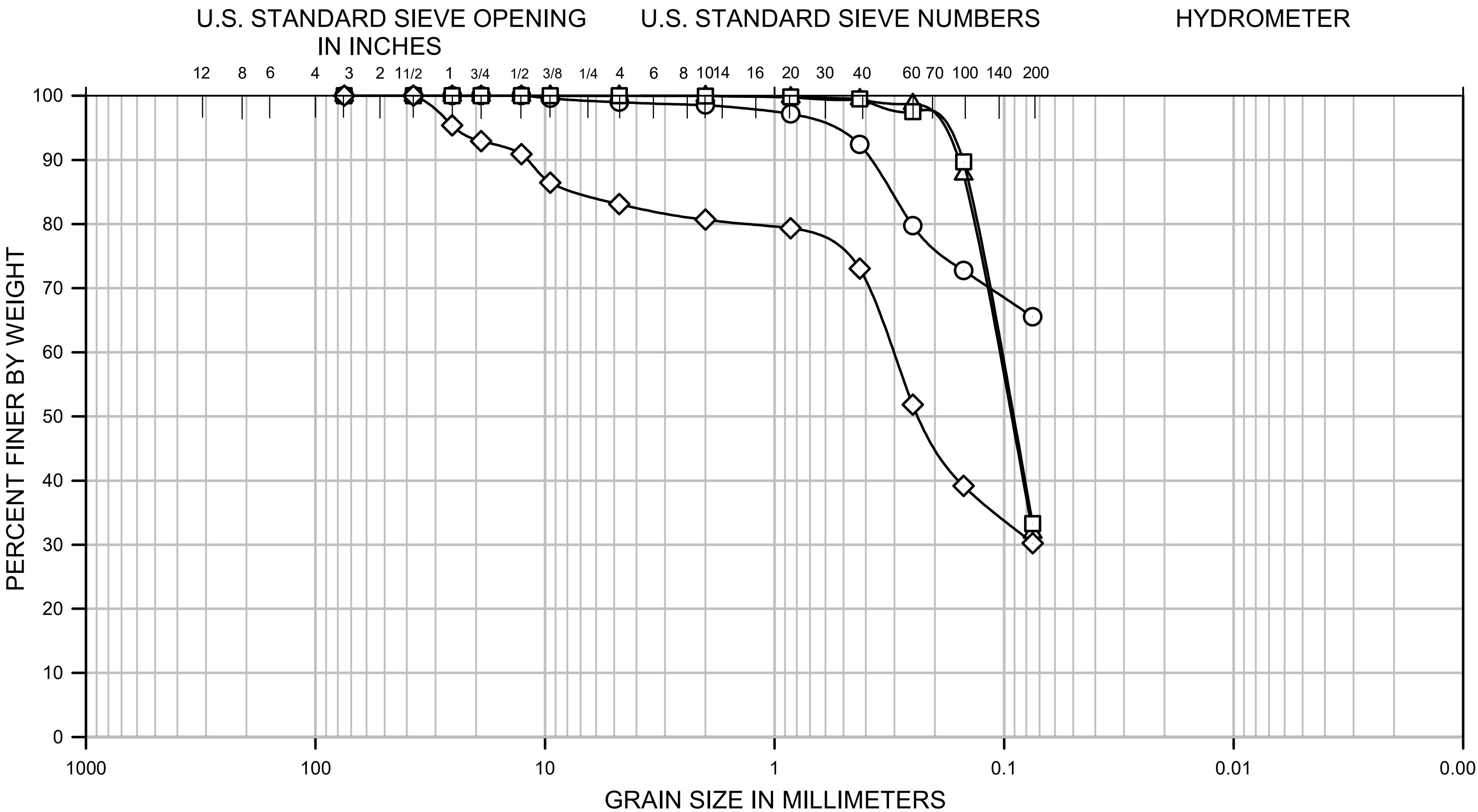
FIG. D-2



COBBLES	GRAVEL		SAND			FINES	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay

Boring No.	Sample No.	Depth	Classification	Nat W%	LL	PL	PI
─○─ WL-20	S-2	10 ft	Fine sandy SILT	27	--	--	--
─△─ WL-21	S-2	7 ft	Silty fine SAND	37	--	--	--
─□─ WL-22	S-5	40 ft	Silty fine SAND	30	--	--	--
─◇─ GF-02	S-1	6 ft	Silty SAND with gravel	--	--	--	--

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MECHANICAL GRADATIONS
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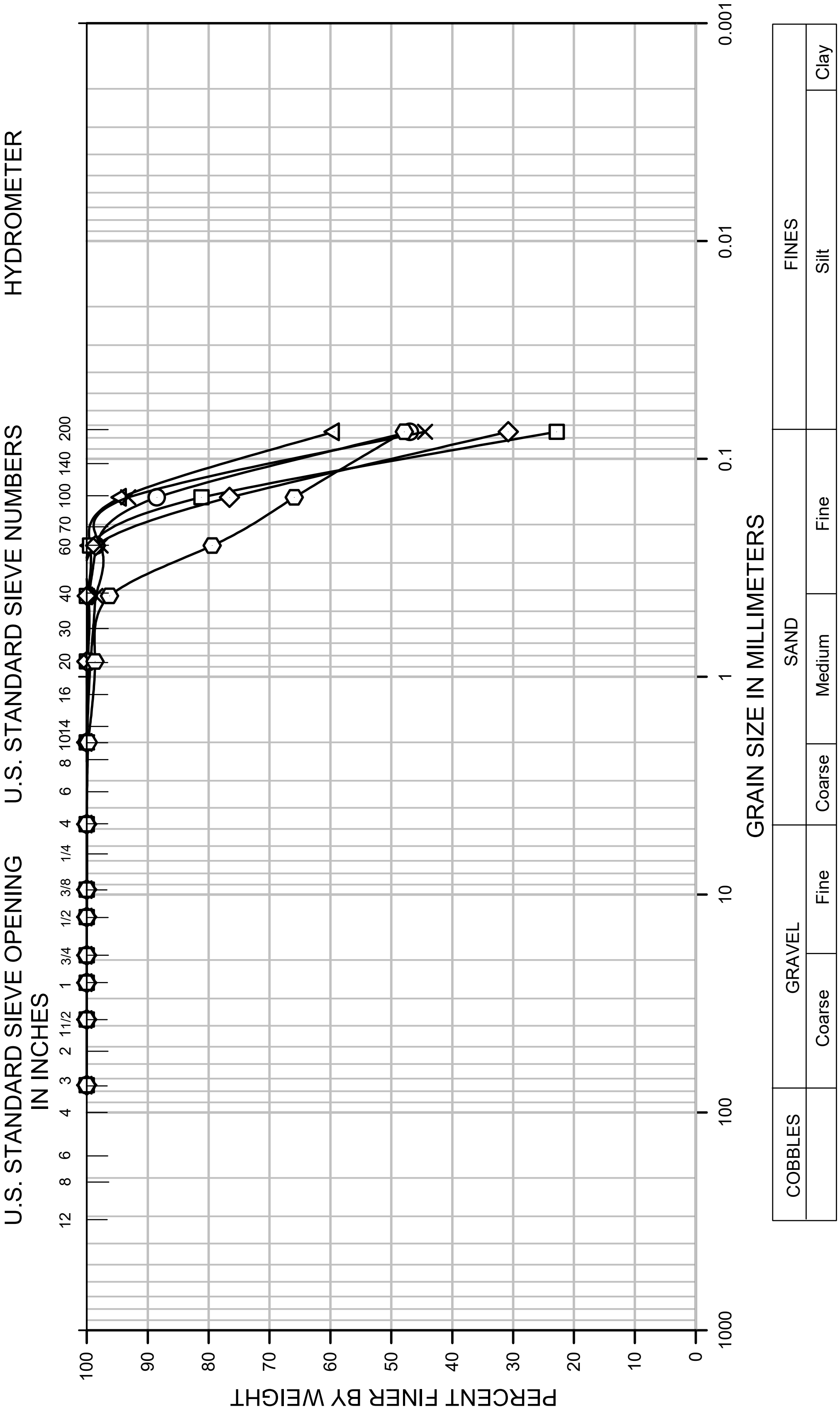
FIG. D-3



	Test Pit No.	Sample No.	Depth	Classification	Nat W%	LL	PL	PI
○	TP-B1	S-1	5 ft	silty FINE SAND	28	--	--	--
◁	TP-E1	S-1	5 ft	fine sandy SILT	29	--	--	--
□	TP-H1	S-1	3 ft	silty FINE SAND	14	--	--	--
◇	TP-J1	S-3	3 ft	silty FINE SAND	53	--	--	--
✕	TP-J2	S-1	4 ft	silty FINE SAND	37	--	--	--
⬡	TP-R3	S-3	3 ft	sandy SILT	27	--	--	--

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MECHANICAL GRADATIONS
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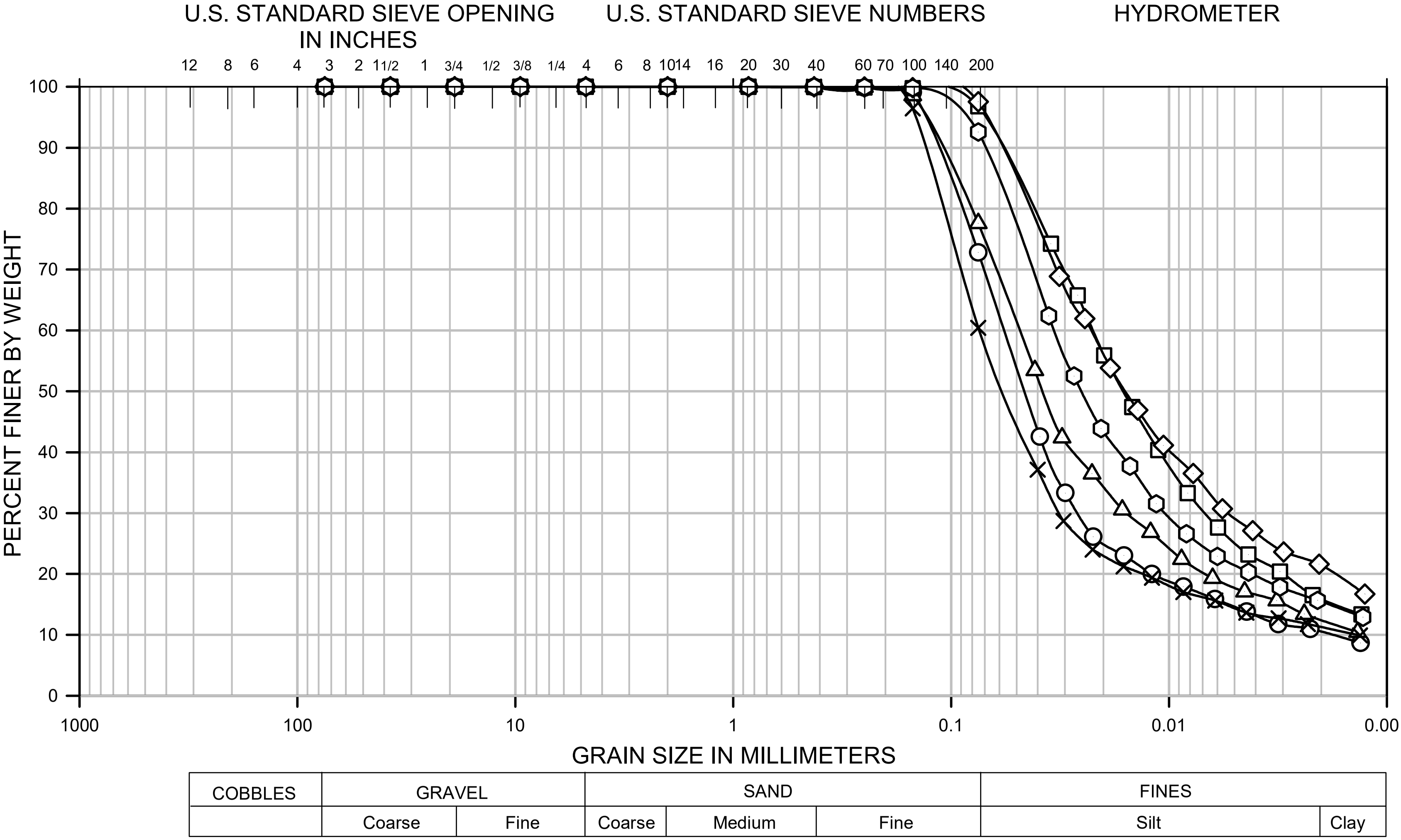
FIG. D-4



Boring No.		Sample No.	Depth	Classification	Nat W%	LL	PL	PI
○	EL-01	S-1	5 ft	Slightly clayey, sandy SILT	31	--	--	--
△	EL-01	S-6	30 ft	Slightly clayey, sandy SILT	42	--	--	--
□	EL-02	S-8	35 ft	Slightly clayey SILT, trace sand	34	--	--	--
◇	EL-03	S-2	10 ft	Slightly clayey SILT, trace sand	45	--	--	--
×	EL-04	S-3	15 ft	Slightly clayey, very sandy SILT	33	--	--	--
⬡	EL-04	S-9	37 ft	Slightly clayey, slightly sandy SILT	39	--	--	--

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HYDROMETERS
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FIG. D-5

COBBLES	GRAVEL		SAND			FINES	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay

Boring No.	Sample No.	Depth	Classification	Nat W%	LL	PL	PI
○ EL-06	S-3	15 ft	Slightly clayey SILT, trace sand	63	--	--	--
△ EL-06	S-7	30 ft	Slightly clayey SILT, trace sand	44	--	--	--
□ EL-07	S-6	25 ft	Clayey SILT, trace sand	43	50	29	21
◇ EL-08	S-4	20 ft	Clayey SILT	43	--	--	--
× EL-10	S-2	10 ft	Slightly sandy, clayey SILT	32	42	30	12
⬡ EL-12	S-1	5 ft	Slightly clayey, slightly silty SAND	--	--	--	--

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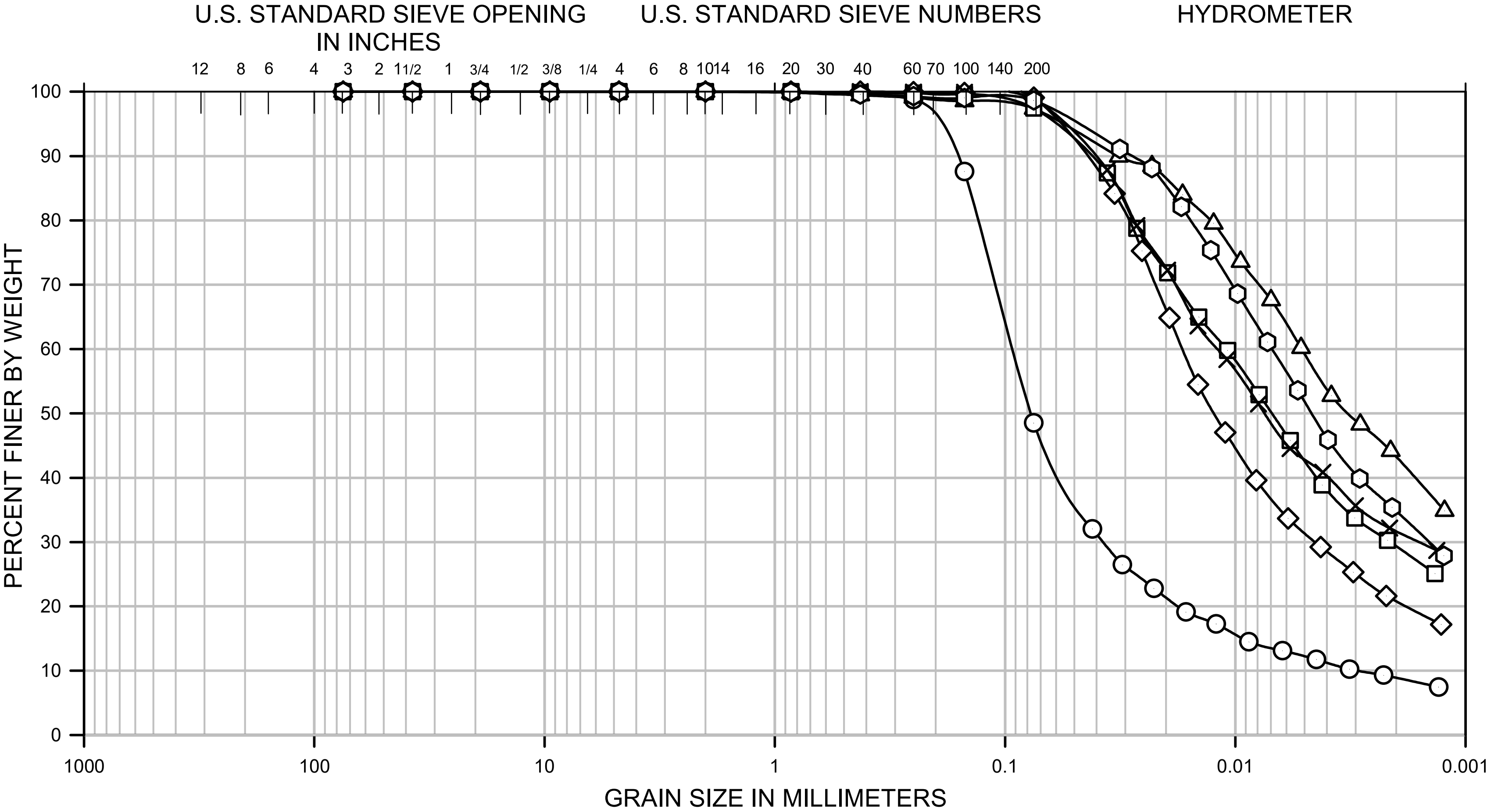
FIG. D-6



COBBLES	GRAVEL		SAND			FINES	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay

Boring No.	Sample No.	Depth	Classification	Nat W%	LL	PL	PI
○ WL-01	S-3	15 ft	Slightly clayey, silty fine SAND	41	--	--	--
△ WL-02	S-6	27 ft	Silty CLAY, trace sand	61	83	38	45
□ WL-03	S-5	25 ft	Clayey SILT, trace sand	56	40	30	10
◇ WL-05	S-10	45 ft	Slightly clayey SILT, trace sand	58	--	--	--
× WL-06	S-4	18 ft	Clayey SILT, trace sand	37	57	31	26
⬡ WL-07	S-5	20 ft	Clayey SILT, trace sand	51	--	--	--

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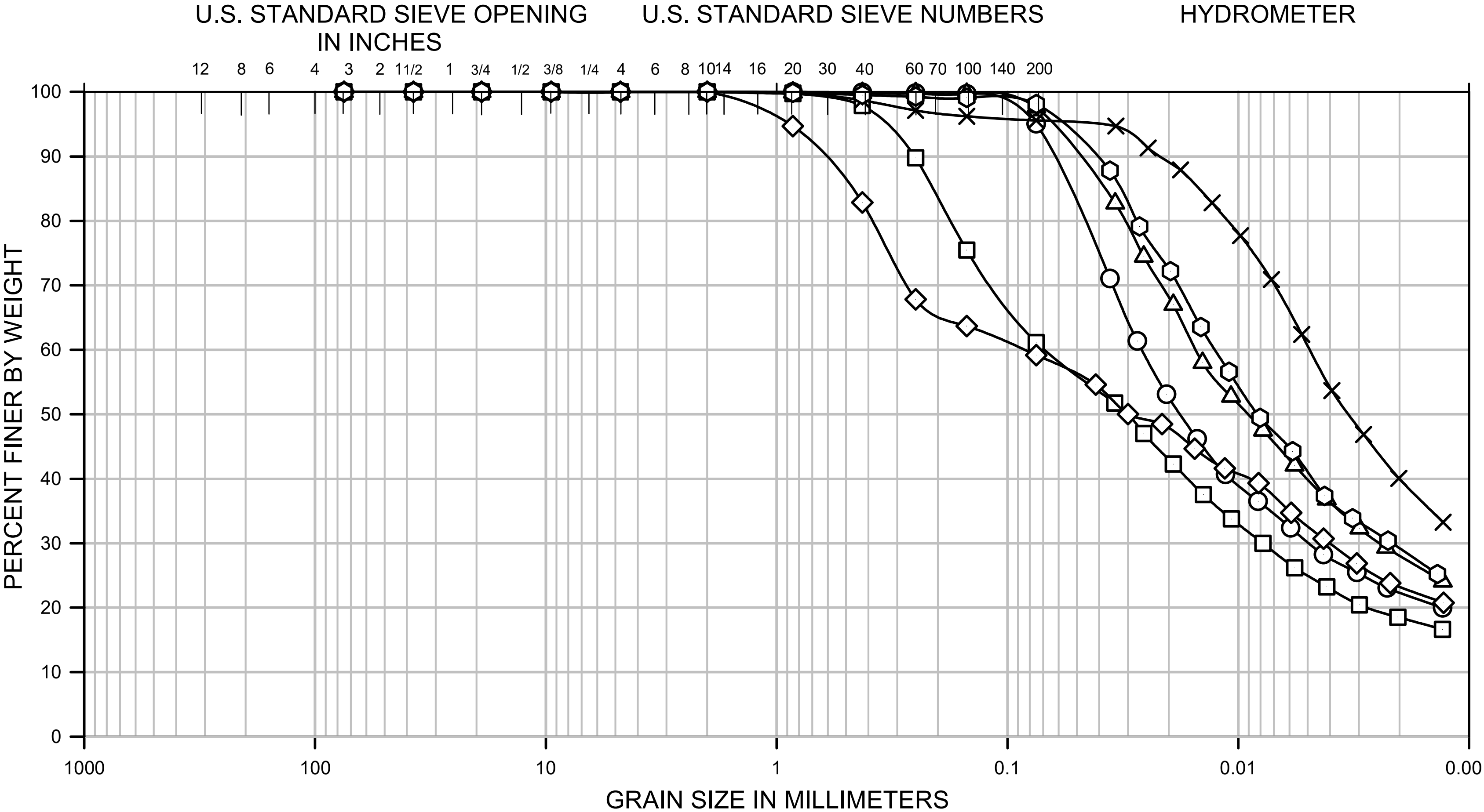
FIG. D-7



COBBLES	GRAVEL		SAND			FINES	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay

Boring No.	Sample No.	Depth	Classification	Nat W%	LL	PL	PI
○ WL-10	S-3	15 ft	Slightly sandy, slightly clayey SILT	40	--	--	--
△ WL-10	S-4	18 ft	Clayey SILT, trace sand	42	55	31	24
□ WL-13	S-1	5 ft	Slightly clayey, sandy SILT	39	--	--	--
◇ WL-14	S-3	10 ft	Slightly clayey, very sandy SILT	40	--	--	--
× WL-23	S-1	8 ft	Slightly sandy, clayey SILT	45	45	30	15
⬡ BR-01	S-3	10 ft	Clayey SILT, trace sand	48	--	--	--

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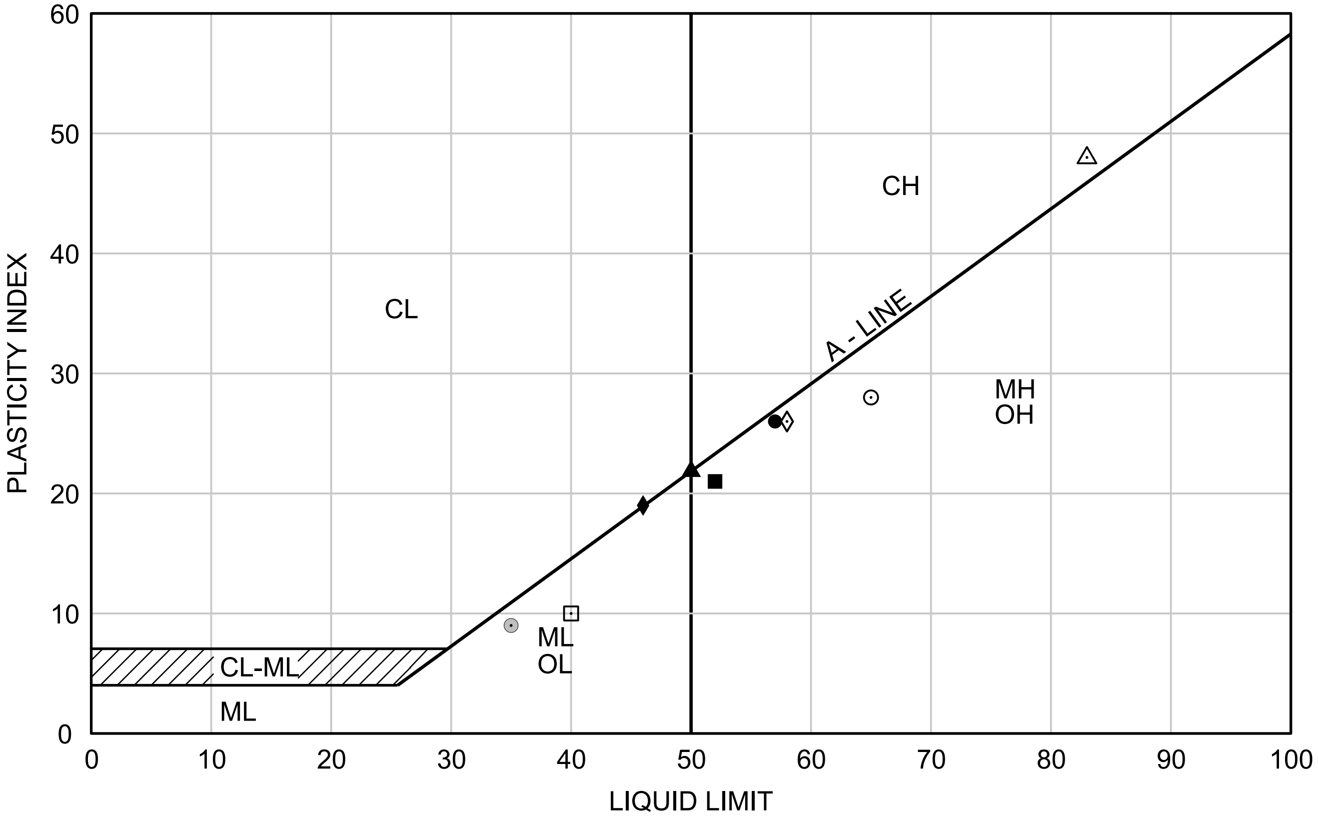
FIG. D-8



LEGEND

	BORING	SAMPLE NO.	DEPTH (FT)
⊙	WL-01	S-4	20-21.5
△	WL-02	S-6	27-28.5
⊡	WL-03	S-5	25-26.5
◊	WL-04	S-3	20-21.5
●	WL-06	S-4	18-19.5
▲	WL-07	S-3	15-16.5
■	WL-07	S-14	60-61.5
♦	WL-08	S-2	10-11.5
⊙	WL-09	S-2	10-11.5

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2436/Lab/P1.AI NAU

PLASTICITY CHART

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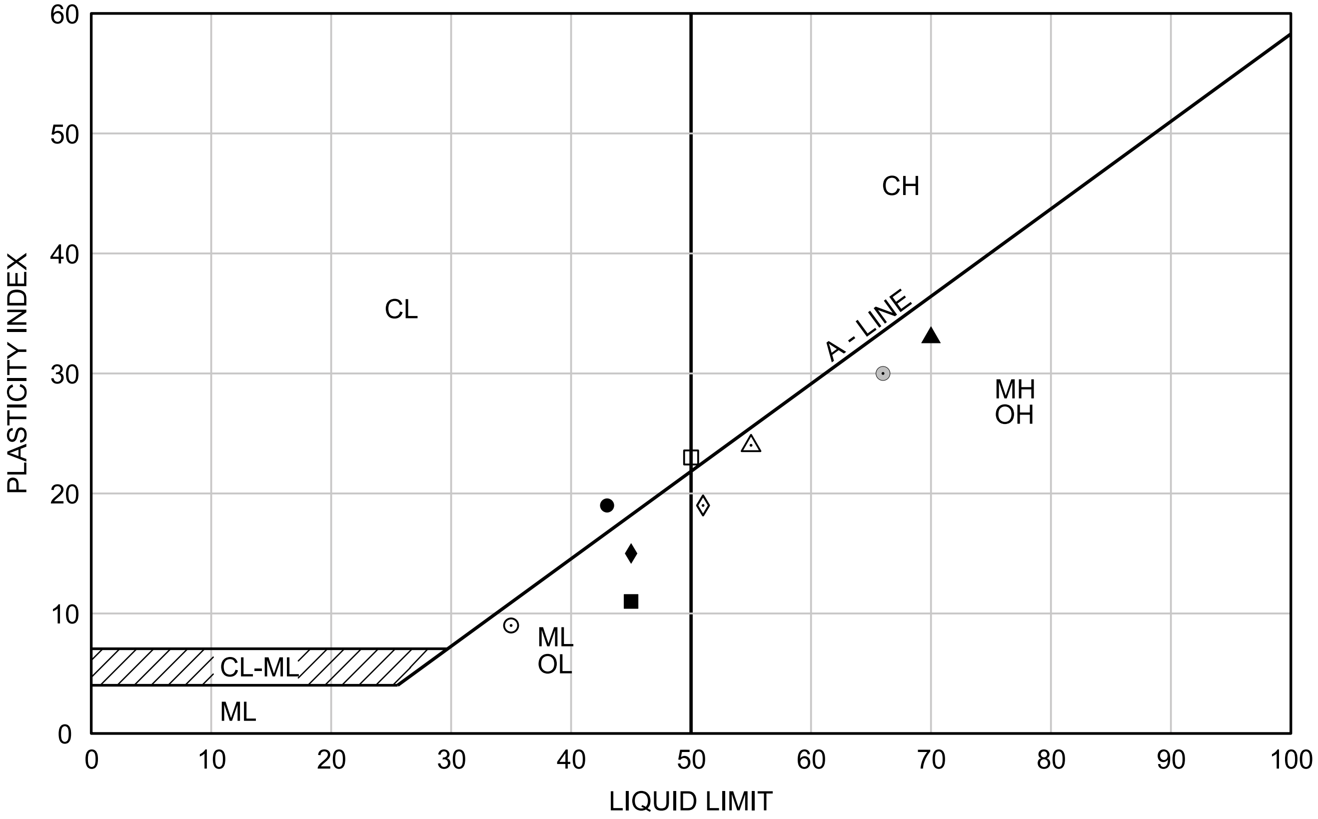
FIG. D-9



LEGEND

	BORING	SAMPLE NO.	DEPTH (FT)
⊙	WL-10	S-1	5-6.5
△	WL-10	S-4	18-20
⊡	WL-10	S-4b	18-20
◊	WL-12	S-3	10-11.5
●	WL-17	S-1	5-6.5
▲	WL-21	S-7	20-21.5
■	WL-22	S-3	20-21.5
♦	WL-23	S-1	8-9.5
⊙	WL-23	S-3	20-21.5

2436/Lab/P2.AI NAU

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PLASTICITY CHART

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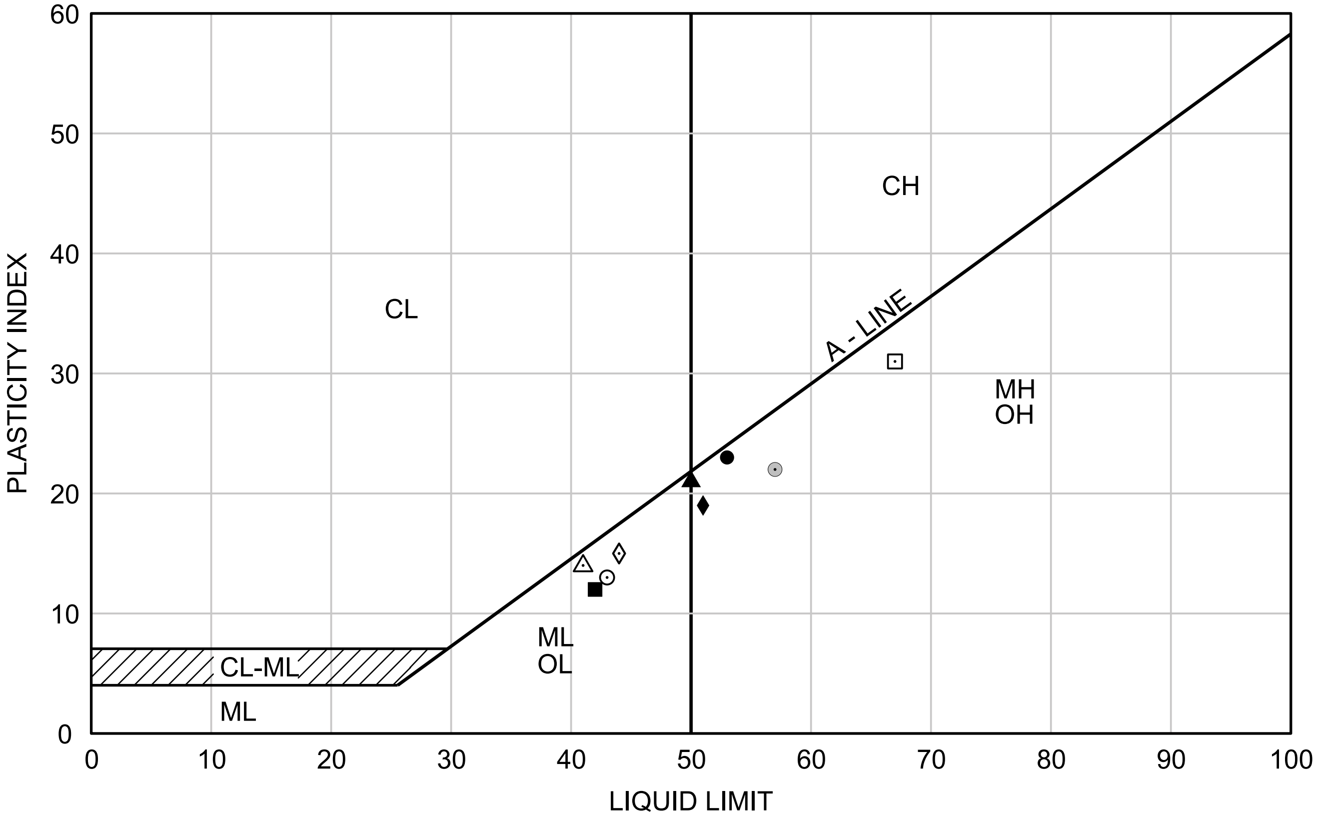
FIG. D-10



LEGEND

	BORING	SAMPLE NO.	DEPTH (FT)
⊙	EL-01	S-3	15-16.5
△	EL-04	S-6	25-26.5
⊡	EL-05	S-3	15-17
◊	EL-06	S-2	10-11.5
●	EL-06	S-5	22-23.5
▲	EL-07	S-6	25-27
■	EL-10	S-2	10-11.5
♦	EL-12	S-8	40-41.5
⊙	BR-02	S-2	7-8.5

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PLASTICITY CHART

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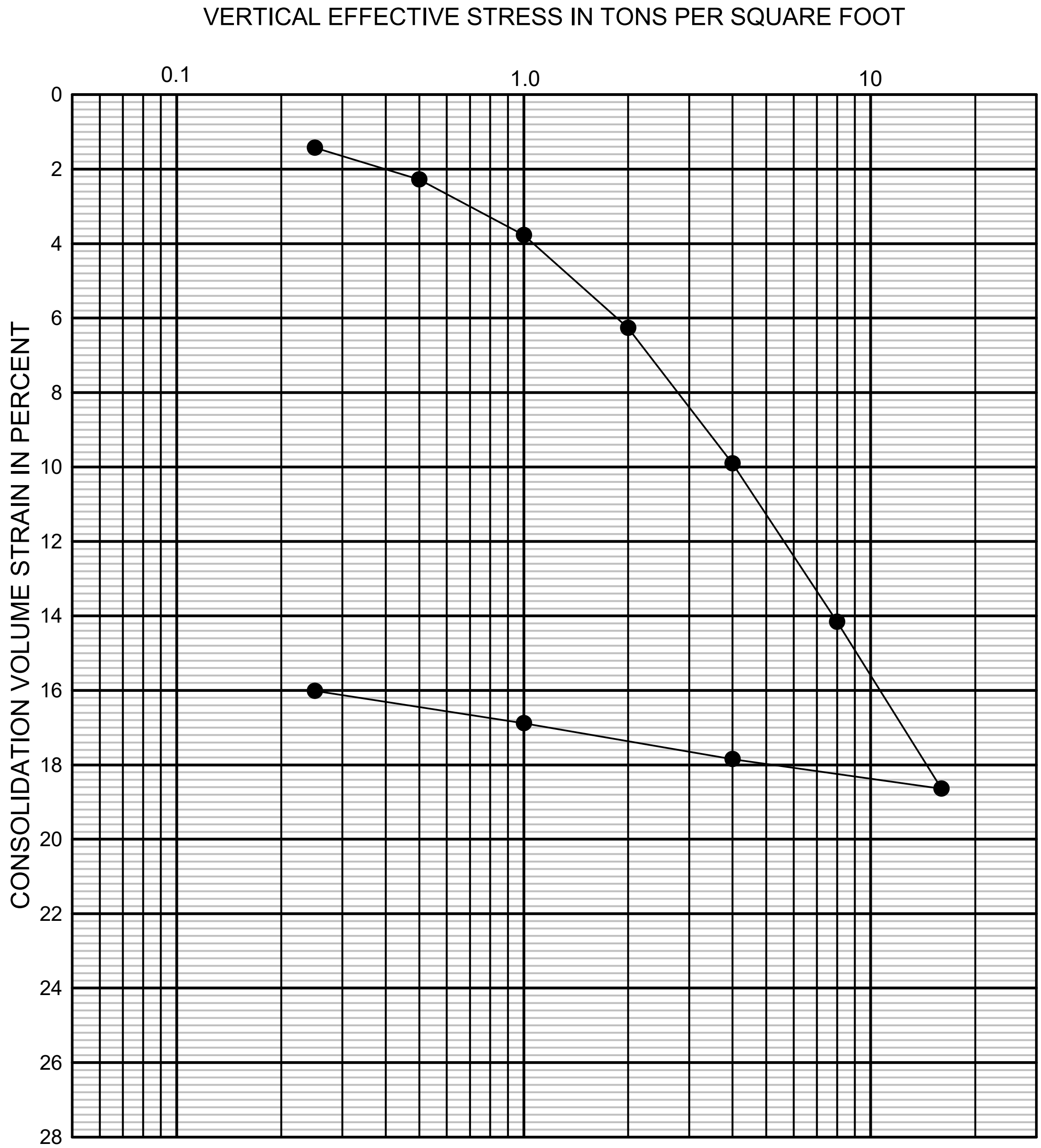
FIG. D-11

2436/Lab/P3.AI NAU



$C_{\varepsilon c}$ = 0.15

$C_{\varepsilon r}$ = 0.016

P'_o = 1.04 tsf

P'_c = 2.00 tsf

Boring No. EL-01 Sample No. S-6 Depth of Sample 30 to 32 ft.

Soil Description Slightly clayey, sandy SILT

☒ Undisturbed ☐ Re-compacted

Initial Conditions:

Height 0.75 inches

Diameter 2.50 inches

Wet Density 111 lb/ft^3

Water Content 42 %

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EL-01, S-6
CONSOLIDATION TEST

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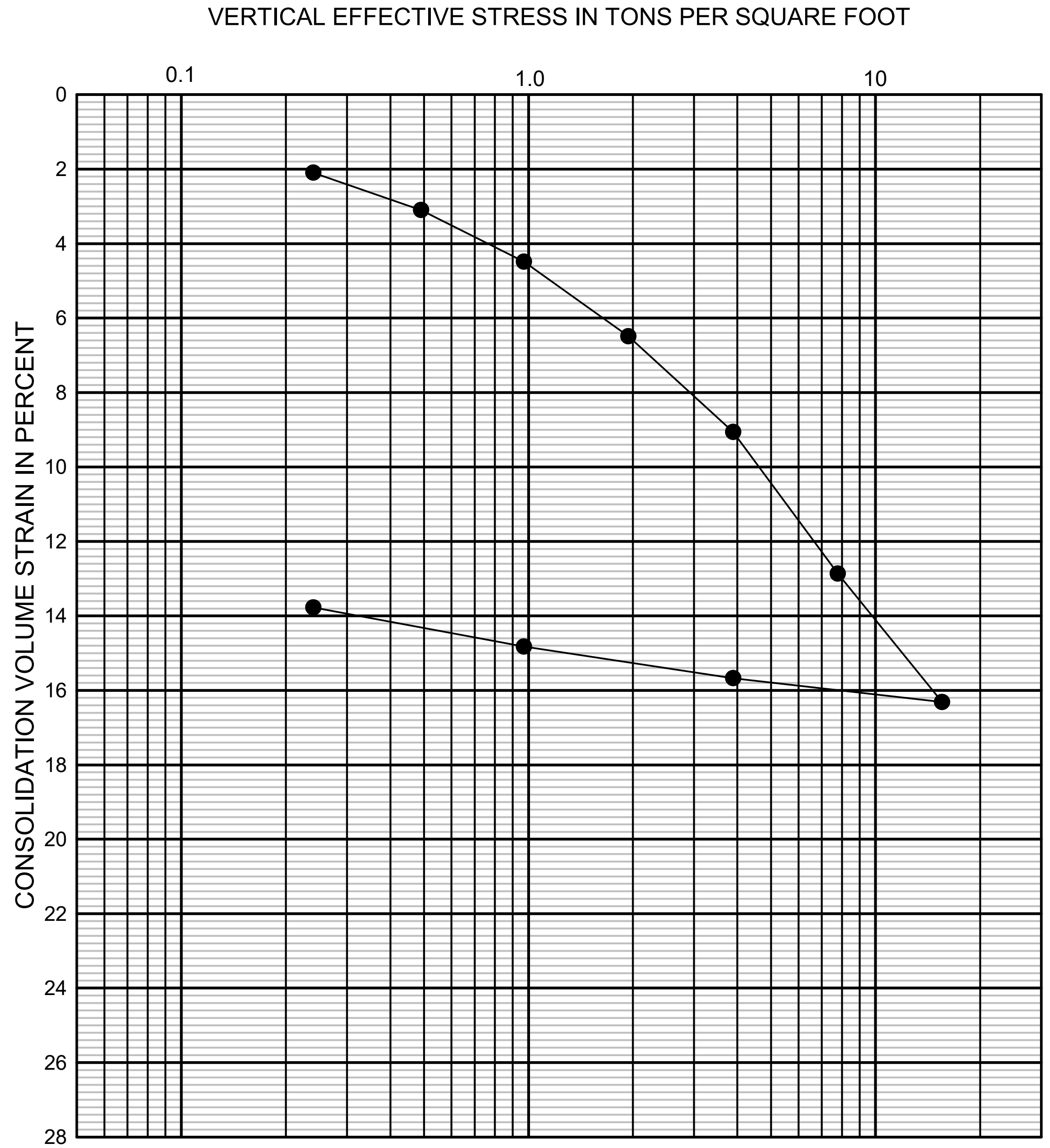
FIG. D-12



$C_{\varepsilon c}$ = 0.13

$C_{\varepsilon r}$ = 0.016

P'_o = 0.87 tsf

P'_c = 1.95 tsf

Boring No. EL-04 Sample No. S-3 Depth of Sample 15 to 17 ft.

Soil Description Slightly clayey, very sandy SILT

☒ Undisturbed ☐ Re-compacted

Initial Conditions:

Height 0.80 inches

Diameter 2.50 inches

Wet Density 116 lb/ft^3

Water Content 33 %

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EL-04, S-3
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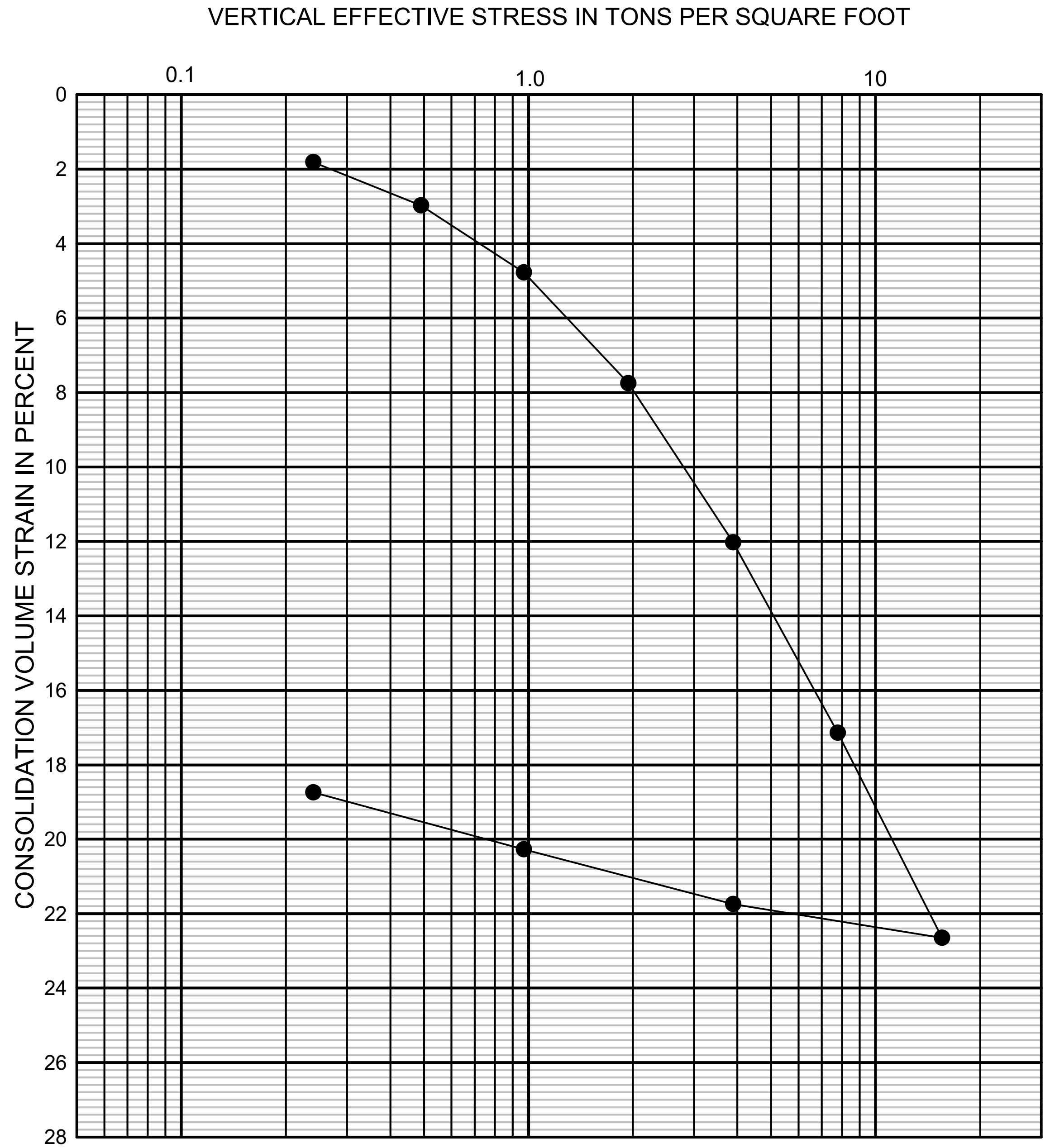
FIG. D-13



$C_{\varepsilon c}$ = 0.18

$C_{\varepsilon r}$ = 0.025

P'_o = 0.93 tsf

P'_c = 1.62 tsf

Boring No. EL-07 Sample No. S-6 Depth of Sample 25 to 27 ft.

Soil Description Clayey SILT, trace sand

☒ Undisturbed ☐ Re-compacted

Initial Conditions: Height 0.80 inches Wet Density 109 lb/ft^3

Diameter 2.50 inches Water Content 43 %

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EL-07, S-6
CONSOLIDATION TEST

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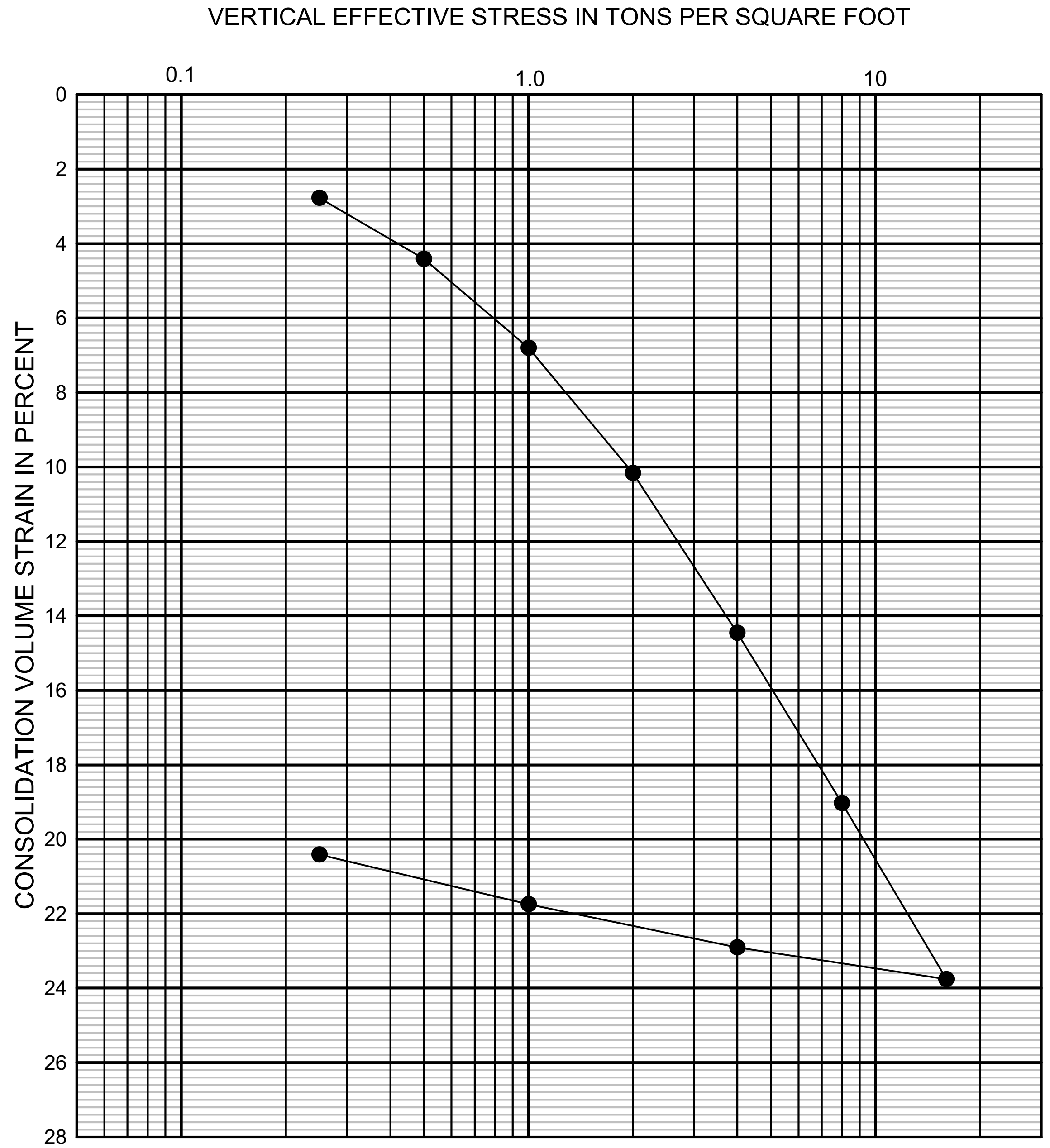
FIG. D-14



$C_{\varepsilon c}$ = 0.16 P'$_o$ = 0.93 tsf

$C_{\varepsilon r}$ = 0.020 P'$_c$ = 1.22 tsf

Boring No. WL-03 Sample No. S-5 Depth of Sample 25 to 27 ft.

Soil Description Clayey SILT

☒ Undisturbed ☐ Re-compacted

Initial Conditions: Height 0.75 inches Wet Density 108 lb/ft^3

Diameter 2.50 inches Water Content 45 %

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WL-03, S-5
CONSOLIDATION TEST

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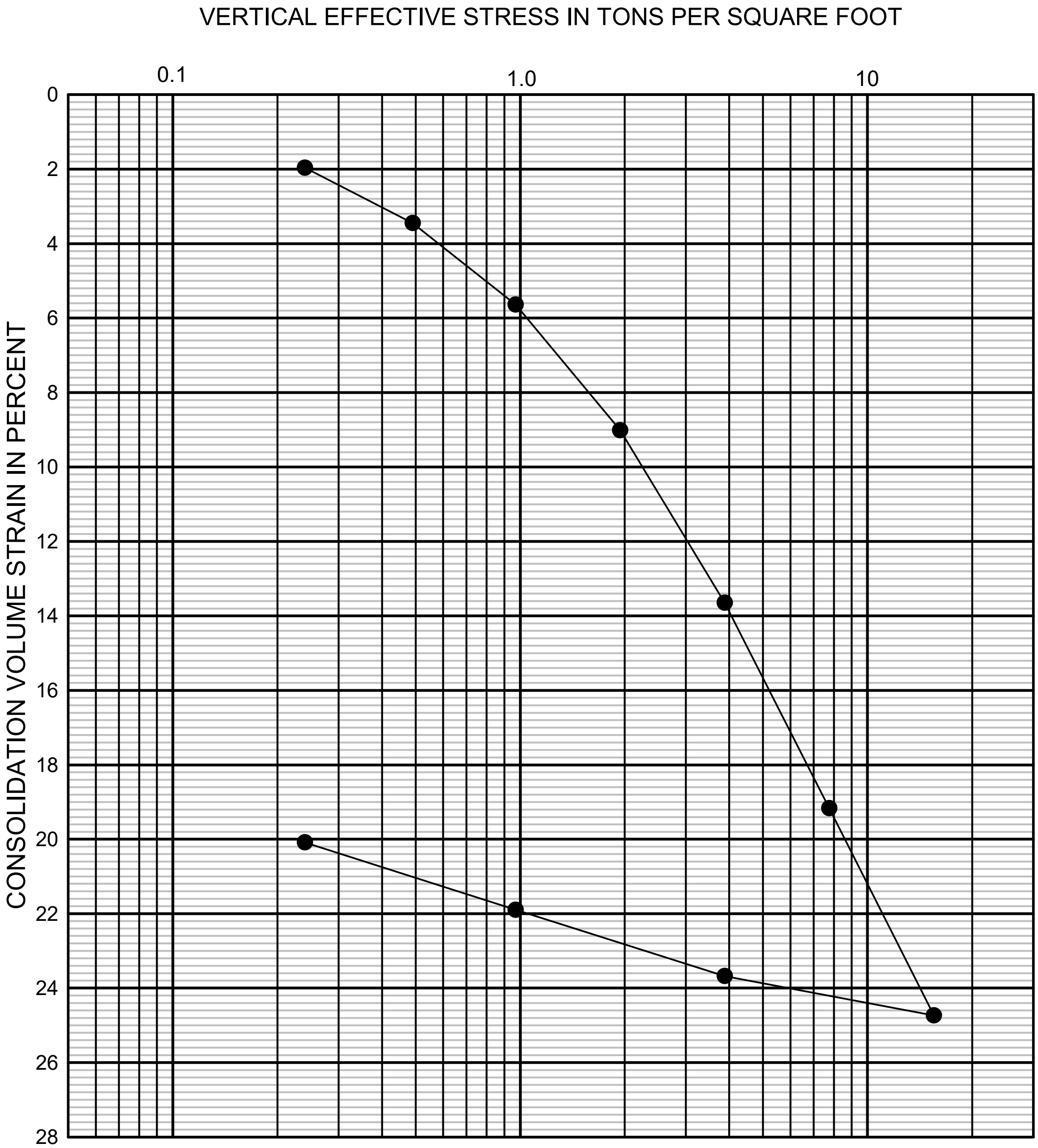
FIG. D-15



$C_{\varepsilon c}$ = 0.19

$C_{\varepsilon r}$ = 0.030

P'_o = 0.65 tsf

P'_c = 1.32 tsf

Boring No. WL-06 Sample No. S-4 Depth of Sample 18 to 20 ft.

Soil Description Clayey SILT

☒ Undisturbed ☐ Re-compacted

Initial Conditions: Height 0.80 inches Wet Density 107 lb/ft^3

Diameter 2.50 inches Water Content 46 %

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WL-06, S-4
CONSOLIDATION TEST

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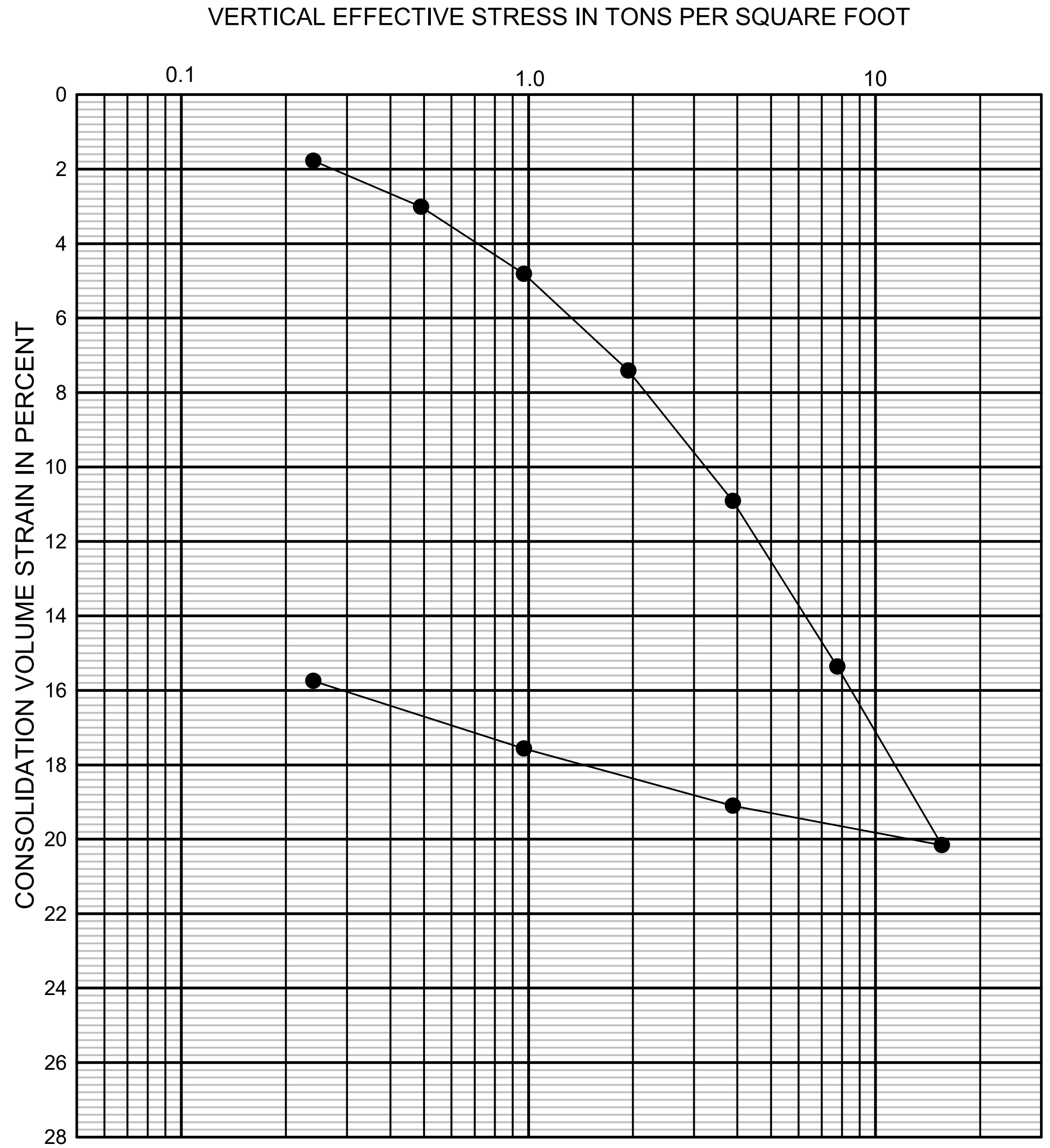
FIG. D-16



$C_{\varepsilon c}$ = 0.16

$C_{\varepsilon r}$ = 0.027

P'_o = 0.55 tsf

P'_c = 1.68 tsf

Boring No. WL-23 Sample No. S-1 Depth of Sample 8 to 10 ft.

Soil Description Slightly sandy, clayey SILT

☒ Undisturbed ☐ Re-compacted

Initial Conditions:

Height 0.80 inches

Diameter 2.50 inches

Wet Density 109 lb/ft^3

Water Content 45 %

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WL-23, S-1
CONSOLIDATION TEST

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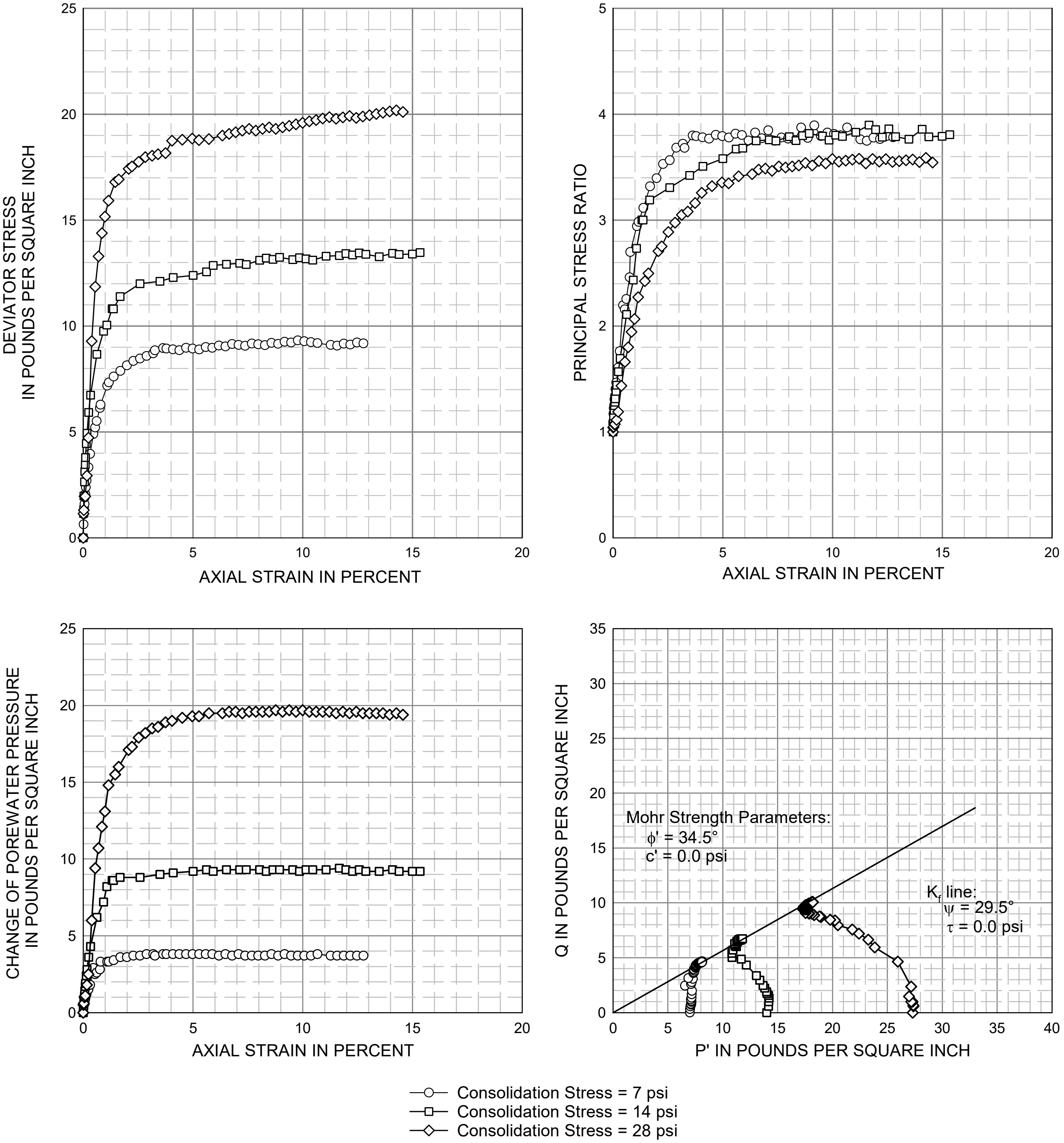
FIG. D-17



☒ Undisturbed ☐ Re-compacted

Boring No. EL-03 Sample No. S-3 Depth of Sample 15 to 17 ft.

Soil Description SOFT, gray, slightly sandy, slightly clayey SILT

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EL-03, S-3
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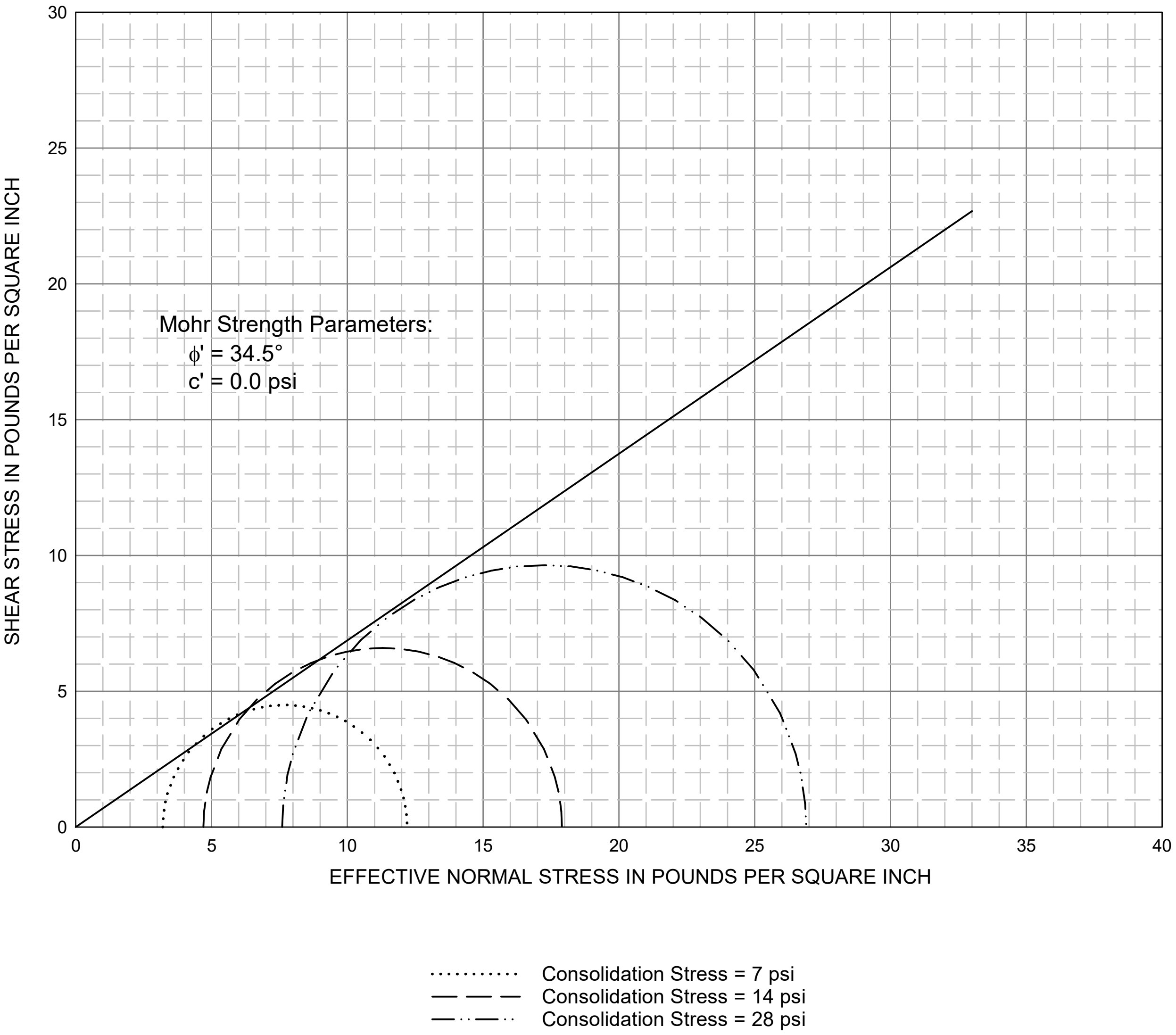
FIG. D-18



☒ Undisturbed ☐ Re-compacted

Boring No. EL-03 Sample No. S-3 Depth of Sample 15 to 17 ft.

Soil Description SOFT, gray, slightly sandy, slightly clayey SILT

Failure Defined as: Maximum Principal Stress Ratio

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EL-03, S-3
MOHR'S CIRCLES

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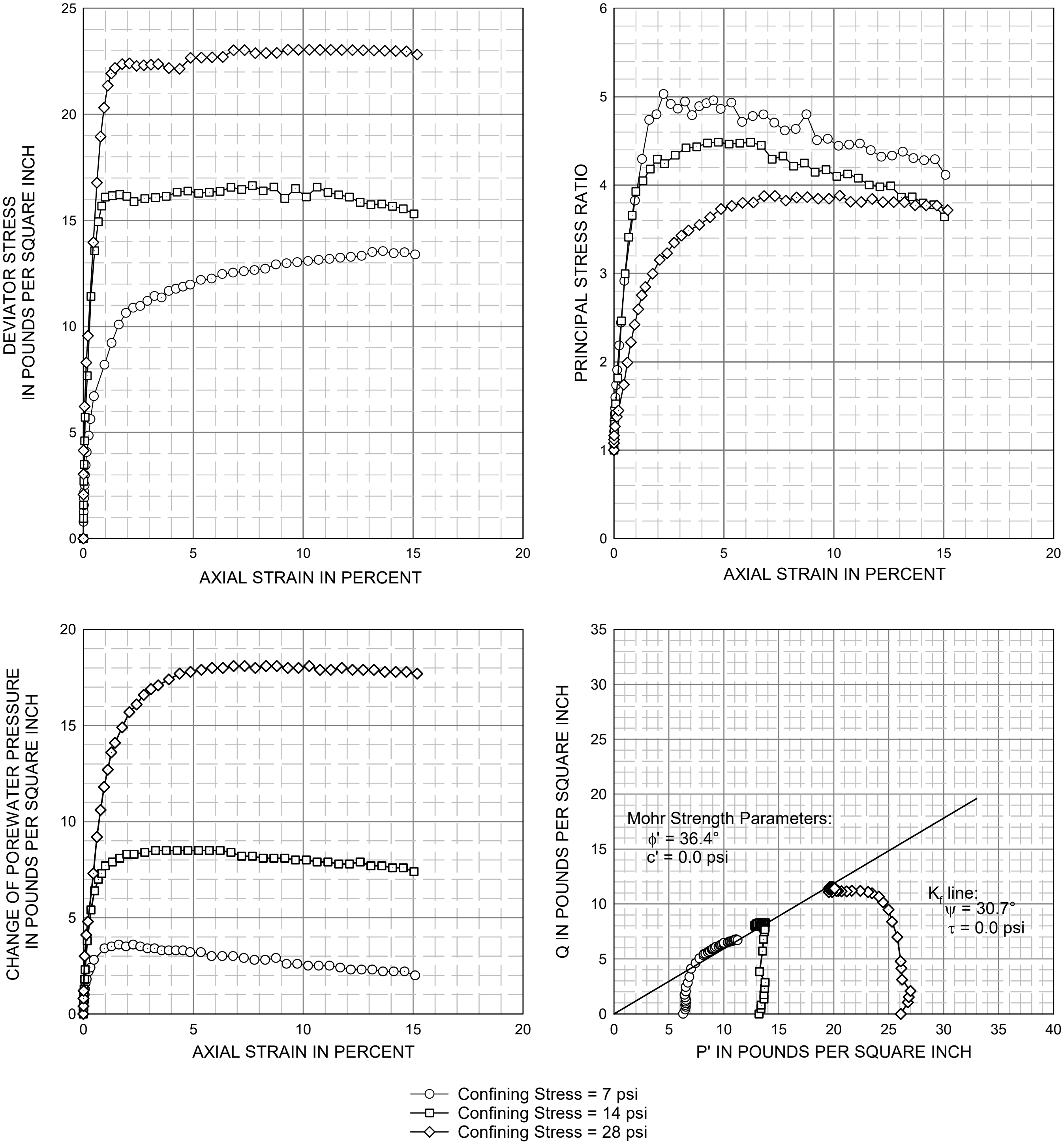
PROJ. 2613
FIG. D-19



Mohr Strength Parameters:
$\phi' = 36.4°$
$c' = 0.0$ psi

K_f line:
$\psi = 30.7°$
$\tau = 0.0$ psi

☒ Undisturbed ☐ Re-compacted

Boring No. WL-10 Sample No. S-4 Depth of Sample 18 to 20 ft.

Soil Description SOFT, gray, clayey SILT, trace sand

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WL-10, S-4
CU TRIAXIAL SUMMARY

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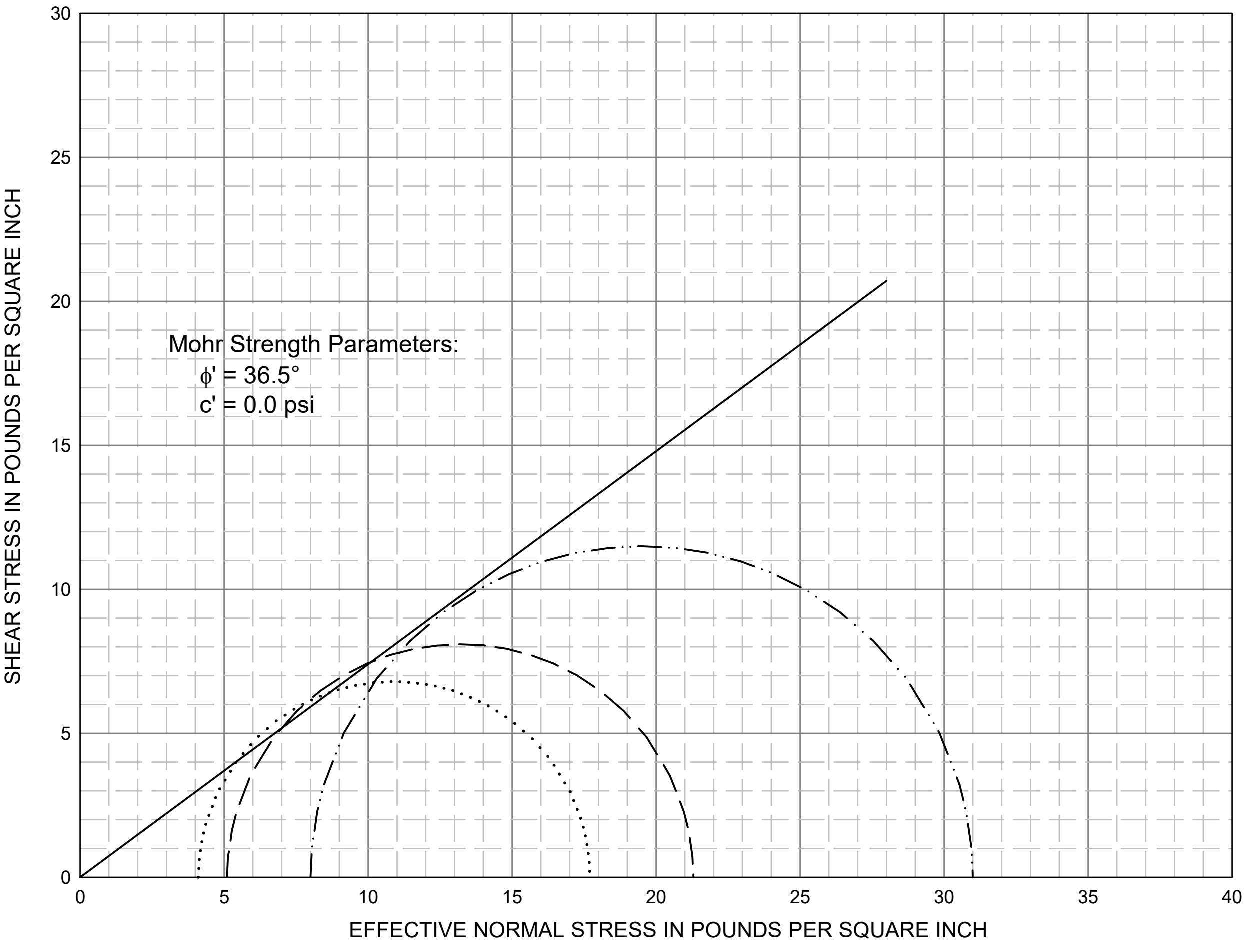
FIG. D-20



··········	Confining Stress = 7 psi
— — —	Confining Stress = 14 psi
—··—··	Confining Stress = 28 psi

☒ Undisturbed ☐ Re-compacted

Boring No. WL-10 Sample No. S-4 Depth of Sample 18 to 20 ft.

Soil Description SOFT, gray, clayey SILT, trace sand

Failure Defined as: Maximum Principal Stress Ratio

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WL-10, S-4
MOHR'S CIRCLES

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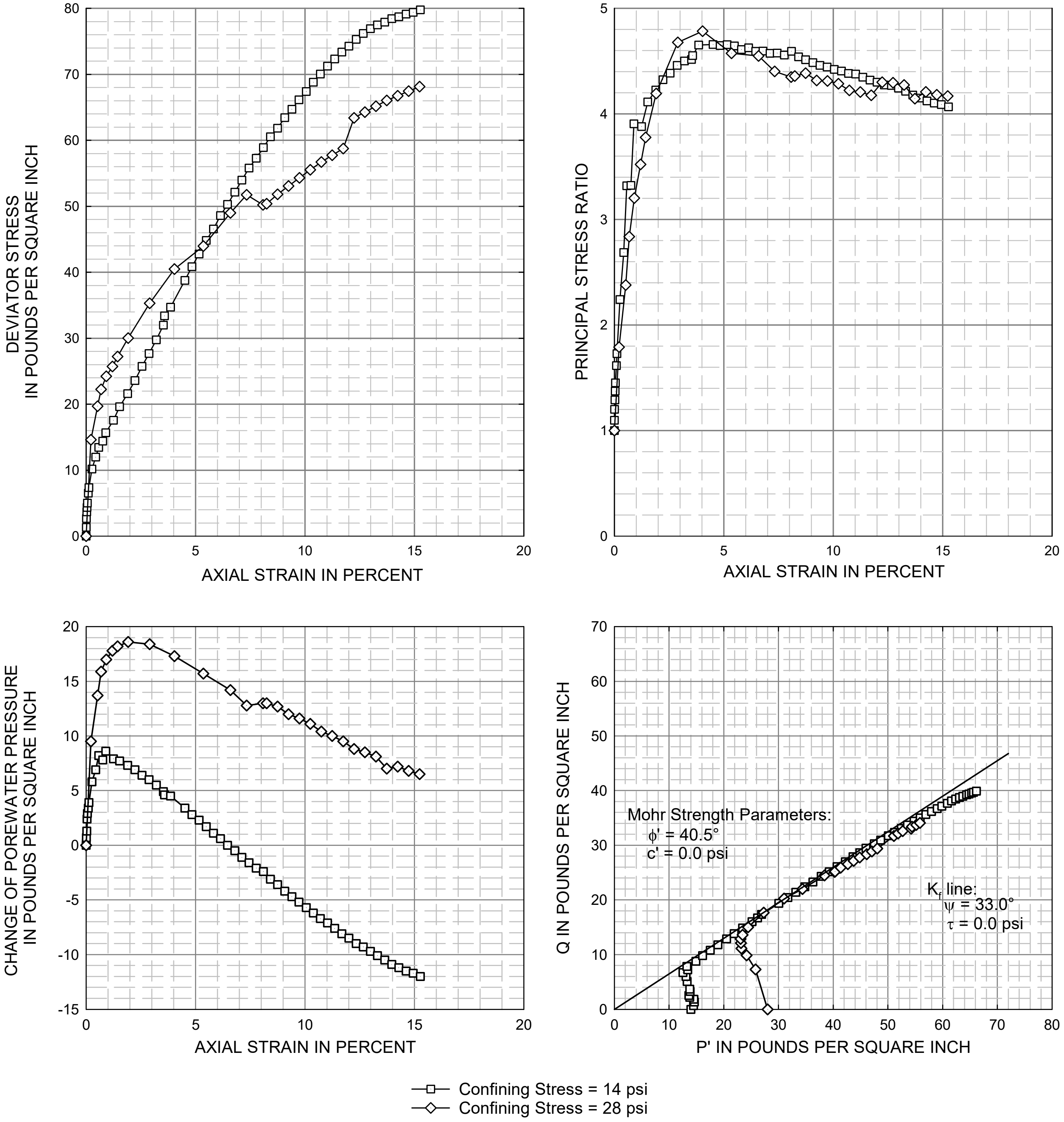
FIG. D-21



☒ Undisturbed ☐ Re-compacted

Boring No. WL-21 Sample No. S-2 Depth of Sample 5 to 7 ft.

Soil Description LOOSE, brown-gray, silty SAND

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WL-21, S-2
CU TRIAXIAL SUMMARY

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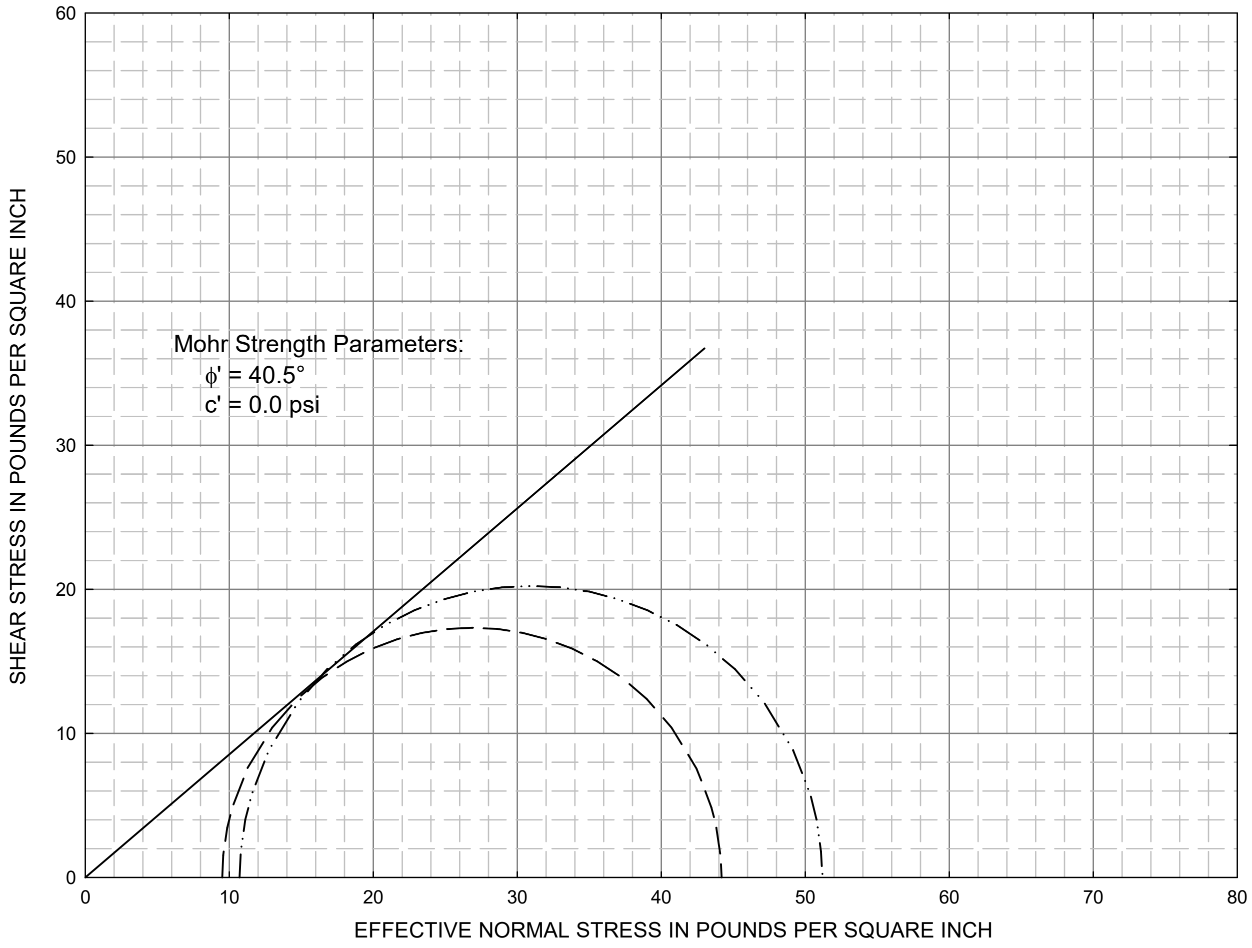
FIG. D-22



— — — Confining Stress = 14 psi
—··—·· Confining Stress = 28 psi

☒ Undisturbed ☐ Re-compacted

Boring No. WL-21 Sample No. S-2 Depth of Sample 5 to 7 ft.

Soil Description LOOSE, brown-gray, silty SAND

Failure Defined as: Maximum Principal Stress Ratio

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WL-21, S-2
MOHR'S CIRCLES

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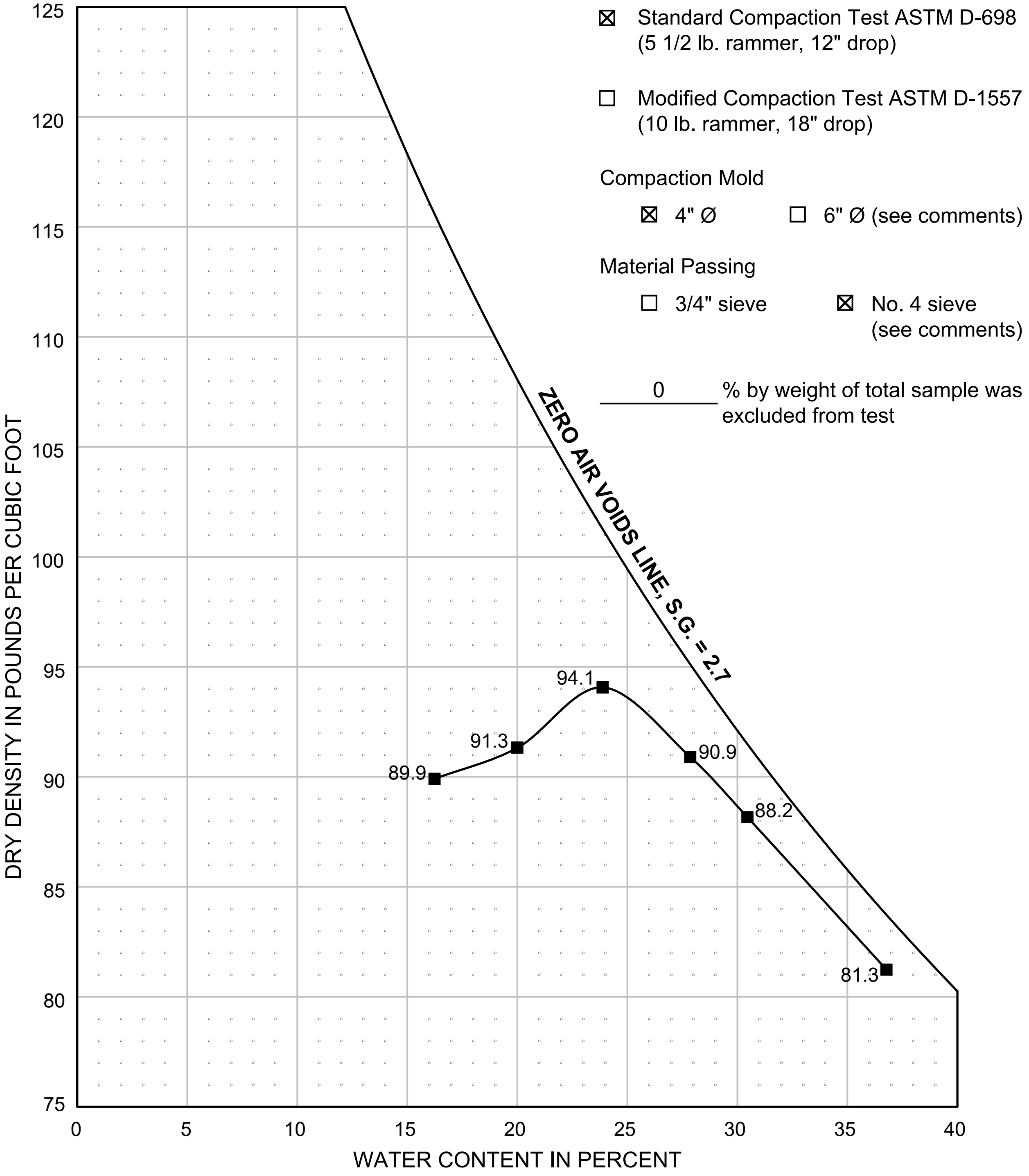
FIG. D-23



☒ Standard Compaction Test ASTM D-698
(5 1/2 lb. rammer, 12" drop)

☐ Modified Compaction Test ASTM D-1557
(10 lb. rammer, 18" drop)

Compaction Mold

☒ 4" Ø ☐ 6" Ø (see comments)

Material Passing

☐ 3/4" sieve ☒ No. 4 sieve (see comments)

0 % by weight of total sample was excluded from test

SAMPLE	SOIL DESCRIPTION	MAX. DRY DENSITY IN PCF	WATER CONTENT IN PERCENT	
			OPTIMUM	NATURAL
S-1	■ Poorly graded, slightly clayey SILT	94.1	24%	50%

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COMPACTION TEST

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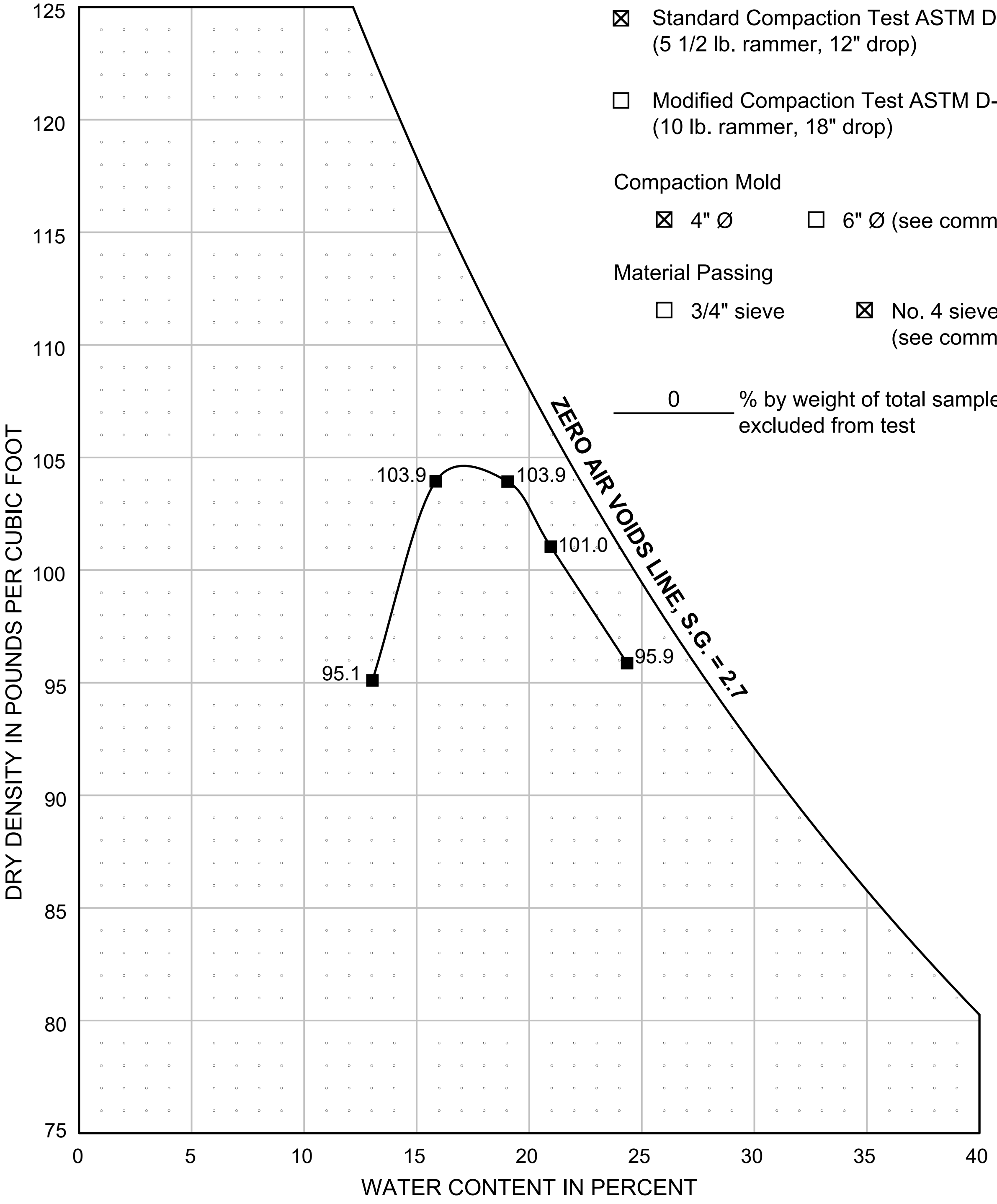
FIG. D-24

2613/C-23.ai NAU



☒ Standard Compaction Test ASTM D-698
(5 1/2 lb. rammer, 12" drop)

☐ Modified Compaction Test ASTM D-1557
(10 lb. rammer, 18" drop)

Compaction Mold

☒ 4" Ø ☐ 6" Ø (see comments)

Material Passing

☐ 3/4" sieve ☒ No. 4 sieve (see comments)

0 % by weight of total sample was excluded from test

SAMPLE	SOIL DESCRIPTION	MAX. DRY DENSITY IN PCF	WATER CONTENT IN PERCENT	
			OPTIMUM	NATURAL
S-1	■ Poorly graded, fine sandy SILT	104.1	17.5%	29%

2613/C-24.ai NAU

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COMPACTION TEST

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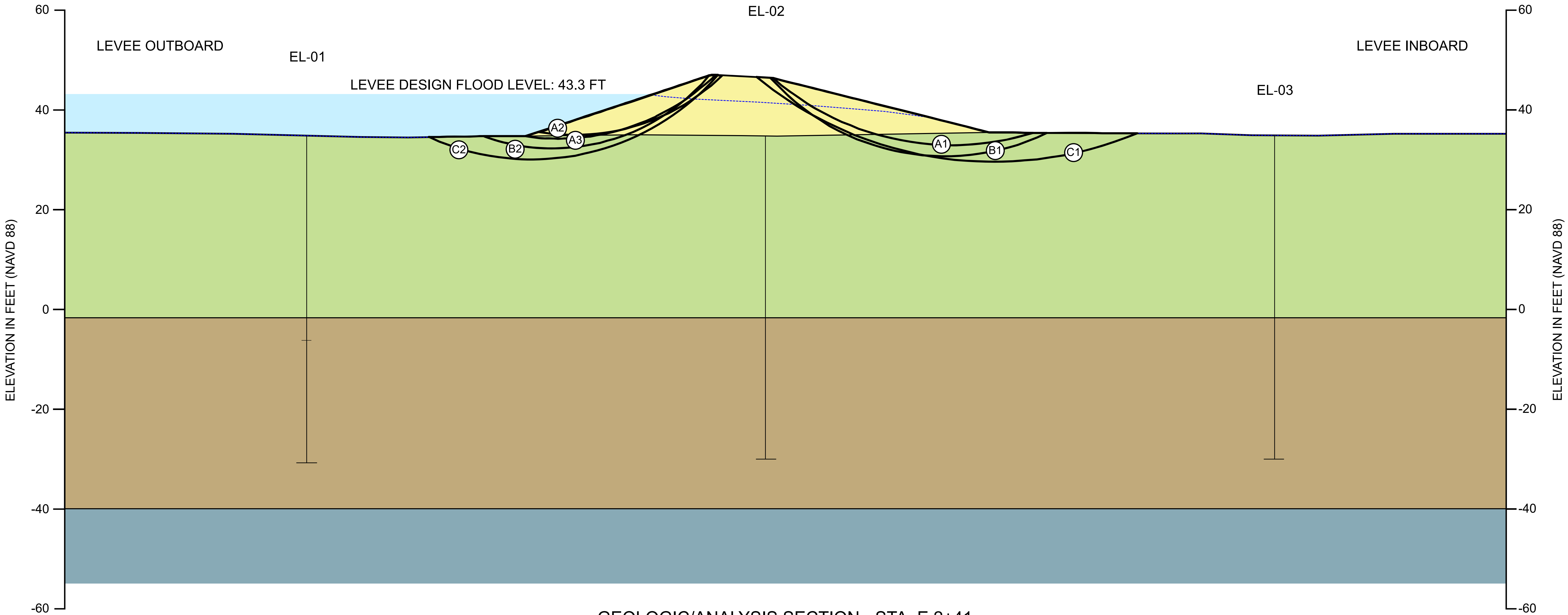
FIG. D-25

Appendix E – Geologic/Analyses Cross-Sections

🟨	Fill	MEDIUM DENSE, silty SAND and sandy SILT
🟩	Alluvium	SOFT, slightly sandy, clayey SILT
🟫	Alluvium	MEDIUM STIFF, slightly clayey SILT
🟦	Flood Deposit	DENSE, sandy GRAVEL and COBBLES
🟪	Gibbons Alluvial Fan	LOOSE to MEDIUM DENSE, gravely SAND and sandy GRAVEL

FAILURE SCENARIO	WATER CONDITION	INBOARD		OUTBOARD		MINIMUM ALLOWABLE FS	MEETS REQUIRED FS
		FS	SLIP SURFACE	FS	SLIP SURFACE		
LONG-TERM (STEADY-STATE SEEPAGE)	LEVEE DESIGN FLOOD	1.8	A1	2.1	A2	1.4	YES
RAPID DRAWDOWN	PARTIALLY DRAINED PHREATIC SURFACE	-	-	1.2	A3	1.0	YES
END OF CONSTRUCTION	AT GROUND SURFACE	2.8	B1	2.2	B2	1.3	YES
EARTHQUAKE (PSEUDO-STATIC K = 0.15g)	AT GROUND SURFACE	1.4	C1	1.3	C2	1.0	YES

SEEPAGE SCENARIOS	INBOARD	MINIMUM REQUIREMENTS	MEETS REQUIRED
EXIT GRADIENT AT LANDWARD TOE	0.29	<0.5	YES



GEOLOGIC/ANALYSIS SECTION - STA. E 2+41

0 20 40
SCALE IN FEET

2613/4.1-90%/E-1 - E2+41.ai NAU

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GEOLOGIC/ANALYSIS
CROSS SECTION

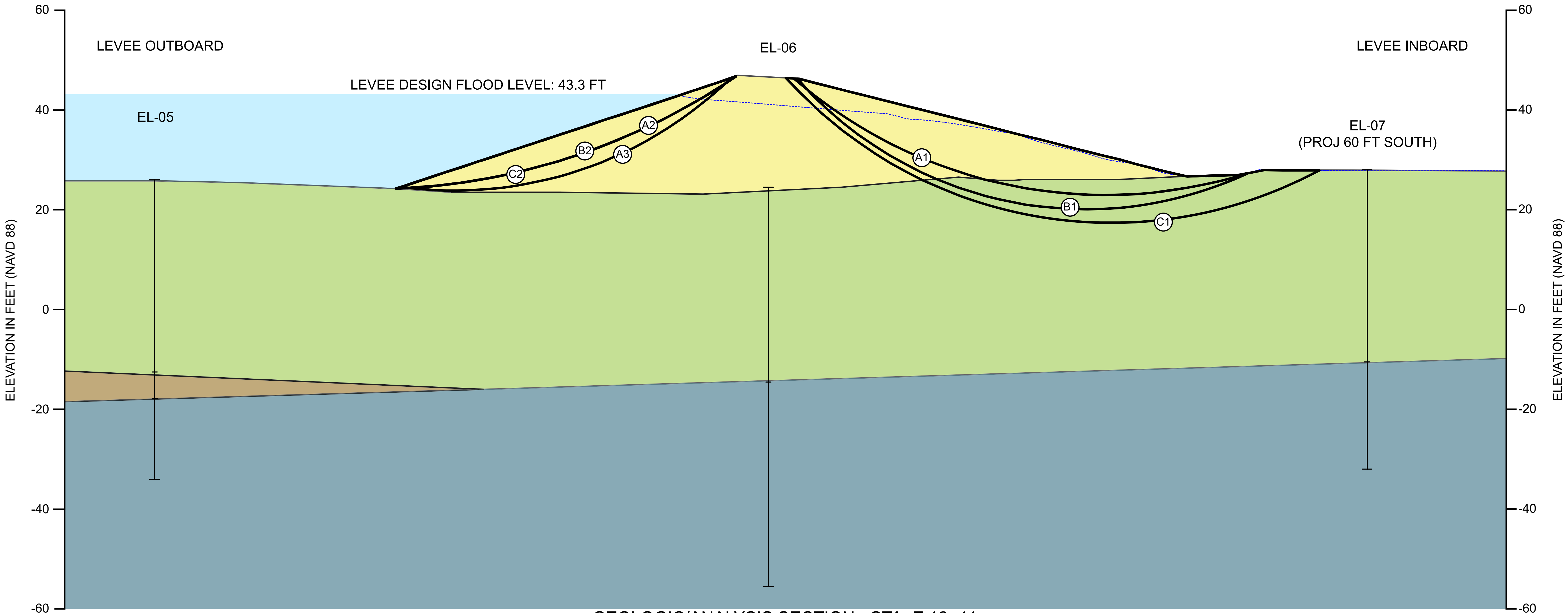
STEIGERWALD LEVEE DESIGN
WASHOUGAL, WASHINGTON

AUG 2018
PROJ. 2613
FIG. E-1

🟨	Fill	MEDIUM DENSE, silty SAND and sandy SILT
🟩	Alluvium	SOFT, slightly sandy, clayey SILT
🟫	Alluvium	MEDIUM STIFF, slightly clayey SILT
🟦	Flood Deposit	DENSE, sandy GRAVEL and COBBLES
🟪	Gibbons Alluvial Fan	LOOSE to MEDIUM DENSE, gravely SAND and sandy GRAVEL

		INBOARD		OUTBOARD			
FAILURE SCENARIO	**WATER CONDITION**	**FS**	**SLIP SURFACE**	**FS**	**SLIP SURFACE**	**MINIMUM ALLOWABLE FS**	**MEETS REQUIRED FS**
LONG-TERM (STEADY-STATE SEEPAGE)	LEVEE DESIGN FLOOD	1.6	A1	2.1	A2	1.4	YES
RAPID DRAWDOWN	PARTIALLY DRAINED PHREATIC SURFACE	-	-	1.2	A3	1.0	YES
END OF CONSTRUCTION	AT GROUND SURFACE	2.7	B1	2.1	B2	1.3	YES
EARTHQUAKE (PSEUDO-STATIC K = 0.15g)	AT GROUND SURFACE	1.6	C1	1.4	C2	1.0	YES

SEEPAGE SCENARIOS	INBOARD	MINIMUM REQUIREMENTS	MEETS REQUIRED
EXIT GRADIENT AT LANDWARD TOE	0.40	<0.5	YES



GEOLOGIC/ANALYSIS SECTION - STA. E 12+41

0 20 40
SCALE IN FEET

2613/4.1-90%/E-2 - E12+41.ai NAU

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GEOLOGIC/ANALYSIS
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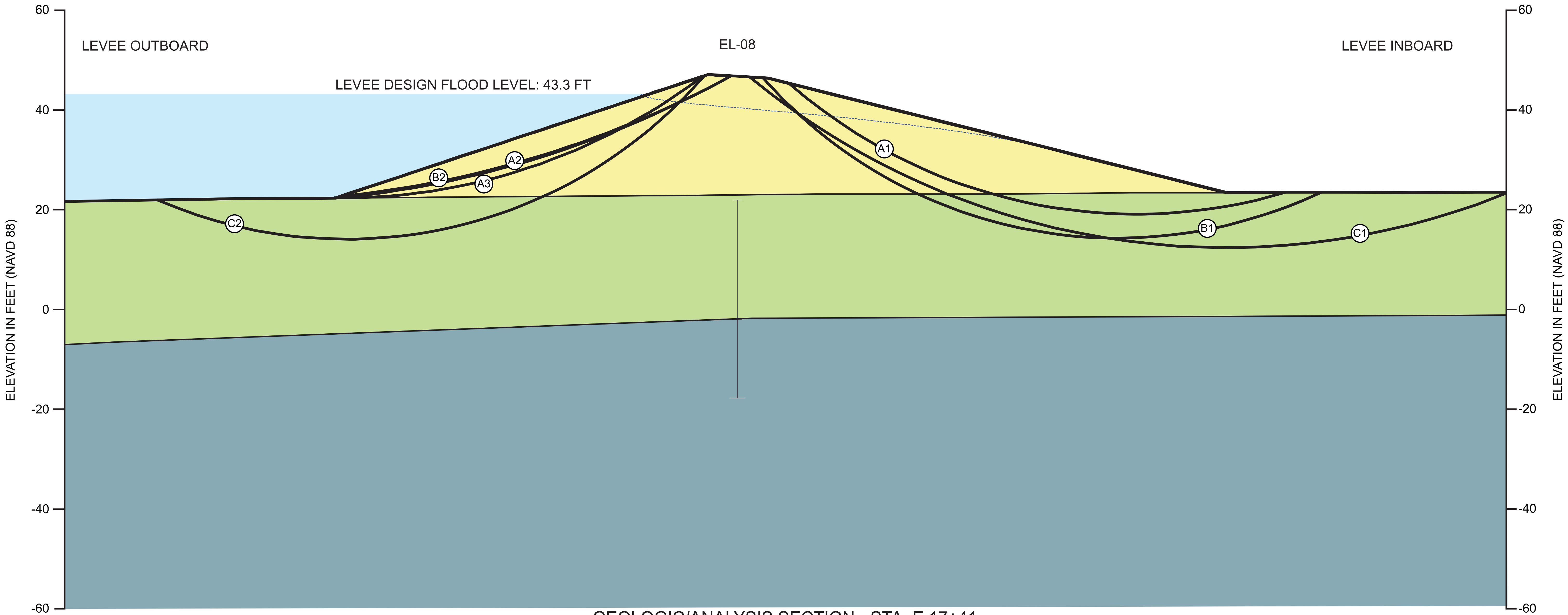
PROJ. 2613

FIG. E-2

🟨	Fill	MEDIUM DENSE, silty SAND and sandy SILT
🟩	Alluvium	SOFT, slightly sandy, clayey SILT
🟫	Alluvium	MEDIUM STIFF, slightly clayey SILT
🟦	Flood Deposit	DENSE, sandy GRAVEL and COBBLES
🟪	Gibbons Alluvial Fan	LOOSE to MEDIUM DENSE, gravely SAND and sandy GRAVEL

		INBOARD		OUTBOARD			
FAILURE SCENARIO	**WATER CONDITION**	**FS**	**SLIP SURFACE**	**FS**	**SLIP SURFACE**	**MINIMUM ALLOWABLE FS**	**MEETS REQUIRED FS**
LONG-TERM (STEADY-STATE SEEPAGE)	LEVEE DESIGN FLOOD	1.6	A1	2.3	A2	1.4	YES
RAPID DRAWDOWN	PARTIALLY DRAINED PHREATIC SURFACE	-	-	1.2	A3	1.0	YES
END OF CONSTRUCTION	AT GROUND SURFACE	2.7	B1	2.1	B2	1.3	YES
EARTHQUAKE (PSEUDO-STATIC K = 0.15g)	AT GROUND SURFACE	1.4	C1	1.2	C2	1.0	YES

SEEPAGE SCENARIOS	**INBOARD**	**MINIMUM REQUIREMENTS**	**MEETS REQUIRED**
EXIT GRADIENT AT LANDWARD TOE	0.37	<0.5	YES



GEOLOGIC/ANALYSIS SECTION - STA. E 17+41

0 20 40
SCALE IN FEET

2613/4.1-90%/E-3 - E17-41.ai NAU

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CROSS SECTION

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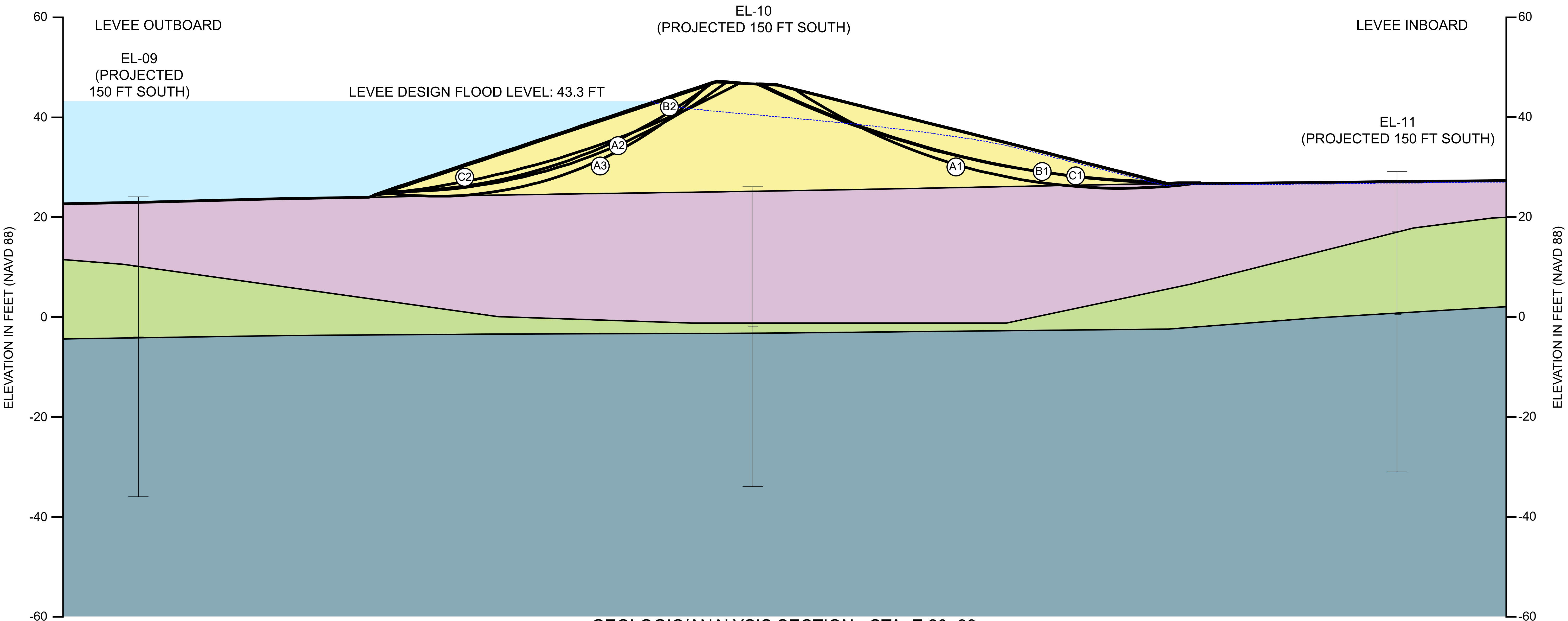
PROJ. 2613
FIG. E-3

🟨	Fill	MEDIUM DENSE, silty SAND and sandy SILT
🟩	Alluvium	SOFT, slightly sandy, clayey SILT
🟫	Alluvium	MEDIUM STIFF, slightly clayey SILT
🟦	Flood Deposit	DENSE, sandy GRAVEL and COBBLES
🟪	Gibbons Alluvial Fan	LOOSE to MEDIUM DENSE, gravely SAND and sandy GRAVEL

		INBOARD		OUTBOARD			
FAILURE SCENARIO	**WATER CONDITION**	**FS**	**SLIP SURFACE**	**FS**	**SLIP SURFACE**	**MINIMUM ALLOWABLE FS**	**MEETS REQUIRED FS**
LONG-TERM (STEADY-STATE SEEPAGE)	LEVEE DESIGN FLOOD	1.6	A1	2.3	A2	1.4	YES
RAPID DRAWDOWN	PARTIALLY DRAINED PHREATIC SURFACE	-	-	1.3	A3	1.0	YES
END OF CONSTRUCTION	AT GROUND SURFACE	2.8	B1	2.1	B2	1.3	YES
EARTHQUAKE (PSEUDO-STATIC K = 0.15g)	AT GROUND SURFACE	1.7	C1	1.4	C2	1.0	YES

SEEPAGE SCENARIOS	INBOARD	MINIMUM REQUIREMENTS	MEETS REQUIRED
EXIT GRADIENT AT LANDWARD TOE	0.39	<0.5	YES



GEOLOGIC/ANALYSIS SECTION - STA. E 20+99

0 20 40
SCALE IN FEET

2613/4.1-90%/E-4 - E20+99.ai NAU

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GEOLOGIC/ANALYSIS
CROSS SECTION

STEIGERWALD LEVEE DESIGN
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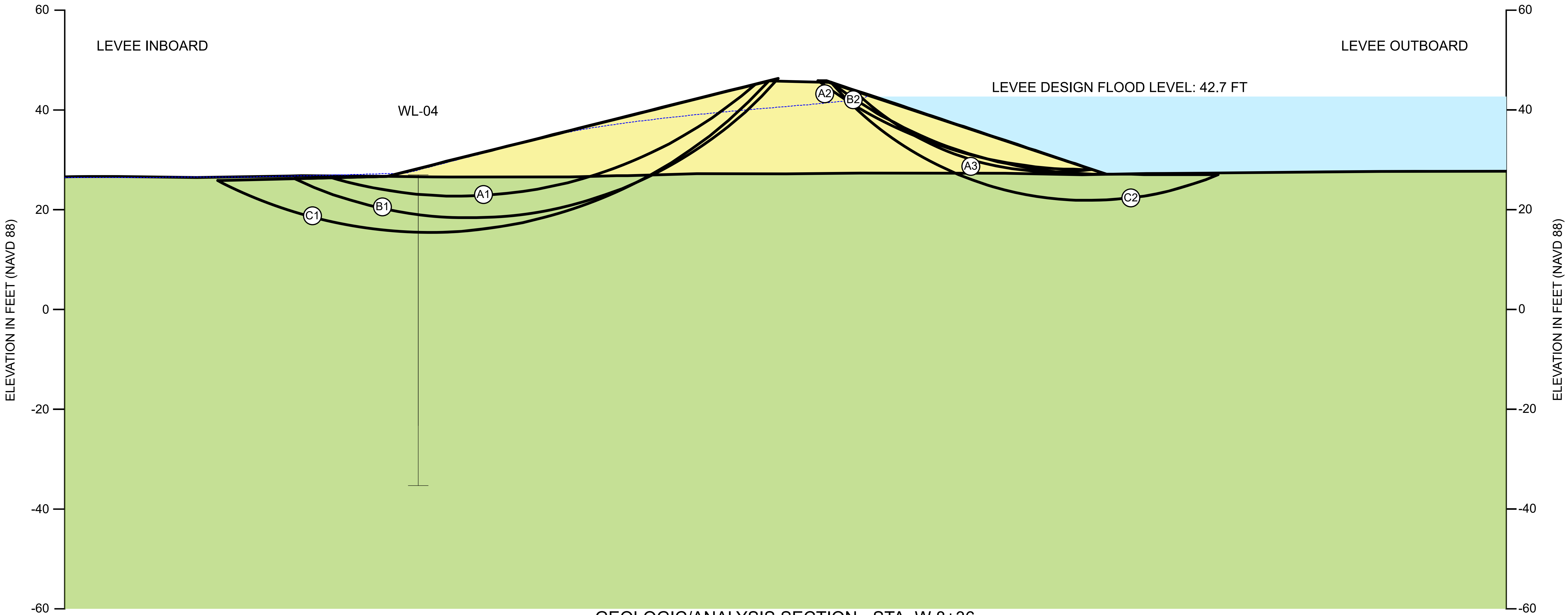
PROJ. 2613

FIG. E-4

🟨	Fill	MEDIUM DENSE, silty SAND and sandy SILT
🟩	Alluvium	SOFT, slightly sandy, clayey SILT
🟫	Alluvium	MEDIUM STIFF, slightly clayey SILT
🟦	Flood Deposit	DENSE, sandy GRAVEL and COBBLES
🟪	Gibbons Alluvial Fan	LOOSE to MEDIUM DENSE, gravely SAND and sandy GRAVEL

		INBOARD		OUTBOARD			
FAILURE SCENARIO	**WATER CONDITION**	**FS**	**SLIP SURFACE**	**FS**	**SLIP SURFACE**	**MINIMUM ALLOWABLE FS**	**MEETS REQUIRED FS**
LONG-TERM (STEADY-STATE SEEPAGE)	LEVEE DESIGN FLOOD	1.6	A1	2.2	A2	1.4	YES
RAPID DRAWDOWN	PARTIALLY DRAINED PHREATIC SURFACE	-	-	1.2	A3	1.0	YES
END OF CONSTRUCTION	AT GROUND SURFACE	2.6	B1	2.1	B2	1.3	YES
EARTHQUAKE (PSEUDO-STATIC K = 0.15g)	AT GROUND SURFACE	1.5	C1	1.4	C2	1.0	YES

SEEPAGE SCENARIOS	**INBOARD**	**MINIMUM REQUIREMENTS**	**MEETS REQUIRED**
EXIT GRADIENT AT LANDWARD TOE	0.31	<0.5	YES



GEOLOGIC/ANALYSIS SECTION - STA. W 8+36

0 20 40
SCALE IN FEET

2613/4.1-90%/E-5 - W8+36.ai NAU

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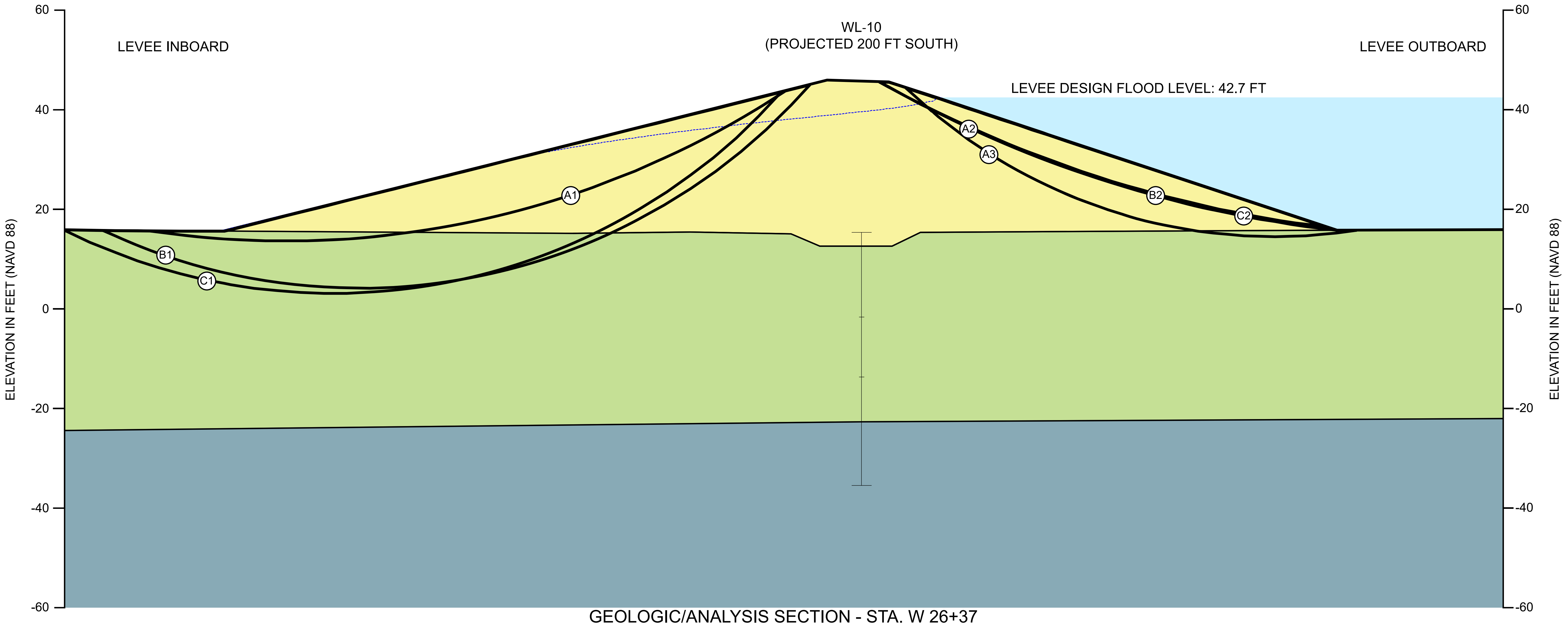
PROJ. 2613
FIG. E-5

🟨	Fill	MEDIUM DENSE, silty SAND and sandy SILT
🟩	Alluvium	SOFT, slightly sandy, clayey SILT
🟫	Alluvium	MEDIUM STIFF, slightly clayey SILT
🟦	Flood Deposit	DENSE, sandy GRAVEL and COBBLES
🟪	Gibbons Alluvial Fan	LOOSE to MEDIUM DENSE, gravely SAND and sandy GRAVEL

		INBOARD		OUTBOARD			
FAILURE SCENARIO	**WATER CONDITION**	**FS**	**SLIP SURFACE**	**FS**	**SLIP SURFACE**	**MINIMUM ALLOWABLE FS**	**MEETS REQUIRED FS**
LONG-TERM (STEADY-STATE SEEPAGE)	LEVEE DESIGN FLOOD	1.5	A1	2.3	A2	1.4	YES
RAPID DRAWDOWN	PARTIALLY DRAINED PHREATIC SURFACE	-	-	1.2	A3	1.0	YES
END OF CONSTRUCTION	AT GROUND SURFACE	2.7	B1	2.1	B2	1.3	YES
EARTHQUAKE (PSEUDO-STATIC K = 0.15g)	AT GROUND SURFACE	1.6	C1	1.4	C2	1.0	YES

SEEPAGE SCENARIOS	INBOARD	MINIMUM REQUIREMENTS	MEETS REQUIRED
EXIT GRADIENT AT LANDWARD TOE	0.35	<0.5	YES



GEOLOGIC/ANALYSIS SECTION - STA. W 26+37

0 20 40
SCALE IN FEET

2613/4.1-90%/E-6 - W25+10.ai NAU

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GEOLOGIC/ANALYSIS
CROSS SECTION

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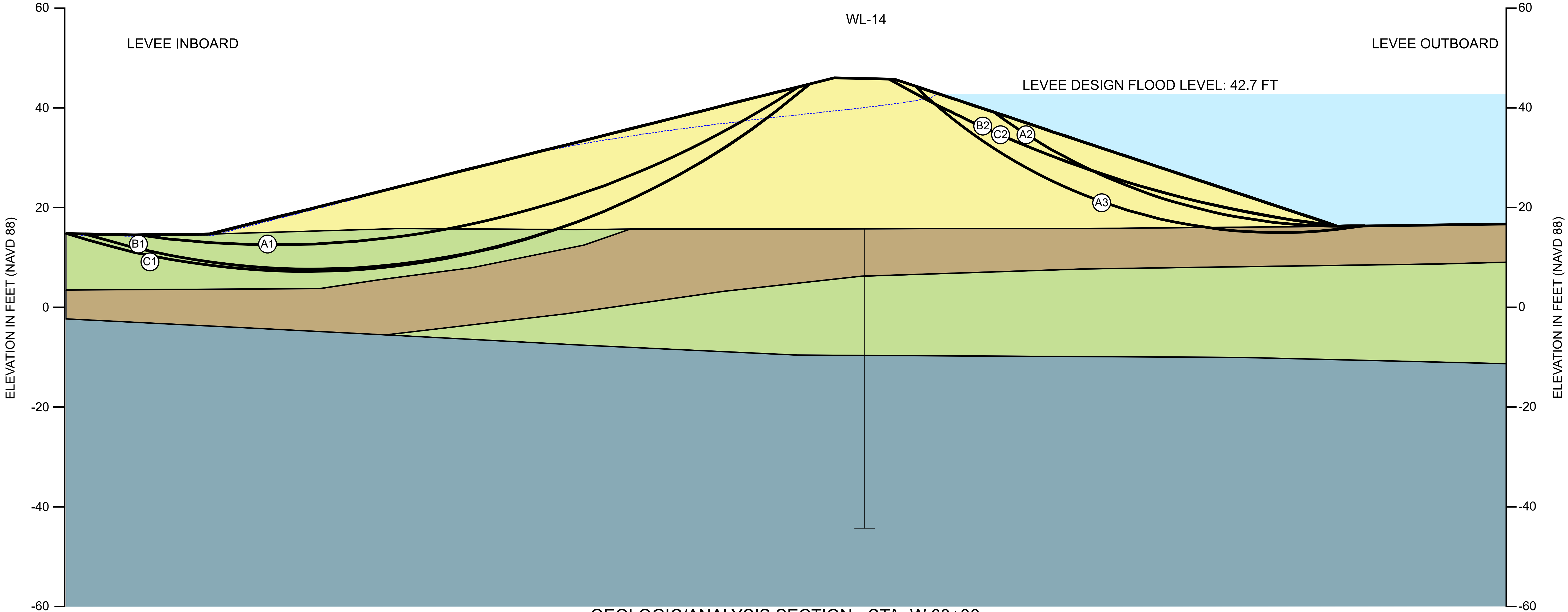
FIG. E-6

🟨	Fill	MEDIUM DENSE, silty SAND and sandy SILT
🟩	Alluvium	SOFT, slightly sandy, clayey SILT
🟫	Alluvium	MEDIUM STIFF, slightly clayey SILT
🟦	Flood Deposit	DENSE, sandy GRAVEL and COBBLES
🟪	Gibbons Alluvial Fan	LOOSE to MEDIUM DENSE, gravely SAND and sandy GRAVEL

		INBOARD		OUTBOARD			
FAILURE SCENARIO	**WATER CONDITION**	**FS**	**SLIP SURFACE**	**FS**	**SLIP SURFACE**	**MINIMUM ALLOWABLE FS**	**MEETS REQUIRED FS**
LONG-TERM (STEADY-STATE SEEPAGE)	LEVEE DESIGN FLOOD	1.5	A1	2.3	A2	1.4	YES
RAPID DRAWDOWN	PARTIALLY DRAINED PHREATIC SURFACE	-	-	1.2	A3	1.0	YES
END OF CONSTRUCTION	AT GROUND SURFACE	2.6	B1	2.1	B2	1.3	YES
EARTHQUAKE (PSEUDO-STATIC K = 0.15g)	AT GROUND SURFACE	1.6	C1	1.4	C2	1.0	YES

SEEPAGE SCENARIOS	**INBOARD**	**MINIMUM REQUIREMENTS**	**MEETS REQUIRED**
EXIT GRADIENT AT LANDWARD TOE	0.33	<0.5	YES



GEOLOGIC/ANALYSIS SECTION - STA. W 33+36

0 20 40
SCALE IN FEET

2613/4.1-90%/E-7 - W33+10.ai NAU

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GEOLOGIC/ANALYSIS
CROSS SECTION

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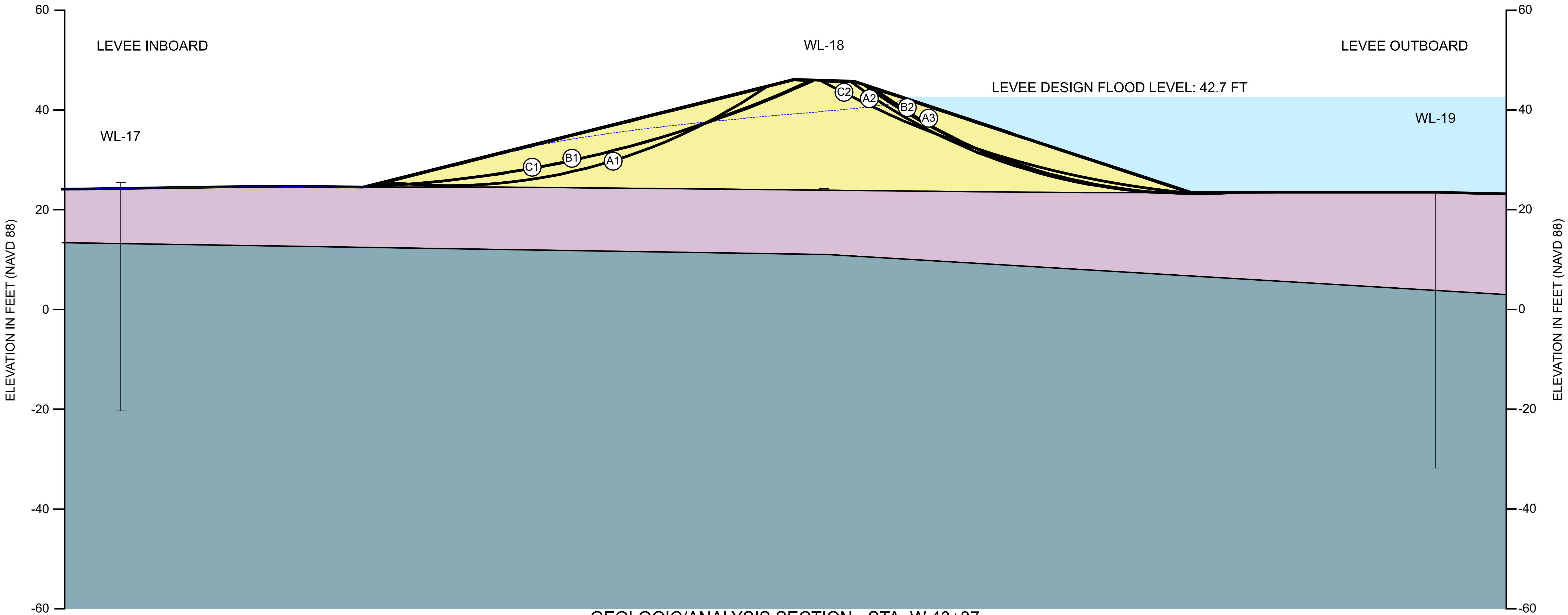
FIG. E-7

🟨	Fill	MEDIUM DENSE, silty SAND and sandy SILT
🟩	Alluvium	SOFT, slightly sandy, clayey SILT
🟫	Alluvium	MEDIUM STIFF, slightly clayey SILT
🟦	Flood Deposit	DENSE, sandy GRAVEL and COBBLES
🟪	Gibbons Alluvial Fan	LOOSE to MEDIUM DENSE, gravely SAND and sandy GRAVEL

		INBOARD		OUTBOARD			
FAILURE SCENARIO	**WATER CONDITION**	**FS**	**SLIP SURFACE**	**FS**	**SLIP SURFACE**	**MINIMUM ALLOWABLE FS**	**MEETS REQUIRED FS**
LONG-TERM (STEADY-STATE SEEPAGE)	LEVEE DESIGN FLOOD	1.6	A1	2.3	A2	1.4	YES
RAPID DRAWDOWN	PARTIALLY DRAINED PHREATIC SURFACE	-	-	1.2	A3	1.0	YES
END OF CONSTRUCTION	AT GROUND SURFACE	2.8	B1	2.1	B2	1.3	YES
EARTHQUAKE (PSEUDO-STATIC K = 0.15g)	AT GROUND SURFACE	1.7	C1	1.4	C2	1.0	YES

SEEPAGE SCENARIOS	INBOARD	MINIMUM REQUIREMENTS	MEETS REQUIRED
EXIT GRADIENT AT LANDWARD TOE	0.32	<0.5	YES



GEOLOGIC/ANALYSIS SECTION - STA. W 43+37

0 20 40
SCALE IN FEET

2613/4.1-90%/E-8 - W43+10.ai NAU

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GEOLOGIC/ANALYSIS
CROSS SECTION

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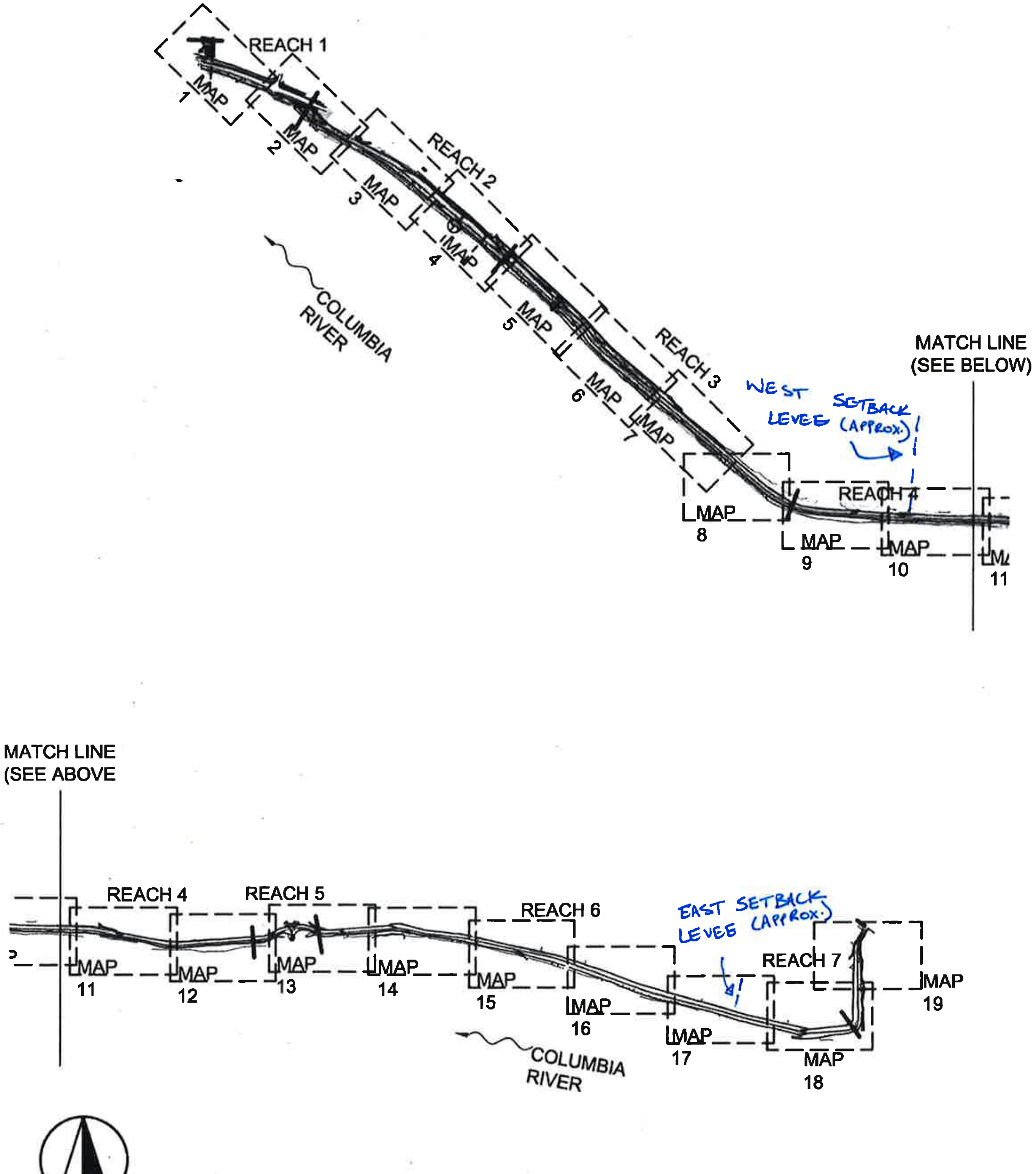
FIG. E-8

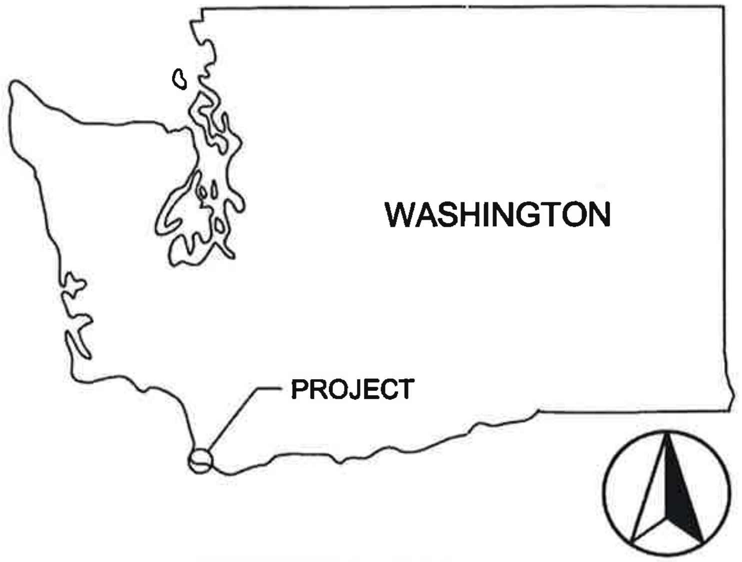
Appendix F – Selected Levee Embankment Data

Extracted from "Camas-Washougal Levee FEMA Certification Engineering Evaluations"

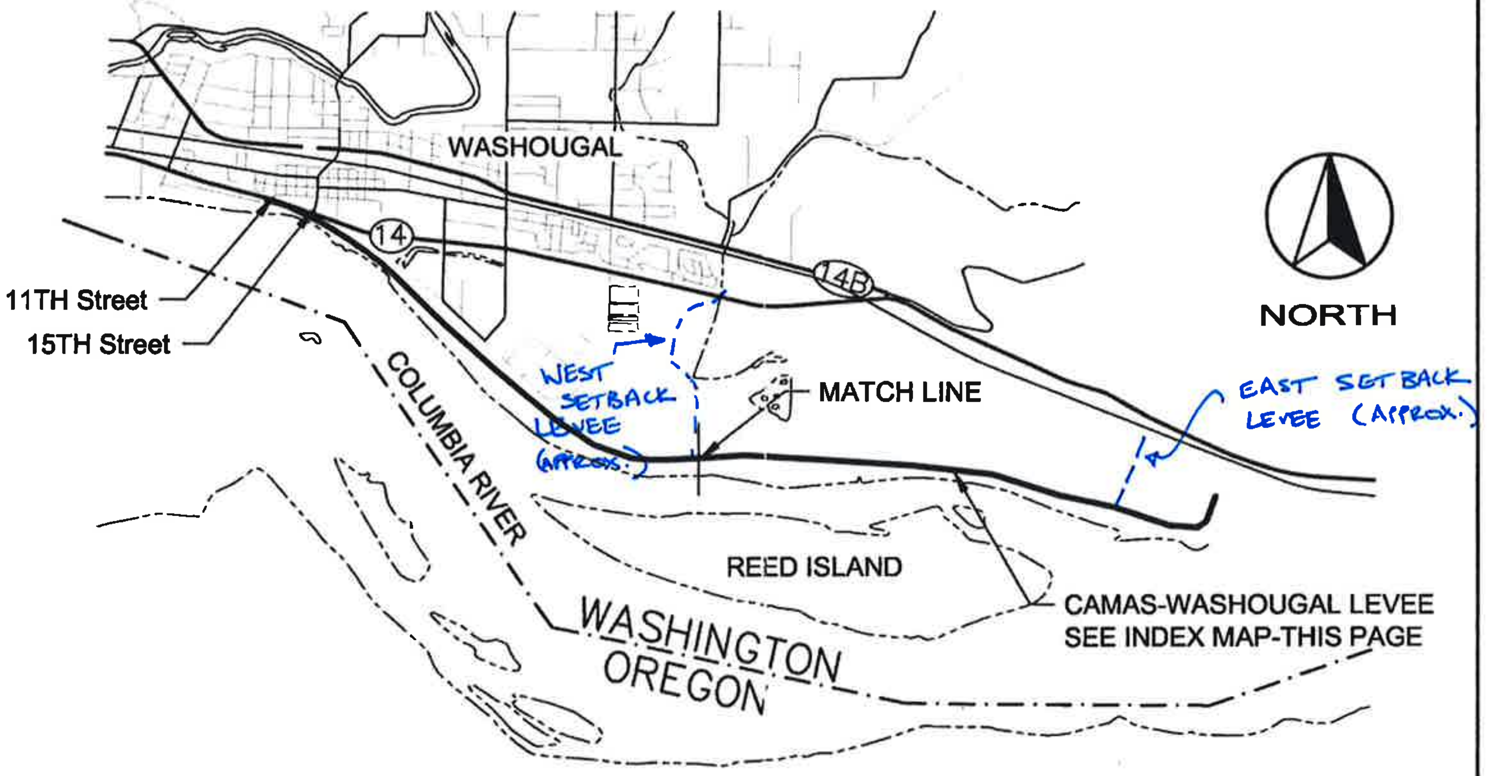
Cornforth Consultants, Inc., 2012



INDEX MAP
NOT TO SCALE



REGIONAL MAP
NOT TO SCALE



VICINITY MAP
NOT TO SCALE

2192/Camas Levee-Existing.dwg NAU

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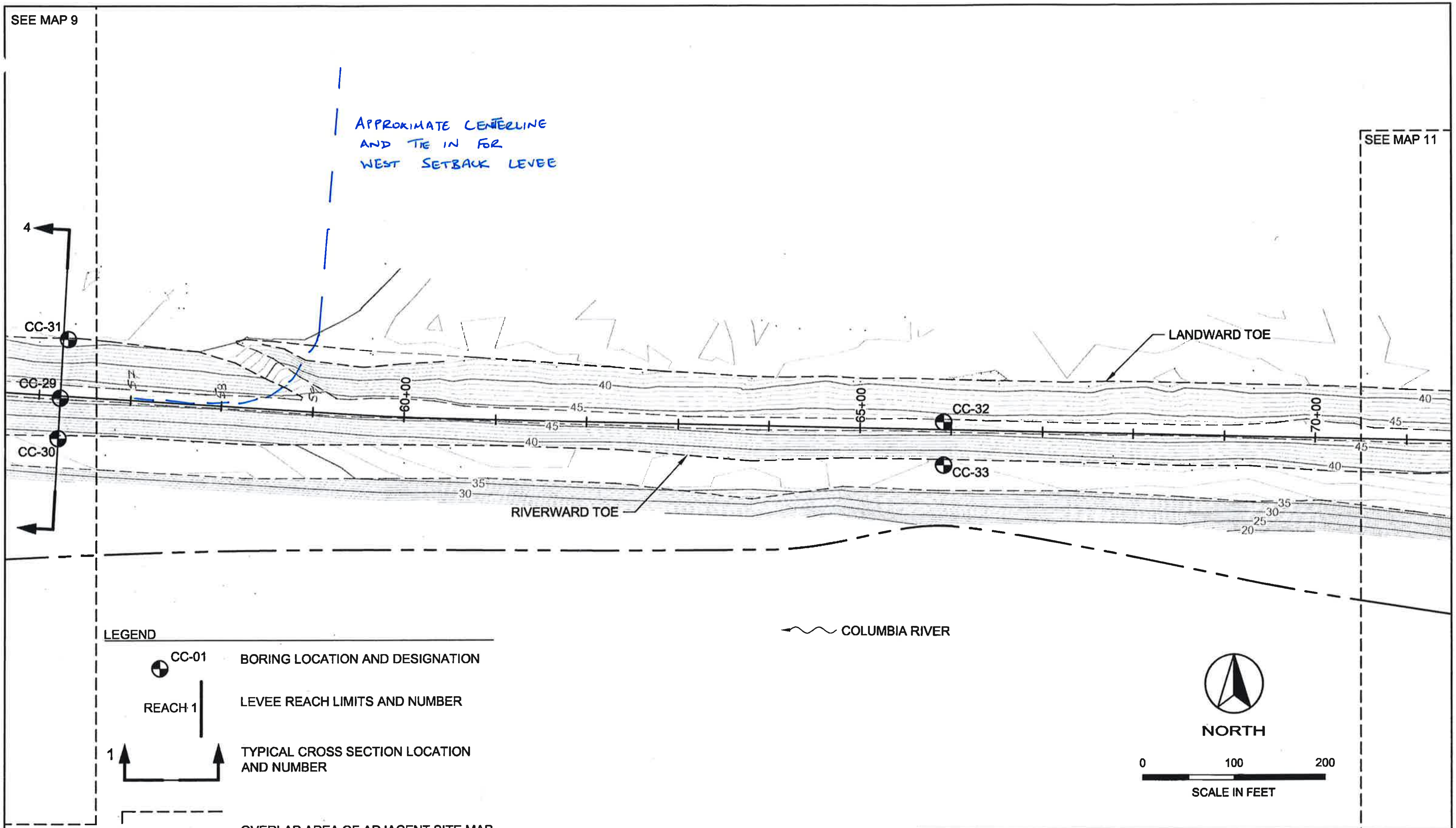
LOCATION MAP

CAMAS-WASHOUGAL LEVEE EVALUATIONS
WASHOUGAL, WASHINGTON

FEB 2012
PROJ. 2192
FIG. 1

Selected data extracted from:
Camas Washougal Levee FEMA Certification Engineering Evaluations Report
Cornforth Consultants, 2012



APPROXIMATE CENTERLINE
AND TIE IN FOR
WEST SETBACK LEVEE

LEGEND

CC-01	BORING LOCATION AND DESIGNATION
REACH 1	LEVEE REACH LIMITS AND NUMBER
1	TYPICAL CROSS SECTION LOCATION AND NUMBER
	OVERLAP AREA OF ADJACENT SITE MAP
	APPROXIMATE SHORELINE

2192/Camas Levee-Existing.dwg NAU

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MAP 10

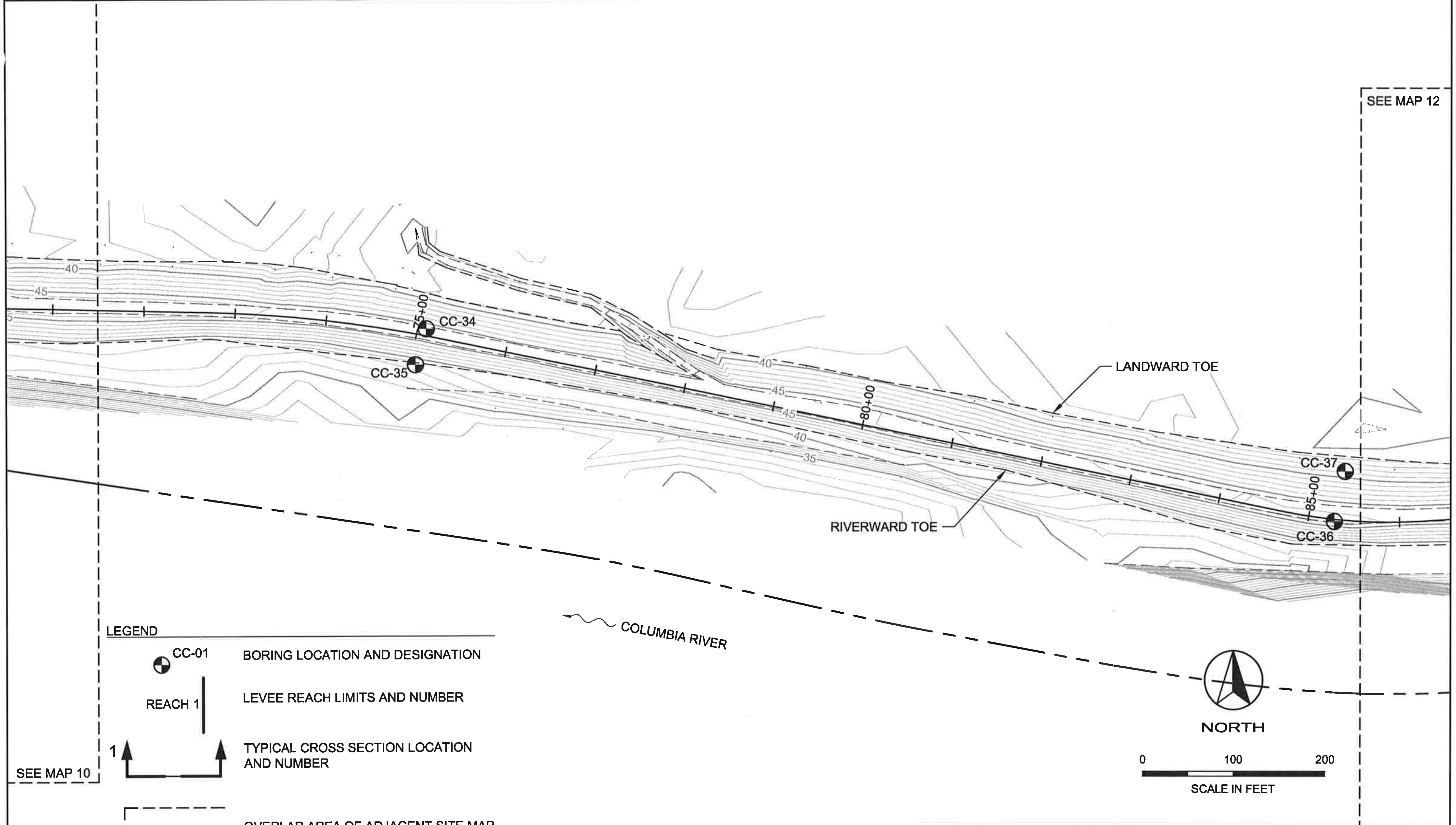
CAMAS-WASHOUGAL LEVEE EVALUATIONS
WASHOUGAL, WASHINGTON

FEB 2012

PROJ. 2192

FIG. 11

Selected data extracted from:
Camas Washougal Levee FEMA Certification Engineering Evaluations Report
Cornforth Consultants, 2012



LEGEND

CC-01	BORING LOCATION AND DESIGNATION
REACH 1	LEVEE REACH LIMITS AND NUMBER
1	TYPICAL CROSS SECTION LOCATION AND NUMBER
	OVERLAP AREA OF ADJACENT SITE MAP
	APPROXIMATE SHORELINE

2192/Camas Levee-Existing.dwg NAU

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MAP 11

CAMAS-WASHOUGAL LEVEE EVALUATIONS
WASHOUGAL, WASHINGTON

FEB 2012
PROJ. 2192
FIG. 12

Selected data extracted from:
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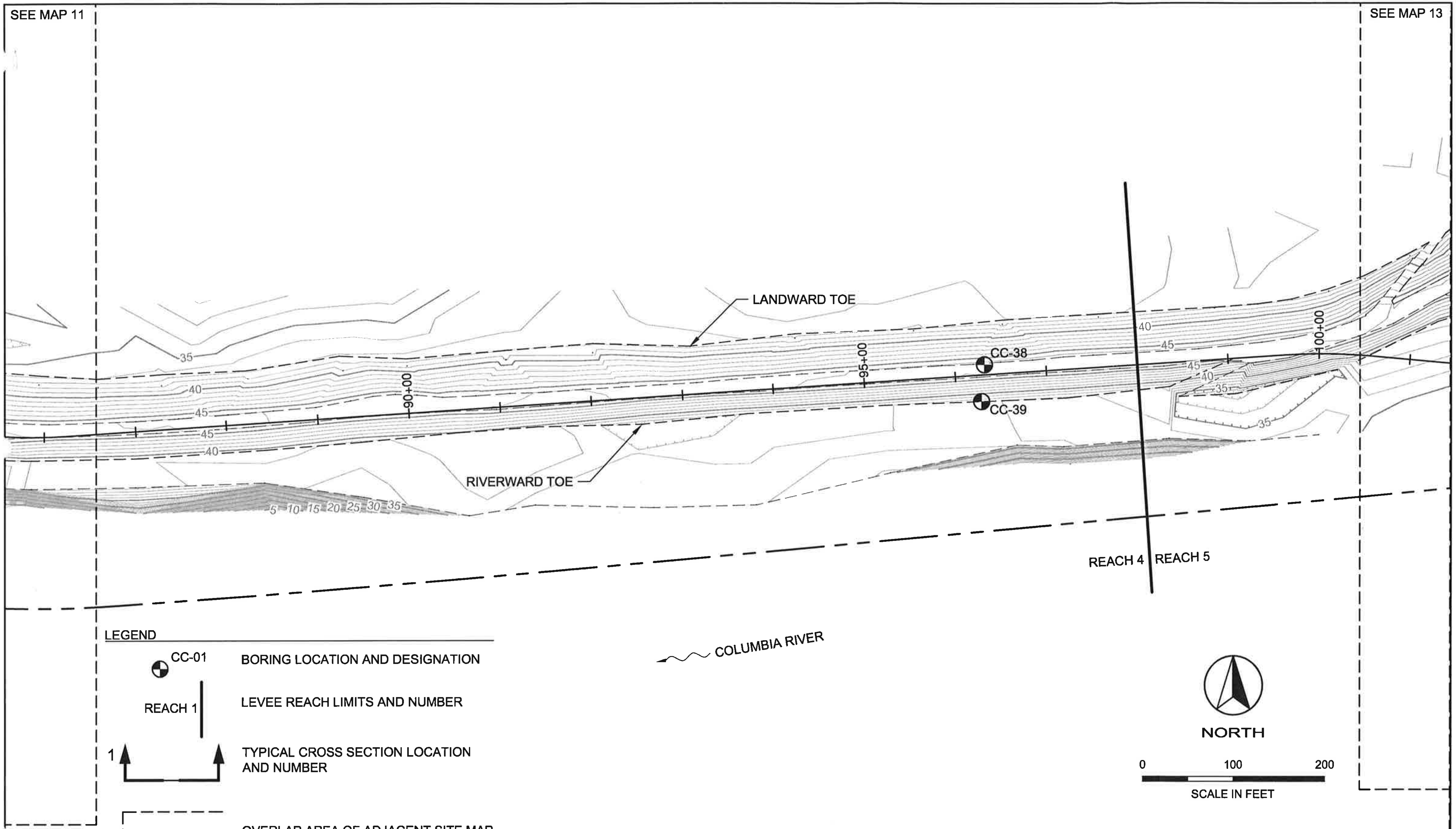
Cornforth Consultants, 2012



LEGEND

CC-01	BORING LOCATION AND DESIGNATION
REACH 1	LEVEE REACH LIMITS AND NUMBER
1	TYPICAL CROSS SECTION LOCATION AND NUMBER
	OVERLAP AREA OF ADJACENT SITE MAP
	APPROXIMATE SHORELINE

2192/Camas Levee-Existing.dwg NAU

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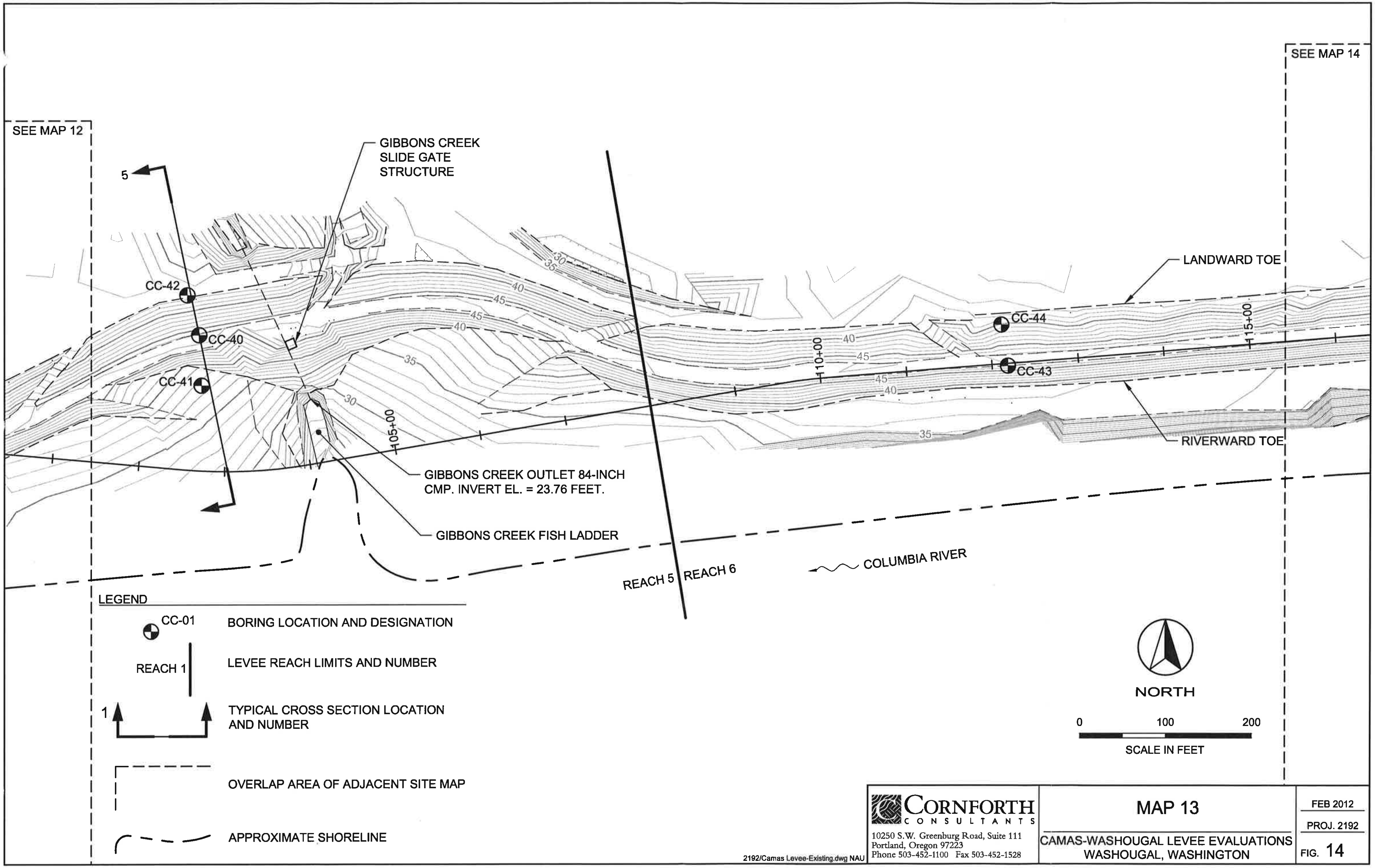
MAP 12

CAMAS-WASHOUGAL LEVEE EVALUATIONS
WASHOUGAL, WASHINGTON

FEB 2012
PROJ. 2192
FIG. 13

Selected data extracted from:
Camas Washougal Levee FEMA Certification Engineering Evaluations Report
Cornforth Consultants, 2012



2192/Camas Levee-Existing.dwg NAU

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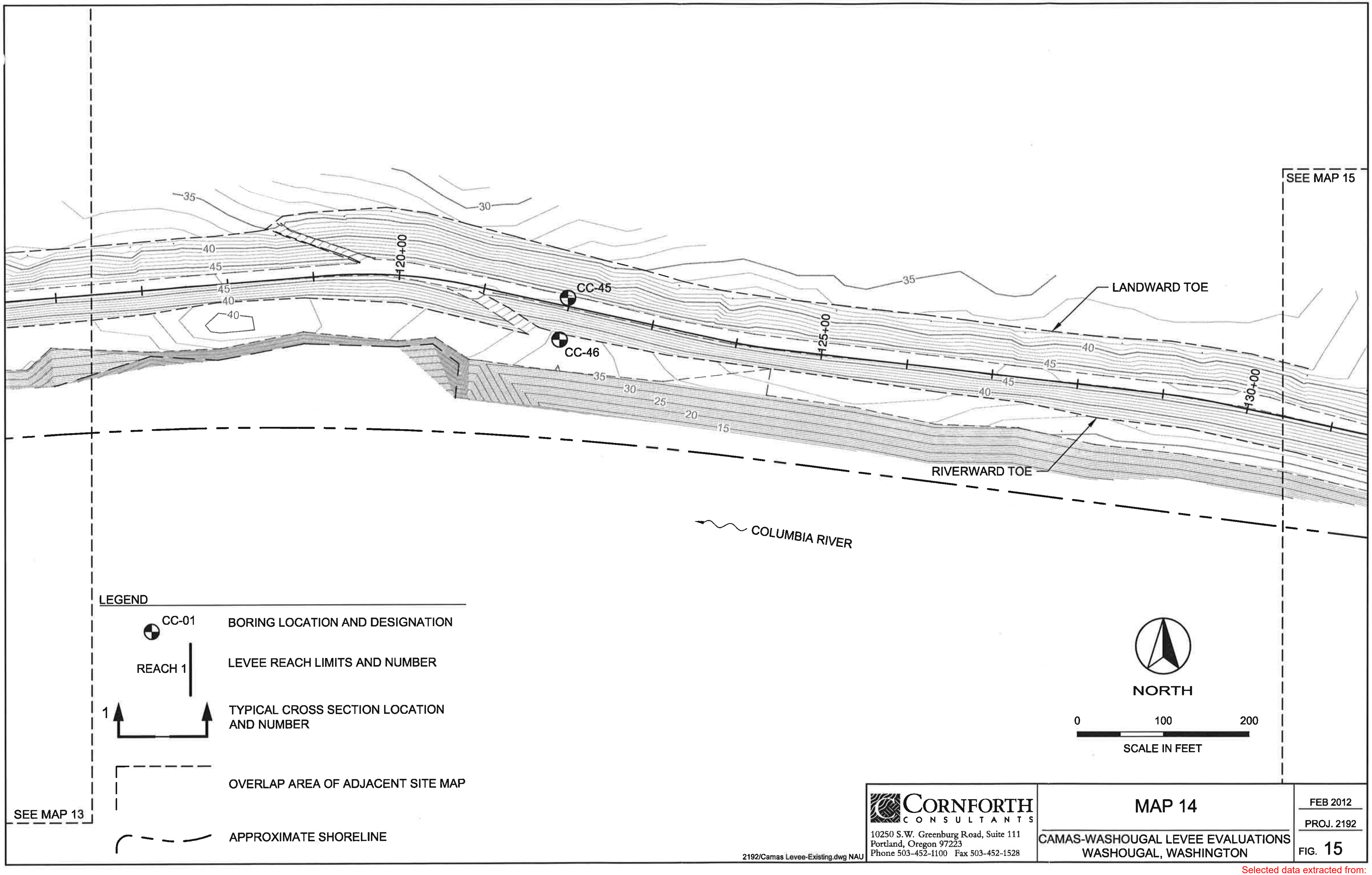
MAP 13

CAMAS-WASHOUGAL LEVEE EVALUATIONS
WASHOUGAL, WASHINGTON

FEB 2012
PROJ. 2192
FIG. 14

Selected data extracted from:
Camas Washougal Levee FEMA Certification Engineering Evaluations Report
Cornforth Consultants, 2012



2192/Camas Levee-Existing.dwg NAU

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MAP 14

CAMAS-WASHOUGAL LEVEE EVALUATIONS
WASHOUGAL, WASHINGTON

FEB 2012

PROJ. 2192

FIG. 15

Selected data extracted from:
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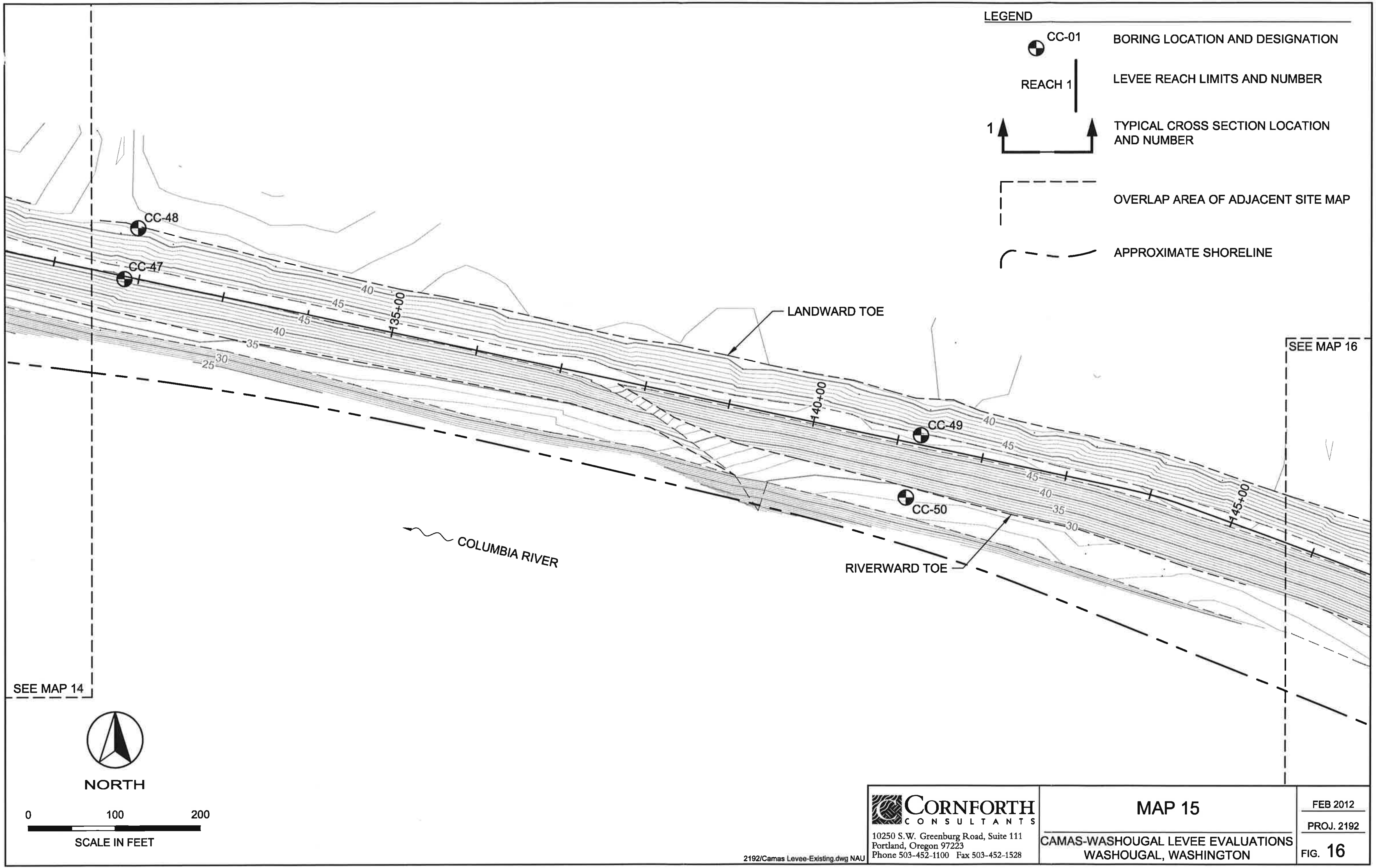
Cornforth Consultants, 2012



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MAP 15

CAMAS-WASHOUGAL LEVEE EVALUATIONS
WASHOUGAL, WASHINGTON

FEB 2012
PROJ. 2192
FIG. 16

Selected data extracted from:
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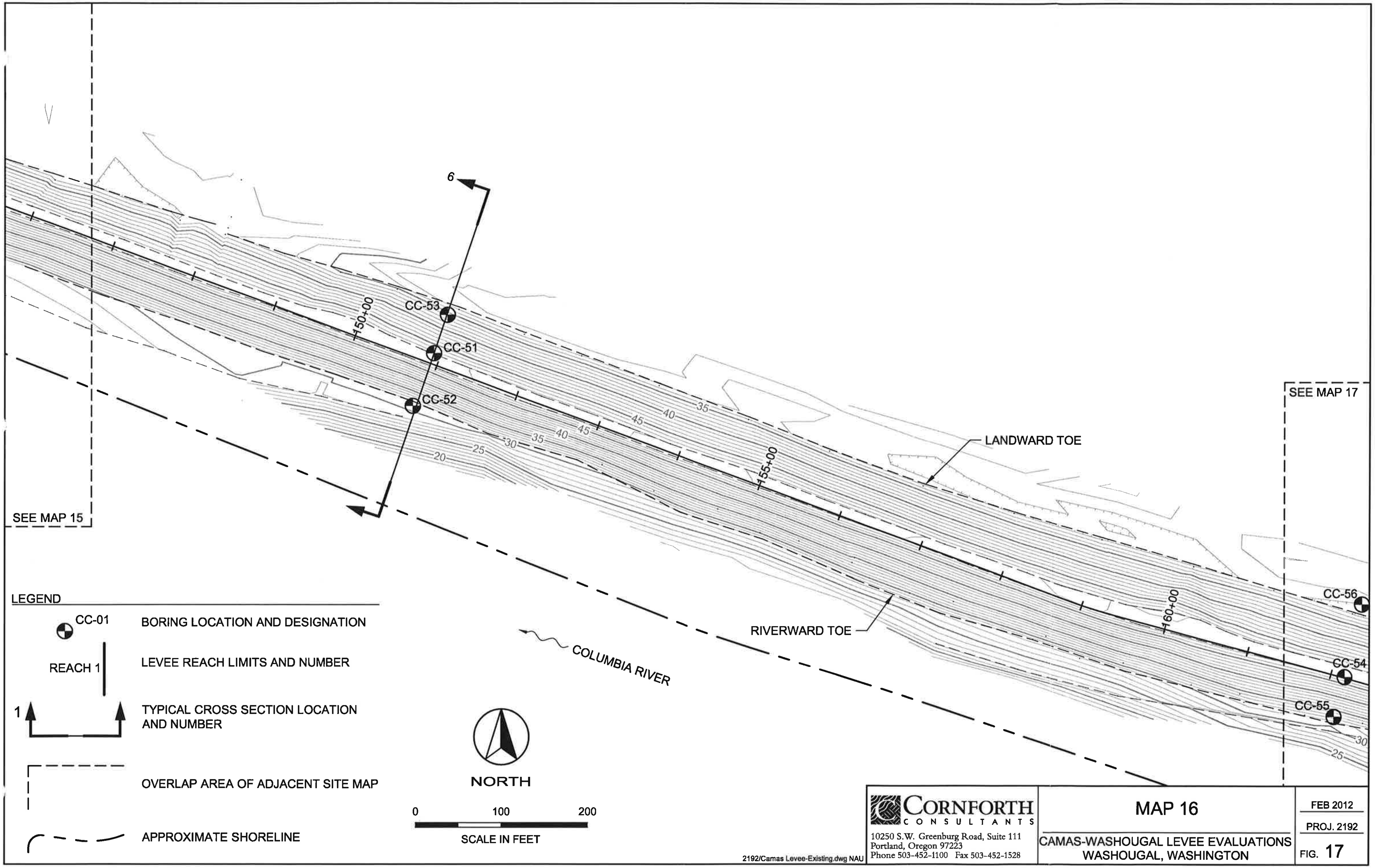
Cornforth Consultants, 2012



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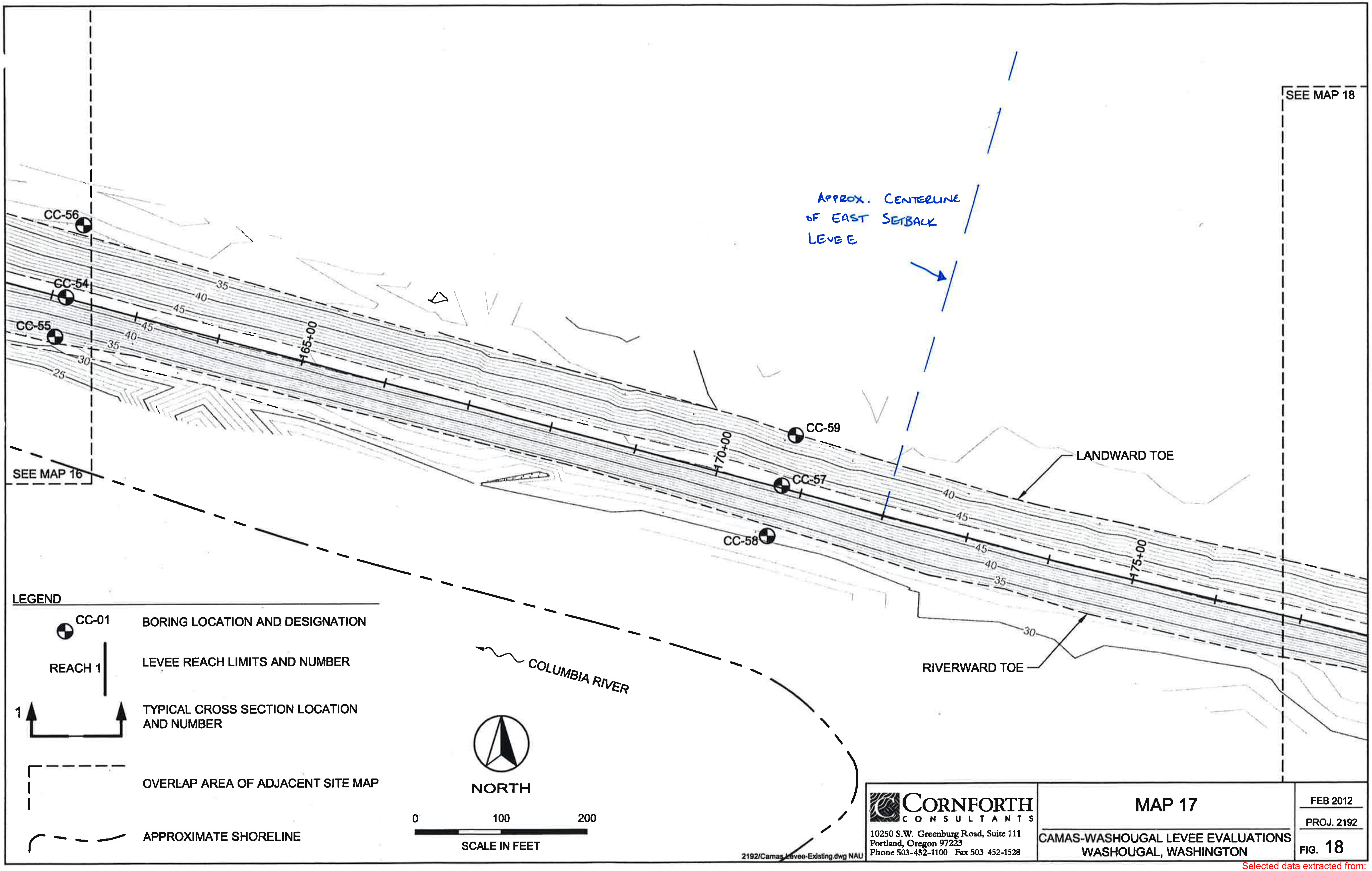
MAP 16

CAMAS-WASHOUGAL LEVEE EVALUATIONS
WASHOUGAL, WASHINGTON

FEB 2012
PROJ. 2192
FIG. 17

Selected data extracted from:
Camas Washougal Levee FEMA Certification Engineering Evaluations Report
Cornforth Consultants, 2012



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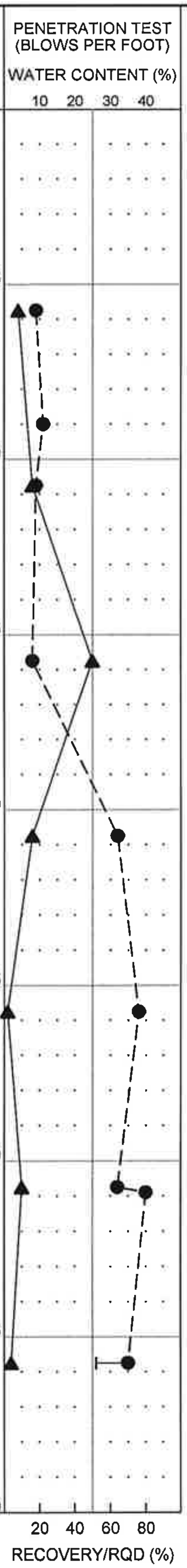
MAP 17

CAMAS-WASHOUGAL LEVEE EVALUATIONS
WASHOUGAL, WASHINGTON

FEB 2012
PROJ. 2192
FIG. 18

Selected data extracted from:
Camas Washougal Levee FEMA Certification Engineering Evaluations Report
Cornforth Consultants, 2012

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION	SAMPLE NO.	SAMPLE PEN. DATA	GROUND WATER/ INSTRUMENT INSTALLATION
		SURFACE ELEVATION: 46.6 FT.			
		LOOSE to MEDIUM DENSE, gray, fine SAND, trace silt, trace mica (LEVEE EMBANKMENT)	S-1	1 2 2	
			S-2		
			S-3	3 4 4	
			S-4	6 11 14	
28.6	18	LOOSE; brown, fine to meddium, slightly silty SAND; trace mica (RIVER ALLUVIUM)	S-5	2 4 4	
			S-6	0 0 1	
19.6	27	VERY SOFT, gray SILT; trace fine sand, trace mica, trace organics (RIVER ALLUVIUM)	S-7	0 2 3	
15.6	31	VERY LOOSE, gray, fine SAND, trace mica (RIVER ALLUVIUM)			
13.6	33	VERY SOFT, dark gray, clayey SILT, trace mica (RIVER ALLUVIUM)	S-8	0 0 2	
10.1	36.5	Bottom of Boring: 36.5 FT			



LEGEND

- ▨ 2-INCH O.D. SPLIT SPOON
- ☒ 3-INCH O.D. SPLIT SPOON
- ▯ 3-INCH O.D. THIN WALL SAMPLER
- ▥ 3-INCH O.D. PITCHER TUBE SAMPLER
- * NO SAMPLE RECOVERY
- ▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED
- LIQUID LIMIT, WATER CONTENT, PLASTIC LIMIT
- ▲ STANDARD PENETRATION TEST (BLOWS/FT.)
- ● WATER CONTENT IN PERCENT
- ▨ CORE RECOVERY IN PERCENT
- ▩ RQD IN PERCENT
-] PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT FROM BOTTOM TO TOP

HAMMER ASSEMBLY: AUTO TRIP

SPT SAMPLER: NO LINER - RECESSED ID

DRILL ROD USED: NWJ

BOREHOLE DIAM.: 9-INCH

DRILLER: MAJOR DRILLING

DATE START: 9/12/2011 FINISH: 9/12/2011

DRILLING TECHNIQUE: HOLLOW STEM AUGER

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SUMMARY BORING LOG CC-29

CAMAS/WASHOUGAL LEVEE EVAL.
WASHOUGAL, WA

DEC 2011

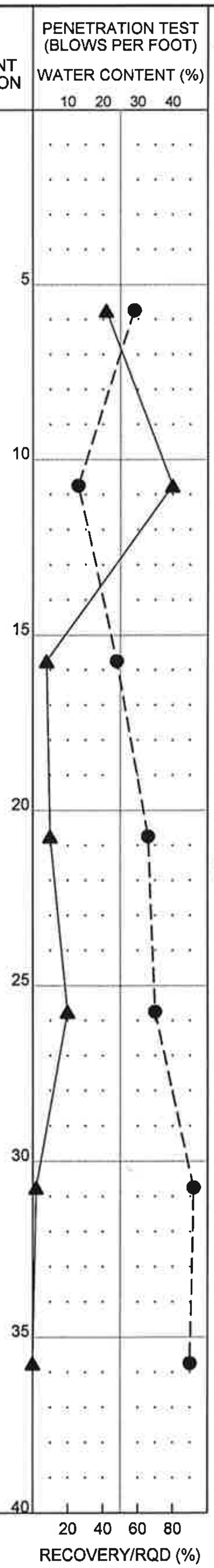
PROJ 2192

FIG. A-29

Selected data extracted from:
Camas Washougal Levee FEMA Certification Engineering Evaluations Report
Cornforth Consultants, 2012

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION	SAMPLE NO.	PEN. DATA
		SURFACE ELEVATION: 46.5 FT.		
		MEDIUM DENSE to DENSE, brown, fine SAND; trace mica and silt (LEVEE EMBANKMENT)		
			S-1	7 10 11
			S-2 *	
			S-3	17 19 21
32.5	14	LOOSE, brown, silty, fine SAND; trace mica (RIVER ALLUVIUM)		
			S-4	3 2 2
			S-5	4 3 2
			S-6	6 5 5
18.5	28	VERY SOFT, gray, clayey SILT; trace mica (RIVER ALLUVIUM)		
			S-7	2 0 1
			S-8	0 0 0
10.0	36.5	Bottom of Boring: 36.5 FT		

GROUND WATER/ INSTRUMENT INSTALLATION



LEGEND

▨	2-INCH O.D. SPLIT SPOON
☒	3-INCH O.D. SPLIT SPOON
◫	3-INCH O.D. THIN WALL SAMPLER
▥	3-INCH O.D. PITCHER TUBE SAMPLER
*	NO SAMPLE RECOVERY
▼ MM/DD/YY	GROUND WATER LEVEL AND DATE OBSERVED
├●─┤	LIQUID LIMIT WATER CONTENT PLASTIC LIMIT
▲	STANDARD PENETRATION TEST (BLOWS/FT.)
●	WATER CONTENT IN PERCENT
▨	CORE RECOVERY IN PERCENT
■	RQD IN PERCENT
] PT-1	PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT FROM BOTTOM TO TOP

HAMMER ASSEMBLY: AUTO TRIP
SPT SAMPLER: NO LINER - RECESSED ID
DRILL ROD USED: NWJ
BOREHOLE DIAM.: 5-INCH

DRILLER: MAJOR DRILLING
DATE START: 9/12/2011 FINISH: 9/12/2011
DRILLING TECHNIQUE: MUD ROTARY

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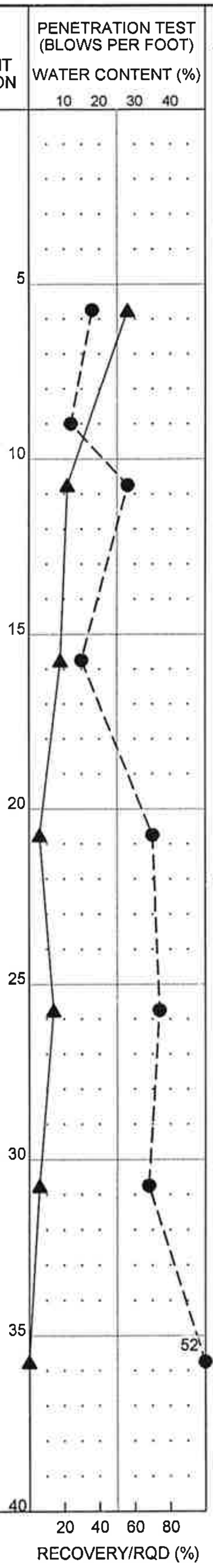
SUMMARY BORING LOG CC-32

CAMAS/WASHOUGAL LEVEE EVAL.
WASHOUGAL, WA

DEC 2011
PROJ 2192
FIG. A-32

Selected data extracted from:
Camas Washougal Levee FEMA Certification Engineering Evaluations Report
Cornforth Consultants, 2012

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION	SAMPLE NO.	PEN. DATA	GROUND WATER/ INSTRUMENT INSTALLATION
		SURFACE ELEVATION: 45.9 FT.			
		MEDIUM DENSE, brown, fine SAND; trace mica and silt (LEVEE EMBANKMENT)			
			S-1	11 13 15	
			S-2		
			S-3	7 6 5	
			S-4	4 4 5	
27.9	18	VERY LOOSE to LOOSE, brown and gray, silty, fine SAND; trace mica (RIVER ALLUVIUM)			
			S-5	3 2 1	
			S-6	5 4 3	
			S-7	3 1 2	
12.9	33	VERY SOFT, gray, clayey SILT; trace mica and organics (RIVER ALLUVIUM)			
			S-8	0 0 0	
9.4	36.5	Bottom of Boring: 36.5 FT			



LEGEND

▨	2-INCH O.D. SPLIT SPOON
☒	3-INCH O.D. SPLIT SPOON
◫	3-INCH O.D. THIN WALL SAMPLER
▥	3-INCH O.D. PITCHER TUBE SAMPLER
*	NO SAMPLE RECOVERY
▼ MM/DD/YY	GROUND WATER LEVEL AND DATE OBSERVED
├─●─┤	LIQUID LIMIT WATER CONTENT PLASTIC LIMIT
▲	STANDARD PENETRATION TEST (BLOWS/FT.)
●	WATER CONTENT IN PERCENT
▨	CORE RECOVERY IN PERCENT
▩	RQD IN PERCENT
] PT-1	PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT FROM BOTTOM TO TOP

HAMMER ASSEMBLY: AUTO TRIP
DRILL ROD USED: NWJ
SPT SAMPLER: NO LINER - RECESSED ID
BOREHOLE DIAM.: 5-INCH

DRILLER: MAJOR DRILLING
DATE START: 9/9/2011 FINISH: 9/9/2011
DRILLING TECHNIQUE: MUD ROTARY

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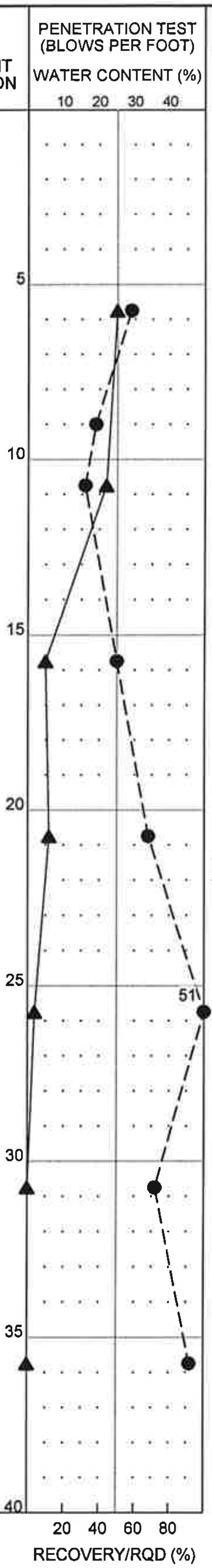
SUMMARY BORING LOG CC-34

CAMAS/WASHOUGAL LEVEE EVAL.
WASHOUGAL, WA

DEC 2011
PROJ 2192
FIG. A-34

Selected data extracted from:
Camas Washougal Levee FEMA Certification Engineering Evaluations Report
Cornforth Consultants, 2012

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION SURFACE ELEVATION: 46.6 FT.	SAMPLE NO.	PEN. DATA	GROUND WATER/ INSTRUMENT INSTALLATION
		MEDIUM DENSE, brown, fine SAND; trace mica and silt (LEVEE EMBANKMENT)			
			S-1	10 11 14	
			S-2		
			S-3	9 11 11	
32.6	14	LOOSE, brown, sandy SILT; trace mica (RIVER ALLUVIUM)			
			S-4	3 2 3	
			S-5	0 4 2	
23.6	23	SOFT, gray and brown, slightly clayey SILT (RIVER ALLUVIUM)			
			S-6	0 0 2	
18.6	28	LOOSE, brown, silty fine SAND; trace mica (RIVER ALLUVIUM)			
			S-7	0 0 0	
13.6	33	VERY SOFT, gray, silty CLAY; (RIVER ALLUVIUM)			
			S-8	0 0 0	
10.1	36.5	Bottom of Boring: 36.5 FT			



LEGEND

▨ 2-INCH O.D. SPLIT SPOON

☒ 3-INCH O.D. SPLIT SPOON

▯ 3-INCH O.D. THIN WALL SAMPLER

▥ 3-INCH O.D. PITCHER TUBE SAMPLER

* NO SAMPLE RECOVERY

▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED

LIQUID LIMIT
WATER CONTENT
PLASTIC LIMIT

▲ STANDARD PENETRATION TEST (BLOWS/FT.)

● WATER CONTENT IN PERCENT

▨ CORE RECOVERY IN PERCENT

■ RQD IN PERCENT

] PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT FROM BOTTOM TO TOP

HAMMER ASSEMBLY: AUTO TRIP
SPT SAMPLER: NO LINER - RECESSED ID
DRILL ROD USED: NWJ
BOREHOLE DIAM.: 5-INCH

DRILLER: MAJOR DRILLING
DATE START: 9/8/2011 FINISH: 9/8/2011
DRILLING TECHNIQUE: MUD ROTARY

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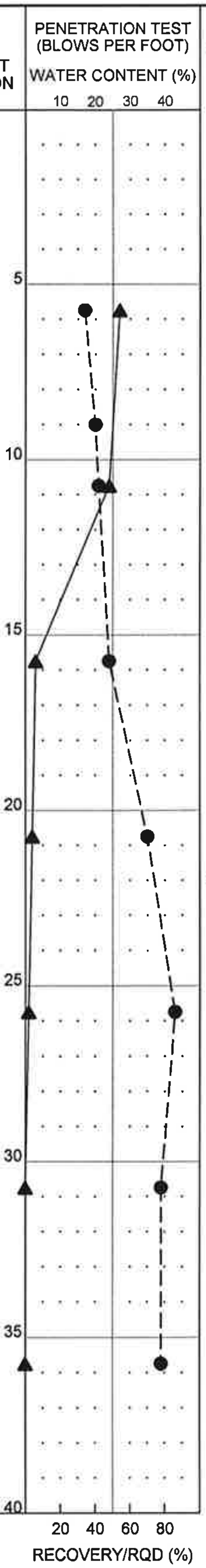
SUMMARY BORING LOG CC-36

CAMAS/WASHOUGAL LEVEE EVAL.
WASHOUGAL, WA

DEC 2011
PROJ 2192
FIG. A-36

Selected data extracted from:
Camas Washougal Levee FEMA Certification Engineering Evaluations Report
Cornforth Consultants, 2012

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION SURFACE ELEVATION: 46.7 FT.	SAMPLE NO.	SAMPLE PEN. DATA	GROUND WATER/ INSTRUMENT INSTALLATION
		MEDIUM DENSE, brown, fine SAND; trace silt and mica (LEVEE EMBANKMENT)	S-1	9 14 13	
			S-2		
			S-3	9 12 12	
32.7	14	VERY LOOSE, brown, sandy SILT; trace mica (RIVER ALLUVIUM)	S-4	3 2 1	
			S-5	1 1 1	
23.7	23	VERY SOFT, brown, slightly clayey SILT; trace fine sand and mica (RIVER ALLUVIUM)	S-6	1 0 1	
			S-7	0 0 0	
			S-8	0 0 0	
10.2	36.5	Bottom of Boring: 36.5 FT			



LEGEND

- ▨ 2-INCH O.D. SPLIT SPOON
- ☒ 3-INCH O.D. SPLIT SPOON
- ◫ 3-INCH O.D. THIN WALL SAMPLER
- ▥ 3-INCH O.D. PITCHER TUBE SAMPLER
- * NO SAMPLE RECOVERY
- ▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED
- ├●┤ LIQUID LIMIT / WATER CONTENT / PLASTIC LIMIT
- ▲ STANDARD PENETRATION TEST (BLOWS/FT.)
- ● WATER CONTENT IN PERCENT
- ▨ CORE RECOVERY IN PERCENT
- ■ RQD IN PERCENT
-] PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT FROM BOTTOM TO TOP

HAMMER ASSEMBLY: AUTO TRIP

SPT SAMPLER: NO LINER - RECESSED ID

DRILL ROD USED: NWJ

BOREHOLE DIAM.: 5-INCH

DRILLER: MAJOR DRILLING
DATE START: 9/8/2011 FINISH: 9/8/2011
DRILLING TECHNIQUE: MUD ROTARY

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SUMMARY BORING LOG CC-38

CAMAS/WASHOUGAL LEVEE EVAL.
WASHOUGAL, WA

DEC 2011

PROJ 2192

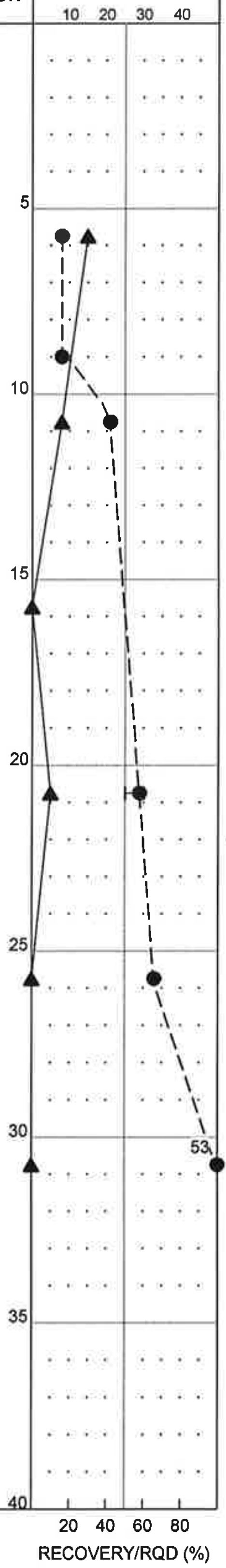
FIG. A-38

Selected data extracted from:
Camas Washougal Levee FEMA Certification Engineering Evaluations Report
Cornforth Consultants, 2012

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION SURFACE ELEVATION: 46.5 FT.	SAMPLE NO.	PEN. DATA	GROUND WATER/ INSTRUMENT INSTALLATION
		MEDIUM DENSE, brown, slightly silty fine SAND; trace mica (LEVEE EMBANKMENT)	S-1	4 8 7	
38.5	8	VERY LOOSE to LOOSE, gray-brown, silty fine SAND to fine sandy SILT; trace mica (RIVER ALLUVIUM)	S-2		
			S-3	3 4 4	
			S-4 *	0 0 0	
			S-5	0 2 3	
			S-6	0 0 0	
18.5	28	VERY SOFT, gray, clayey SILT; trace mica (RIVER ALLUVIUM)	S-7	0 0 0	
15.0	31.5	Bottom of Boring: 31.5 FT			

PENETRATION TEST (BLOWS PER FOOT)

WATER CONTENT (%)



LEGEND

▨	2-INCH O.D. SPLIT SPOON
☒	3-INCH O.D. SPLIT SPOON
◫	3-INCH O.D. THIN WALL SAMPLER
▥	3-INCH O.D. PITCHER TUBE SAMPLER
*	NO SAMPLE RECOVERY
▼ MM/DD/YY	GROUND WATER LEVEL AND DATE OBSERVED
├●─┤	LIQUID LIMIT WATER CONTENT PLASTIC LIMIT
▲	STANDARD PENETRATION TEST (BLOWS/FT.)
●	WATER CONTENT IN PERCENT
▨	CORE RECOVERY IN PERCENT
▩	RQD IN PERCENT
] PT-1	PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT FROM BOTTOM TO TOP

HAMMER ASSEMBLY: AUTO TRIP
SPT SAMPLER: NO LINER - RECESSED ID
DRILL ROD USED: NWJ
BOREHOLE DIAM.: 9-INCH

DRILLER: MAJOR DRILLING
DATE START: 9/7/2011 FINISH: 9/7/2011
DRILLING TECHNIQUE: HOLLOW STEM AUGER

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SUMMARY BORING LOG CC-40

CAMAS/WASHOUGAL LEVEE EVAL.
WASHOUGAL, WA

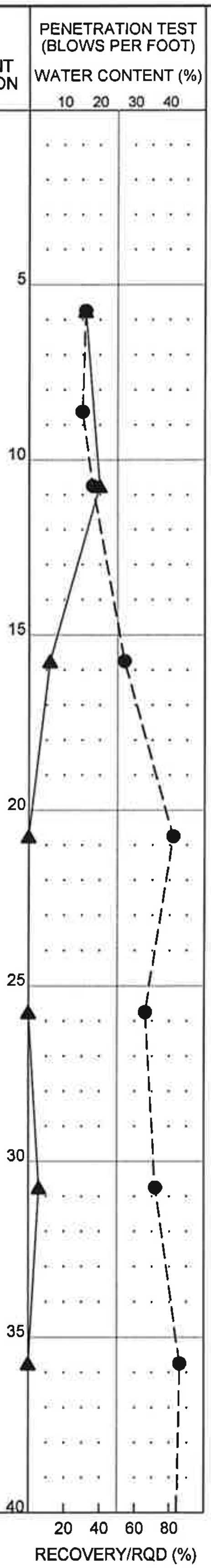
DEC 2011

PROJ 2192

FIG. A-40

Selected data extracted from:
Camas Washougal Levee FEMA Certification Engineering Evaluations Report
Cornforth Consultants, 2012

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION SURFACE ELEVATION: 47.1 FT.	SAMPLE NO.		PEN. DATA	GROUND WATER/ INSTRUMENT INSTALLATION
		VERY LOOSE to MEDIUM DENSE, brown, slightly silty, fine SAND; trace mica (LEVEE EMBANKMENT)				
			S-1	▨	7 8 8	
			S-2	☒		
			S-3	▨	9 10 10	
			S-4	▨	3 3 3	
29.1	18	VERY SOFT, brown, slightly clayey SILT; trace mica (RIVER ALLUVIUM)				
			S-5	▨	0 0 0	
			S-6	▨	0 0 0	
			S-7	▨	0 2 1	
14.1	33	VERY SOFT, gray, clayey SILT; trace organics (RIVER ALLUVIUM)				
			S-8	▨	0 0 0	
7.1	40					



LEGEND

▨	2-INCH O.D. SPLIT SPOON
☒	3-INCH O.D. SPLIT SPOON
▯	3-INCH O.D. THIN WALL SAMPLER
▥	3-INCH O.D. PITCHER TUBE SAMPLER
*	NO SAMPLE RECOVERY
▼ MM/DD/YY	GROUND WATER LEVEL AND DATE OBSERVED
├●─	LIQUID LIMIT WATER CONTENT PLASTIC LIMIT
▲	STANDARD PENETRATION TEST (BLOWS/FT.)
●	WATER CONTENT IN PERCENT
▨	CORE RECOVERY IN PERCENT
▩	RQD IN PERCENT
] PT-1	PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT FROM BOTTOM TO TOP

HAMMER ASSEMBLY: AUTO TRIP
SPT SAMPLER: NO LINER - RECESSED ID
DRILL ROD USED: NWJ
BOREHOLE DIAM.: 5-INCH

DRILLER: MAJOR DRILLING
DATE START: 9/6/2011 FINISH: 9/6/2011
DRILLING TECHNIQUE: MUD ROTARY

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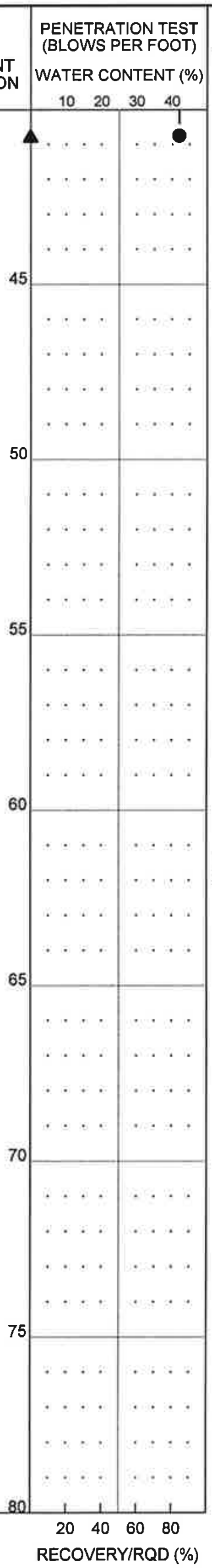
SUMMARY BORING LOG
CC-43 (1 of 2)

CAMAS/WASHOUGAL LEVEE EVAL.
WASHOUGAL, WA

DEC 2011
PROJ 2192
FIG. A-43

Selected data extracted from:
Camas Washougal Levee FEMA Certification Engineering Evaluations Report
Cornforth Consultants, 2012

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION SURFACE ELEVATION: 47.1 FT.	SAMPLE NO.		SAMPLE PEN. DATA	GROUND WATER/ INSTRUMENT INSTALLATION
		(continued from previous page)	S-9	▨	0 0 0	
5.6	41.5	Bottom of Boring: 41.5 FT				



LEGEND

▨	2-INCH O.D. SPLIT SPOON
☒	3-INCH O.D. SPLIT SPOON
▯	3-INCH O.D. THIN WALL SAMPLER
▥	3-INCH O.D. PITCHER TUBE SAMPLER
*	NO SAMPLE RECOVERY
▼ MM/DD/YY	GROUND WATER LEVEL AND DATE OBSERVED
├●─	LIQUID LIMIT WATER CONTENT PLASTIC LIMIT
▲	STANDARD PENETRATION TEST (BLOWS/FT.)
●	WATER CONTENT IN PERCENT
▨	CORE RECOVERY IN PERCENT
▩	RQD IN PERCENT
] PT-1	PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT FROM BOTTOM TO TOP

HAMMER ASSEMBLY: AUTO TRIP

SPT SAMPLER: NO LINER - RECESSED ID

DRILL ROD USED: NWJ

BOREHOLE DIAM.: 5-INCH

DRILLER: MAJOR DRILLING
DATE START: 9/6/2011 FINISH: 9/6/2011
DRILLING TECHNIQUE: MUD ROTARY

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SUMMARY BORING LOG
CC-43 (2 of 2)

CAMAS/WASHOUGAL LEVEE EVAL.
WASHOUGAL, WA

DEC 2011

PROJ 2192

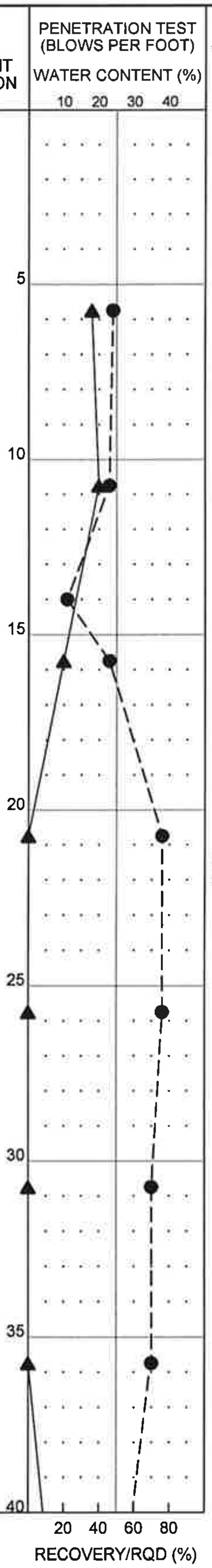
FIG. A-43

Selected data extracted from:
Camas Washougal Levee FEMA Certification Engineering Evaluations Report
Cornforth Consultants, 2012

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION SURFACE ELEVATION: 46.5 FT.
		MEDIUM DENSE, brown, fine SAND; trace mica and silt. (LEVEE EMBANKMENT)
28.5	18	VERY SOFT, gray-brown, slightly clayey to clayey SILT: trace mica (RIVER ALLUVIUM)
8.5	38	LOOSE, brown, slightly sandy SILT; trace mica (RIVER ALLUVIUM)

SAMPLE NO.	PEN. DATA
S-1	5 9 9
S-2	7 10 10
S-3	
S-4	5 5 5
S-5	0 0 0
S-6	0 0 0
S-7	0 0 0
S-8	0 0 0

GROUND WATER/ INSTRUMENT INSTALLATION



LEGEND

- ▨ 2-INCH O.D. SPLIT SPOON
- ☒ 3-INCH O.D. SPLIT SPOON
- ◫ 3-INCH O.D. THIN WALL SAMPLER
- ▥ 3-INCH O.D. PITCHER TUBE SAMPLER
- * NO SAMPLE RECOVERY
- ▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED
- ├●┤ LIQUID LIMIT, WATER CONTENT, PLASTIC LIMIT
- ▲ STANDARD PENETRATION TEST (BLOWS/FT.)
- ● WATER CONTENT IN PERCENT
- ▨ CORE RECOVERY IN PERCENT
- ▩ RQD IN PERCENT
-] PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT FROM BOTTOM TO TOP

HAMMER ASSEMBLY: AUTO TRIP
SPT SAMPLER: NO LINER - RECESSED ID
DRILL ROD USED: NWJ
BOREHOLE DIAM.: 5-INCH

DRILLER: MAJOR DRILLING
DATE START: 9/6/2011 FINISH: 9/6/2011
DRILLING TECHNIQUE: MUD ROTARY

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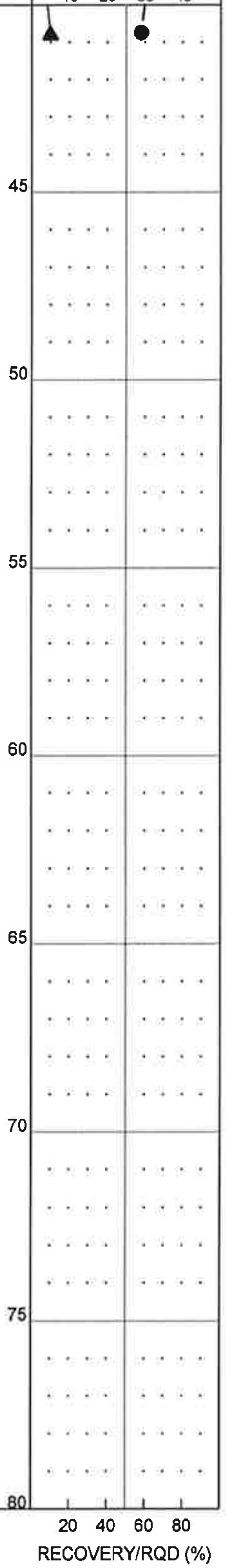
SUMMARY BORING LOG CC-45 (1 of 2)

CAMAS/WASHOUGAL LEVEE EVAL.
WASHOUGAL, WA

DEC 2011
PROJ 2192
FIG. A-45

Selected data extracted from:
Camas Washougal Levee FEMA Certification Engineering Evaluations Report
Cornforth Consultants, 2012

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION SURFACE ELEVATION: 46.5 FT.	SAMPLE NO.	SAMPLE PEN. DATA	GROUND WATER/ INSTRUMENT INSTALLATION	PENETRATION TEST (BLOWS PER FOOT) WATER CONTENT (%) 10 20 30 40
5.0	41.5	(continued from previous page)	S-9	5 3 2		
		Bottom of Boring: 41.5 FT				



LEGEND

- ▨ 2-INCH O.D. SPLIT SPOON
- ☒ 3-INCH O.D. SPLIT SPOON
- ◫ 3-INCH O.D. THIN WALL SAMPLER
- ▥ 3-INCH O.D. PITCHER TUBE SAMPLER
- * NO SAMPLE RECOVERY
- ▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED
- ├●┤ LIQUID LIMIT, WATER CONTENT, PLASTIC LIMIT
- ▲ STANDARD PENETRATION TEST (BLOWS/FT.)
- ● WATER CONTENT IN PERCENT
- ▨ CORE RECOVERY IN PERCENT
- ▩ RQD IN PERCENT
-] PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT FROM BOTTOM TO TOP

HAMMER ASSEMBLY: AUTO TRIP

SPT SAMPLER: NO LINER - RECESSED ID

DRILL ROD USED: NWJ

BOREHOLE DIAM.: 5-INCH

DRILLER: MAJOR DRILLING

DATE START: 9/6/2011 FINISH: 9/6/2011

DRILLING TECHNIQUE: MUD ROTARY

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SUMMARY BORING LOG CC-45 (2 of 2)

CAMAS/WASHOUGAL LEVEE EVAL.
WASHOUGAL, WA

DEC 2011

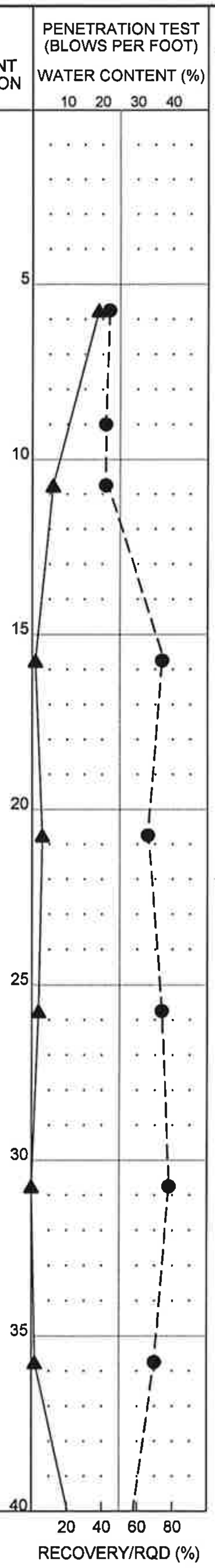
PROJ 2192

FIG. A-45

Selected data extracted from:
Camas Washougal Levee FEMA Certification Engineering Evaluations Report
Cornforth Consultants, 2012

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION SURFACE ELEVATION: 46.2 FT.	SAMPLE NO.	PEN. DATA
		LOOSE to MEDIUM DENSE, brown, fine SAND; trace silt and mica (LEVEE EMBANKMENT)		
			S-1	8 9 10
			S-2	
			S-3	4 3 3
34.2	12	VERY SOFT, brown, slightly clayey SILT; trace mica (RIVER ALLUVIUM)		
			S-4	0 0 1
28.2	18	LOOSE, brown, fine sandy SILT; trace mica (RIVER ALLUVIUM)		
			S-5	0 0 3
			S-6	1 1 1
19.2	27	VERY SOFT, gray and brown, clayey SILT; (RIVER ALLUVIUM)		
			S-7	0 0 0
13.2	33	VERY LOOSE to MEDIUM DENSE, brown, slightly slity SAND; trace mica (RIVER ALLUVIUM)		
			S-8	3 0 1
6.2	40			

GROUND WATER/ INSTRUMENT INSTALLATION



LEGEND

- ▨ 2-INCH O.D. SPLIT SPOON
- ☒ 3-INCH O.D. SPLIT SPOON
- ◫ 3-INCH O.D. THIN WALL SAMPLER
- ▥ 3-INCH O.D. PITCHER TUBE SAMPLER
- * NO SAMPLE RECOVERY
- ▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED
- LIQUID LIMIT, WATER CONTENT, PLASTIC LIMIT
- ▲ STANDARD PENETRATION TEST (BLOWS/FT.)
- ● WATER CONTENT IN PERCENT
- ▨ CORE RECOVERY IN PERCENT
- ▩ RQD IN PERCENT
-] PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT FROM BOTTOM TO TOP

HAMMER ASSEMBLY: AUTO TRIP
SPT SAMPLER: NO LINER - RECESSED ID
DRILL ROD USED: NWJ
BOREHOLE DIAM.: 5-INCH

DRILLER: MAJOR DRILLING
DATE START: 9/2/2011 FINISH: 9/2/2011
DRILLING TECHNIQUE: MUD ROTARY

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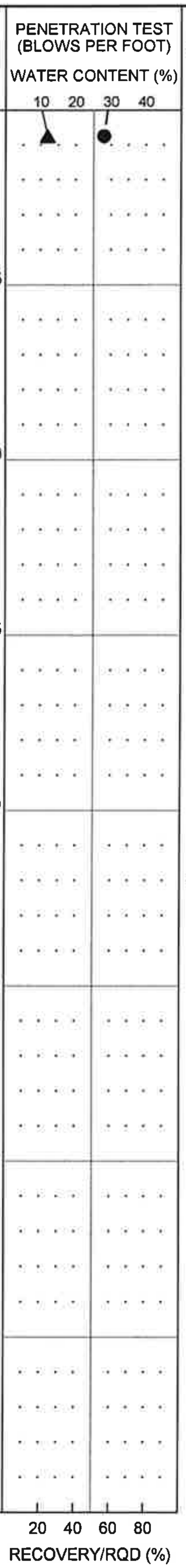
SUMMARY BORING LOG CC-47 (1 of 2)

CAMAS/WASHOUGAL LEVEE EVAL.
WASHOUGAL, WA

DEC 2011
PROJ 2192
FIG. A-47

Selected data extracted from:
Camas Washougal Levee FEMA Certification Engineering Evaluations Report
Cornforth Consultants, 2012

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION SURFACE ELEVATION: 46.2 FT.	SAMPLE NO.		SAMPLE PEN. DATA	GROUND WATER/ INSTRUMENT INSTALLATION
		(continued from previous page)	S-9	▨	9 7 5	
4.7	41.5	**Bottom of Boring: 41.5 FT**				



LEGEND

▨	2-INCH O.D. SPLIT SPOON
☒	3-INCH O.D. SPLIT SPOON
▯	3-INCH O.D. THIN WALL SAMPLER
▥	3-INCH O.D. PITCHER TUBE SAMPLER
*	NO SAMPLE RECOVERY
▼ MM/DD/YY	GROUND WATER LEVEL AND DATE OBSERVED
├●┤	LIQUID LIMIT WATER CONTENT PLASTIC LIMIT
▲	STANDARD PENETRATION TEST (BLOWS/FT.)
●	WATER CONTENT IN PERCENT
▨	CORE RECOVERY IN PERCENT
▩	RQD IN PERCENT
] PT-1	PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT FROM BOTTOM TO TOP

HAMMER ASSEMBLY: AUTO TRIP
DRILL ROD USED: NWJ

SPT SAMPLER: NO LINER - RECESSED ID
BOREHOLE DIAM.: 5-INCH

DRILLER: MAJOR DRILLING
DATE START: 9/2/2011 FINISH: 9/2/2011
DRILLING TECHNIQUE: MUD ROTARY

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SUMMARY BORING LOG
CC-47 (2 of 2)

CAMAS/WASHOUGAL LEVEE EVAL.
WASHOUGAL, WA

DEC 2011
PROJ 2192
FIG. A-47

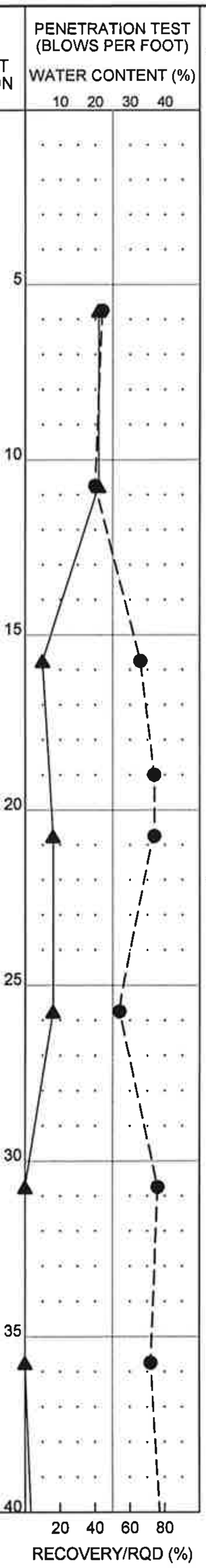
Selected data extracted from:
Camas Washougal Levee FEMA Certification Engineering Evaluations Report
Cornforth Consultants, 2012

SURFACE ELEVATION: 47.7 FT.

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION
		MEDIUM DENSE, brown, fine SAND; trace silt and mica (LEVEE EMBANKMENT)
34.7	13	MEDIUM STIFF, brown, slightly clayey SILT; trace mica (RIVER ALLUVIUM)
24.7	23	LOOSE, brown, silty fine SAND; trace mica (RIVER ALLUVIUM)
18.7	29	VERY SOFT, brown, slightly clayey SILT; trace mica (RIVER ALLUVIUM)
9.7	38	VERY LOOSE, brown, slightly silty fine SAND; trace mica (RIVER ALLUVIUM)
7.7	40	

SAMPLE NO.	PEN. DATA
S-1	7 12 9
S-2	8 9 12
S-3	2 2 3
S-4	
S-5	3 4 4
S-6	3 2 6
S-7	0 0 0
S-8	0 0 0

GROUND WATER/ INSTRUMENT INSTALLATION



LEGEND

- ▨ 2-INCH O.D. SPLIT SPOON
- ☒ 3-INCH O.D. SPLIT SPOON
- ◫ 3-INCH O.D. THIN WALL SAMPLER
- ▥ 3-INCH O.D. PITCHER TUBE SAMPLER
- * NO SAMPLE RECOVERY
- ▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED
- ├●┤ LIQUID LIMIT, WATER CONTENT, PLASTIC LIMIT
- ▲ STANDARD PENETRATION TEST (BLOWS/FT.)
- ● WATER CONTENT IN PERCENT
- ▨ CORE RECOVERY IN PERCENT
- ▩ RQD IN PERCENT
-] PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT FROM BOTTOM TO TOP

HAMMER ASSEMBLY: AUTO TRIP
SPT SAMPLER: NO LINER - RECESSED ID
DRILL ROD USED: NWJ
BOREHOLE DIAM.: 5-INCH

DRILLER: MAJOR DRILLING
DATE START: 9/1/2011 FINISH: 9/1/2011
DRILLING TECHNIQUE: MUD ROTARY

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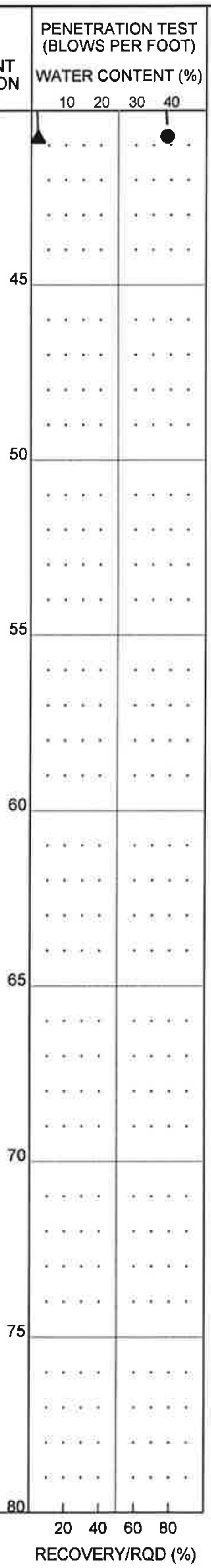
SUMMARY BORING LOG CC-49 (1 of 2)

CAMAS/WASHOUGAL LEVEE EVAL.
WASHOUGAL, WA

DEC 2011
PROJ 2192
FIG. A-49

Selected data extracted from:
Camas Washougal Levee FEMA Certification Engineering Evaluations Report
Cornforth Consultants, 2012

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION SURFACE ELEVATION: 47.7 FT.	SAMPLE NO.		SAMPLE PEN. DATA	GROUND WATER/ INSTRUMENT INSTALLATION
		(continued from previous page)	S-9	▨	1 1 1	
6.2	41.5	Bottom of Boring: 41.5 FT				



LEGEND

- ▨ 2-INCH O.D. SPLIT SPOON
- ☒ 3-INCH O.D. SPLIT SPOON
- ▯ 3-INCH O.D. THIN WALL SAMPLER
- ▥ 3-INCH O.D. PITCHER TUBE SAMPLER
- * NO SAMPLE RECOVERY
- ▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED
- LIQUID LIMIT / WATER CONTENT / PLASTIC LIMIT
- ▲ STANDARD PENETRATION TEST (BLOWS/FT.)
- ● WATER CONTENT IN PERCENT
- ▨ CORE RECOVERY IN PERCENT
- ▩ RQD IN PERCENT
-] PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT FROM BOTTOM TO TOP

HAMMER ASSEMBLY: AUTO TRIP

SPT SAMPLER: NO LINER - RECESSED ID

DRILL ROD USED: NWJ

BOREHOLE DIAM.: 5-INCH

DRILLER: MAJOR DRILLING

DATE START: 9/1/2011 FINISH: 9/1/2011

DRILLING TECHNIQUE: MUD ROTARY

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SUMMARY BORING LOG
CC-49 (2 of 2)

CAMAS/WASHOUGAL LEVEE EVAL.
WASHOUGAL, WA

DEC 2011

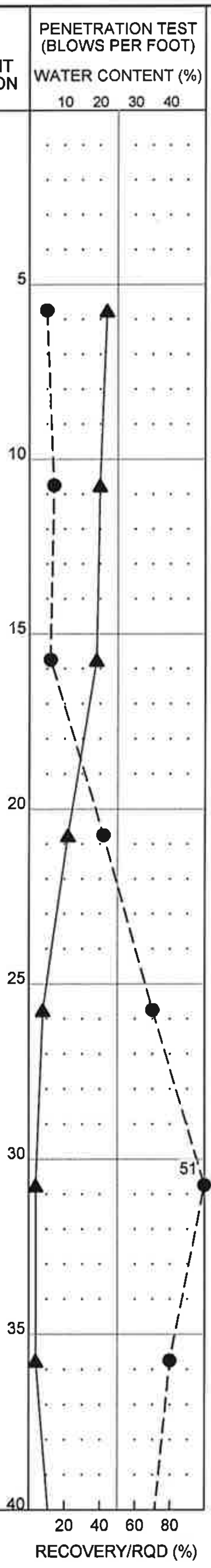
PROJ 2192

FIG. A-49

Selected data extracted from:
Camas Washougal Levee FEMA Certification Engineering Evaluations Report
Cornforth Consultants, 2012

SURFACE ELEVATION: 47.9 FT.

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION	SAMPLE NO.		PEN. DATA	GROUND WATER/ INSTRUMENT INSTALLATION
		MEDIUM DENSE, brown, fine SAND; trace mica and silt (LEVEE EMBANKMENT)				
			S-1	G	Grab	
			S-2	▨	7 11 11	
			S-3	G	Grab	
			S-4	▨	7 10 10	
			S-5	G	Grab	
			S-6	▨	6 9 10	
			S-7	▨	6 5 6	
24.9	23	SOFT, gray, slightly clayey SILT; trace mica (RIVER ALLUVIUM)				
			S-8	▨	2 2 2	
			S-9	▨	0 1 1	
			S-10	▨	0 0 2	
9.9	38	LOOSE to MEDIUM DENSE, gray, slightly silty, fine SAND; trace mica (RIVER ALLUVIUM)				



LEGEND

- ▨ 2-INCH O.D. SPLIT SPOON
- ☒ 3-INCH O.D. SPLIT SPOON
- ▯ 3-INCH O.D. THIN WALL SAMPLER
- ▥ 3-INCH O.D. PITCHER TUBE SAMPLER
- * NO SAMPLE RECOVERY
- ▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED
- ├●┤ LIQUID LIMIT, WATER CONTENT, PLASTIC LIMIT
- ▲ STANDARD PENETRATION TEST (BLOWS/FT.)
- ● WATER CONTENT IN PERCENT
- ▨ CORE RECOVERY IN PERCENT
- ▩ RQD IN PERCENT
-] PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT FROM BOTTOM TO TOP

HAMMER ASSEMBLY: AUTO TRIP

SPT SAMPLER: NO LINER - RECESSED ID

DRILL ROD USED: NWJ

BOREHOLE DIAM.: 9-INCH

DRILLER: MAJOR DRILLING
DATE START: 8/30/2011 FINISH: 8/30/2011
DRILLING TECHNIQUE: HOLLOW STEM AUGER

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SUMMARY BORING LOG CC-51 (1 of 3)

CAMAS/WASHOUGAL LEVEE EVAL.
WASHOUGAL, WA

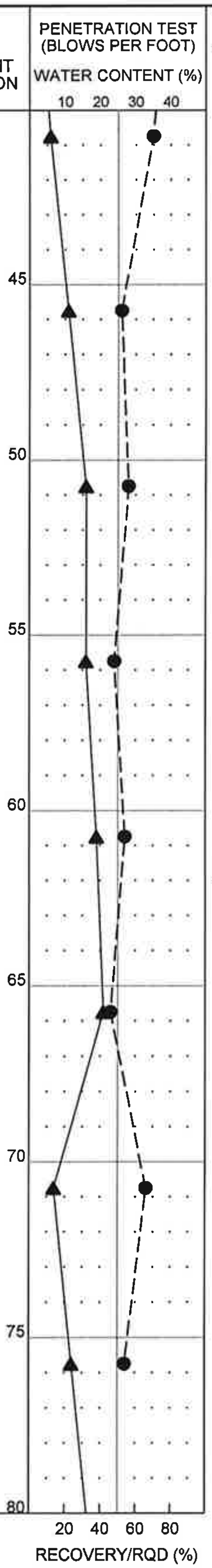
DEC 2011

PROJ 2192

FIG. A-51

Selected data extracted from:
Camas Washougal Levee FEMA Certification Engineering Evaluations Report
Cornforth Consultants, 2012

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION SURFACE ELEVATION: 47.9 FT.	SAMPLE NO.	PEN. DATA	GROUND WATER/ INSTRUMENT INSTALLATION
		(continued from previous page)	S-11	2 2 4	
			S-12	6 5 6	
			S-13	8 8 8	
			S-14	8 9 7	
			S-15	10 9 10	
			S-16	10 11 10	
			S-17	7 2 5	
			S-18	8 4 8	



LEGEND

▨ 2-INCH O.D. SPLIT SPOON

☒ 3-INCH O.D. SPLIT SPOON

☐ 3-INCH O.D. THIN WALL SAMPLER

☐ 3-INCH O.D. PITCHER TUBE SAMPLER

* NO SAMPLE RECOVERY

▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED

LIQUID LIMIT

WATER CONTENT

PLASTIC LIMIT

▲ STANDARD PENETRATION TEST (BLOWS/FT.)

● WATER CONTENT IN PERCENT

▨ CORE RECOVERY IN PERCENT

▩ RQD IN PERCENT

] PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT FROM BOTTOM TO TOP

HAMMER ASSEMBLY: AUTO TRIP
SPT SAMPLER: NO LINER - RECESSED ID
DRILL ROD USED: NWJ
BOREHOLE DIAM.: 9-INCH

DRILLER: MAJOR DRILLING
DATE START: 8/30/2011 FINISH: 8/30/2011
DRILLING TECHNIQUE: HOLLOW STEM AUGER

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Phone 503-452-1100 Fax 503-452-1528

SUMMARY BORING LOG CC-51 (2 of 3)

CAMAS/WASHOUGAL LEVEE EVAL.
WASHOUGAL, WA

DEC 2011

PROJ 2192

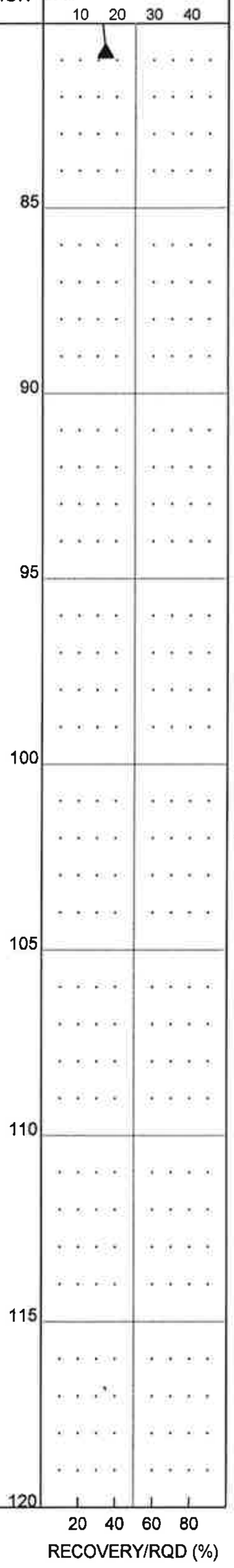
FIG. A-51

Selected data extracted from:
Camas Washougal Levee FEMA Certification Engineering Evaluations Report
Cornforth Consultants, 2012

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION SURFACE ELEVATION: 47.9 FT.	SAMPLE NO.		SAMPLE PEN. DATA	GROUND WATER/ INSTRUMENT INSTALLATION
-33.6	81.5	(continued from previous page)	S-19 *	▨	12 8 9	
		Bottom of Boring: 81.5 FT				

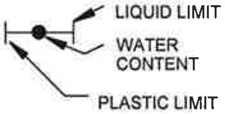
PENETRATION TEST (BLOWS PER FOOT)

WATER CONTENT (%)



LEGEND

- ▨ 2-INCH O.D. SPLIT SPOON
- ☒ 3-INCH O.D. SPLIT SPOON
- ◫ 3-INCH O.D. THIN WALL SAMPLER
- ▥ 3-INCH O.D. PITCHER TUBE SAMPLER
- * NO SAMPLE RECOVERY
- ▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED



- ▲ STANDARD PENETRATION TEST (BLOWS/FT.)
- ● WATER CONTENT IN PERCENT
- ▨ CORE RECOVERY IN PERCENT
- ▒ RQD IN PERCENT
-] PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT FROM BOTTOM TO TOP

HAMMER ASSEMBLY: AUTO TRIP

SPT SAMPLER: NO LINER - RECESSED ID

DRILL ROD USED: NWJ

BOREHOLE DIAM.: 9-INCH

DRILLER: MAJOR DRILLING
DATE START: 8/30/2011 FINISH: 8/30/2011
DRILLING TECHNIQUE: HOLLOW STEM AUGER

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SUMMARY BORING LOG CC-51 (3 of 3)

CAMAS/WASHOUGAL LEVEE EVAL.
WASHOUGAL, WA

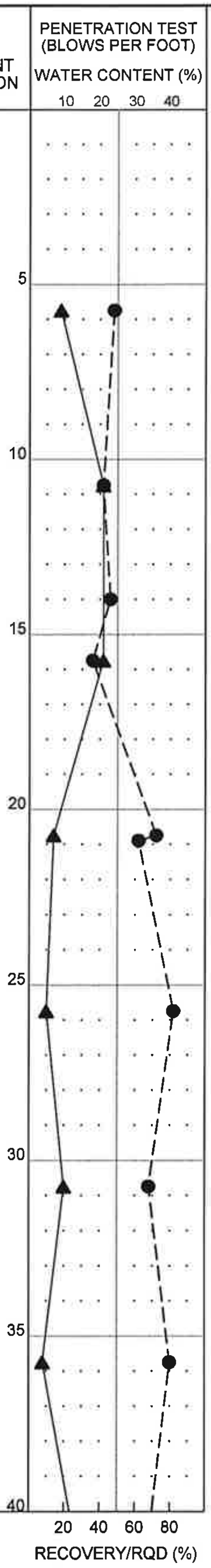
DEC 2011

PROJ 2192

FIG. A-51

Selected data extracted from:
Camas Washougal Levee FEMA Certification Engineering Evaluations Report
Cornforth Consultants, 2012

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION SURFACE ELEVATION: 47.4 FT.	SAMPLE NO.	SAMPLE PEN. DATA	GROUND WATER/ INSTRUMENT INSTALLATION
		LOOSE to MEDIUM DENSE, brown, fine SAND; trace mica (LEVEE EMBANKMENT)			
			S-1	3 4 5	
			S-2	9 10 11	
			S-3		
			S-4	8 10 11	
26.4	21	LOOSE, gray, slightly sandy SILT; trace mica, trace organics (RIVER ALLUVIUM)	S-5	4 3 4	
			S-6	1 3 2	
			S-7	3 3 7	
			S-8	0 0 4	
9.4	38	LOOSE to MEDIUM DENSE, gray, fine SAND; trace silt, trace mica (RIVER ALLUVIUM)			



LEGEND

▨ 2-INCH O.D. SPLIT SPOON

☒ 3-INCH O.D. SPLIT SPOON

◫ 3-INCH O.D. THIN WALL SAMPLER

▥ 3-INCH O.D. PITCHER TUBE SAMPLER

* NO SAMPLE RECOVERY

▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED

├●┤ LIQUID LIMIT, WATER CONTENT, PLASTIC LIMIT

▲ STANDARD PENETRATION TEST (BLOWS/FT.)

● WATER CONTENT IN PERCENT

▨ CORE RECOVERY IN PERCENT

▩ RQD IN PERCENT

] PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT FROM BOTTOM TO TOP

HAMMER ASSEMBLY: AUTO TRIP
SPT SAMPLER: NO LINER - RECESSED ID
DRILL ROD USED: NWJ
BOREHOLE DIAM.: 5-INCH

DRILLER: MAJOR DRILLING
DATE START: 8/29/2011 FINISH: 8/29/2011
DRILLING TECHNIQUE: MUD ROTARY

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SUMMARY BORING LOG CC-54 (1 of 2)

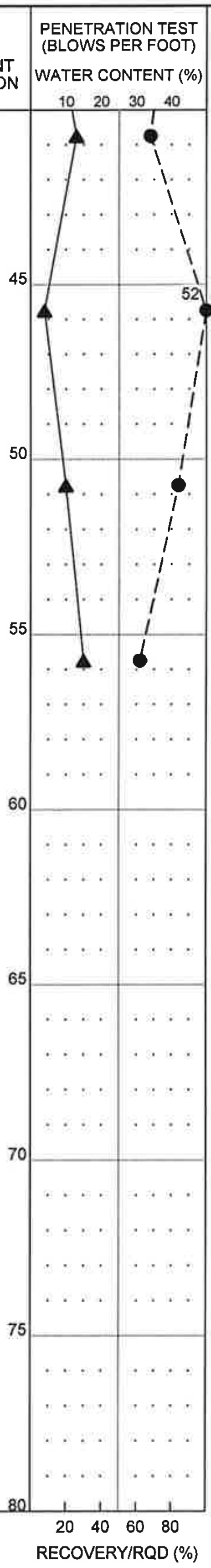
CAMAS/WASHOUGAL LEVEE EVAL.
WASHOUGAL, WA

DEC 2011
PROJ 2192
FIG. A-54

Selected data extracted from:
Camas Washougal Levee FEMA Certification Engineering Evaluations Report
Cornforth Consultants, 2012

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION SURFACE ELEVATION: 47.4 FT.	SAMPLE NO.	SAMPLE PEN. DATA	GROUND WATER/ INSTRUMENT INSTALLATION
		(continued from previous page)	S-9	7 5 8	
			S-10	2 1 3	
			S-11	4 3 7	
			S-12	7 9 6	
-9.1	56.5	Bottom of Boring: 56.5 FT			

PENETRATION TEST (BLOWS PER FOOT)
WATER CONTENT (%)



LEGEND

▨ 2-INCH O.D. SPLIT SPOON

☒ 3-INCH O.D. SPLIT SPOON

◫ 3-INCH O.D. THIN WALL SAMPLER

▥ 3-INCH O.D. PITCHER TUBE SAMPLER

* NO SAMPLE RECOVERY

▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED

LIQUID LIMIT
WATER CONTENT
PLASTIC LIMIT

▲ STANDARD PENETRATION TEST (BLOWS/FT.)

● WATER CONTENT IN PERCENT

▨ CORE RECOVERY IN PERCENT

▩ RQD IN PERCENT

] PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT FROM BOTTOM TO TOP

HAMMER ASSEMBLY: AUTO TRIP
SPT SAMPLER: NO LINER - RECESSED ID
DRILL ROD USED: NWJ
BOREHOLE DIAM.: 5-INCH

DRILLER: MAJOR DRILLING
DATE START: 8/29/2011 FINISH: 8/29/2011
DRILLING TECHNIQUE: MUD ROTARY

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SUMMARY BORING LOG CC-54 (2 of 2)

CAMAS/WASHOUGAL LEVEE EVAL.
WASHOUGAL, WA

DEC 2011

PROJ 2192

FIG. A-54

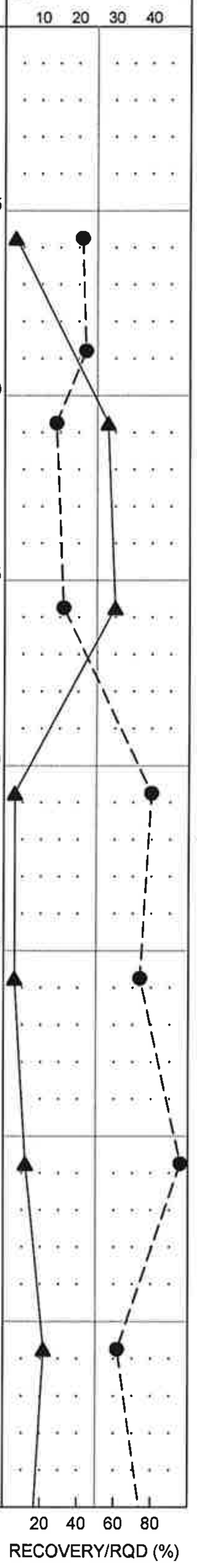
Selected data extracted from:
Camas Washougal Levee FEMA Certification Engineering Evaluations Report
Cornforth Consultants, 2012

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION SURFACE ELEVATION: 47.7 FT.	SAMPLE NO.	PEN. DATA
		MEDIUM DENSE, brown, fine SAND; trace silt and mica (LEVEE EMBANKMENT)		
			S-1	2 1 2
			S-2	
			S-3	11 12 16
			S-4	10 14 16
29.7	18	LOOSE, gray, slightly sandy SILT; trace mica (RIVER ALLUVIUM)		
			S-5	2 1 2
			S-6	3 1 2
			S-7	4 2 4
14.7	33	LOOSE to MEDIUM DENSE, gray, slightly silty, fine SAND; trace mica (RIVER ALLUVIUM)		
			S-8	7 4 7

GROUND WATER/ INSTRUMENT INSTALLATION

PENETRATION TEST (BLOWS PER FOOT)

WATER CONTENT (%)



LEGEND

- ▨ 2-INCH O.D. SPLIT SPOON
- ☒ 3-INCH O.D. SPLIT SPOON
- ◫ 3-INCH O.D. THIN WALL SAMPLER
- ◫ 3-INCH O.D. PITCHER TUBE SAMPLER
- * NO SAMPLE RECOVERY
- ▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED
- LIQUID LIMIT / WATER CONTENT / PLASTIC LIMIT
- ▲ STANDARD PENETRATION TEST (BLOWS/FT.)
- ● WATER CONTENT IN PERCENT
- ▨ CORE RECOVERY IN PERCENT
- ▩ RQD IN PERCENT
-] PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT FROM BOTTOM TO TOP

HAMMER ASSEMBLY: AUTO TRIP
SPT SAMPLER: NO LINER - RECESSED ID
DRILL ROD USED: NWJ
BOREHOLE DIAM.: 5-INCH

DRILLER: MAJOR DRILLING
DATE START: 8/26/2011 FINISH: 8/26/2011
DRILLING TECHNIQUE: MUD ROTARY

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SUMMARY BORING LOG
CC-57 (1 of 2)

CAMAS/WASHOUGAL LEVEE EVAL.
WASHOUGAL, WA

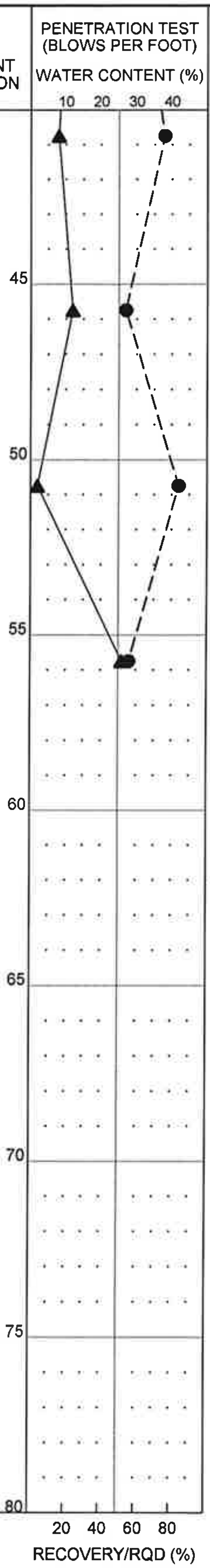
DEC 2011

PROJ 2192

FIG. A-57

Selected data extracted from:
Camas Washougal Levee FEMA Certification Engineering Evaluations Report
Cornforth Consultants, 2012

ELEVATION IN FEET	DEPTH IN FEET	MATERIAL DESCRIPTION SURFACE ELEVATION: 47.7 FT.	SAMPLE		GROUND WATER/ INSTRUMENT INSTALLATION
			NO.	PEN. DATA	
		(continued from previous page)	S-9	2 3 5	
			S-10	9 8 4	
-0.3	48	SOFT, gray, slightly clayey, SILT; trace mica (RIVER ALLUVIUM)	S-11	0 0 2	
-5.3	53	MEDIUM DENSE, gray, silty, fine SAND; trace mica (RIVER ALLUVIUM)	S-12	10 10 16	
-8.8	56.5	Bottom of Boring: 56.5 FT			



LEGEND

- ▨ 2-INCH O.D. SPLIT SPOON
- ☒ 3-INCH O.D. SPLIT SPOON
- ▯ 3-INCH O.D. THIN WALL SAMPLER
- ▥ 3-INCH O.D. PITCHER TUBE SAMPLER
- * NO SAMPLE RECOVERY
- ▼ MM/DD/YY GROUND WATER LEVEL AND DATE OBSERVED
- LIQUID LIMIT / WATER CONTENT / PLASTIC LIMIT
- ▲ STANDARD PENETRATION TEST (BLOWS/FT.)
- ● WATER CONTENT IN PERCENT
- ▨ CORE RECOVERY IN PERCENT
- ▩ RQD IN PERCENT
-] PT-1 PACKER TEST INTERVAL

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL
2. BOREHOLE WAS BACKFILLED WITH CEMENT-BENTONITE GROUT FROM BOTTOM TO TOP

HAMMER ASSEMBLY: AUTO TRIP
SPT SAMPLER: NO LINER - RECESSED ID
DRILL ROD USED: NWJ
BOREHOLE DIAM.: 5-INCH

DRILLER: MAJOR DRILLING
DATE START: 8/26/2011 FINISH: 8/26/2011
DRILLING TECHNIQUE: MUD ROTARY

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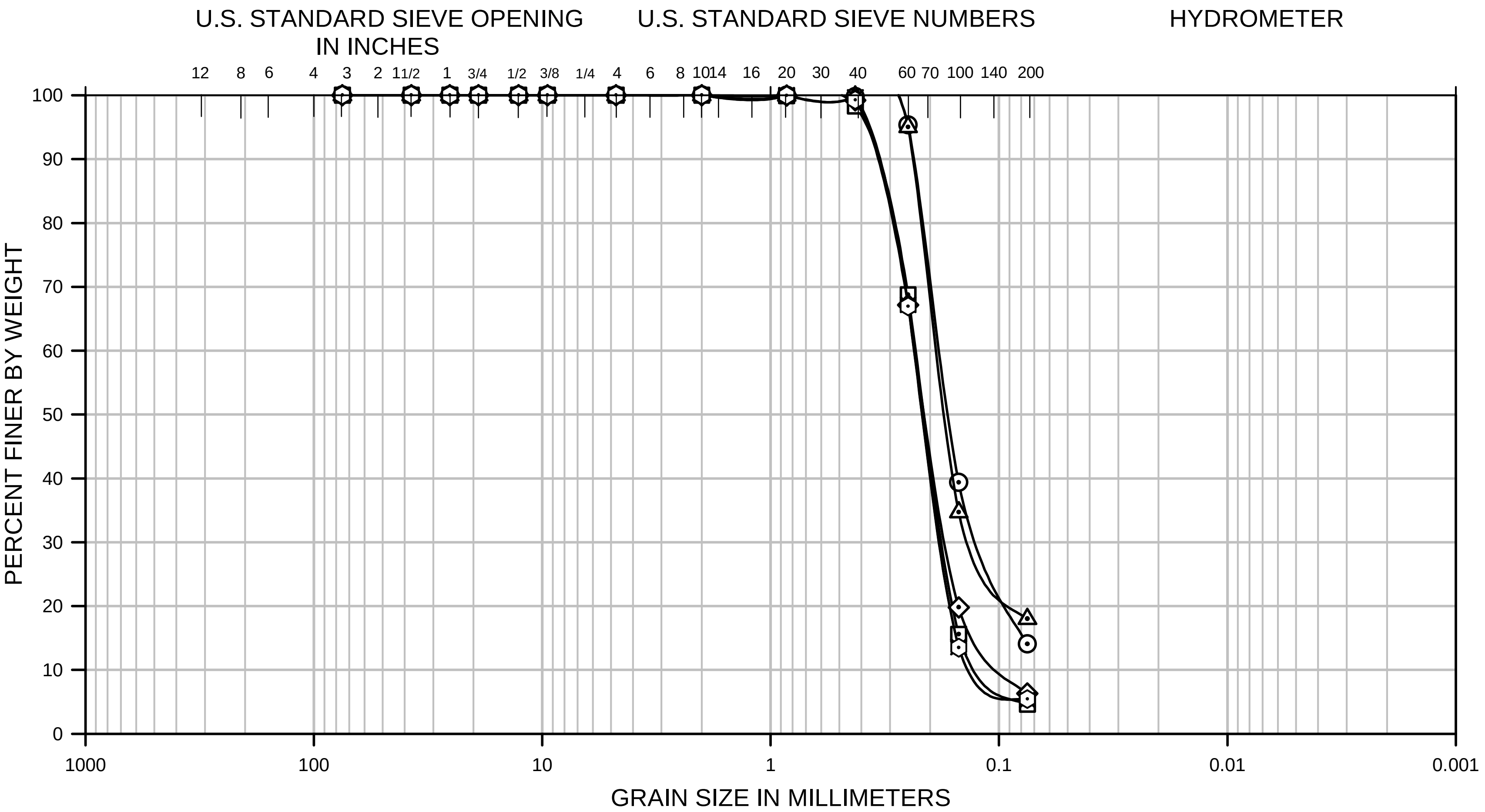
SUMMARY BORING LOG
CC-57 (2 of 2)

CAMAS/WASHOUGAL LEVEE EVAL.
WASHOUGAL, WA

DEC 2011
PROJ 2192
FIG. A-57

Selected data extracted from:
Camas Washougal Levee FEMA Certification Engineering Evaluations Report
Cornforth Consultants, 2012



COBBLES	GRAVEL		SAND			FINES	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay

Boring No.	Sample No.	Depth	Classification	Nat W%	LL	PL	PI
⊙ CC-01	S3	15	FINE SAND	21			
△ CC-05	S3	15	FINE SAND	19			
⊡ CC-17	S1	5	FINE SAND	6			
◇ CC-29	S2	10	FINE SAND	11			
× CC-40	S2	10	FINE SAND	8			
⬡ CC-51	S2	10	FINE SAND	5			

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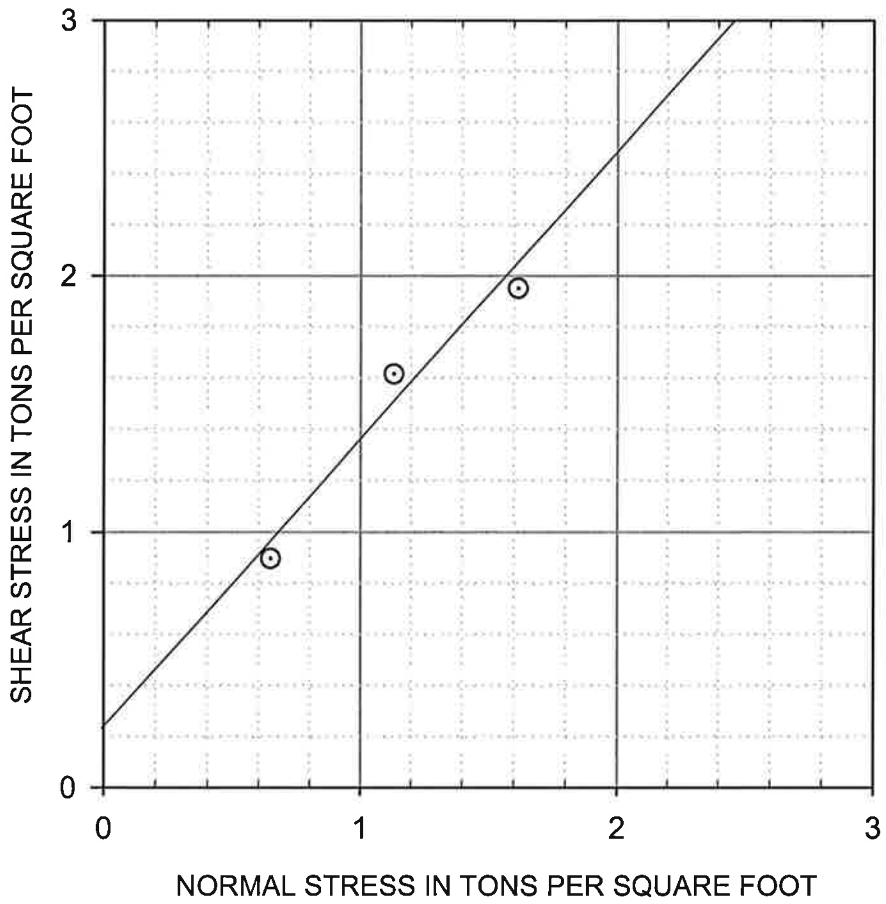
GRADATION GRAPH

LEVEE EMBANKMENT, MECH., A
CAMAS WASHOUGAL LEVEE EVALUATION
CAMAS, WASHINGTON

OCT 2011
PROJ. 2192
FIG. B1

Selected data extracted from:
Camas Washougal Levee FEMA Certification Engineering Evaluations Report
Cornforth Consultants, 2012



Boring No. CC-1 Sample No. S-3 Depth of Sample 13 to 15 ft.

Soil Description MEDIUM DENSE, brown, fine SAND; trace mica, occasional silt lenses (LEVEE EMBANKMENT FILL)

☒ Undisturbed ☐ Compacted ☒ Consolidated ☐ Unconsolidated

Liquid Limit: Non-Plastic Plastic Limit: Non-Plastic

RESULTS:

Normal Stress (ton/ft.^{2})	0.64	1.13	1.62
⊙ Peak Stress (ton/ft.^{2})	0.90	1.61	1.95

PEAK STRENGTH PARAMETERS:

c' = 0.26 ton/ft.^{2}

Φ' = 47.4 degrees

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DIRECT SHEAR TEST
MOHR STRENGTH ENVELOPE

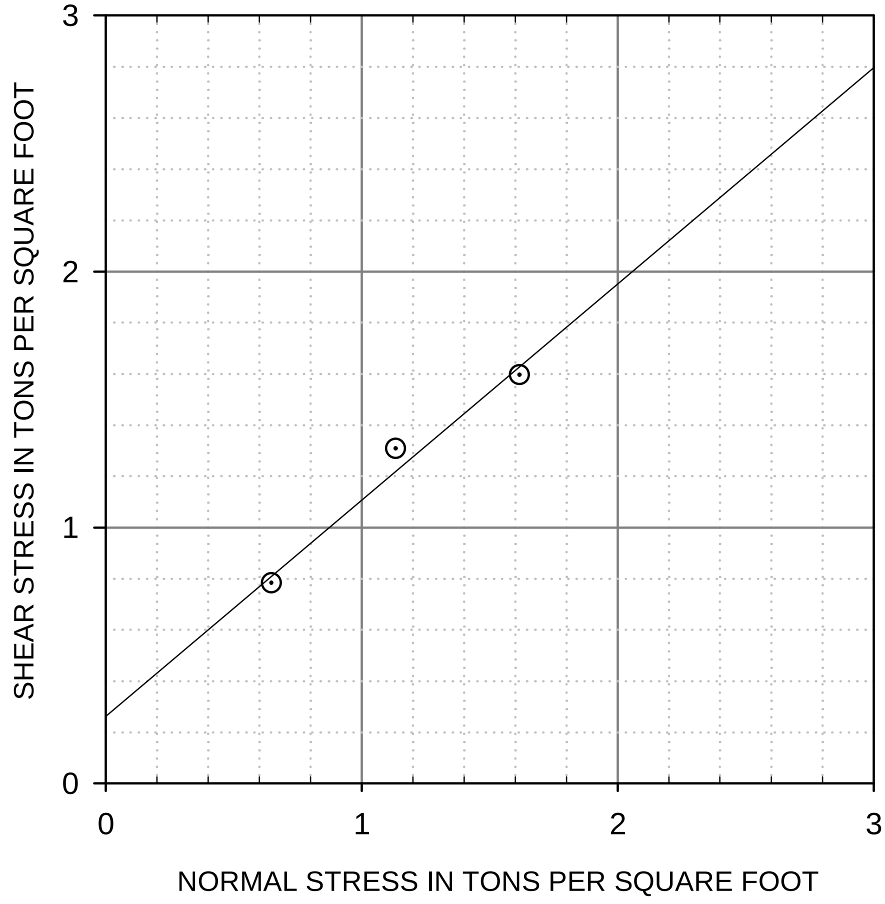
CAMAS-WASHOUGAL FEMA LEVEE EVAL.
CAMAS, WA

NOV 2011

PROJ. 2192

FIG. B14

Selected data extracted from:
Camas Washougal Levee FEMA Certification Engineering Evaluations Report
Cornforth Consultants, 2012



Boring No. CC-29 Sample No. S-2 Depth of Sample 8 to 10 ft.

Soil Description MEDIUM DENSE, brown, fine SAND; trace mica, occasional silt lenses (LEVEE EMBANKMENT FILL)

☒ Undisturbed ☐ Compacted ☒ Consolidated ☐ Unconsolidated

Liquid Limit: Non-Plastic Plastic Limit: Non-Plastic

RESULTS:

Normal Stress (ton/ft.^{2})	0.64	1.13	1.62
⊙ Peak Stress (ton/ft.^{2})	0.78	1.31	1.60

PEAK STRENGTH PARAMETERS:

c' = 0.28 ton/ft.^{2}

Φ' = 40.0 degrees

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DIRECT SHEAR TEST
MOHR STRENGTH ENVELOPE

CAMAS-WASHOUGAL FEMA LEVEE EVAL.
CAMAS, WA

NOV 2011

PROJ. 2192

FIG. B15

Selected data extracted from:
Camas Washougal Levee FEMA Certification Engineering Evaluations Report
Cornforth Consultants, 2012