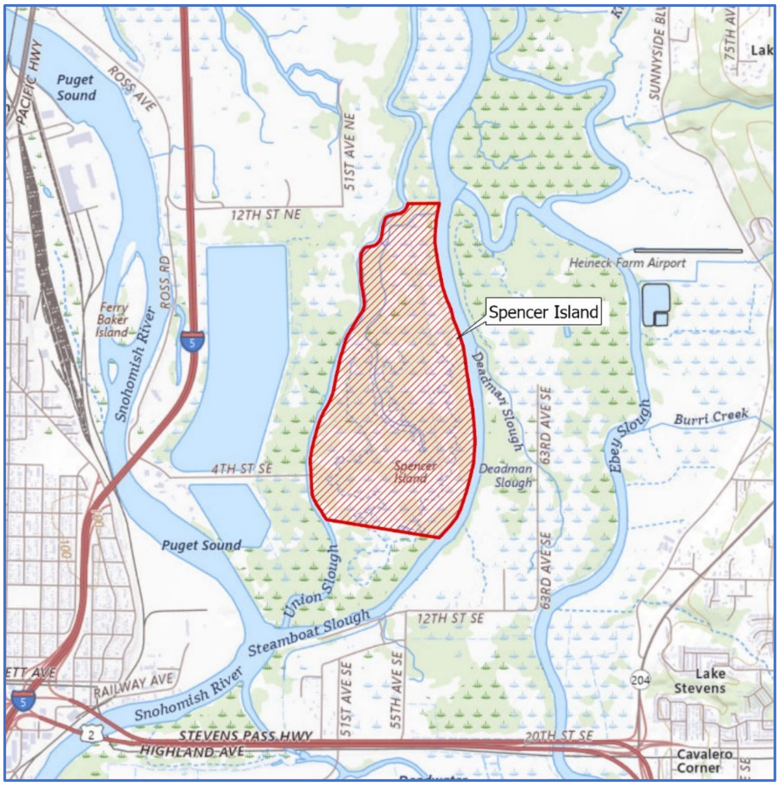
Annex B

Geotechnical Annex

SPENCER ISLAND ECOSYSTEM RESTORATION PROJECT

DESIGN DOCUMENTATION REPORT

ANNEX B - GEOTECHNICAL



This Annex is intended for presenting supplemental reports referenced within the body of the Design Documentation Report (DDR).

Prepared by

US Army Corps of Engineers®
Seattle District

CENWS-END-G

LIST OF ANNEXES

ANNEX B-1: PRELIMINARY SITE INVESTIGATION

DEPARTMENT OF THE ARMY
CORPS OF ENGINEERS, SEATTLE DISTRICT
P.O. BOX 3755
SEATTLE, WASHINGTON 98124-3755

MEMORANDUM FOR RECORD

PROJECT: Spencer Island Ecosystem Restoration Project

SUBJECT: Preliminary Geotechnical Investigation

DATE: 31 July 2023

PURPOSE

To support planning and feasibility assessments for the Spencer Island Ecosystem Restoration project, a preliminary site investigation and study of existing documentation was conducted to better inform the impacts to project features and site development.

SUPPORTING DOCUMENTATION

No existing geotechnical explorations or reports were available for review at Spencer Island, however, a Geotechnical Engineering Report for the Smith Island Estuary Restoration Project was produced by Shannon & Wilson. The Smith Island project site is located approximately 1 mile north along Union Slough from vehicular access bridge to Spencer Island. Explorations in this location (see attached Figure 1) identified the presence of soft to very soft clayey estuarine silt present for a depth of 13 to 26 feet under lain by medium dense, clean silty alluvial sand extending to approximately 75 feet in depth. Although soil stratigraphy, properties and design parameters will vary, given the proximity to the project site and environmental similarities, general assumptions can be drawn for planning and feasibility assessments.

PRELIMINARY SITE INVESTIGATION

On July 13, 2023 USACE conducted a preliminary site investigation for the Spencer Island Ecosystem Restoration project to assess the immediate underlying subsurface conditions. Three locations were assessed advancing a 3 inch sampling barrel via hand auger to depths ranging from 5 to 7 feet. Disturbed samples were collected while advancing to the final depth of the augured holes. In addition to the samples collected, dynamic cone penetrometer (DCP) tests were performed to assess the relative insitu density of the materials encountered. DCPs were performed using a 15 pound steel mass falling 20" to strike an anvil to penetrate a 1.5" diameter 45° (vertex angle) cone that has been seated in the bottom of the hand-augered hole. Figure 1 provides the rough locations of hand augers. See the attached exploration logs for description of the materials encountered.

The hand augers were performed at the slope toes of the access dikes along Union and Steamboat Slough. Subsurface soils encountered can be summarized as 6 to 12 inches of sod/grass and turf underlain by 2 to 4 feet of fill (predominantly hog fuel/mulch) before encountering the native estuarine silt. DCP tests conducted recorded blows of between 2 to 4 blows per 1.75 inch increment indicating that the insitu density of shall soils are very soft to soft (see the attached exploration logs and Photos 1 & 2 for representative samples).

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SMITH ISLAND EMBANKMENT ANALYSIS

The Geotechnical Engineering Report referenced above, discusses settlement analysis that was conducted for embankment construction. For areas that have not been previously loaded by embankment fill, initial consolidation/settlement may be as great as 2 to 3 feet (this analysis was conducted assuming 9 to 11 feet tall embankment). After the initial settlement occurs (generally after about a year) the areas of fill would continue to consolidate an additional 3 to 12 inches over a span of 10 to 20 years and will continue beyond. As part of the design and is common practice in these environments, the dikes are to be monitored and maintained throughout the dike's design life.

SPENCER ISLAND EMBANKMENTS

Deformations were observed within the surface of the dikes at Spencer Island that roughly correlate to those magnitudes of settlement discussed in the report, in particular areas of dikes which have been poorly maintained over time. Establishing access roads or the placement of additional fill will likely induce additional settlement despite primary consolidation having already occurred and depending on the footprint of the previously placed material. An additional factor that will impact the long-term performance of the dike height is presence of hog fuel or mulch being present at the base of the embankments. This material is highly compressible, organic, and depending on variety of field conditions will degrade over time, inducing additional settlement in the embankments.

PRELIMINARY SPENCER ISLAND FOUNDATION RECOMMENDATIONS

Based on the observations during the preliminary site investigations and documentation in the Geotechnical Engineering Report, any vehicular bridges, pedestrian boardwalk, or other structure requiring a foundation will need to be constructed on deep foundation elements extending 20 to 40 feet in depth depending on the structure type (such as drilled shafts vs driven piles), axial and lateral resistance required as well as the design guidance followed.

FUTURE SITE INVESTIGATIONS

As the restoration project transitions into design phase and the project scope and features are better defined, a more rigorous subsurface exploration should be conducted to better define the underlying soil stratigraphy and design parameters for the site.

For additional questions, concerns or access to the Shannon & Wilson Geotechnical Engineering Report at Smith Island, contact Frank Crossley available at frank.crossley@usace.army.mil or 206-889-0665.

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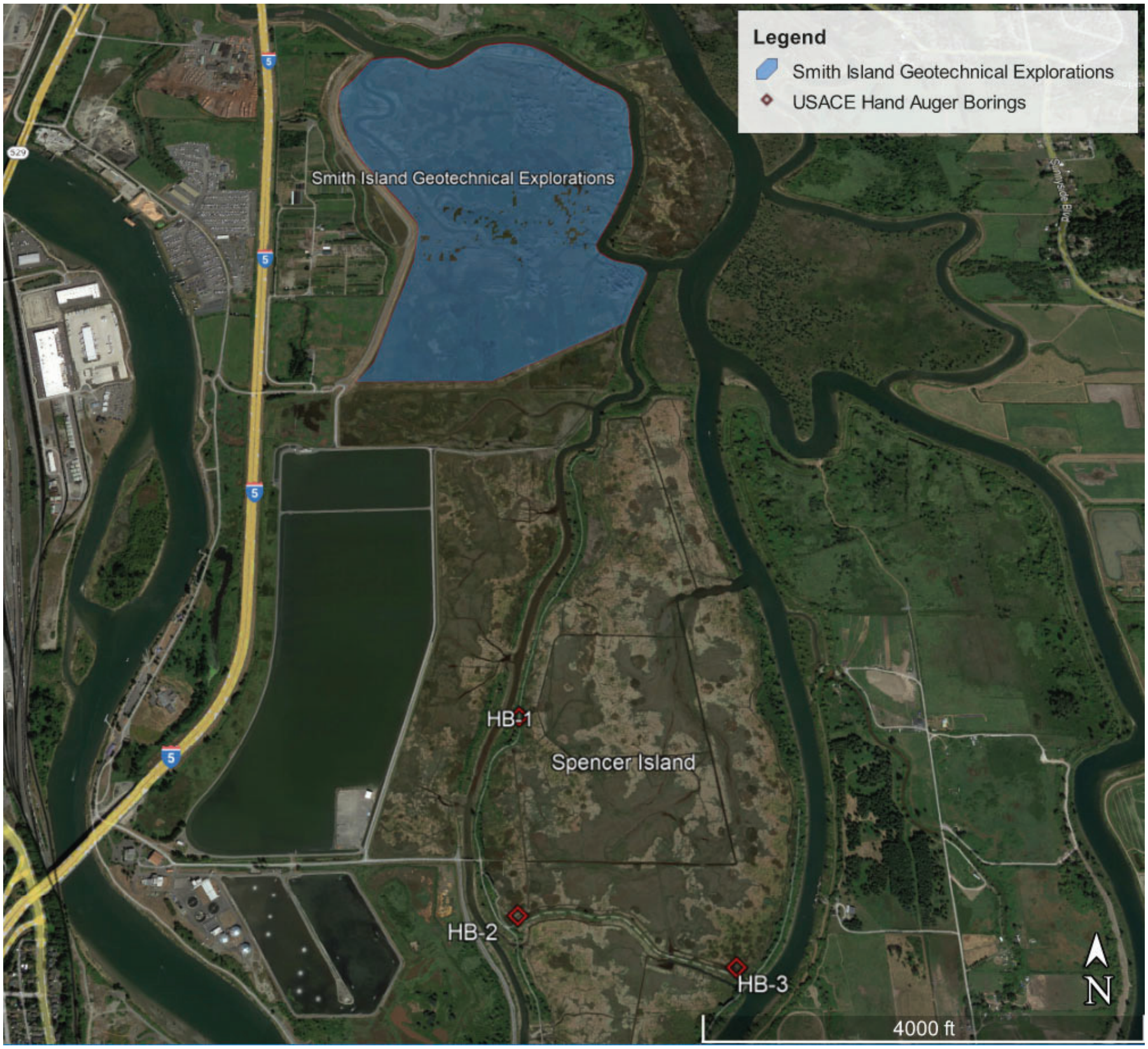

Figure 1. Explorations at Smith and Spencer Islands

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Photo 1. Hog Fuel/Mulch

Photo 2. Estuarine Silt

USACE EXPLORATION LOG		
Exploration Type	Hand Auger Borings & Dynamic Cone Penetrometer Tests	
Designation	HB - 1	
Personnel	Frank Crossley, PE	
Date	13-Jul-23	
DEPTH	DESCRIPTION/OBSERVATIONS	BLOWS/1.75"
0.5	2" Ballast and crushed rock gravel (Fill)	
1		
1.5	Hog fuel/mulch (Fill)	
2		
2.5		
3		
3.5		
4	Gray soft clayey silt (Estuarine Silt)	
4.5		
5		3
5.5		
6		
6.5		
7		
7.5		

Notes:
- Classification of soil types and use the existing Geotechnical Design Report for Smith Island. No laboratory tests were peformed to verify description.
- Exploration terminated at -5'

USACE EXPLORATION LOG		
Exploration Type	Hand Auger Borings & Dynamic Cone Penetrometer Tests	
Designation	HB - 2	
Personnel	Frank Crossley, PE	
Date	13-Jul-23	
DEPTH	DESCRIPTION/OBSERVATIONS	BLOWS/1.75"
0.5	Grass and turf	
1		
1.5	Dry, brown, clayey silt (Fill)	
2		4
2.5		
3	Hog fuel/mulch (Fill)	
3.5		
4		
4.5		
5		
5.5	Gray soft clayey silt (Estuarine Silt)	
6		4
6.5		
7		
7.5		

Notes:
- Classification of soil types and use the existing Geotechnical Design Report for Smith Island. No laboratory tests were peformed to verify description.
- Hand auger is approxately 2 feet below the top of the cross-dike
- Exploration terminated at -6'

USACE EXPLORATION LOG		
Exploration Type	Hand Auger Borings & Dynamic Cone Penetrometer Tests	
Designation	HB - 3	
Personnel	Frank Crossley, PE	
Date	13-Jul-23	
DEPTH	DESCRIPTION/OBSERVATIONS	BLOWS/1.75"
0.5	Grass and turf	
1		
1.5	Hog fuel/mulch (Fill)	
2		
2.5		
3		
3.5	Brown organic silt (Estuarine Silt)	
4		4
4.5		
5	Gray soft clayey silt (Estuarine Silt)	
5.5		
6		4
6.5		
7		
7.5		

Notes:
- Classification of soil types and use the existing Geotechnical Design Report for Smith Island. No laboratory tests were peformed to verify description.
- Hand auger is approxately 2 feet below the top of the cross-dike
- Groundwater was encounter at -3 feet.
- Exploration terminated at -6'

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CORPS OF ENGINEERS, SEATTLE DISTRICT
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SEATTLE, WASHINGTON 98124-3755

ANNEX B-2:
PRELIMINARY GEOTECHNICAL ENGINEERING REPORT FOR SMITH ISLAND ESTUARY RESTORATION PROJECT

Preliminary Geotechnical Engineering Report
Smith Island Estuary Restoration Project
Snohomish County, Washington

October 10, 2013

SHANNON & WILSON, INC.

GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

Excellence. Innovation. Service. Value.

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Submitted To:
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Otak
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By:
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400 N 34th Street, Suite 100
Seattle, Washington 98103

21-1-12405-060

GEOTECHNICAL ENGINEERING REPORT
SMITH ISLAND ESTUARY RESTORATION PROJECT
SNOHOMISH COUNTY, WASHINGTON

EXECUTIVE SUMMARY

This geotechnical engineering report presents the results of subsurface field explorations, laboratory testing, geotechnical engineering studies, updated groundwater modeling studies, and design recommendations for the Smith Island Estuary Restoration Project (the Project) in Snohomish County, Washington. The purpose of this study was to evaluate subsurface conditions at the site and to provide geotechnical recommendations for the design and construction of the setback levee and associated structures.

The Project will include breaching an existing levee, constructing a new setback levee, filling existing drainage channels, and installing levee-related drainage systems. Levee stability and seepage evaluation and design were performed in general accordance with U.S. Army Corps of Engineers guidelines and procedures.

Recommendations are provided for levee construction, including the installation of geosynthetic reinforcement below the levee, a drainage and soil piping protection zone within the landward side of the levee, and a landward drain trench.

Settlement calculations indicate the levee will settle approximately 20 to 36 inches from beginning of embankment construction to about one year following embankment construction. To compensate for this settlement, we recommend the levee crest be overbuilt by 3 feet. Compression of soil under the levee will continue post-construction. We estimate 3 to 12 inches of post-levee final grading secondary compression in the 10 to 20 years starting one year after embankment construction. Maintenance and levee monitoring should be conducted throughout the levee life. Where settlement occurs, fill should be placed to restore the levee to the design top-of-levee elevation.

Low levels of arsenic that exceed the State of Washington (the State) – Model Toxics Cleanup Act Method A cleanup level standards, yet are lower than the State Marine Sediment Cleanup Standards, were detected in some of the explorations conducted at the site. Recommendations are provided for disposal and on-site handling of these soils.

An update to the MODFLOW groundwater model assessing seepage flows into Tidal Channel B, which is of concern to the adjacent property owner, was performed in support of Project design. The results of the groundwater modeling indicate that seepage flows into Tidal Channel B would result in a net decrease in seepage to Tidal Channel B resulting from the proposed construction of the levee setback and drainage trench.

Recommendations are provided for levee construction; excavation dewatering; and drainage trench, storage pond, and tide gate pipe construction. Estimates of settlement of the Puget Sound Energy (PSE) natural gas pipeline and preliminary recommendations for measures to protect the pipe and to reduce potential for seepage along the PSE pipe where it will cross beneath the proposed levee are provided. Additional information regarding haul route and construction site access, levee breaching and ditch filling, and levee erosion and scour protection are provided in other supporting letter reports on each topic that are separate from this geotechnical report.

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FIGURES (cont.)

APPENDICES

1.0 INTRODUCTION

This report presents the results of our subsurface explorations, laboratory testing, and geotechnical engineering studies for the Smith Island Estuary Restoration Project in Snohomish County, Washington. The purpose of this study was to evaluate subsurface conditions at the site and to provide geotechnical recommendations for the design and construction of the setback levee.

Our scope of services included evaluation for temporary haul routes and existing levee breaching. On March 8, 2013, we produced a letter assessing the existing haul routes on site and provided recommendations for constructing new routes. On April 4, 2013, we produced a letter evaluating potential methods, sequences, and material quantities for breaching the existing levee and filling ditches in the estuary.

Our services for this study were conducted in general accordance with the 2012/2013 Snohomish County Civil Engineering On-call Contract dated December 14, 2012. Notice to proceed was provided through a Subconsultant Agreement, Task Assignment 1, provided by Otak, Inc. (Otak) and signed by us on December 21, 2012.

2.0 SITE AND PROJECT DESCRIPTION

Snohomish County (the County) is proposing to restore tidal influence to approximately 400 acres of Smith Island within the Snohomish River delta. The Smith Island Estuary Restoration Project (the Project) will expand the tidal wetlands of the Snohomish River delta and promote long-term conservation of tidal wetland functions. The Project site is east of Interstate 5, north of the City of Everett's Water Pollution Control Facility, and west and south of Union Slough (Figure 1, Vicinity Map). The Project will include the following elements:

- An existing levee near the north and east edges of the island will be breached to restore tidal influence.
- A new setback levee will be constructed near the west and south edges of the Project site. The setback levee will have a design top-of-levee elevation +15 feet (North American Vertical Datum of 1988 [NAVD88]), which is approximately 3 to 11 feet above existing ground surface.
- Selected existing drainage channels will be filled to prevent fish from being stranded at low tide.
- A storage pond, a pump station, and tide gates will be constructed to facilitate drainage from behind the new setback levee.

The approximate locations of these elements are indicated in Figure 2, Site and Exploration Plan.

Our scope of services was to complete field explorations and geotechnical engineering analyses to support the design of the setback levee, levee breaching, wetland restoration, drainage and other site improvements. Specific tasks included:

- Evaluating the earthquake ground motions at the site and the potential for liquefaction to occur during a design earthquake.
- Recommending materials for levee construction.
- Evaluating seepage through and beneath the levee.
- Evaluating levee stability during different design conditions.
- Evaluating filter design along riprap erosion protection.
- Evaluating settlement (magnitude and rate) at the ground surface beneath the levee under static loading conditions.
- Evaluating stress increases, settlement, and deformation of buried utilities crossing under the new levee fill and for the tidegate and pump station pipeline crossing.
- Providing considerations for levee construction.
- Preparing this report.

3.0 LITERATURE REVIEW

Several geotechnical and hydrogeologic studies have previously been performed on Smith Island. We retrieved historical information from published sources, the County, and Shannon & Wilson, Inc. files to help plan site explorations, interpret site geology, and characterize subsurface information for our analyses. A list of the reports obtained and relied on for this study is provided in Section 13.0, Site Data References. The approximate locations of the historical explorations are shown in Figure 2.

4.0 LEVEE DESIGN STANDARDS

The Smith Island levee setback evaluations and design recommendations in this report follow the applicable U.S. Army Corps of Engineers (USACE), engineering manuals and regulations in accordance with the request of Snohomish County and Diking District No. 5 (DD5) that the levee be designed to have an acceptable rating in the USACE PL84-99 program. A number of manuals and guidelines apply to the Project design, including:

- USACE, 2001 EM 500-1-1 “Civil Emergency Management Program” PL84-99 requirements
- USACE, 2001, EP 500-1-1 “Civil Emergency Management Program Procedures”

- USACE, 2000, EM 1110-2-1913 “Design and Construction of Levees”
- USACE, 2004, EM 1110-2-2300 “General Design and Construction Considerations for Earth and Rock-Fill Dams”
- USACE, 2003, EM 1110-2-1902 “Slope Stability”
- USACE, 2005, ETL 1110-2-569 “Design Guidance for Levee Underseepage”
- USACE, 1987, EM 1110-2-1413 “Hydrologic Analysis for Interior Areas”
- USACE, 1995, ER 1110-2-1806 “Earthquake Design and Evaluation for Civil Works Projects”
- USACE, 2012, EC 1110-2-6067 “Engineering and Design: USACE Process for the National Flood Insurance Program (NFIP) Levee System Evaluation”
- USACE, 2005, ETL 1110-2-6-571 “Guidelines for Landscape Planting and Vegetation Management at Levees, Floodwalls, Embankment Dams, and Appurtenant Structures”

A summary table was developed and presented to Snohomish County and DD5 at the June 11, 2013 monthly DD5 meeting held at the City of Everett offices meeting (Appendix G). The table was presented, and has been recently updated, to show how the geotechnical engineering studies and designs were performed in accordance with USACE guidelines and engineering manuals and technical letters, and how the levee will remain eligible in the USACE PL84-99 program. It is our opinion that the design exceeds the minimum requirements to remain eligible in the USACE PL84-99 program, and provides a higher level of protection than required for eligibility in the program.

5.0 SUBSURFACE EXPLORATIONS

Five soil borings and eight cone penetration tests (CPTs) were performed for this task assignment to improve our understanding of the subsurface conditions along the proposed setback levee alignment. Two CPTs and one boring (CPT-1-13, CPT-2-13, B-1-13) extended to approximately 91 feet below grade. The remaining CPTs and borings extended between about 35 and 50 feet below grade. Approximate exploration locations are shown in Figure 2. A description of the field methods and procedures used to conduct the explorations is included in Appendix A. Logs of the borings and CPTs are presented as Figures A-2 through A-14 in Appendix A.

6.0 ENVIRONMENTAL SOIL SAMPLING

Due to the suspected presence of elevated arsenic concentrations in the soil at the site, samples were collected from each boring for laboratory analyses. The laboratory results were used to select the appropriate method for disposing of the drill cuttings. The suspected source of the arsenic contamination was airfall of emissions from the former Asarco Everett Smelter, located to the west of the site. For each boring, one soil sample was collected from the near surface (approximately 2.5 feet below ground surface [bgs]) and one sample was collected at depth (approximately 10 feet bgs). The shallow sample was intended to assess the potential for arsenic near the surface due to the airfall. The deeper sample was intended as a background sample for comparison with the shallow sample. The samples were submitted to Fremont Analytical, Inc., a subcontractor to Shannon & Wilson, Inc., for arsenic analysis by U.S. Environmental Protection Agency (EPA) Method 6020. The shallow samples from the northern- and southern-most borings (B-5-12 and B-1-13, respectively) were also analyzed for lead content as a secondary check for elevated metals concentrations due to smelter emissions.

Shallow soil samples (2.5 feet bgs) collected from borings B-1-13, B-4-12, and B-5-12 contained arsenic concentrations that exceed the Washington State Department of Ecology's (Ecology's) Model Toxics Control Act (MTCA) Method A soil cleanup level of 20 mg/kg. Arsenic was also detected slightly above the cleanup level in the deeper sample (10 feet bgs) collected from boring B-3-13 (22.3 mg/kg).

Lead was detected in the two soil samples (B-1-13, 2.5 feet bgs; and B-5-12, 2.5 feet bgs). The concentrations are below the MTCA Method A cleanup level for lead. However, the concentration detected in the B-5-12 sample (2.5 feet bgs) exceeded the regional background concentration for lead of 24 mg/kg (Ecology, 1994), suggesting, along with the elevated levels of arsenic described above, possible area-wide contamination from the former Everett Smelter. The Fremont Analytical laboratory reports are presented in Appendix C.

7.0 GEOTECHNICAL LABORATORY TESTING

We performed geotechnical laboratory testing on select soil samples retrieved from the borings completed under this task assignment. The laboratory testing program included tests to classify the soil and to determine index and engineering properties of the soil for engineering analyses. Visual classification was performed on all retrieved samples. The Unified Soil Classification System (USCS) described in Appendix A was used to classify the samples. Index testing, including water content determinations, grain size distribution analyses, and Atterberg Limits tests, were completed on select disturbed samples. One-dimensional consolidation tests and triaxial compression tests were performed on select, relatively undisturbed samples. Test procedure descriptions and laboratory test results are presented in Appendix B.

8.0 SITE SUBSURFACE CONDITIONS AND GEOLOGY

8.1 Geologic Setting

The Snohomish River flows from the Cascade Mountains along the eastern margin of the Puget Lowland Basin to a lowland delta in the central part of the basin. Pleistocene (approximately 2 million to 10,000 years ago) glacial and Holocene (past 10,000 years) river processes have largely shaped the topography and near-surface geology along the river.

Geologists generally agree that during the Pleistocene, continental ice sheets advanced into the Puget Lowland from Canada at least six times. Each glaciation deposited new sediment and partially eroded previous sediments. The weight of the glacial ice resulted in compaction (overconsolidation) of the underlying soils. Subglacial meltwater streams eroded into overconsolidated soil, forming the northwest-trending trough through which the Snohomish River flows before emptying into Possession Sound. Trough filling began in the late Pleistocene with glacial recessional outwash and lake deposits. Early in the Holocene Epoch, marine, estuary, and alluvial sediment sequentially buried glacial deposits.

Near the Project site, the Snohomish River distributes its flow into a network of tidally influenced sloughs. Union Slough borders the Project site to the north and east. Three smaller sloughs dissect the land between Interstate 5 and Union Slough. Figure 2 shows these as Tidal Channels A, B, and C. These tidal channels discharge to Union Slough or the Snohomish River, so the tidal influence from Puget Sound is attenuated. High tides and Snohomish River floods prior to construction of levees resulted in silt overbank and estuary deposits across the delta surface. Estuary and alluvial deposits filled the valley to its present elevation.

8.2 Geologic Units

We interpreted the geologic units based on the soil type, sedimentary structures, stratification, and the presence and type of organic matter (e.g., wood, shells, etc.). In some instances we used a dual geologic designation (e.g., Ha/He) to represent interbedded and transitional zones. For these instances, attributes of the first geologic unit listed were more dominant within the layer/sample. Geologic unit designations are shown in the report profile and boring logs. The following descriptions are based on data collected from the borings and CPTs performed for this task, and the historic borings and test pits performed by others.

The soil units encountered in the subsurface were deposited during the Holocene. The nomenclature used for each geologic unit begins with H for Holocene, and is followed by a letter, which represents the depositional environment. A number may be used to further subdivide a unit, with 1 being shallowest. A brief summary of the nomenclature used in this report follows. Figures 4 and 5 present subsurface profiles that show our interpretation of the extents of geologic units encountered in the subsurface explorations.

8.2.1 Estuarine Deposits (He)

The Snohomish River drains into Possession Sound where fresh river water mingles with the saltwater of Puget Sound. Prior to construction of the existing levee, high tides and Snohomish River flood events spread sediment-laden water over the low-relief alluvial plain of the site and deposited silt with sand lenses and organics in a low-energy environment. For the purposes of this report, we are not distinguishing between tidal and flood overbank deposits, and are collectively calling estuarine layers deposited by these processes as He.

He deposits encountered in the explorations along the proposed levee alignment are divided into three layers. The upper layer, He_1, extends from the surface to about 4 to 8 feet bgs and consists of soft, organic silt and clayey silt, with abundant organics and scattered peat layers. The upper layer typically has scattered sand lenses. Test pits performed by the Snohomish County Department of Public Works (SCDPW) encountered slight to moderate groundwater seepage from these sand lenses. Iron-oxide staining, wood fragments, and logs were locally encountered in this layer. Boring B-1-13 encountered abundant dark brown and orange oxide rinds and stains along fractures and in pockets in this layer.

The second He layer, He_2, underlies He_1 and is about 7 to 20 feet thick. Collectively, He_1 and He_2 range from about 10 to 30 feet thick. He_2 consists of very soft, slightly clayey to clayey silt and organic silt with scattered to abundant sand lenses, seams, and layers. SCDPW test pits encountered moderate to heavy seepage from sand lenses in the He_2. Borings and test pits encountered scattered to locally abundant organics and local iron-oxide staining and wood fragments. Although not encountered in the borings and in only 2 of 73 test pits performed by Snohomish County and CH2M-Hill during prior work for the Project, buried logs are likely to be present in this layer.

Reports of the test pits excavated and observed in the upper two He layers by SCDPW describe the He as easily excavated with minimal sloughing. Sloughing occurred primarily where peat or peaty soils were encountered, or where sands lenses were encountered and groundwater seeped into the test pits (SCDPW, 2012).

Deep explorations extended into an additional He layer (He_3) below about 60 to 80 feet bgs. This soil is similar to He_2 and consists of very soft to medium stiff, silty clay, clayey silt, and organic silt, and medium dense sandy silt with trace to numerous organics. Deep He_3 layers are interlayered with medium dense to dense sand with variable amounts of silt.

8.2.2 Alluvial Deposits (Ha)

Under normal flow conditions, the Snohomish River deposits silt and sand within the banks of its distributary (deltaic) channels. Alluvial (Ha) deposits encountered in the explorations consist of very loose to dense, trace of silt to silty sand. The contact between the upper He_2 layer and Ha ranges from about elevation -20 feet (NAVD88) near the north end of the proposed levee alignment to about elevation -10 feet near the south end of the proposed alignment. Layers of Ha in boring B-1-13, and CPT-1-13 and CPT-2-13, range from about 10 to 30 feet thick. Borings B-2-13, B-4-12, B-5-12, and CPT-3-13 through CPT-8-13 terminated in this unit; therefore, the thickness is unknown at these locations. Ha deposits generally underlie and are interlayered with estuarine and overbank deposits. Iron-oxide-stained layers indicate the presence of fluctuating groundwater. Scattered shells, wood, and fine organic debris are present locally within the deposits.

8.3 Subsurface Soil and Groundwater Conditions at Levee Alignment

The subsurface soil and groundwater conditions at the proposed levee alignment were interpreted from historic subsurface explorations and the borings and CPTs performed for this task. At the surface, the subsurface explorations generally encountered very soft to soft, sandy silt with trace clay, clayey silt and organic silt (He_1 and He_2). Interbeds of silty sand were encountered in the layers. The combined thickness of the He layers encountered in the explorations ranged from about 13 feet (B-5-12) to about 26 feet (B-1-13).

Underlying the estuarine deposits, the subsurface explorations encountered a layer of medium dense, clean to slightly silty sand (Ha). This layer extended to a depth of about 73 to 75 feet in B-1-13, CPT-1-13, and CPT-2-13, and to the limits of our explorations in the other subsurface explorations. Very soft to medium stiff silty clay to clayey silt (He_2) was encountered below the sand in B-1-13, CPT-1-13, and CPT-2-13 to a depth of about 91 feet. In B-1-13, this lower clay/silt layer was underlain by medium dense silty sand to the base of the exploration.

Groundwater levels inferred from the CPT data ranged from about 2 to 6 feet bgs at the time of testing. The groundwater level interpreted from a vibrating wire piezometer installed in boring B-1-13 was about 1½ feet bgs when measured on April 4, 2013. Although not encountered at the time of explorations, puddles and ponding water on the ground surface have been observed during past field visits. We expect the groundwater elevation at the Project site, and the piezometric head in different soil units, to be influenced by the season and river level.

A generalized subsurface profile interpretation of the soil units and groundwater encountered along the proposed setback levee alignment and the Puget Sound Energy (PSE) Pipeline is included as Figures 4 and 5, respectively. Figure 3 presents a summary of the geologic units and their descriptions. An interpretation of the top of alluvial deposit (Ha) elevation across the site is included as Figure 6.

9.0 ENGINEERING RECOMMENDATIONS AND CONCLUSIONS

9.1 Levee Section

A Typical Levee Section is provided in Figure 7. This figure provides our recommendations for dimensions, geometries, and material for the proposed setback levee. The recommendations are based on the conceptual levee section proposed by Dike District 5 (DD5), and amended based on our understanding of the Project, our analyses results, and our experience with similar levee Projects.

A drainage ditch and a horizontal drainage layer have been incorporated into the proposed conceptual levee plans. The horizontal drainage layer is necessary to mitigate forces associated with seepage through and underneath the levee, and to meet global stability minimum factors of safety (FS) for the steady-state seepage condition. The minimum FSs meet criteria set forth by the USACE in Design and Construction of Levees, *Engineering Manual 1110-2-1913* (USACE, 2000) and *Slope Stability, Engineering Manual 1110-2-1902* (USACE, 2003). The drainage ditch is landside of the permanent access road and hydraulically connects to the horizontal drainage layer. The ditch will drain to a storage pond located at the north end of the site (see Figure 2). The storage pond design capacity includes the calculated flow from the proposed drainage ditch.

A basal reinforcement geosynthetic is recommended beneath the levee and permanent access road footprint. Installing the geosynthetic will help both with levee construction and with meeting USACE global stability FS requirements. The geosynthetic will also aid in subgrade stabilization for haul route operations and for future levee and levee system maintenance activities.

Design information for the drainage ditch, horizontal drainage layer, and basal reinforcement geosynthetic are discussed later in this report.

9.2 Fill Material

Fill material for the levee should be well-graded soil with a minimum 30 percent passing the No. 200 sieve, and free of organic and deleterious materials. Levee fill in contact with the basal reinforcement geosynthetic should have a maximum particle size of 1¼ inch. We recommend that levee fill placed elsewhere not exceed a particle size of 3 inches. The recommended levee fill gradation is included in Figure 7.

Soil with a fines content equal to or greater than 20 percent is generally sensitive to moisture at the time of compaction. We recommend that soil delivered to the site for use as levee fill be within 2 percent of the optimum moisture content prior to delivery, so that the soil can be placed and compacted without additional on-site processing. Soil stockpiled on site should be maintained within 2 percent of the optimum for compaction.

We recommend the horizontal drainage layer in the levee be constructed using free-draining sand meeting the requirements presented in Section 8.3.4 of this report. We recommend the aggregate for the permanent access road and levee road surfacing be crushed surfacing base course (CSBC) meeting the criteria defined in Section 9-03.9(3) of the 2012 Washington State Department of Transportation (WSDOT) Standard Specification.

Topsoil placed on the levee slopes, above the levee fill and riprap, should meet the requirements of WSDOT Standard Specifications 9-14.1(2) for Topsoil Type B (WSDOT, 2012). We anticipate topsoil stripped from the site, and peat layers if encountered, may be suitable for reuse as topsoil at the site, provided that the material is not found to contain arsenic, lead, or other contaminants to a degree that precludes its use for this application.

9.3 Levee Analyses

Four levee cross sections were selected for seepage and stability analyses. One section was located at the PSE pipeline crossing at the south end of the proposed setback levee. The remaining three cross sections were selected to represent typical soil conditions along the levee alignment, differing levee geometries with respect to height and slope, and anticipated scour and tidal channel geometries with respect to depth and slope. The selected levee cross section locations are shown in Figure 2. The approximate levee station, levee design height, and base widths for each cross section are summarized in the table below:

Selected Levee Cross Sections			
Cross Section Designation	**Approximate Levee Station**	**Levee Design Height[1] (ft)**	**Levee Base Width (ft)**
A-A'	11+03	9	69
B-B'	29+11	9	69
C-C'	51+86	11	81
D-D'	65+75	10	75

Note:
[1] Levee design crest elevation is +15 feet (North American Vertical Datum of 1988). Levee design height is based on surveyed existing ground surface and design crest elevation.
ft = feet

Based on USACE guidelines, the following conditions were evaluated for each of the four levee cross sections:

- Case 1 – End of construction
- Case 2a – Rapid drawdown from full flood stage
- Case 2b – Tidal drawdown from the Mean Higher High Water (MHHW) level to the Mean Lower Low Water (MLLW) level
- Case 3 – Steady-state seepage from full flood stage

Results of our levee global stability and seepage analyses are discussed in the following sections. The methodology and supporting documentation for the analyses are summarized in Appendix E. The model geometries for the different cases are shown as global stability analysis output figures, and included as Figures E-1 through E-17, in Appendix E.

9.3.1 Seepage Analyses Results (Exit Gradients)

Upward exit hydraulic gradients, i_v, and seepage flow rates for steady state flow conditions during the design flood (Case 3), are summarized in Table 1. The USACE Technical Letter ETL 1110-2-569 *Design Guidance for Levee Underseepage* (USACE, 2005) recommends that levees be designed to achieve a FS against piping (quick condition) of 1.6. The FS is equal to the critical gradient (i_c) divided by the estimated upward hydraulic gradient (i_v). We estimate that the critical gradient is approximately 0.48 for the He_1 layer. Therefore, to maintain a FS of 1.6, i_v at the levee toe during the design flood condition must be below 0.48/1.6 = 0.3.

The estimated i_v values were at or below 0.3 for the levee design section shown in Figure 7. Preliminary analyses indicated that i_v values greater than 0.3 would develop at the base of a landside open drainage trench when this feature was included in the model. This was when a sand seam was modeled in layer He_1 and He_2, such as the analysis Section C-C' based on Borings B-4-12 and SW04. Although the sand seam was encountered in only two explorations along the levee alignment, we anticipate that similar conditions likely exist along the seback levee alignment. Therefore, we recommend that for the entire length of the levee, the drainage trench be filled with free-draining material and not be open. The free draining material should be surrounded with a filter to reduce potential for piping.

For Section D-D', we performed a steady-state seepage analysis (Case 3) using scoured conditions and incorporating the effect of the 90-degree bend in the levee where the proposed levee meets the existing levee. At this corner on the landside, seepage would be coming from two directions (i.e., from both legs of the bend). To account for this, we assumed a 75 percent increase in pressure head on the waterside in our analysis.

The seepage flow rates presented in Table 1 represent the volume of water (per day, per foot of levee length) that we estimate may flow from the waterside of the levee to the drainage trench and Tidal Channel B on the landward side of the levee (Figure 2). For Sections A-A', B-B', and D-D' the flow is estimated to principally exit to the drainage ditch. For Section C-C', where a sand seam is modeled in the estuary deposit, approximately 40 percent of the flow is estimated to exit at the drainage trench and the remaining 60 percent is estimated to seep through the sand seam toward Tidal Channel B. Otak has performed an interior drainage analysis and developed pond, tidegate and pump station designs, which account for these seepage flow rates and stormwater surface runoff.

9.3.2 Seepage Analyses Results (Interior Drainage Seepage Estimates)

Potential seepage may effect the interior drainage systems. For the project the setback will influence groundwater flow and seepage conditions in and around the setback levee system and interior drainage/Tidal Channel B system. Groundwater studies have been performed for the Environmental Impact Statement assessing salt-water intrusion effects on local groundwater well supplies. This geotechnical report includes additional groundwater modeling (MODFLOW), as well as SEEP-W modeling of the proposed levee setback and a proposed drainage trench to estimate the effects on adjacent interior drainage areas, specifically Tidal Channel B (Appendix F).

The MODFLOW and SEEP-W modeling analysis of the proposed levee setback project and the seepage drainage trench indicate the project will likely result in an overall net decrease in seepage to Tidal Channel B (Table 2). The primary reason for this is that a 75 to 95 percent efficient drainage trench will collect existing seepage flows, as well collect increases in levee setback through and underseepage, thereby reducing the overall amount of seepage flows into

Tidal Channel B. The analysis also indicates that increases in salinity are not likely as seepage will be collected and routed north along the drainage trench, and future high tide and flood flow groundwater recharge conditions on the marsh surface which have lower salinity concentrations as compared with existing Union Slough and Snohomish River conditions.

9.3.3 Stability Analysis Results

Minimum FS values for each design case and each analysis cross section are summarized in Table 2 and described in detail in Appendix E. Recommended minimum FS values (design criteria) presented in the USACE's *Levee Design and Construction Manual EM 1110-2-1913* (USACE, 2000) and *Slope Stability Manual EM 1110-2-1902* (USACE, 2003) for the various design cases are shown in the bottom row of Table 2. The levee design as evaluated satisfies the minimum recommended FS criteria for the cases using a basal reinforcement geosynthetic with a minimum design tensile strength as summarized in Table 2. Specific recommendations regarding the reinforcement geosynthetic are provided in the following section.

9.3.4 Levee Basal Reinforcement

To meet recommended global stability FS values presented by the USACE, we recommend a reinforcement geosynthetic be installed at the base of the levee. Minimum recommended long-term design strength (LTDS) and short-term design strength (STDS) are provided in Table 2. The LTDS assumes a 75-year design life and includes reduction factors (RFs) for construction damage, durability, chemical degradation, and material creep. The STDS is the strength required during fill placement to meet the end of construction global stability FS. We recommend the STDS include a RF for construction damage and a creep RF assuming 60 days of loading. Long-term durability and chemical degradation factors do not need to be applied for the STDS. Reinforcement geosynthetic should be placed such that the machine direction is oriented perpendicular to the levee alignment and continuous, with no seams or overlap, from levee toe to levee toe. Adjacent reinforcement panels should overlap a minimum of 12 inches.

Based on the required minimum tensile strengths estimated during our global stability analyses, we recommend a Miragrid 20XT, Synteen SF180, or equivalent reinforcement geosynthetic be assumed for cost estimating purposes.

For this scope of services, we only evaluated levee side slopes of 3 horizontal to 1 vertical (3H:1V). However, we anticipate that steeper landside levee slopes may be feasible if higher-strength basal reinforcement is used. Increasing the strength of the reinforcement will likely increase the cost of the geosynthetic. We anticipate that this cost increase could be partially or completely offset by a reduction in the volume, and therefore cost, for imported fill and the value of the increased area of restored wetland that results from use of the steeper slopes. Further analyses would be required to evaluate steeper side slopes, the required basal reinforcing strength needed, and slope stability.

9.3.5 Horizontal Drainage Layer

Our analyses indicated that to accommodate seepage through the levee and meet stability criteria, a horizontal drainage layer should be constructed below the landside portion of the levee. We recommend the drainage layer be at least 2 feet thick and extend 20 feet from the landside toe of the levee (Figure 7). This drainage layer should be hydraulically connected to the CSBC of the permanent access road. We recommend the drain material be filter-compatible with the foundation and levee fill material and a free-draining sand or gravel, such as 9-03.13 *Backfill for Sand Drains* or 9-03.13(1) *Sand Drainage Blanket* of the 2012 WSDOT Standard Specifications (WSDOT, 2012).

9.3.6 Drainage Trench

We recommend that a drainage trench be constructed along the landward side of the levee to collect seepage water and stormwater and convey these flows north to the storage pond. The drainage trench would provide drainage protection and reduce seepage to Tidal Channel B (Figure 7). The seepage analyses results indicate that constructing this structure as an open trench could cause a quick condition, i.e., soil erosion and piping caused by seepage, along parts of the ditch unless the bottom and sides of the ditch are lined with a (or have and underlying) multi-layered filter zone and rock cover. The thickness of the filter layer would essentially fill the ditch, and overexcavation and placement of filter layers would be necessary to meet ditch grading and profile conditions to maintain drainage conveyance. Also, an open ditch would likely have periodic maintenance using excavators, which could damage the liner and filter layers. For these reasons, an enclosed drainage trench with a perforated drain pipe, granular fill and filter materials leading to the storage pond is recommended.

9.3.7 Settlement

We calculated settlement along the proposed levee using the commercial program Settle3D (Rocscience, 2012). Settle3D calculates three-dimensional stresses and one-dimensional displacements of a subgrade due to applied surface loads. In our analyses, we assumed that the levee would be initially over-built to an elevation higher than the design crest elevation (15 feet, NAVD88) to account for the settlement.

Levee geometry (height, crest width, and slope angles) and subsurface soil (soil type and relative density) are factors that contribute to the magnitude and distribution of settlement along the length of the levee. We analyzed four levee cross sections (A-A', B-B', C-C', and D-D') along the proposed alignment to characterize differing levee geometry and subsurface soil conditions.

Based on subsurface data, the subgrade soil beneath the proposed levee alignment consist of about 13 to 26 feet of soft to very soft sandy to clayey silt underlain by medium dense clean to slightly silty sand to a depth of about 70 feet. Soil deformation parameters including elastic moduli for the alluvial sands, and overconsolidation ratios, compression and recompression indices, and coefficients of consolidation for the estuary silts, were estimated using the results of laboratory consolidation tests (6 current tests and 105 existing tests), CPT correlations, and in situ porewater dissipation tests.

The results of our settlement analyses for the four cross sections are presented in Table 3 and shown in Figures 8 through 11. Our calculations show total ground surface settlement from beginning of embankment construction to about one year following embankment construction at the analyzed locations would range from about 27 to 30 inches. Because of uncertainty in the soil profile and settlement calculations, we recommend assuming that the levee will settle approximately 20 to 36 inches. For levee design and fill volume estimates, we recommend assuming that the levee crest will be over-built by 3 feet. Our settlement analyses included this over-build height in the applied fill load.

The estimated settlements are due primarily to consolidation of the estuarine clayey silt layers, and are therefore time dependent. We anticipate that 50 percent of the primary consolidation settlement will occur within 1 month of the load application, and that 90 percent will be complete within 2 to 3 months of load application. Because it will likely take several months to construct the levee fill, much of the anticipated primary consolidation settlement will occur during Project construction. To better estimate fill quantities overall and locally along the levee alignment, we recommend that the settlement be monitored during construction and for at least 30 days after substantial completion. We recommend that final crest grading and the installation of the road surfacing not occur until either primary consolidation settlement is complete and a prediction of the remaining settlement is made based on the monitoring data. The prediction of remaining settlement magnitude should be considered in determining the elevation to which the crest is to be graded.

We estimate post-construction secondary compression settlement between 3 and 12 inches at the ground surface during the first year after primary consolidation is complete and after the Contractor finishes final grading. These values are included in the total ground surface settlement calculation results presented in Table 3. Secondary compression settlement will continue at a decreasing rate with time. The magnitude of secondary compression in the subsequent 10 to 20 years could be on the same order of magnitude as those that occur during the first year of post-levee final grading secondary compression, i.e., 3 to 12 inches.

Due to uncertainties in the subsurface profile and settlement calculations in general, provisions should be made to survey the top of levee after construction. We recommend a survey occur approximately 1 and 5 years after construction is completed. We anticipate the settlement in some areas will exceed our estimates because the subsurface conditions differ from those encountered in the subsurface explorations. These differences could include thicker layers that will consolidate leading to larger total settlement, and layers that drain more slowly than anticipated, leading to longer consolidation time. If post-construction surveys or periodic levee inspections indicate the levee crown is below the design elevation, additional levee fill should be placed. You should consult with us if more than 1 foot of cumulative post-construction settlement of the embankment occurs (requiring fill) or if chronic settlement occurs, e.g., small amounts of fill that are needed annually. Larger than expected or chronic settlement could be indications that a subgrade failure has occurred. Maintenance records should document date, location, magnitude of settlement, and thickness of fill placed on the levee.

9.4 Liquefaction Analyses

Liquefaction is a phenomenon which occurs in loose, saturated, mostly granular soil when the water pressure in the pore spaces increases to a level that is sufficient to separate the soil grains from each other. When a saturated soil experiences partial or full liquefaction, porewater pressure between the soil grains increases. This causes a reduction in the soil's effective stress, strength, and stiffness.

The liquefaction potential along the proposed setback levee alignment was evaluated based on the anticipated design life of the levee and USACE EC 110-2-6067, *USACE Process for the National Flood Insurance Program (NFIP) Levee System Evaluation* (USACE, 2010). A ground motion level corresponding to a 50 percent probability of exceedance in 75 years, or about a 100-year return period, was used in our analyses. The determination of the site ground motions and the results of the liquefaction analyses are discussed in the following sections. Plots of the FS against liquefaction versus depth and a discussion of the analysis method are included in Appendix D.

9.4.1 Ground Motions

The modal magnitude and soft rock peak ground acceleration (PGA) for the design ground motion level were determined based on results of the 2008 U.S. Geologic Survey (USGS) probabilistic seismic hazard analyses (Petersen and others, 2008; USGS, 2012b). Based on the USGS interactive deaggregation and Project location, we estimate design magnitude and soft rock PGAs of 6.6 and 0.12g, respectively.

The soft rock PGA is modified for subsurface conditions within 100 feet of the ground surface. Based on the subsurface conditions encountered in the explorations, we recommend that the site be classified as Site Class E in accordance with the definition from the 2012 American Association of State Highway and Transportation Officials (AASHTO) Load and Resistance Factor Design Bridge Design Specifications (AASHTO, 2012). Based on a Site Class E, we recommend the design PGA be 0.28g.

9.4.2 Liquefaction Analyses Results

Our interpretation of the results from the empirical procedures is that the alluvial deposits (Ha) beneath the levee footprint are potentially liquefiable under the design seismic ground motions. According to the CPT-based results, the upper estuarine deposits (He_1 and He_2) contain scattered, potentially liquefiable seams of alluvial deposits. The SPT-based results indicate that the upper estuarine deposits except for the sand seams will not liquefy. We anticipate that for the design seismic event, the alluvial deposits will fully liquefy and that the upper estuarine deposits will undergo a loss of shear strength due to elevated porewater pressures, but will not fully liquefy.

9.4.3 Potential Liquefaction-induced Risks

Potential effects of liquefaction include settlement, a reduction in soil shear strength, and potential embankment instability or lateral spreading.

We estimate settlement of 2 to 14 inches could occur due to liquefaction during a design-level earthquake. This settlement could reduce the flood level of protection of the levee until the levee is built back to the design crest elevation.

A loss of shear strength below the levee would reduce the global stability FS, and possibly lead to localized global stability failure of the levee. Lateral spreading could occur along the north part of the levee where scour and excavation for a storage pond will lower the grades adjacent to the levee. Liquefaction-induced hazards may occur over a small area or over hundreds of feet. The costs associated with such a failure could be great because repair could require complete replacement of the failed section.

9.4.4 Mitigation Measures

The design team and County have discussed the seismic resistance of the proposed levee, potential vulnerabilities, and possible mitigation measures to lower the risk. Alternatives to address seismic vulnerability may include one or more of the following:

- Do not increase the seismic resistance. Perform repairs as needed following an earthquake.
- Increase the strength of the basal reinforcement layer beneath the levee
- Install a pile foundation below the levee
- Perform jet grouting or deep soil mixing to increase soil strength
- Densify the alluvial deposits using vibratory techniques

We understand the County and DD5 selected the first alternative: perform repairs as needed following an earthquake.

9.5 Pipe Crossings

9.5.1 Puget Sound Energy (PSE) Pipeline

A PSE natural gas pipeline crosses the southern portion of the site (Figure 2). Plans dated May 2003, with revisions in September 2003 and March 2004, show the pipe bottom 4 feet below grade where the proposed levee crosses the pipeline. At this location, the pipeline is listed as a 16-inch-outside diameter, 0.344-inch-wall thickness, carbon steel pipe, encased in a 2-inch-thick concrete annulus. The pipeline is to remain in service during construction of the levee.

We estimate a total settlement of approximately 10 to 15 inches will occur at the bottom of the pipeline due to levee construction. Approximately 90 percent of the primary consolidation settlement is anticipated to occur within 2 to 3 months of the fill being placed. The remaining primary consolidation settlement is anticipated to occur within one year. We estimate post-construction secondary compression settlement of 1 to 3 inches would occur during the first year after primary consolidation settlement is complete. Settlement results at the bottom of the PSE pipeline are presented in Table 3 and shown in Figure 12.

The USACE *Levee Design and Construction Manual EM 1110-2-1913* (USACE, 2000) recommends that existing pressurized pipes be relocated over proposed new levees. If the PSE pipeline cannot be relocated to cross over the proposed levee and instead must be left in place, the pipe should be assessed to determine if it needs to be protected from excessive angular distortion and stresses caused by the levee construction and the completed levee fill.

Alternatives for pipeline protection include:

- Constructing a relieving slab above the pipe and below the fill, supported on pin piles that extend through the compressible estuary deposit and into the underlying alluvial sand. This method poses some risk because a gap may develop beneath slab as the surrounding soil settles; creating a seepage pathway beneath the levee and cause piping failure.
- Widening the levee at the pipe crossing to decrease the angular distortion and associated stresses in the pipe.
- Cement-treating the estuarine soil below the pipeline to decrease settlement.

Discussion with the pipeline owner is necessary to identify tolerable angular distortion limits and stresses for the pipe. Further analyses may be warranted depending on the selected mitigation option.

9.5.2 Tide Gate Pipe

We understand that a 36-inch-diameter, pipe with tide gate (tide gate pipe) will be installed beneath the existing dike west of the intersection of the new levee and existing levee. The tide gate pipe will allow water to flow out of the storage pond, on the landside of the levee, to Union Slough during low tide. Based on preliminary Otak permit application drawings, we understand that the invert of the tide gate pipe will be at elevation -2.14 feet (NAVD88).

Because Union Slough is subject to tidal cycles with a MHHW elevation of about 9.2 feet (USGS, 2012a), the excavation for the pipe the tide gate installation on the waterside of the existing levee will need to be protected using sheet piles. The excavation for the tide gate pipe installation will need to be dewatered. Due to the fine-grained nature of the near surface soils (He_1 and He_2), well points may be required. Additional analyses to evaluate dewatering requirements and anticipated flow rates of dewatering systems will be performed during levee final design.

9.5.3 Seepage and Piping Mitigation

Utilities and utility backfill can create paths for seepage and piping beneath the levee. We understand the only utilities crossing under the new or existing levee will be the PSE pipeline to the south and the tide gate pipe to the north. Where it will be beneath the proposed setback levee, the existing PSE pipeline should be excavated and exposed during levee construction so that the pipeline trench backfill can be evaluated. If the pipeline trench backfill could present a seepage path beneath the proposed levee, we recommend replacing the trench backfill under, and within at least 20 feet outside, the levee footprint. We recommend replacing the trench backfill with suitable soil that will not create a preferential seepage path, and providing measures to mitigate piping. This design should be coordinated with the pipeline owner.

Selection of proper backfill material for the tide gate pipe trench is critical for long-term functionality of the levee system at this location. If, due to either poor compaction, the material gradation, potential for cracking of the backfill, or the backfill material has a higher permeability than that of the surrounding levee material, then preferential water flow pathways could develop through the trench backfill or along the pipe. This could lead to internal piping of soil which could erode soil around the pipe, compromise the integrity of the levee, and may eventually lead to a breach. We recommend that the tide gate pipe trench backfill soil meet the criteria for the new levee fill, as presented in Figure 7, with oversize material that could damage the pipe removed. As recommended by EM 1110-2-1913 (USACE, 2000), the trench backfill should be compacted to at least 95 percent of its modified Proctor maximum dry density (ASTM International [ASTM] D 1557). An 18-inch annular thickness of drainage fill, the same material specified and used for the horizontal drainage blanket below the landward side of the levee (see Section 8.3.4), should be installed around the pipe for the landside third of the pipe length.

9.6 Storage Pond

We understand that a storage pond will be constructed on the landside of the levee at the north end of the Project site (see Figure 2). This pond will collect water from Tidal Channel B and the levee drainage trench. The water level in this pond will be controlled by the tide gate and pump station described earlier in this report. Based on preliminary Otak permit application drawings, we understand that the bottom of the pond will be at elevation -3.14 feet (NAVD88). We recommend permanent cut slopes for the pond be 3H:1V or flatter.

As described in Sections 8.3.1 and 8.3.5, high steady-state design flood seepage exit gradients were analyzed when a drainage ditch was introduced in the model. Therefore, seepage mitigation measures will be required if the storage pond is to be constructed as shown in the preliminary Otak permit application drawings. Potential mitigation measures could include relief wells and/or an aggregate filter lining. Mitigation measures such as filter diaphragms and blankets should be evaluated and developed as the Project design advances.

9.7 Farmland Tile Drains

We understand buried irrigation features such as tile drains may exist in the fields beneath the levee footprint. The tile drains and remnants of broken tile drains would provide drainage pathways beneath the levee and increase seepage behind the levee. These pathways could lead to progressive piping and eventual failure of the levee.

The specific locations of the tile drains are unknown. We recommend that prior to construction, 5-foot-deep observation trenches be excavated along the landside and waterside toe of the proposed levee for the full levee length. If tile drains are found, they should be removed beneath the levee and to 20 feet outside the levee footprint. Backfill for the tile drain excavations and other excavations made beneath the levee footprint should consist of soil meeting the requirements for new levee fill. Observation trench backfill beyond the levee toe could be soil that meets the requirements for new levee fill or that matches the undisturbed adjacent soil type(s) and unit weight. If an observation trench is converted to a drainage trench, then backfill should meet the drainage trench fill requirements.

9.8 Riprap Design

We understand the proposed levee design will include riprap erosion protection on the waterside face of the levee. Where riprap is placed in contact with the finer-grained levee fill soil, groundwater flow between the riprap and underlying soil could cause soil movement and internal erosion. This soil movement and erosion could cause undermining and failure of the armoring and subgrade soil. To mitigate this, we recommend placing a filter between the riprap and the underlying soil. The filter could consist of a filter geotextile or an aggregate filter layer. We recommend a geotextile only be used on slopes of 2H:1V or flatter.

Design of the riprap and riprap filter will be provided in a separate document.

10.0 CONSTRUCTION CONSIDERATIONS

10.1 Environmental Construction Considerations

Low levels of arsenic were detected at the site that exceed the MTCA Method A cleanup level in three shallow soil samples (approximately 2.5 feet bgs) and one deep sample (approximately 10 feet bgs) collected from the current subsurface explorations performed along the proposed levee alignment. MTCA Method A arsenic levels of 20 mg/kg were exceeded in four of the ten soil samples tested at the site:

- B1, 2.5ft-bgs = 32.8 mg/Kg, 10ft-bgs = 19.4 mg/Kg (Arsenic)

- B2, 2.5ft-bgs = 15.6 mg/Kg, 10ft-bgs = 13.6 mg/Kg (Arsenic)
- B3, 2.5ft-bgs = 14.8 mg/Kg, 10ft-bgs = 22.7 mg/Kg (Arsenic)
- B4, 2.5ft-bgs = 29.9 mg/Kg, 10ft-bgs = 7.87 mg/Kg (Arsenic)
- B5, 2.5ft-bgs = 20.3 mg/Kg, 10ft-bgs = 9.35 mg/Kg (Arsenic)

The presence of a hazardous material in excess of a cleanup level presents issues for handling and disposal of excavated soil as well as health and safety issues for workers exposed to the contaminated soil during construction. Our interpretation of the Snohomish County Environmental Impact Statement and State regulations indicate the site will be subject to two separate regulatory standards at the site:

- Disturbed upland areas of the levee and landward of the levee fall under the Washington State (Washington Administrative Code [WAC] 173-340) MTCA Method A level of 20 mg/kg for arsenic.

- Disturbed soils and earthwork located in the (new) shoreline/tidal marsh side of the levee must meet the Washington State (WAC 173-204) Marine Sediment Management Standard level of 57 mg/kg.

In general, soil containing contamination in excess of an applicable cleanup criterion may not be re-used at the site it is excavated from, and must therefore be disposed of at an appropriate facility such as a Resource Conservation and Recovery Act Subtitle D landfill. However, Ecology has published guidance (Ecology, 2007) for owners of large properties affected by area-wide smelter contamination that provides for re-use of arsenic- and lead-contaminated soil at the site. Under this guidance, the re-use options include covering the polluted soil (for which the level of allowable contamination will vary across the site depending upon landward or marine areas) to create a barrier between the contamination and people at the ground surface, and/or mixing soil with deeper uncontaminated soil to effectively dilute the surface contamination to below-cleanup level concentrations. Under the soil covering scenario, the guidance document recommends covering the soil with bark, gravel, sand, clean soil and grass, rubber playground mats, concrete, or asphalt. In the case where a natural covering (i.e., bark, gravel, sand, or clean soil and grass) is to be used, the covering should be 6 to 12 inches thick and the contaminated soil should first be covered with a layer of heavy-duty plastic or weed barrier fabric. Soil mixing is recommended when the arsenic concentrations are below 40 mg/kg for upland areas subject to MTCA standards and 80 mg/kg for areas subject to marine standards. All site soil is expected to conform to these criteria.

For either case, the soils should be tested after mixing to make sure that the resulting arsenic concentration is below 20 or 57 mg/kg for upland and marine areas, respectively. Regardless of the final approach, it is essential that the final disposition of the soil be determined. This will include soil sampling and associated as-built documentation of the soil arsenic concentrations.

Regarding worker exposure, no simple relationship exists between the concentration of arsenic in soil and the potential worker exposure if the arsenic becomes airborne. Therefore, if arsenic is present and is disturbed during construction, an evaluation must be made whether or not workers are exposed to concentrations in air in excess of the action level of 5 micrograms per cubic meter ($\mu g/m^3$). If the action level is exceeded, requirements for training, medical monitoring, and air sampling are triggered. If the permissible exposure level of 10 $\mu g/m^3$ is exceeded, more requirements must be met, including use of respiratory protection equipment. Additional information pertaining to worker health and safety is available in WAC 296-842, Respirators, and WAC 296-848, Arsenic. Prior to conducting work that may disturb arsenic-containing soil and cause a potential employee exposure, the Contractor must conduct an initial exposure assessment in accordance with WAC 296-848-20060.

10.2 Site Preparation and Grading

Clearing and grubbing for the proposed levee should be done in accordance with Section 7-2, Foundation Preparation and Treatment, of the 2000 USACE EM 1110-2-1913, *Design and Construction of Levees* (USACE, 2000). Site preparation should commence by collecting and diverting all sources of surface water into storm drainage and/or treatment facilities. We anticipate that this work will include constructing temporary erosion and sedimentation control measures, and draining the ponded water on the site.

Following the demolition of existing structures where present, the ground should be cleared of trees, brush, and existing fill or debris. The area should then be grubbed of stumps and large roots, and stripped of the topsoil or underlying soil which contains significant amounts of roots or other objectionable debris and organic material. We recommend assuming the average stripping depth will be 10 inches for cost estimating; however, stripping should occur to the depth needed to remove topsoil, sod, and roots greater than ½-inch in diameter, which may be locally greater or less than 10 inches. We recommend that organic-rich soil be stockpiled for later use as topsoil.

Following stripping, the exposed soil should be graded to a uniform, smooth surface. Soft, loose, or wet zones that inhibit construction of the basal reinforcement geosynthetic should be removed.

10.3 Reuse of On-site Soil

We anticipate excavations for the levee subgrade preparation will consist primarily of stripping topsoil. Deeper excavations made for the PSE pipeline, tide gate pipe, storage pond, and erosion launch aprons will be made in the upper estuary deposits. These excavations will be made mostly below the groundwater table; therefore, excavated soil will have high moisture content at the time they are excavated.

In our opinion, some of the estuarine deposits could be suitable for levee fill. Layers with high organic content and peat should be expected in the estuarine deposits. These materials should be segregated and not used as levee fill if they have an organic content exceeding 1 percent by dry unit weight. The Contractor should be advised that the on-site soil will likely require moisture conditioning before placement and compaction. If the Contractor proposes to mix imported soil with onsite soil to provide levee fill, different soils should be thoroughly blended and moisture conditioned prior to hauling to and placement on the levee, and the organic content of the blended materials should not exceed 1 percent by dry unit weight. The Contractor should perform tests to show that the moisture content of the mixed soil is suitable for compaction.

10.4 Fill Placement and Compaction

We recommend that the levee fill and horizontal drainage layer be compacted to a minimum 90 percent of the modified Proctor maximum dry density (ASTM D 1557). We recommend that the CSBC for the permanent access road and the levee road surfacing be placed and compacted in accordance with Section 4-04 of the 2012 WSDOT Standard Specifications. The loose lift thickness for the fill before compaction should not exceed 8 inches with heavy equipment compactors and 4 inches for hand-operated compaction equipment.

Fill should be placed and compacted in uniform horizontal lifts. Where the levee ties into the existing levee at the north end of the alignment, the fill should be keyed into the slopes by excavating a bench into the soil as recommended in Section 2-03.3(14), Embankment Construction, of the 2012 WSDOT Standard Specifications.

Topsoil should be placed and graded in accordance with Project requirements.

10.5 Utilities

We understand the only utilities crossing under the new or existing levee will be the PSE pipeline to the south and the tide gate pipe to the north. However, we recommend that that the Contractor check with utility owners and collect as-built information in the work vicinity prior to construction for confirmation. If other utilities are present, they should be relocated and/or specifically addressed where they could be affected by levee construction or could affect levee performance.

Soft or loose subgrade soil could be present where the levee embankment crosses the PSE pipeline. If present, the soft or loose subgrade could be excavated and replaced with levee fill to the top of the pipeline, or to a depth approved by the utility owner. During backfill of the gas and tide gate pipes, we recommend 2 feet of fill be placed above the pipe crown prior to using large compaction equipment. PSE procedures and requirements for performing work around their pipeline and for pipe backfill should be identified and considered in the plans and specifications. Proper equipment should be selected by Contractor to prevent damage to the gas and tide gate pipes during excavation, backfill placement, and compaction.

Live loads that will occur within a 2H:1V surface that extend up from the extents of the PSE/William pipeline and the tide gate pipe should be reviewed once equipment is selected by the Contractor. The Contractor should be required to prepare a pipeline protection plan for work it does within the PSE/William pipeline right-of-way.

10.6 Basal Reinforcement Installation

The Contractor should take care to protect the basal reinforcement geosynthetic from damage during installation. Installation of the geosynthetic should be done in accordance with the manufacturer's recommendations. The Contractor should be responsible for selecting equipment and operations that do not damage the geosynthetic. In general, we recommend a minimum 24 inches of fill be placed over the geosynthetic prior to wheeled construction equipment operating over it. Track rigs and rollers could operate above the geosynthetic with a minimum 8 inches of fill placed over it.

The geosynthetic should be placed on top of the prepared subgrade with its machine direction perpendicular to the levee alignment. It should be stretched tight and held with stakes prior to placing backfill. Backfill should not be pushed onto the geosynthetic, but dumped from an excavator or loader bucket. To reduce damage, soil should not be dropped from greater than 3 feet. Fill may be spread after the geosynthetic is covered with a minimum of 8 inches of soil.

10.7 Temporary Excavation Slopes

Temporary excavation slopes should be the responsibility of the Contractor because the Contractor is responsible for its own means and methods, and is continuously at the site and able to observe the nature and conditions of the soil and groundwater encountered. All current and applicable safety regulations regarding excavation slopes and shoring should be followed.

Because the proposed construction may require temporary excavations that differ from the geometries of the proposed Project structures (e.g., storage pond, tide gate pipe), the contract documents should require a submittal in which the Contractor explains how it intends to construct those features.

For planning purposes, we recommend assuming that excavations below current grade will occur below the groundwater table. Temporary, unsupported, open-cut slopes excavated below the groundwater will depend on whether the excavations are:

- Dewatered such that seepage does not occur into the excavation or is greatly reduced,
- Dewatered using sumps during excavation such that seepage does occur, or
- Excavations are made in the wet without lowering the water level in the excavation below the groundwater table.

If the Contractor elects to dewater prior to excavating or makes the excavation in the wet, we anticipate temporary excavation slopes might be made no steeper than 1.75H:1V. Excavations that are not dewatered should be attempted only if:

- Backfill to be placed in the water is not settlement sensitive. Subgrade soil typically is disturbed by the excavation operations and cannot be adequately observed below the water. Soft and/or loose sediment typically forms in excavations made in the wet. These soft and/or loose layers can be several feet thick and expected to settle up 12 inches.
- The backfill does not need to be compacted. Densifying backfill below the water line is not practical unless the material is coarse.
- Precise line and grade control of the excavation is not required.

If the Contractor does not dewater prior to excavating and seepage into the excavation is removed using sumps, we anticipate temporary excavation slopes of 2.5H:1V or flatter could be required.

The USACE *Levee Design and Construction Manual EM 1110-2-1913* (USACE, 2000) requires that excavation side slopes in existing levees be no steeper than 1H:1V. Considering that portions of the existing levee are currently at this slope, we recommend assuming excavation for the tide gate pipe can be cut at this slope assuming the excavation zone is dewatered prior to excavating into saturated soils or below the groundwater surface. We recommend excavating a test pit at the tide gate location to observe the existing levee material and to assess appropriate cut slopes.

Flatter cut slopes may be required where loose/soft soil or seepage is encountered or if wet weather conditions are present.

10.8 Surface Water and Groundwater Control

We recommend installing surface and groundwater controls to provide proper drainage of the excavations made for the levee, utilities and pipeline crossings, storage pond, and other features associated with the Project. In our opinion, temporary dewatering will be required to make relatively dry excavations at the site. Because of the high fines content in the upper estuarine deposits, and elevated groundwater table, we anticipate drainage from the soil will generally be poor and difficult to manage. We expect the surficial soils to become saturated during rainstorms, resulting in overland flow. We also expect seeps and possible water pressure-induced instabilities in along the floor of deeper foundation excavations, and that performing these excavations may require advance dewatering, and special dewatering equipment and construction methods.

The Contractor is typically responsible for dewatering using their own means and methods. However, the contract specifications should include dewatering language and submittal requirements (possibly as special provisions) that require the Contractor to demonstrate their understanding of the soils and groundwater conditions, and require the Contractor to develop a dewatering plan showing how they will meet the requirements of the construction specifications. We caution against using a prescriptive specification such as, “The Contractor shall fully dewater all excavation and fill areas to a minimum 1.0 foot below the soil surface,” as this simplified approach can cause several issues such as requiring dewatering over large areas that may not be necessary or difficult to enforce. We recommend the specifications include a requirement that the Contractor monitor performance of their dewatering system, have appropriate equipment and backup systems, and submit daily reports on the dewatering system performance and groundwater conditions.

A plan may include an array of dewatering provisions including:

- Drainage ditches, pipes and diversion structures used to intercept and redirect flow from construction areas
- Sumps and pumps
- Wells
- Wells points

The Contractor's dewatering plan should include provisions that are appropriately matched to the proposed construction feature, soil and groundwater conditions, and construction methods. The specifications should require that the Contractor submit dewatering plans complete with supporting engineering calculations and analyses. The dewatering plan and calculations and analyses should be performed and stamped by a licensed professional engineer, engineering geologist, or hydrogeologist. The dewatering plan should include discussion on how the dewatering system will work and how the dewatering system should be operated including any treatment proposed to meet applicable permit and regulatory requirements. During construction, dewatering operations should be closely monitored to confirm that the Contractor is following their plans and that they are meeting the specification plan and permit criteria.

10.9 Wet Weather and Wet Condition Considerations

In the Project area, wet weather generally begins about mid-October and continues through about May, although rainy periods may occur at any time of year. The soil for the proposed levee embankment contains sufficient fines that will produce an unstable mixture when wet. Such soil is highly susceptible to changes in water content and tends to become difficult or impossible to compact if its moisture content significantly exceeds the optimum by more than about 2 percent. During wet weather, ponding in the Project area could occur. Performing earthwork during dry weather would reduce problems and costs associated with rainwater, trafficability, and the handling of wet soil. We recommend earthwork be scheduled for the dry-weather months of June through September. Even during that time, wet weather and wet conditions should be anticipated in the Project schedule. We recommend the specifications require the Contractor provide a schedule that demonstrates production rates and anticipated wet weather and wet conditions delays. The contract documents should include provisions for wet weather/wet condition earthwork.

11.0 ADDITIONAL SERVICES

Geotechnical and environmental recommendations that are used as a basis for design are developed from a limited number of explorations and tests. Consequently, there may be a need for adjustment in the field, and we therefore recommend that Shannon & Wilson, Inc. be retained to observe the geotechnical aspects of the construction. Construction observation should include site excavation, levee breaching, backfilling of drainage channels, utility/pipeline installation, levee embankment placement, dewatering and compaction, quality assurance and testing, tide gate installation, erosion control, groundwater control, and environmentally contaminated soil and/or quality monitoring. Construction observation would allow us to evaluate the subsurface conditions and levee fill as they are exposed and placed during construction, to make recommendations as needed, and to determine that the work is accomplished in accordance with our recommendations.

12.0 LIMITATIONS

This report was prepared for the exclusive use of Otak and the SCDPW, and other members of the design team for specific application to the design of the Smith Island Estuary Restoration Project as it relates to the geotechnical aspects discussed in this report. It should be made available to prospective contractors and/or the Contractor for information on factual data only, and not as a warranty of subsurface conditions.

The interpretations, analyses, conclusions, and recommendations contained in this report are based on our observation of site conditions as they existed during our site visits, and our interpretation of subsurface conditions based on explorations we performed; subsurface exploration logs prepared by others; geologic and hydrogeologic data for the Project site; and information provided to us and documents we reviewed describing the construction, maintenance, and operation history of the facilities evaluated. The professional opinions, recommendations, and conclusions contained in this report for the levee system are valid for a period not greater than 10 years from the date of this report. This time limitation is included in recognition that the conditions of levee systems can and do change with time as do the conditions that lead to water surface elevation determinations. If new information becomes available to Shannon & Wilson, Inc., such as the performance during a significant flood event, the professional opinions, recommendations, and conclusions contained in this report may be modified by Shannon & Wilson, Inc.

Our interpretation of existing conditions and analyses, and resulting conclusions and recommendations, rely on data provided by others, including, but not limited to, survey data, subsurface data, levee geometry information (plans and cross sections), levee system design and construction data, levee system maintenance and operation data, and design flood water surface elevations and hydrographs. Shannon & Wilson makes no warranty, express or implied, as to the accuracy of the data relied on. Within the limitations of the scope, schedule, and budget of this Project, the analyses, conclusion, and recommendations presented in this report were prepared in accordance with generally accepted professional engineering principles and practices in use in the area of the Project at the time this report was prepared.

We assume that our interpretations of subsurface conditions are representative of subsurface conditions at the site. Unanticipated soil and groundwater conditions are commonly encountered and cannot be fully determined by taking soil samples, drilling test borings, or pushing probes. Such unexpected conditions frequently require that additional expenditures be made to attain a properly constructed Project. Therefore, some contingency fund is recommended to accommodate such potential extra costs. If subsurface conditions different from our observations or interpretation are encountered or appear to be present, or if levee or levee facility performance appears to be different than we observed or interpreted from information provided to us, 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 issuance of this report and start of construction at the site, or if conditions have changed due to natural causes or construction at or near the site, we recommend that site conditions and this report be reviewed to determine the applicability of the conclusions and recommendations.

Levee systems are a collection of components that must function as a complete, integrated system to be effective. It is not practical or possible to completely know all of the engineering properties of levees and their foundations. Consequently, uncertainty exists as to actual levee system behavior and performance. Robust regular inspections and high water monitoring for levees, floodwalls, appurtenances, and features should be performed. Any deficiency should be remediated as appropriate based on observed conditions, uncertainty, and potential consequences.

It must be understood that some seepage is normal and acceptable when water is elevated. Uses incompatible with this seepage should not be allowed in areas protected by levee systems. Excavations near or in levees and floodwalls could compromise the levee system and should not be performed without proper engineering and construction controls. The potential impact of these excavations depends on many factors, including, but not limited to subsurface and groundwater conditions, excavation depth, distance from levee toe, levee geometry, and difference in elevation of water on the waterside of the levee and the excavation. Penetrations through and below levees should be assessed individually because penetrations have the potential to produce rapid failures of levees as they can provide a preferential seepage path or an open conveyance for water.

The scope of our services for this report did not include any assessment or evaluations regarding the presence or absence of wetlands. Hazardous material testing for the presence total metals (EPA Method 6020) and lead were completed for the disposal of the drill spoils. No other assessment or evaluations regarding hazardous or toxic materials in the soil, surface water, groundwater or air on or below or around the site, or the evaluation for the disposal of contaminated soils or groundwater were performed.

groundwater or air on or below or around the site, or the evaluation for the disposal of contaminated soils or groundwater were performed.

We have prepared the document, "Important Information About Your Geotechnical/ Environmental Report," as Appendix F to assist you and others in understanding the use and limitations of our report.

There are three primary authors contributing to this report. Stan Boyle is the project principal in charge and responsible for geotechnical engineering elements of this report. Stephen Thomas is the lead hydrogeologist responsible for groundwater, seepage and salt-water intrusion elements of this report. David Cline is the project manager and lead hydraulic/civil engineer responsible for coordinating various aspects of the levee geotechnical, groundwater and interior drainage designs with Otak and Snohomish County.

SHANNON & WILSON, INC.

10/10/13

Stanley R. Boyle, Ph.D., P.E.
Vice President

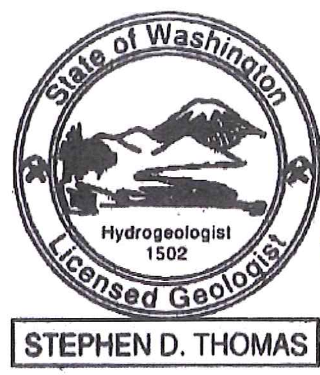

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TABLE 1
SEEPAGE ANALYSIS SUMMARY

Analysis Location	Analysis Geometry		Design Flood Level Steady-state Seepage Analysis		
	Levee Design Height, H[1] (ft)	Levee Base Width (ft)	Q (ft^3/day/ft)	% Q in Drainage Trench	i_V [2, 3] (ft/ft)
A-A' (Station 11+03)	9	69	5.0	99%	0.18
B-B' (Station 29+11)	9	69	5.0	85%	0.17
C-C' (Station 51+86)	11	81	12.0	36%	0.30
D-D' (Station 65+75)	10	75	5.0	99%	0.23[(5)]

Notes:

1 Design levee crest elevation is fixed at +15 feet (North American Vertical Datum of 1988). Levee design height is a function of existing ground surface elevation.

2 U.S. Army Corps of Engineers Technical Letter ETL 1110-2-569 (2005) recommends that levees should be designed to maintain a factor of safety against a quick (piping) condition of 1.6. Based on the density of the He_1 layer, this corresponds to a required maximum upward exit gradient (i_v) of 0.30.

3 Exit gradients presented in this table occur at the base of a proposed drainage trench on the landside of the permanent access road (west of the levee). Our analyses indicate that this trench must be filled with free-draining material. A perforated pipe may be installed in the trench if additional flow capacity is required.

4 Analysis assumes scoured conditions and incorporates the effect of the 90-degree bend in the levee where the proposed levee meets the existing levee. At this corner on the landside, seepage would be coming from two directions (i.e., from both legs of the bend). To account for this, we artificially increased the pressure head on the waterside by 75 percent (based on past experience and engineering judgment).

5 These rates are based on field monitoring data collected in July and August 2013, and a adjusted for typical flood conditions.

E_{WS} = surface water elevation on the flood side of the levee (east side)

ft = feet

i_V = upward hydraulic gradient averaged over depth of anpticipated piping in front of the levee toe

LS (landside) = side of the levee protected from flooding by the levee (west side)

Q = Estimated groundwater flow per foot of levee length from the Waterside to the Landside of the levee that is anticipated to enter Tidal Channel B (includes water intercepted by the drainage trench that will diverted to Tidal Channel B)

WS (waterside) = side of the levee subject to flooding (east side)

% = percent

TABLE 2
MODFLOW SEEPAGE FLOW ESTIMATES
TO TIDAL CHANNEL B

Flow Condition	Tidal Channel B	Proposed 75% Efficiency Drain Trench (gpm)	Proposed 75% Efficiency Drain Trench (cfs)	Proposed 95% Efficiency Drain Trench (gpm)	Proposed 95% Efficiency Drain Trench (cfs)
Tidal	Existing	46.09	0.10	46.09	0.10
	Proposed	42.51	0.09	35.82	0.08
	Change	-3.58	-0.01	-10.28	-0.02
Flood	Existing	110.22	0.25	110.22	0.25
	Proposed	95.09	0.21	87.46	0.19
	Change	-15.13	-0.03	-22.76	-0.05

Notes:
cfs = cubic feet per second
gpm = gallons per minute
% = percent

TABLE 3
GLOBAL STABILITY ANALYSIS SUMMARY

Analysis Location	Base Reinforcement[1]		Factor of Safety Against Global Instability			
	Short-term Strength, T_{STDS} (lb/ft)	Long-term Strength, T_{LTDS} (lb/ft)	Case 1: End of Construction[2]	Case 2a: Drawdown from Steady State Design Flood [3]	Case 2b: Daily Drawdown from High Tide[4]	Case 3: Steady-state Seepage (Flood Stage = +15 feet)[5]
A-A' (Station 11+03)	6,000	2,100	1.3[6]	1.4	2.2	2.2
B-B' (Station 29+11)	6,000	2,100	1.3	1.6	2.5	2.1
C-C' (Station 51+86)	4,000	2,100	1.4	1.4	1.8	1.8
D-D' (Station 65+75)	5,000	2,100	1.3	1.2 / 1.1[7]	2.2	1.5
USACE Recommended FS	**-**	**-**	**1.3**	**1.0-1.2**	**1.4[8]**	**1.4**

Notes:

[1] A base reinforcement geotextile was included to improve stability. Long-term strength includes reduction factors for chemical degradation, creep strain, construction damage, durability, etc. (if applicable). Short-term includes 60-day creep and construction damage reduction factors.

[2] Assumes that it takes approximately 2 months or longer to construct the levee fill.

[3] Rapid drawdown conditions global stability was calculated using both transient seepage and multi-stage (USACE, 2003) methods. The lowest factors of safety (Fss) from the various methods are reported.

[4] Drawdown from Mean High High Water elevation of +11.1 feet to Mean Low Low Water elevation of -2 feet over a period of 6 hours.

[5] Case 3 only applies to the landside of the levee.

[6] FS from circular failure surface analysis. All other reported FS values are derived from non-circular failure surface analyses.

[7] Analysis applies to area near Union Slough subject to scour during the design flood event.

[8] Assumed higher FS for this drawdown condition because it occurs daily.

ft = feet

lb = pound

NA = case not analyzed

USACE = U.S. Army Corps of Engineers

TABLE 4
SETTLEMENT ANALYSIS SUMMARY

Analysis Location	Analysis Geometry			Settlement Evaluation						
	Levee Design Height, H [1] (ft)	Assumed Over-Build Height, ΔH [2] (ft)	Levee Base Width (ft)	Analysis Depth (ft)	Estimated Settlement				Estimated Time to 50 Percent Primary Consol. Settlement, t_{50} (days)	Estimated Time to 90 Percent Primary Consol. Settlement, t_{90} (days)
					Elastic, Se (inch)	Primary Consol., Sc (inch)	Secondary[3] Compression, Ss (inch)	Total (inch)		
A-A' (Station 8+31)	9	3	69	0 (beneath levee)	< 1/2	24	3	27	20	60
A-A' (Station 8+31)	9	3	69	4 (bottom of PSE pipe)	< 1/2	11	1	12	20	60
B-B' (Station 26+39)	9	3	69	0	< 1/2	24	4	28	15	40
C-C' (Station 49+15)	11	3	81	0	< 1/2	24	6	30	5	15
D-D' (Station 63+05)	10	3	75	0	< 1/2	24	5	29	5	15

Notes:

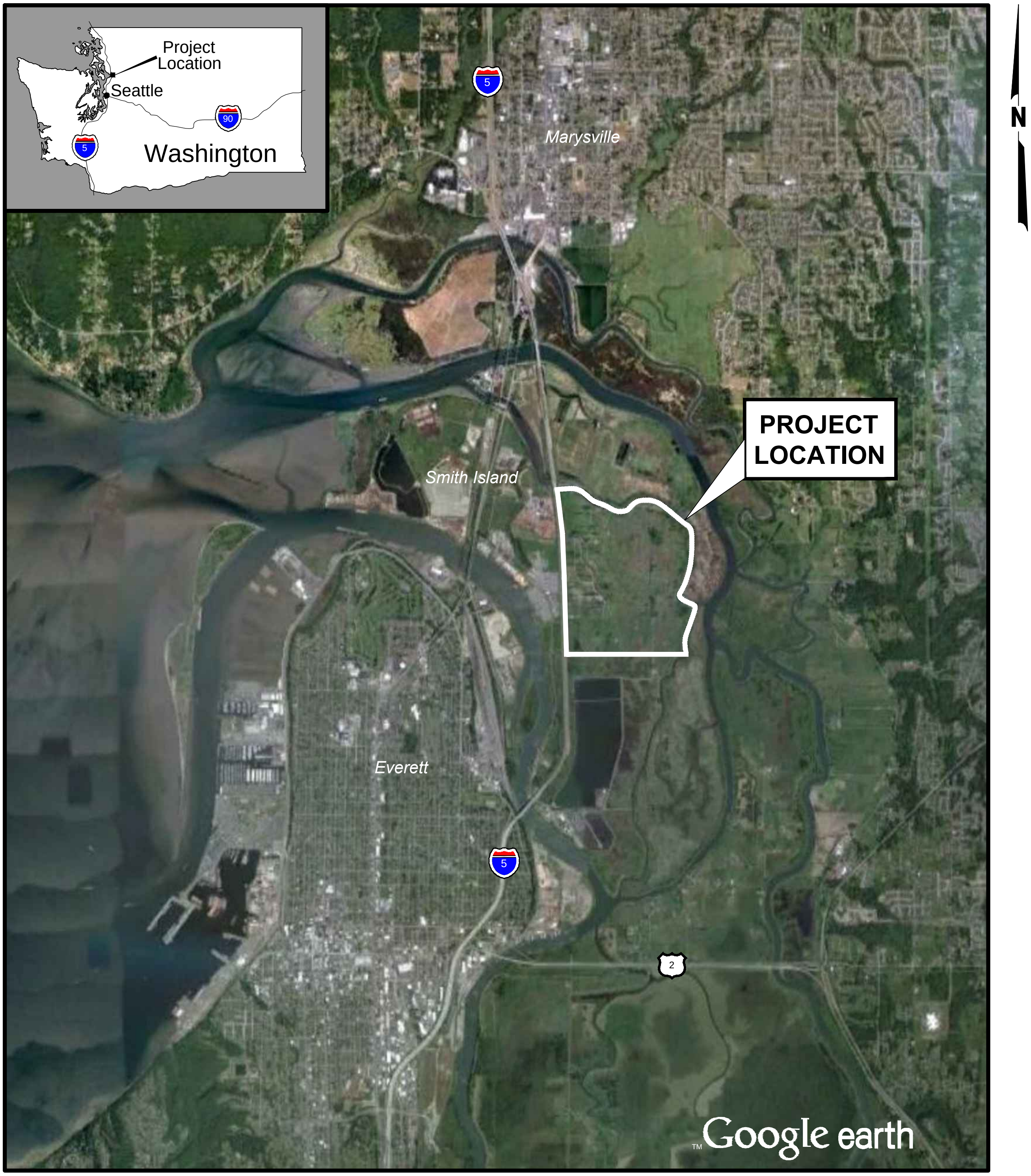
[1] Design levee crest elevation is +15 feet (North American Vertical Datum of 1988). Levee design height is a function of existing ground surface elevation.

[2] Required ΔH was estimated from preliminary Settle3D analyses and historic Washington State Department of Transportation settlement data from the nearby Interstate 5 embankment construction to achieve a levee crest elevation of +15 feet after elastic, primary consolidation, and secondary compression settlement (assumed one year of secondary compression settlement).

[3] Assumes secondary settlement will be substantially complete in one year.

consol. = consolidation

ft = feet



0 1 2

Scale in Miles

NOTE

Map adapted from aerial imagery provided by Google Earth Pro, reproduced by permission granted by Google Earth ™ Mapping Service.

Smith Island Estuary Restoration Project
Snohomish County, Washington

VICINITY MAP

October 2013 21-1-12405-060

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FIG. 1

Filename: I:\WIP\21-1\12405 Smith Island (Snohomish Cty)\CAD_FIGURES\-060\21-1-12405-060 Fig 1.dwg Date: 11-27-2013 Login: SAC

Filename: I:\WIP\21-1\12405 Smith Island (Snohomish Cty)\CAD_FIGURES\-030\21-1-12405-030 Fig 2.dwg Layout: S&E plan (wo Ditch Xref) Date: 11-27-2013 Login: SAC

LEGEND

B-1 — S&W Boring Designation and Approximate Location

CPT-2-13 — S&W Cone Penetration Test Designation and Approximate Location

TP-57 — Snohomish County Public Works Test Pit Designation and Approximate Location (2012)

DW01 — Snohomish County Public Works Boring Designation and Approximate Location (2012)

B-5-02 — Historic Boring Designation and Approximate Location

TP-60-86 — Historic Test Pit Designation and Approximate Location

Generalized Subsurface Profile Location Designation (See Figures 4 and 5)

A A' 11+03 — Analysis Profile Location Designation and Levee Stationing (See Figures 8 through 12)

0 500 1,000

Scale in Feet

NOTE

Figure adapted from electronic files provided by Otak.

Smith Island Estuary Restoration Project
Snohomish County, Washington

SITE AND EXPLORATION PLAN

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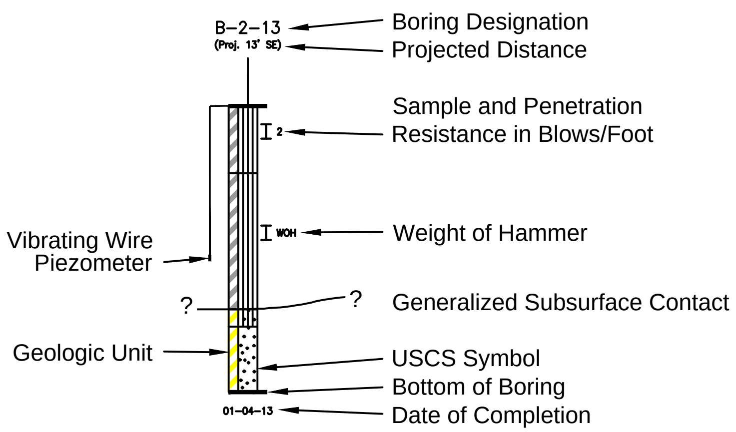
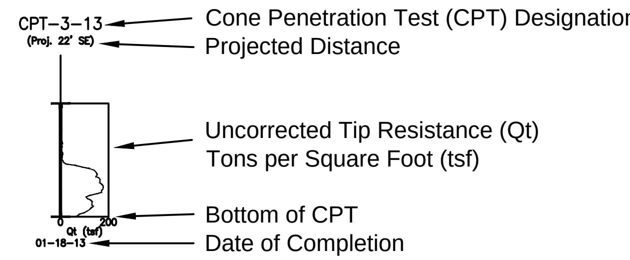
FIG. 2

FIG. 2

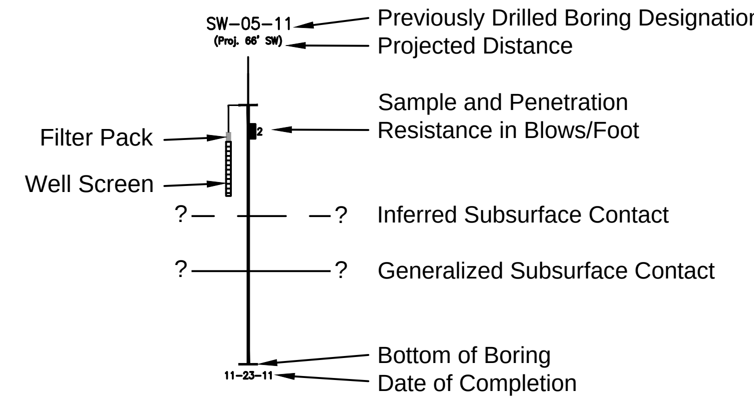
S&W BORING LEGEND



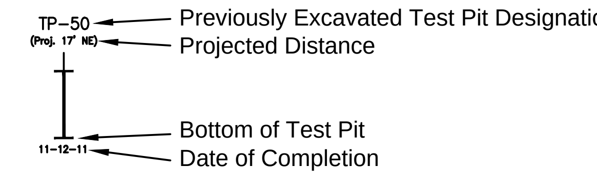
S&W CPT LEGEND



PREVIOUS BORING LEGEND



TEST PIT LEGEND



GENERALIZED GEOLOGY TYPE EXPLANATION

He_1 — ESTUARY DEPOSITS: Soft, organic silt and clayey silt, with scattered sand lenses and peat layers. Local iron-oxide staining. Contains abundant organics and locally scattered wood fragments and logs.

He_2 — ESTUARY DEPOSITS: Very soft, slightly clayey to clayey silt and organic silt with scattered to abundant sand lenses, seams, and layers. Local iron-oxide staining. Contains scattered to locally abundant organics and wood fragments. Buried logs likely present in the deposit.

Ha — ALLUVIAL DEPOSITS: Very loose to dense, trace of silt to silty sand. Iron-oxide staining. Contains locally scattered shells, wood, and fine organic debris.

He_3 — ESTUARY DEPOSITS: Very soft to medium stiff, silty clay, clayey silt, and organic silt, and medium dense sandy silt with trace to numerous organics. Deposit interlayered with medium dense to dense sand with variable amounts of silt.

NOTES

1. The profiles are constructed from surface elevations based on the North American Vertical Datum 1988 (NAVD88).
2. Project area and grades were adapted from files provided by Otak received 1-25-2013.
3. The geology shown is generalized from material observed from subsurface explorations conducted by Shannon & Wilson for this task and by others for previous studies. The geology, as encountered in the subsurface explorations, has been projected into the plane of the profile or section. Elevations and geologic contacts should be considered approximate. Variations between the profile and actual conditions are likely to exist.
4. Water levels shown were measured on various dates. Groundwater fluctuations should be expected.

UNIFIED SOIL CLASSIFICATION SYSTEM

(From USACE Tech Memo 3-357)

GP	SW	CL
GW	SP	ML
GP-GM	SW-SM	OL
GW-GM	SP-SM	CH
GM	SM	MH
GC	SC	OH
		PT

SAMPLE OR TEST TYPES

2" O.D. Split Spoon Sample with 140 lb. Hammer (standard penetration test - SPT)

ST — 3" O.D. Shelby Tube Sample (ST)

1. Dual Symbols (symbols separated by a hyphen, i.e., SP-SM, slightly silty fine SAND) are used for soils with between 5% and 12% fines or when the liquid limit and plasticity index values plot in the CL-ML area of the plasticity chart.
2. Borderline symbols (symbols separated by a slash, i.e., CL/ML, silty CLAY/clayey SILT; GW/SW, sandy GRAVEL/gravelly SAND) indicate that the soil may fall into one of two possible basic groups, based on ASTM D 2488-93 Visual Manual Classification System. The graphic symbol of only the first group symbol is shown on the profile.

RELATIVE DENSITY / CONSISTENCY

COARSE-GRAINED SOILS		FINE-GRAINED/COHESIVE SOILS	
N, SPT, BLOWS/FT.	RELATIVE DENSITY	N, SPT, BLOWS/FT.	RELATIVE CONSISTENCY
0 - 4	Very loose	<2	Very soft
4 - 10	Loose	2 - 4	Soft
10 - 30	Medium dense	4 - 8	Medium stiff
30 - 50	Dense	8 - 15	Stiff
Over 50	Very dense	15 - 30	Very stiff
		Over 30	Hard

Smith Island Estuary Restoration Project
Snohomish County, Washington

LEGEND AND NOTES FOR GEOLOGIC PROFILE

October 2013 — 21-1-12405-060

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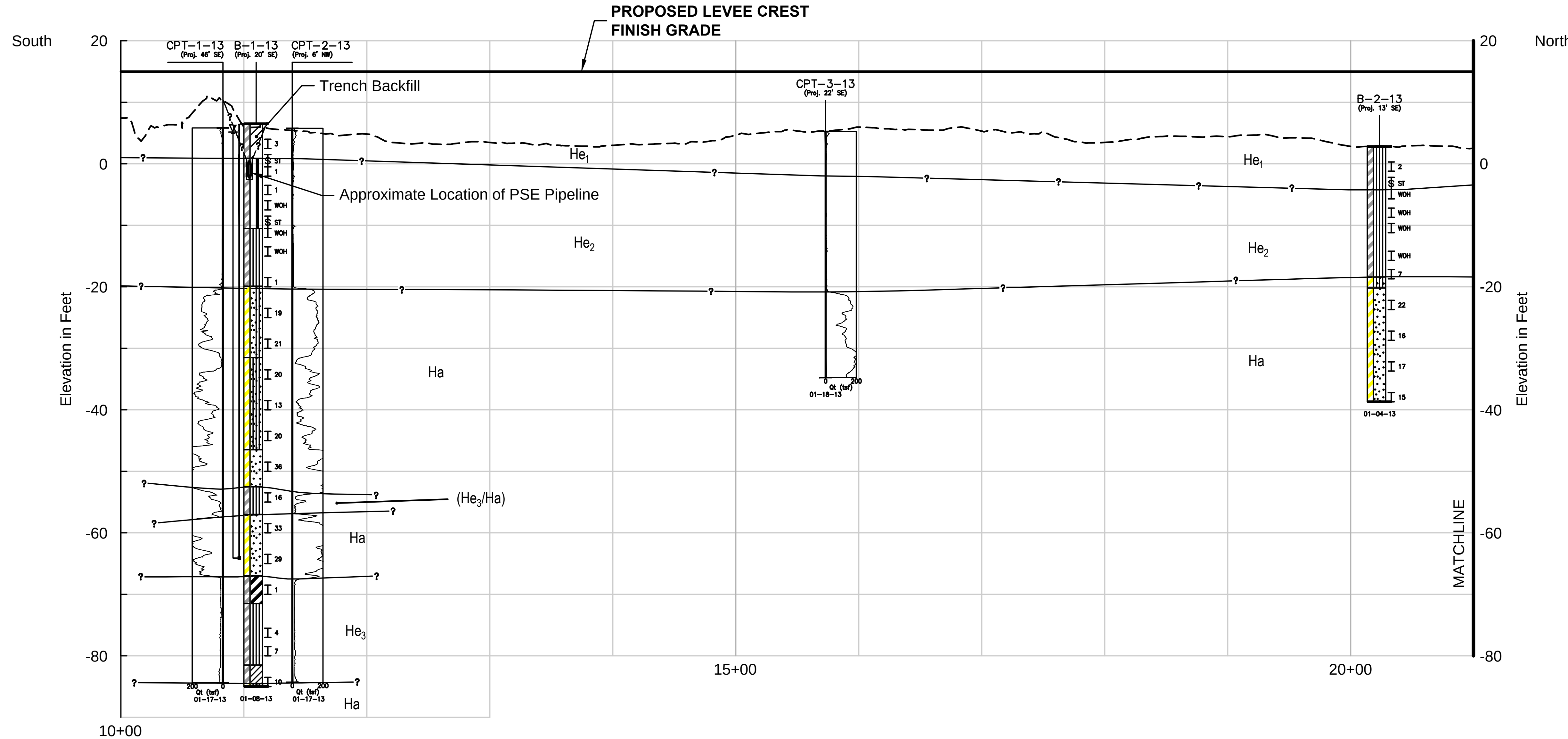
FIG. 3

Filename: I:\WIP\21-1\12405 Smith Island (Snohomish Cty)\CAD\3784-Profile_Alignment.dwg Date: 11-27-2013 Login: SAC



0 100 200
Horizontal Scale in Feet

0 20 40
Vertical Scale in Feet

Vertical Exaggeration = 5X

NOTES

See Figure 3 for legend and notes.

Smith Island Estuary Restoration Project
Snohomish County, Washington

GENERALIZED SUBSURFACE PROFILE ALONG LEVEE ALIGNMENT

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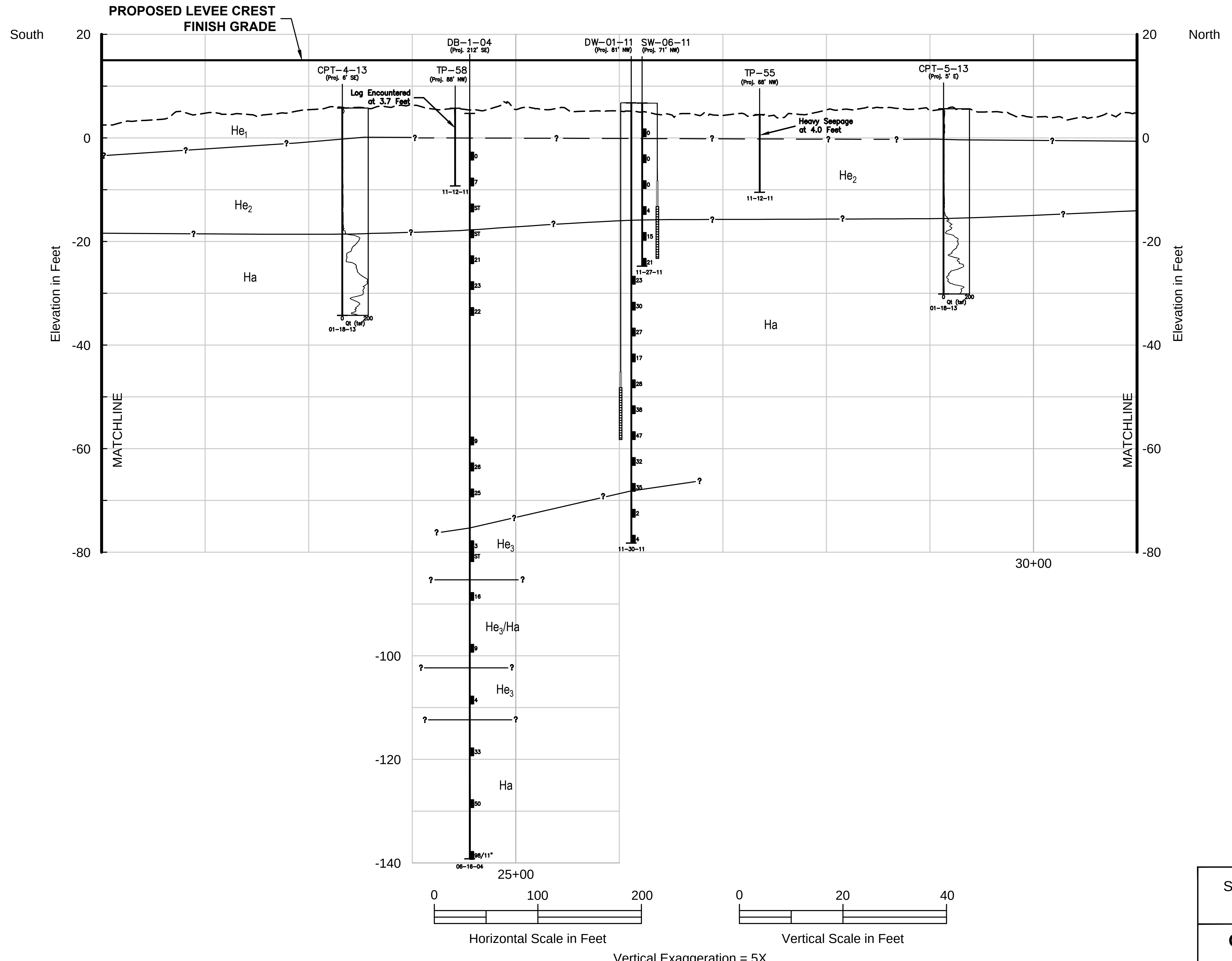
FIG. 4
Sheet 1 of 5

Filename: I:\WP\21-1\12405 Smith Island (Snohomish Cty)\CAD\3784-Profile_Alignment.dwg Date: 11-27-2013 Login: SAC



NOTES

See Figure 3 for legend and notes.

Smith Island Estuary Restoration Project
Snohomish County, Washington

GENERALIZED SUBSURFACE PROFILE ALONG LEVEE ALIGNMENT

October 2013 21-1-12405-060

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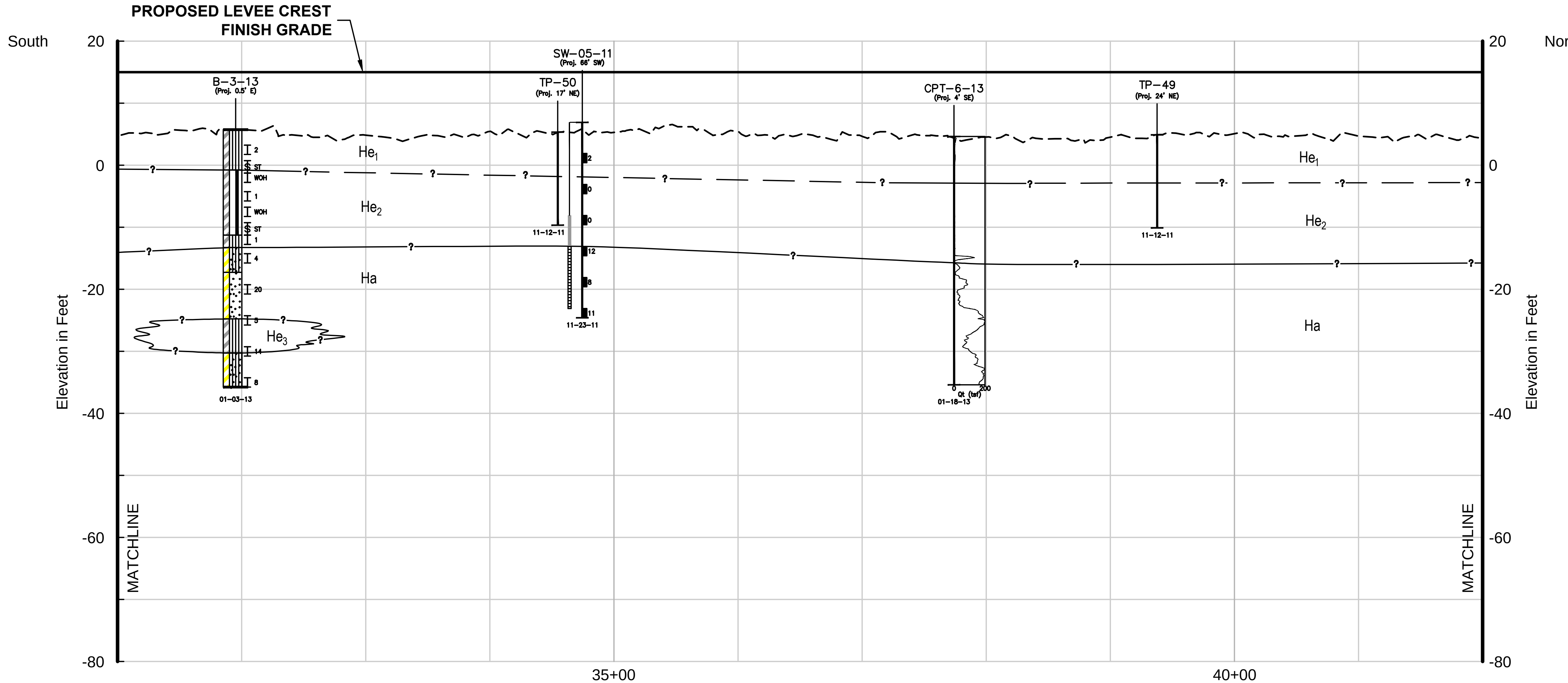
FIG. 4
Sheet 2 of 5

Filename: I:\WP\21-1\12405 Smith Island (Snohomish Cty)\CAD\3784-Profile_Alignment.dwg Date: 11-27-2013 Login: SAC



0 100 200

Horizontal Scale in Feet

0 20 40

Vertical Scale in Feet

Vertical Exaggeration = 5X

NOTES

See Figure 3 for legend and notes.

Smith Island Estuary Restoration Project
Snohomish County, Washington

GENERALIZED SUBSURFACE PROFILE ALONG LEVEE ALIGNMENT

October 2013 21-1-12405-060

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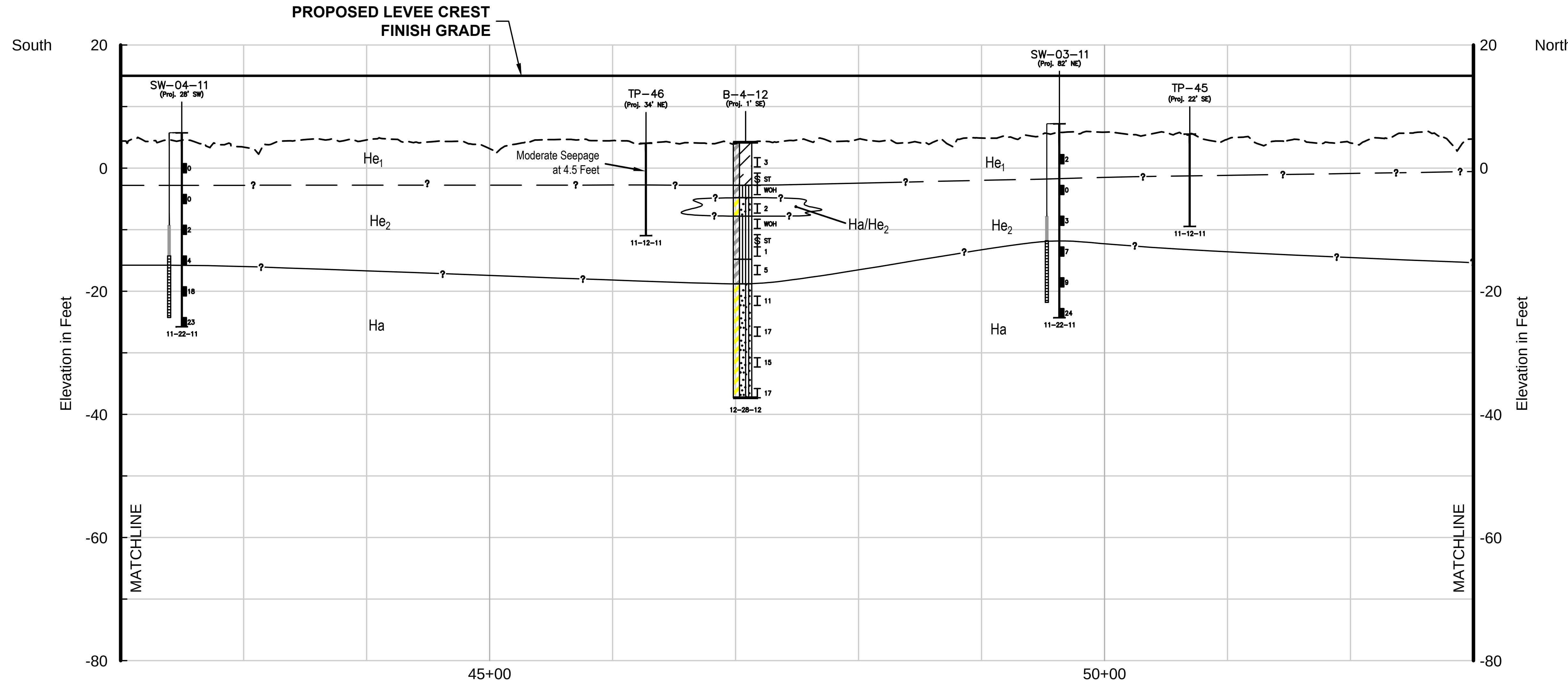
FIG. 4
Sheet 3 of 5

Filename: I:\WIP\21-1\12405 Smith Island (Snohomish Cty)\CAD\3784-Profile_Alignment.dwg Date: 11-27-2013 Login: SAC



0 100 200
Horizontal Scale in Feet

0 20 40
Vertical Scale in Feet

Vertical Exaggeration = 5X

NOTES

See Figure 3 for legend and notes.

Smith Island Estuary Restoration Project
Snohomish County, Washington

GENERALIZED SUBSURFACE PROFILE ALONG LEVEE ALIGNMENT

October 2013 21-1-12405-060

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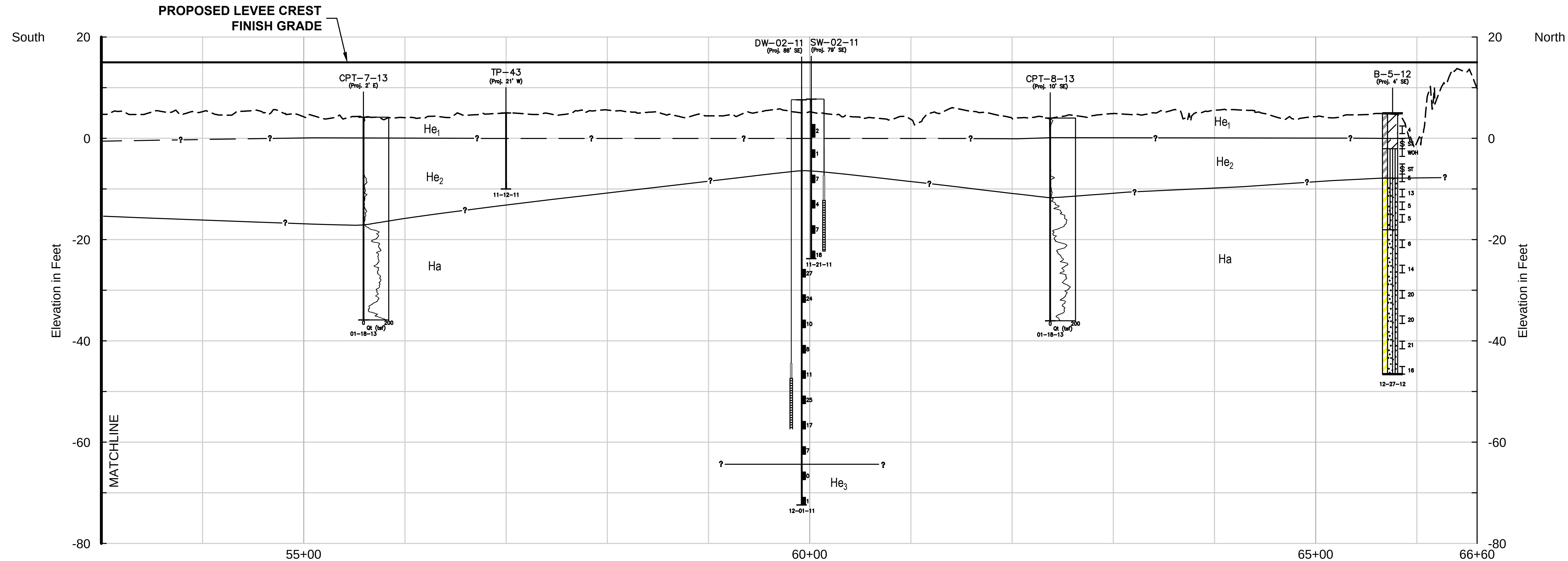
FIG. 4
Sheet 4 of 5

Filename: I:\WP\21-1\12405 Smith Island (Snohomish Cty)\CAD\3784-Profile_Alignment.dwg Date: 11-27-2013 Login: SAC



Horizontal Scale in Feet

Vertical Scale in Feet

Vertical Exaggeration = 5X

NOTES

See Figure 3 for legend and notes.

Smith Island Estuary Restoration Project
Snohomish County, Washington

GENERALIZED SUBSURFACE PROFILE ALONG LEVEE ALIGNMENT

October 2013 21-1-12405-060

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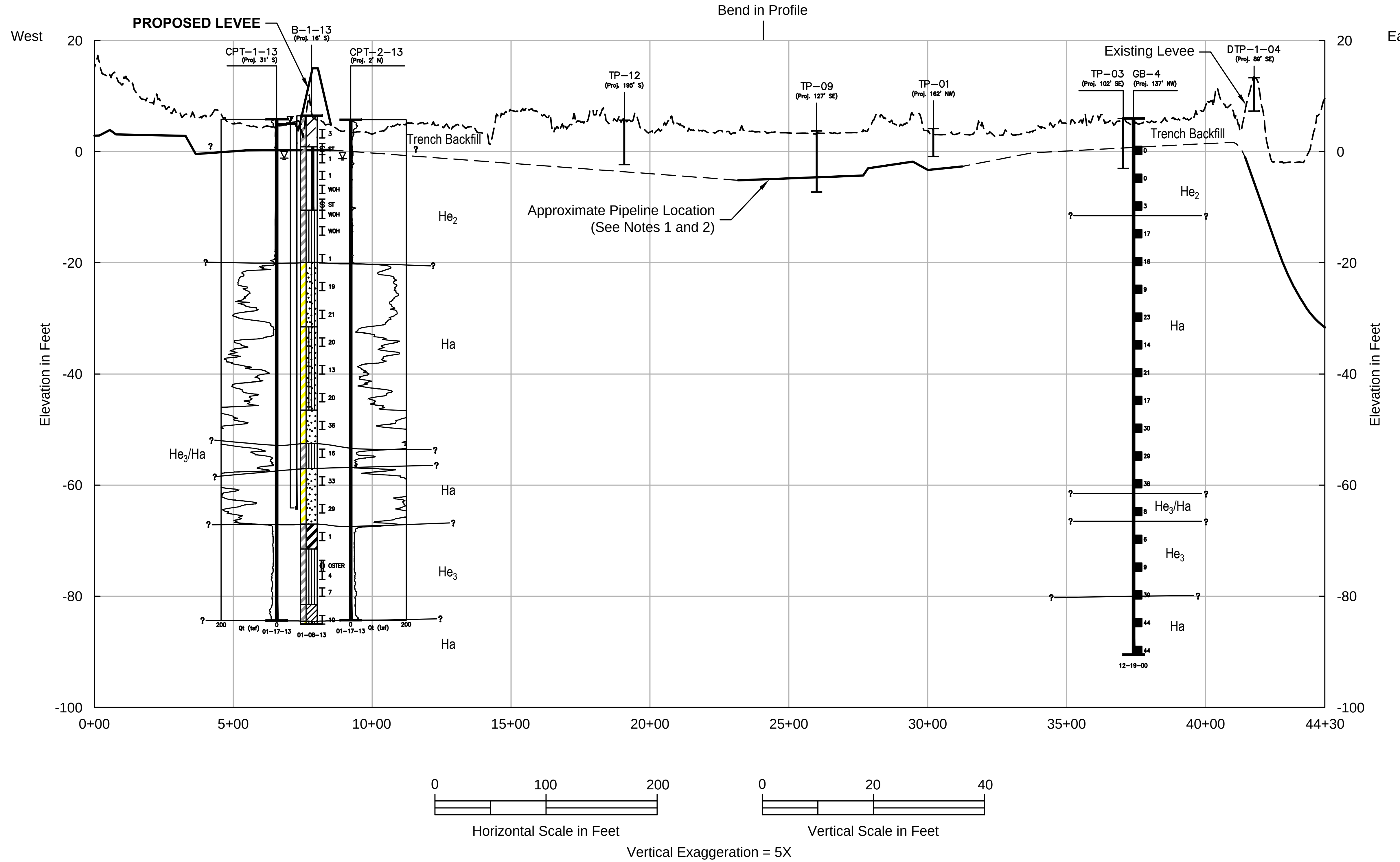
FIG. 4
Sheet 5 of 5

Filename: I:\WIP\21-1\12405 Smith Island (Snohomish Cty)\CAD\3784-Profile_Alignment.dwg Date: 11-27-2013 Login: SAC



NOTES

1. Approximate pipeline location has been adapted from "Northwest Pipeline Corporation, 16 inch Everett Delta Lateral Project" drawings "Site Plan" and "Road Crossing Details" by Williams Gas Pipeline, dated 03-23-2004, and from "Everett Delta Lateral Project, Union, Steamboat and Ebey Slough, Proposed Directional Drill" by Northwest Pipeline Corporation, Willbros Engineers, Inc. dated 11-20-2000.

2. Pipeline between stations 6+11 to 23+17 and 31+24 to 41+05 has been inferred.

3. Pipeline crosses proposed levee at oblique angle. Actual levee slide slopes are at an angle of 3 Horizontal to 1 Vertical (3H:1V).

4. See Figure 3 for legend and additional notes.

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Snohomish County, Washington

GENERALIZED SUBSURFACE PROFILE ALONG PSE PIPELINE

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FIG. 5

Filename: I:\WIP\21-1\12405 Smith Island (Snohomish Cty)\CAD\3784-Profile_Gas Line.dwg Date: 11-27-2013 Login: SAC

0 500 1,000

Scale in Feet

NOTE

Figure adapted from electronic files provided by Otak.

TOP OF Ha LAYER ELEVATION RANGE		
	MIN. ELEVATION (FT)	MAX. ELEVATION (FT)
(yellow)	5	0
(pale green)	0	-5
(light green)	-5	-10
(green)	-10	-15
(dark green)	-15	-20

LEGEND

Ha Encountered in Exploration

Ha Not Encountered in Exploration

Smith Island Estuary Restoration Project
Snohomish County, Washington

Ha LAYER ELEVATION PLAN

October 2013 21-1-12405-060

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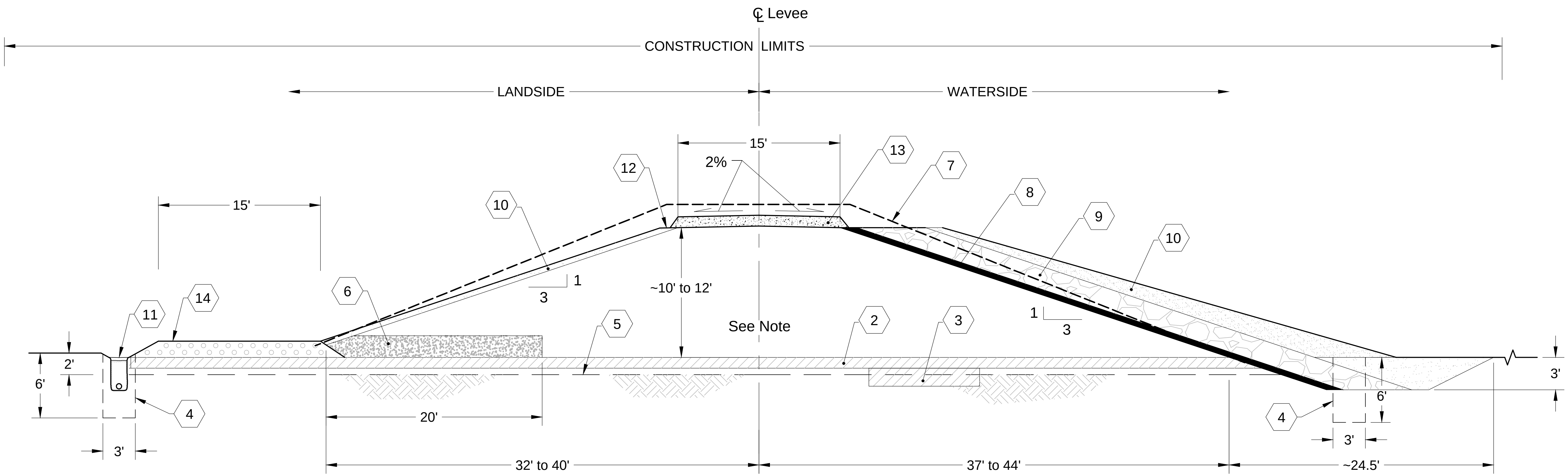
FIG. 6

FIG. 6



TYPICAL LEVEE SECTION DETAIL

LEGEND

1. Construction Limits (30' from Levee Toe)
2. Strip Below Levee Prism (Approx. 10 inches)
3. Subsurface Repair at Locations Selected by Engineer (TBD)
4. Inspection Trenches
5. Basal Reinforcement Geosynthetic (See Note)
6. Horizontal Drainage Layer (2' Thick and Stripping Depth)
7. Pre-Settlement Levee Fill
8. Riprap Bedding/Filter Material
9. Riprap Erosion Protection (~3' Thick)
10. Topsoil (0.5'-1.0' Thick)
11. Drainage Trench
12. Levee Fill Final Grade (Top of Levee at Elevation 15.0')
13. Top of Levee Road Surfacing
14. Permanent Access Road, Toe of Levee (Landside)

NOTE

Levee fill material gradation requirements below.

Sieve Size	% Passing (by Dry Weight)
4 inch	100
3 inch	95 to 100
3/4 inch	85 to 100
US No. 4	70 to 100
US No. 200	Min. 30

Maximum particle size in contact with reinforcement geosynthetic should be 1-1/4 inch or less.

Smith Island Estuary Restoration Project
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CONCEPT LEVEE SECTION

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FIG. 7

Filename: I:\WIP\21-1\12405 Smith Island (Snohomish Cty)\CAD_FIGURES\-060\21-1-12405-060 Fig 7.dwg Date: 11-27-2013 Login: SAC

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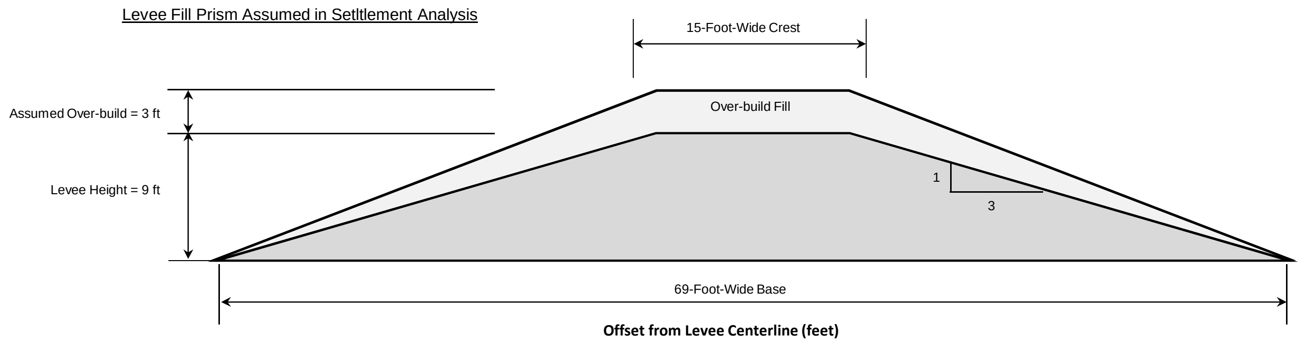

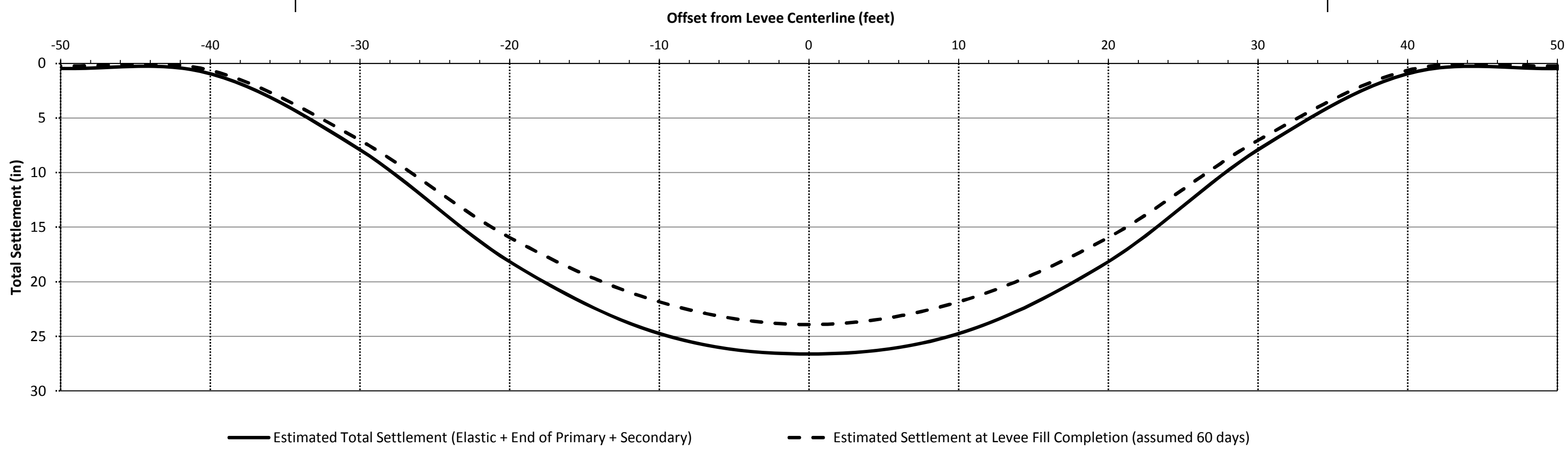

NOTES:

1. Settlement calculations were performed using the computer program Settle3D.
2. Estimated settlement curves presented in this figure were computed by assuming approximate levee fill geometry and subsuface layering. Actual settlement magnitudes and durations could be less or greater. See main report text for discussion.
3. Settlement curves represent estimated settlement of the existing ground surface immediately beneath the levee. Compression of the levee fill material itself is not included.
4. The unit weight of the levee fill was assumed to be 120 pcf.
5. The secondary compression settlement estimate is for one year.

ASSUMED SUBGRADE SOIL CONDITIONS AND PARAMETERS[3]

Soil	Depth (ft)	Total Unit Weight[3] (pcf)	E (ksf)	C_c	C_r	OCR	e_o	C_v (ft^2/day)
He_1	0-4	90	--	1	0.2	6	2.5	1.8
He_2	4-25	105	--	0.25	0.06	2	1	1.4
Ha	25-50	120	1,000	--	--	--	--	--

NOTATION:

- He_1 Very Soft Organic Estuaraine Clayey Silt
- He_2 Very Soft Estuaraine Clayey Silt
- Ha Medium Dense Sand Alluvium
- E Elastic Modulus
- C_c Compression Index
- C_r Recompression Index
- OCR Overconsolidation Ratio
- e_o In Situ Void Ratio
- C_v Coefficient of Consolidation

Smith Island Estuary Restoration Project
Snohomish County, Washington

ESTIMATED SETTLEMENT BENEATH LEVEE SECTION A-A'

October 2013 21-1-12405-060

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FIG. 8

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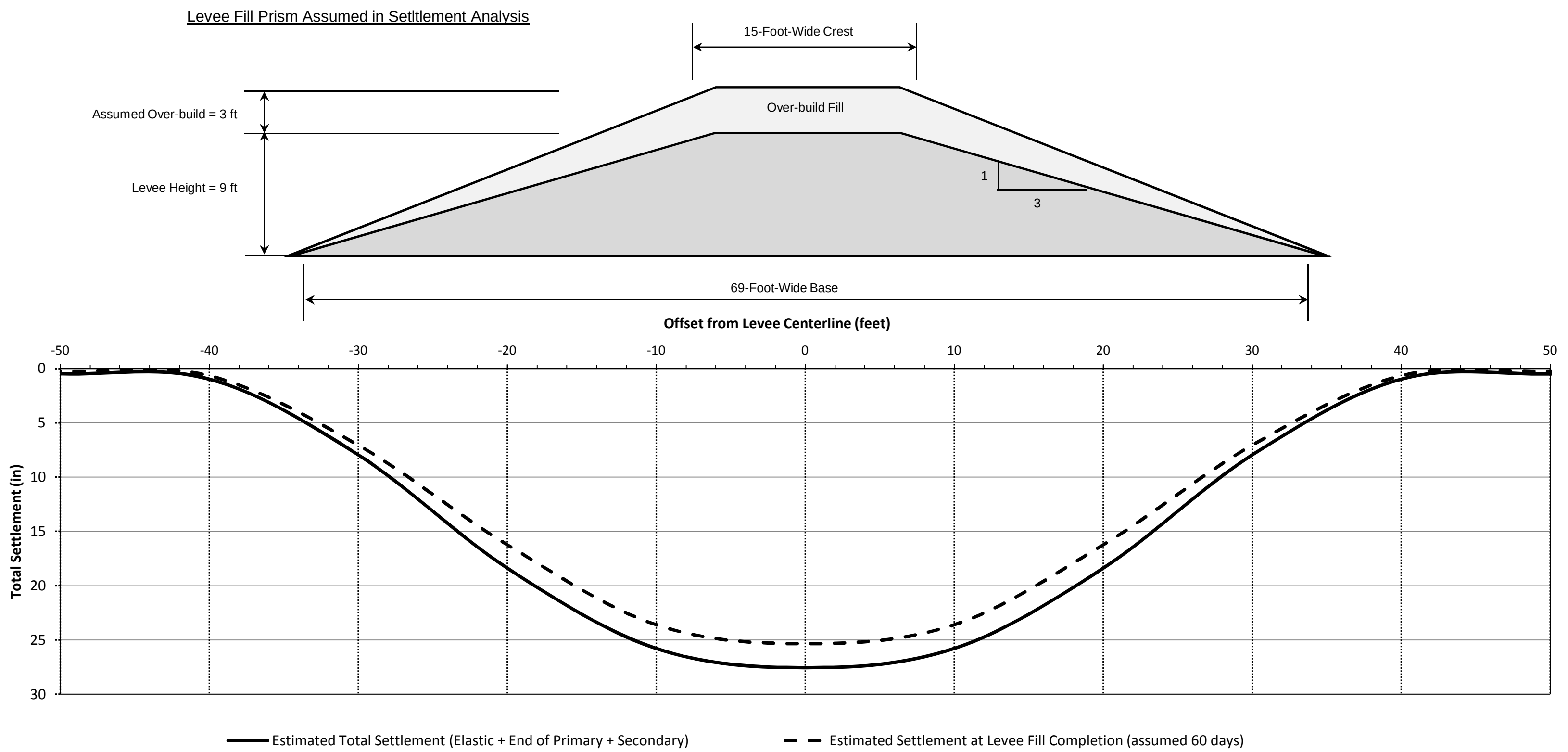

NOTES:

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2. Estimated settlement curves presented in this figure were computed by assuming approximate levee fill geometry and subsuface layering. Actual settlement magnitudes and durations could be less or greater. See main report text for discussion.
3. Settlement curves represent estimated settlement of the existing ground surface immediately beneath the levee. Compression of the levee fill material itself is not included.
4. The unit weight of the levee fill was assumed to be 120 pcf.
5. The secondary compression settlement estimate is for one year.

ASSUMED SUBGRADE SOIL CONDITIONS AND PARAMETERS[3]

Soil	Depth (ft)	Total Unit Weight[3] (pcf)	E (ksf)	C_c	C_r	OCR	e_o	C_v (ft^2/day)
He_1	0-6	90	--	1	0.2	6	2.5	1.8
He_2	6-21	105	--	0.25	0.06	2	1	1.4
Ha	21-50	120	1,000	--	--	--	--	--

NOTATION:

- He_1 Very Soft Organic Estuaraine Clayey Silt
- He_2 Very Soft Estuaraine Clayey Silt
- Ha Medium Dense Sand Alluvium
- E Elastic Modulus
- C_c Compression Index
- C_r Recompression Index
- OCR Overconsolidation Ratio
- e_o In Situ Void Ratio
- C_v Coefficient of Consolidation

Smith Island Estuary Restoration Project
Snohomish County, Washington

ESTIMATED SETTLEMENT BENEATH LEVEE SECTION B-B'

October 2013 21-1-12405-060

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FIG. 9

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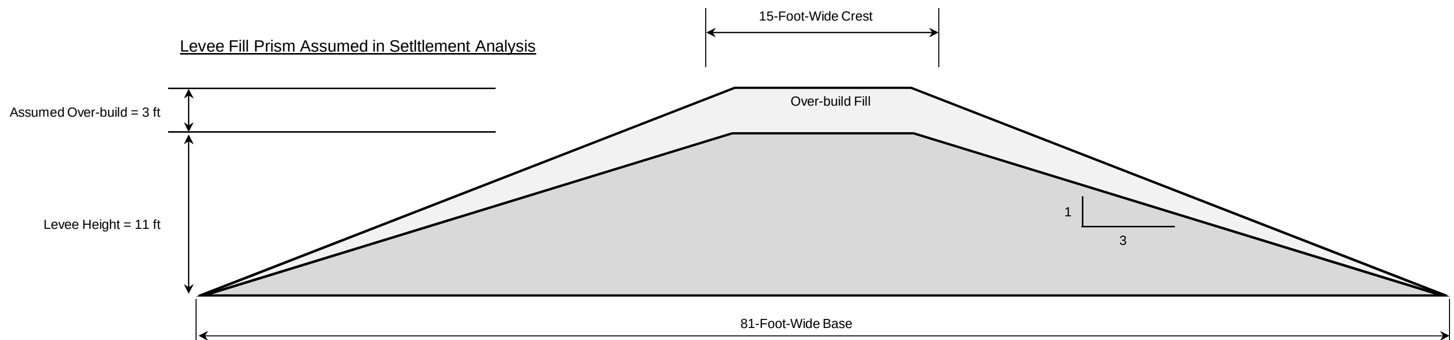

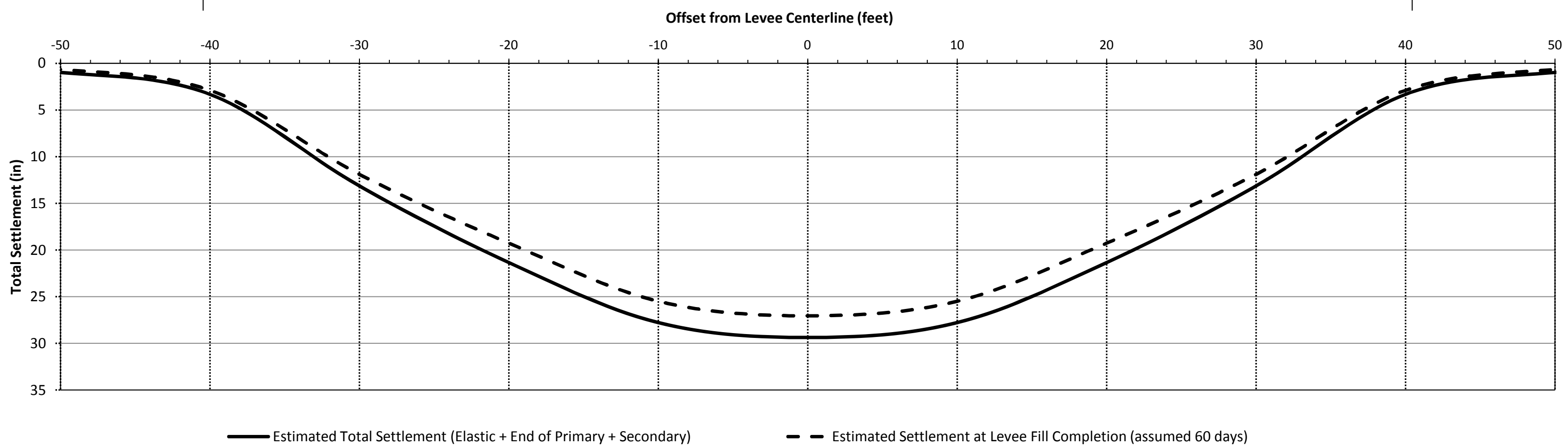

NOTES:

1. Settlement calculations were performed using the computer program Settle3D.
2. Estimated settlement curves presented in this figure were computed by assuming approximate levee fill geometry and subsuface layering. Actual settlement magnitudes and durations could be less or greater. See main report text for discussion.
3. Settlement curves represent estimated settlement of the existing ground surface immediately beneath the levee. Compression of the levee fill material itself is not included.
4. The unit weight of the levee fill was assumed to be 120 pcf.
5. The secondary compression settlement estimate is for one year.

ASSUMED SUBGRADE SOIL CONDITIONS AND PARAMETERS[3]

Soil	Depth (ft)	Total Unit Weight[3] (pcf)	E (ksf)	C_c	C_r	OCR	e_o	C_v (ft^2/day)
He_1	0-9	90	--	1	0.2	6	2.5	1.8
Ha	9-13	120	1,000	--	--	--	--	--
He_2	13-23	105	--	0.25	0.06	2	1	1.4
Ha	23-50	120	1,000	--	--	--	--	--

NOTATION:

- He_1 Very Soft Organic Estuaraine Clayey Silt
- He_2 Very Soft Estuaraine Clayey Silt
- Ha Medium Dense Sand Alluvium
- E Elastic Modulus
- C_c Compression Index
- C_r Recompression Index
- OCR Overconsolidation Ratio
- e_o In Situ Void Ratio
- C_v Coefficient of Consolidation

Smith Island Estuary Restoration Project
Snohomish County, Washington

ESTIMATED SETTLEMENT BENEATH LEVEE SECTION C-C'

October 2013 21-1-12405-060

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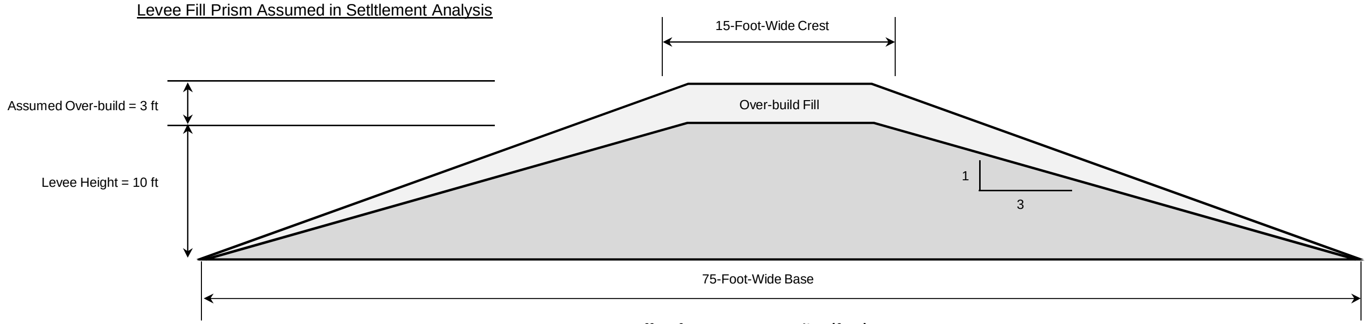
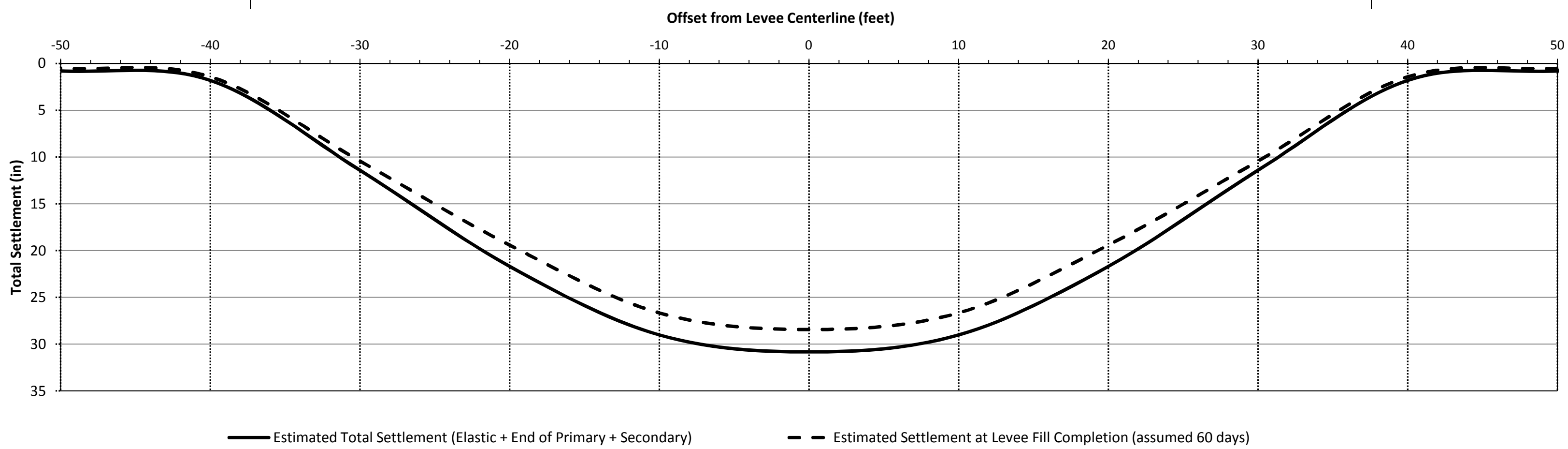
FIG. 10

oth

Levee Fill Prism Assumed in Setltlement Analysis





NOTES:

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2. Estimated settlement curves presented in this figure were computed by assuming approximate levee fill geometry and subsuface layering. Actual settlement magnitudes and durations could be less or greater. See main report text for discussion.
3. Settlement curves represent estimated settlement of the existing ground surface immediately beneath the levee. Compression of the levee fill material itself is not included.
4. The unit weight of the levee fill was assumed to be 120 pcf.
5. The secondary compression settlement estimate is for one year.

ASSUMED SUBGRADE SOIL CONDITIONS AND PARAMETERS[3]

Soil	Depth (ft)	Total Unit Weight[3] (pcf)	E (ksf)	C_c	C_r	OCR	e_o	C_v (ft^2/day)
He_1	0-7	90	--	1	0.2	6	2.5	1.8
He_2	7-23	105	--	0.25	0.06	2	1	1.4
Ha	23-50	120	1,000	--	--	--	--	--

NOTATION:

- He_1 Very Soft Organic Estuaraine Clayey Silt
- He_2 Very Soft Estuaraine Clayey Silt
- Ha Medium Dense Sand Alluvium
- E Elastic Modulus
- C_c Compression Index
- C_r Recompression Index
- OCR Overconsolidation Ratio
- e_o In Situ Void Ratio
- C_v Coefficient of Consolidation

Smith Island Estuary Restoration Project
Snohomish County, Washington

**ESTIMATED SETTLEMENT
BENEATH LEVEE
SECTION D-D'**

October 2013 | 21-1-12405-060

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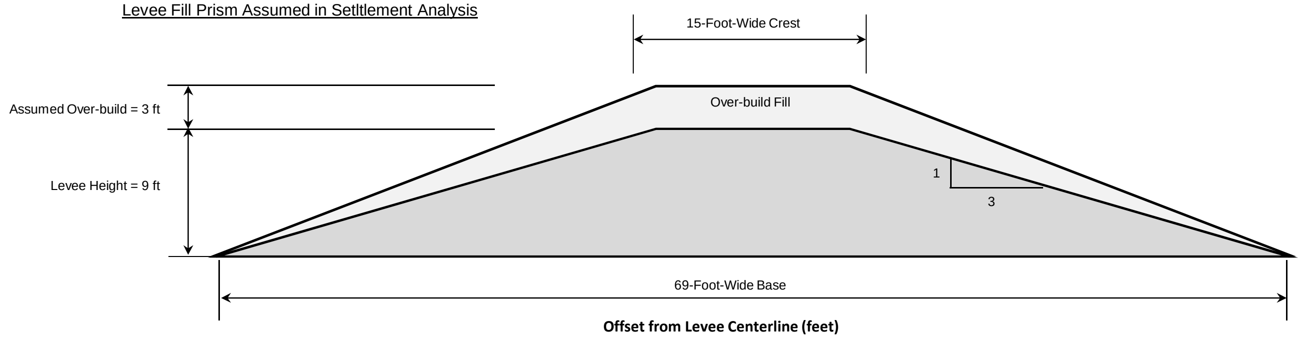
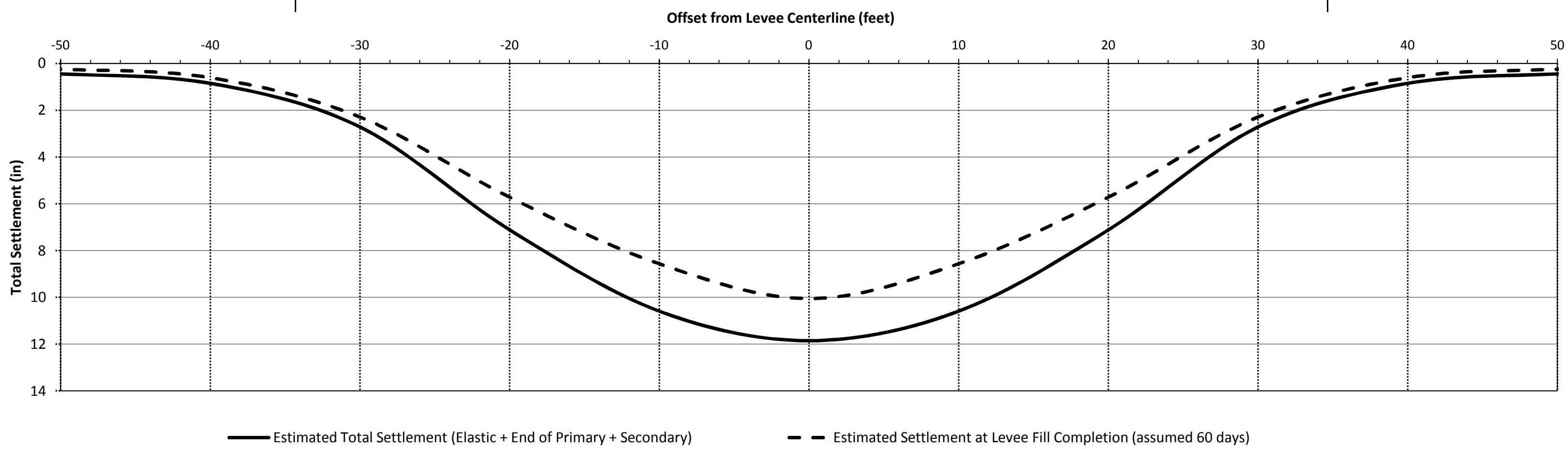
FIG. 11

oth

Levee Fill Prism Assumed in Setltlement Analysis





NOTES:

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2. Estimated settlement curves presented in this figure were computed by assuming approximate levee fill geometry and subsuface layering. Actual settlement magnitudes and durations could be less or greater. See main report text for discussion.
3. Settlement curves represent estimated settlement of the existing ground surface immediately beneath the levee. Compression of the levee fill material itself is not included.
4. The unit weight of the levee fill was assumed to be 120 pcf.
5. The secondary compression settlement estimate is for one year.

ASSUMED SUBGRADE SOIL CONDITIONS AND PARAMETERS[3]

Soil	Depth (ft)	Total Unit Weight[3] (pcf)	E (ksf)	C_c	C_r	OCR	e_o	C_v (ft^2/day)
He_1	0-4	90	--	1	0.2	6	2.5	1.8
He_2	4-25	105	--	0.25	0.06	2	1	1.4
Ha	25-50	120	1,000	--	--	--	--	--

NOTATION:

- He_1 Very Soft Organic Estuaraine Clayey Silt
- He_2 Very Soft Estuaraine Clayey Silt
- Ha Medium Dense Sand Alluvium
- E Elastic Modulus
- C_c Compression Index
- C_r Recompression Index
- OCR Overconsolidation Ratio
- e_o In Situ Void Ratio
- C_v Coefficient of Consolidation

Smith Island Estuary Restoration Project
Snohomish County, Washington

ESTIMATED SETTLEMENT BENEATH LEVEE SECTION A-A' AT BOTTOM OF PSE PIPELINE

October 2013 21-1-12405-060

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. 12

APPENDIX A

SUBSURFACE EXPLORATIONS AND IN SITU TESTING

APPENDIX A

SUBSURFACE EXPLORATIONS AND IN SITU TESTING

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FIGURES

APPENDIX A

SUBSURFACE EXPLORATIONS AND IN SITU TESTING

A.1 INTRODUCTION

The subsurface exploration and in situ testing program consisted of performing borings and Cone Penetration Tests (CPTs) along the proposed setback levee alignment. Five borings and eight CPTs were performed between December 27, 2012, and January 18, 2013. A review of historical records identified 18 borings and 82 test pits previously completed in the project vicinity. The approximate exploration locations are shown in Figure 2 after the main text of this report.

A.2 PREPARATORY WORK

Prior to drilling borings and advancing CPTs, Shannon & Wilson, Inc. performed a site reconnaissance to mark proposed exploration locations and to record relevant field observations, including access and visible utility conflicts. We used a hand-held global positioning system unit to record exploration locations in the field. After marking the exploration locations, we notified the Call Before You Dig Utility Notification Center and subcontracted Applied Professional Services private utility locate service to identify utilities in the vicinity of the marked exploration locations. Prior to drilling B-1-12 and advancing CPT-1-13 and CPT-2-13, we met with Puget Sound Energy to confirm the location of the gas pipeline near 12th Street Northeast.

A.3 SOIL BORINGS

Five soil borings were drilled along the proposed setback levee alignment to evaluate the subsurface conditions and to develop parameters for our engineering studies. The borings were designated B-1-13 through B-3-13, B-4-12, and B-5-12, and extended approximately 41.5 to 91.5 feet below ground surface (bgs). Drilling of the borings occurred between December 27, 2012, and January 8, 2013. Logs of the soil borings are presented as Figures A-2 through A-6.

A.3.1 Drilling Procedures

Shannon & Wilson, Inc. subcontracted with Boart Longyear, Inc. (Boart) of Fife, Washington, to drill and sample the soil borings using a CME 850 track-mounted drill rig. Previous explorations at the site identified arsenic soil contamination near the ground surface. To mitigate the transport of surface contamination into the subsurface, we used a combination of mud rotary and hollow-stem auger (HSA) drilling techniques. During mud-rotary drilling, the augers from the HSA drilling remained in place, creating a seal between the upper arsenic-impacted soil and the recirculating drilling fluid. HSA drilling techniques were used to sample above 10 feet depth, and mud-rotary drilling techniques were employed below 10 feet depth to the bottom of the boring.

HSA drilling techniques consisted of advancing a continuous-flight auger to remove the soil from the borehole. During drilling, rods were placed in the center of the auger and connected to a plug at the bottom of the hole. Once the desired depth was reached, the center plug and rods were pulled out, leaving the augers in place. The hollow augers acted as a casing and held the borehole open. Samples were obtained by lowering a sampler through the hollow stem.

Mud-rotary drilling techniques involved the use of a rotating tri-cone bit lowered through the hollow augers to the bottom of the borehole. Thick drilling mud, consisting of a bentonite slurry, was pumped from a tank at the ground surface, down the center of the drill rods, and out the tri-cone bit. Cuttings were transported from the bottom of the borehole to the surface by the drilling mud flowing between the drill rods and the sides of the borehole/inside of the auger. The cuttings were deposited in a settling tank at the ground surface installed around the top of the auger, and the mud recirculated.

Waste cuttings removed from the borehole during the drilling process were collected and stored in 55-gallon drums for disposal. Cuttings generated from the HSA portion of boreholes were stored in separate drums from cuttings generated using mud-rotary drilling techniques. After environmental testing and analyses, Boart disposed of the mud-rotary cuttings and Emerald Services, Inc. disposed of HSA cuttings.

Borings B-2-13, B-3-13, B-4-12, and B-5-12 were backfilled with bentonite chips after their completion. A vibrating wire piezometer was installed in boring B-1-13 after its completion.

A.3.2 Split-spoon Soil Sampling

Disturbed soil samples were obtained by a split-spoon sampler in conjunction with the Standard Penetration Test (SPT). SPTs were performed in general accordance with ASTM International (ASTM) Designation: D 1586, Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils (ASTM, 2012). The SPT consists of a 2-inch-outside diameter (O.D.), 1.375-inch-inside diameter (I.D.), split-spoon sampler driven 18 inches into the bottom of the borehole with a 140-pound hammer free falling 30 inches. The number of blows required to cause the last 12 inches of penetration is termed the Standard Penetration Resistance

(N-value). Whenever 50 or more blows are required for 6 inches or less of penetration, the test is terminated and the number of blows and corresponding penetration recorded. The N-values are plotted on the boring logs. These values provide an empirical means for evaluating the relative density of granular soil and the relative consistency (stiffness) of cohesive soil. The relative density or consistency as it is related to the SPT N-value is shown in Figure A-1.

SPTs were generally performed every 2.5 feet to a depth of 20 feet and then every 5 feet to the bottom of the hole. Environmental soil samples were collected from the SPT samples at 2.5 feet bgs and either 10 or 12 feet bgs for each borehole. Results from the environmental analytical testing on these samples helped characterize the HSA and mud rotary cuttings for disposal. Split-spoon samples were sealed in plastic jars to preserve moisture, stored in boxes, and returned to our laboratory for further analyses and testing.

A.3.3 Thin-walled Tube Soil Sampling

At select locations, relatively undisturbed samples were obtained using a 30-inch-long, 3-inch-O.D., thin-walled, steel tube sampler (Shelby tube). The direct-push samples were collected in general accordance with ASTM Designation: D 1587, Standard Practice for Thin-Walled Tube Geotechnical Sampling of Soils (ASTM, 2012). Piston samples were collected in general accordance with ASTM D 6519, Standard Practice for Sampling of Soil Using the Hydraulically Operated Stationary Piston Sampler (ASTM, 2012).

For the direct-push method, the Shelby tube is connected to a sampling head that is attached to the drill rods. The tube is slowly pushed by the hydraulic rams of the drill rig into the soil below the bottom of the drill hole and then retracted to retrieve the sample.

After extraction from the drill holes, the samples were examined from the ends of the tube and carefully sealed using plastic lids and tape to preserve the moisture content. These samples were placed in an upright position and transported to our laboratory for further analyses and testing. At the laboratory, each tube sample was stored in an upright position and in a temperature- and humidity-controlled environment. During sample extraction, each sample was pushed out of the tube in the same direction it entered the tube onto a continuously supported tray. The soil sample was classified and logged and then cut into appropriate lengths for additional testing.

A.3.4 Field Classification

A representative from Shannon & Wilson, Inc. was present throughout the boring explorations to observe the drilling and sampling operations, retrieve representative soil samples for subsequent laboratory testing, and to prepare descriptive field logs of the explorations. Boring sample classifications were based on ASTM Designation D2488, Standard Recommended Practice for Description of Soils (Visual-Manual Procedure). The Unified Soil Classification System (USCS), as described in Figure A-1 of this appendix, was used to classify the material encountered.

A.3.5 Vibrating Wire Piezometer (VWP) Installation

A VWP was installed in boring B-1-13 on January 8, 2013. VWPs are used to measure subsurface pore water pressure and estimate groundwater elevation. A reading of the VWP was conducted on March 13, 2013. The vibrating wire installation depth and the interpreted groundwater depth are plotted on the B-1-13 boring log.

The VWP used for the project was a Geokon Model No. 4500S-350. This model has a 350-kilopascal (50 pounds per square inch) pressure range and consists of a vibrating wire pressure transducer contained in stainless steel housing. The VWP is connected to a signal cable that is routed up the borehole to the ground surface. Where present, pore water pressure acts against a low-air-entry filter at one end of the stainless steel housing. Measured values and calibration information are used to calculate the water pressure acting on the VWP.

A.4 CONE PENETRATION TESTS

Shannon & Wilson subcontracted with In Situ Engineering to perform CPT explorations using a track-mounted rig on January 17 and 18, 2013. The work was completed in general accordance with the procedures outlined in ASTM Designation: D5778, Standard Test Method for Electronic Friction Cone and Piezocone Penetration Testing of Soils. The CPT develops a continuous subsurface profile at a particular location, but does not retrieve a soil sample for laboratory testing. The CPTs, designated CPT-1-13 through CPT-8-13, ranged in depth from about 36 to 90 feet bgs. Logs of the CPT probes are presented as Figures A-7 through A-14.

A.4.1 Field Procedures and Equipment

The piezocone apparatus used for the CPT explorations by In Situ Engineering is a Hogentogler system. During the test, steel rods with a cone tip on the end are pushed hydraulically into the soil at a relatively constant rate of approximately 2 centimeters (cm) per second (0.8 inches per second). Readings are recorded every 5 cm (2 inches). The cone tip is connected to a stationary friction sleeve and has a cross sectional area of 10 cm^2 (1.6 in^2), a surface area of 15 cm^2 (2.3 in^2), and an angle of 30 degrees from the probe axis. The area ratio, the ratio of the water pressure load cell to the projected cone tip area, is 0.8. This ratio is used to correct the measured water pressure from the load cell to obtain an estimate of the actual water pressure acting on the cone tip. The stationary friction sleeve has the same diameter as the cone tip but a surface area of 150 cm^2 (23 in^2). The cone tip and friction sleeve assembly is about 50 cm (20 inches) long and pushed into the ground by an assemblage of connected rods, about 1 meter long each. An electronic cable is prestrung through the rods. This cable provides power to the instruments and communication between the instrument and a computer. The system is powered by a 12-volt deep cycle battery, which is recharged periodically.

The tip, filter element, and friction sleeve assemblies were disassembled and cleaned between holes. Testing was terminated when the penetrometer reached the requested testing depth below ground surface.

A.4.2 Testing Procedures

As the piezocone apparatus penetrates the soil, measurements of tip resistance, sleeve friction, pore pressure, and inclination are electrically transmitted through the electronic cable to the ground surface and then displayed and recorded on a portable computer. The cone has a tip capacity of 10 tons or approximately 1,000 tons per square foot (tsf). Tip measurement accuracy is approximately plus or minus 0.1 tsf. The friction sleeve has a capacity of 10 tsf with a measurement accuracy of plus or minus 0.01 tsf. The cone is a subtraction type cone, which senses the tip resistance on one set of strain gauges and senses tip resistance plus side friction on another set of strain gauges. The frictional reading is determined by electronically subtracting the tip reading from the combined reading. The pore pressure sensor has a capacity of 500 pounds per square foot with a measurement accuracy of plus or minus 0.1 pound per square inch. The inclinometer has a full range capability of 10 degrees with a measurement accuracy of approximately 0.1 degree.

Six pore pressure dissipation tests were conducted in CPTs C-1-13 through C-4-13 at depths ranging from 4½ to 38½ feet bgs. During cone penetration, excess pore pressures may develop. The dissipation tests are performed during a pause in the cone advancement and the dissipation of any excess pore pressure with time is measured and recorded. Dissipation data can then be plotted onto a dissipation curve consisting of pore water pressure (u) verses time (t). The shapes of dissipation curves are useful in evaluating soil type, drainage and in situ static water. The shape of the dissipation curve and the time of dissipation can be used to estimate the coefficient of consolidation and the horizontal permeability coefficient.

Shannon & Wilson, Inc. (S&W), uses a soil classification system modified from the Unified Soil Classification System (USCS). Elements of the USCS and other definitions are provided on this and the following page. Soil descriptions are based on visual-manual procedures (ASTM D 2488-93) unless otherwise noted.

S&W CLASSIFICATION OF SOIL CONSTITUENTS

- MAJOR constituents compose more than 50 percent, by weight, of the soil. Major consituents are capitalized (i.e., SAND).
- Minor constituents compose 12 to 50 percent of the soil and precede the major constituents (i.e., silty SAND). Minor constituents preceded by "slightly" compose 5 to 12 percent of the soil (i.e., slightly silty SAND).
- Trace constituents compose 0 to 5 percent of the soil (i.e., slightly silty SAND, trace of gravel).

MOISTURE CONTENT DEFINITIONS

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

ABBREVIATIONS

ATD	At Time of Drilling
Elev.	Elevation
ft	feet
FeO	Iron Oxide
MgO	Magnesium Oxide
HSA	Hollow Stem Auger
ID	Inside Diameter
in	inches
lbs	pounds
Mon.	Monument cover
N	Blows for last two 6-inch increments
NA	Not applicable or not available
NP	Non plastic
OD	Outside diameter
OVA	Organic vapor analyzer
PID	Photo-ionization detector
ppm	parts per million
PVC	Polyvinyl Chloride
SS	Split spoon sampler
SPT	Standard penetration test
USC	Unified soil classification
WOH	Weight of hammer
WOR	Weight of drill rods
WLI	Water level indicator

GRAIN SIZE DEFINITION

DESCRIPTION	SIEVE NUMBER AND/OR SIZE
FINES	< #200 (0.08 mm)
SAND*	
- Fine	#200 to #40 (0.08 to 0.4 mm)
- Medium	#40 to #10 (0.4 to 2 mm)
- Coarse	#10 to #4 (2 to 5 mm)
GRAVEL*	
- Fine	#4 to 3/4 inch (5 to 19 mm)
- Coarse	3/4 to 3 inches (19 to 76 mm)
COBBLES	3 to 12 inches (76 to 305 mm)
BOULDERS	> 12 inches (305 mm)

* Unless otherwise noted, sand and gravel, when present, range from fine to coarse in grain size.

RELATIVE DENSITY / CONSISTENCY

COARSE-GRAINED SOILS		FINE-GRAINED SOILS	
N, SPT, BLOWS/FT.	RELATIVE DENSITY	N, SPT, BLOWS/FT.	RELATIVE CONSISTENCY
0 - 4	Very loose	Under 2	Very soft
4 - 10	Loose	2 - 4	Soft
10 - 30	Medium dense	4 - 8	Medium stiff
30 - 50	Dense	8 - 15	Stiff
Over 50	Very dense	15 - 30	Very stiff
		Over 30	Hard

WELL AND OTHER SYMBOLS

Bent. Cement Grout	Surface Cement Seal
Bentonite Grout	Asphalt or Cap
Bentonite Chips	Slough
Silica Sand	Bedrock
PVC Screen	
Vibrating Wire	

Smith Island Site Restoration
Snohomish County, Washington

SOIL CLASSIFICATION AND LOG KEY

October 2013 | 21-1-12405-060

SHANNON & WILSON, INC.
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FIG. A-1
Sheet 1 of 2

BORING_CLASS1 21-12405.GPJ SWNEW.GDT 12/3/13

UNIFIED SOIL CLASSIFICATION SYSTEM (USCS)
(From ASTM D 2487-98 & 2488-93)

MAJOR DIVISIONS			GROUP/GRAPHIC SYMBOL	TYPICAL DESCRIPTION
COARSE-GRAINED SOILS *(more than 50% retained on No. 200 sieve)*	Gravels *(more than 50% of coarse fraction retained on No. 4 sieve)*	Clean Gravels *(less than 5% fines)*	GW	Well-graded gravels, gravels, gravel/sand mixtures, little or no fines.
			GP	Poorly graded gravels, gravel-sand mixtures, little or no fines
		Gravels with Fines *(more than 12% fines)*	GM	Silty gravels, gravel-sand-silt mixtures
			GC	Clayey gravels, gravel-sand-clay mixtures
	Sands *(50% or more of coarse fraction passes the No. 4 sieve)*	Clean Sands *(less than 5% fines)*	SW	Well-graded sands, gravelly sands, little or no fines
			SP	Poorly graded sand, gravelly sands, little or no fines
		Sands with Fines *(more than 12% fines)*	SM	Silty sands, sand-silt mixtures
			SC	Clayey sands, sand-clay mixtures
FINE-GRAINED SOILS *(50% or more passes the No. 200 sieve)*	Silts and Clays *(liquid limit less than 50)*	Inorganic	ML	Inorganic silts of low to medium plasticity, rock flour, sandy silts, gravelly silts, or clayey silts with slight plasticity
			CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
		Organic	OL	Organic silts and organic silty clays of low plasticity
	Silts and Clays *(liquid limit 50 or more)*	Inorganic	MH	Inorganic silts, micaceous or diatomaceous fine sands or silty soils, elastic silt
			CH	Inorganic clays or medium to high plasticity, sandy fat clay, or gravelly fat clay
		Organic	OH	Organic clays of medium to high plasticity, organic silts
HIGHLY-ORGANIC SOILS	Primarily organic matter, dark in color, and organic odor		PT	Peat, humus, swamp soils with high organic content (see ASTM D 4427)

NOTE: No. 4 size = 5 mm; No. 200 size = 0.075 mm

NOTES

1. Dual symbols *(symbols separated by a hyphen, i.e., SP-SM, slightly silty fine SAND)* are used for soils with between 5% and 12% fines or when the liquid limit and plasticity index values plot in the CL-ML area of the plasticity chart.

2. Borderline symbols *(symbols separated by a slash, i.e., CL/ML, silty CLAY/clayey SILT; GW/SW, sandy GRAVEL/gravelly SAND)* indicate that the soil may fall into one of two possible basic groups.

Smith Island Site Restoration
Snohomish County, Washington

SOIL CLASSIFICATION AND LOG KEY

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FIG. A-1
Sheet 2 of 2

Total Depth:	91.5 ft.	Northing:	~ 370,454 ft.	Drilling Method:	HSA and Mud Rotary	Hole Diam.:	4 in.
Top Elevation:	~	Easting:	~ 1,313,160 ft.	Drilling Company:	Boart Longyear	Rod Diam.:	NWJ
Vert. Datum:		Station:	~	Drill Rig Equipment:	CME 850	Hammer Type:	Automatic
Horiz. Datum:	NAD 83 WA STP N	Offset:	~	Other Comments:			

SOIL DESCRIPTION

Refer to the report text for a proper understanding of the subsurface materials and drilling methods. The stratification lines indicated below represent the approximate boundaries between material types, and the transition may be gradual.

Soft, brown, organic SILT and slightly clayey to clayey SILT, trace of fine sand; moist; abundant dark brown and orange oxide rinds and stains along fractures and in pockets, scattered to abundant organics; (He_1) OH/MH.

5.6

Very soft, gray, clayey SILT; wet; abundant organics, locally scattered organics, slight sulfur odor, organic silt layers; (He_2) MH.
- Oxide-stained blocky pockets above 7 feet.
- Abundant interwoven roots and fibrous organics in sample S-5.
- About 1-inch-thick slightly silty sand layer at about 16.2 feet.

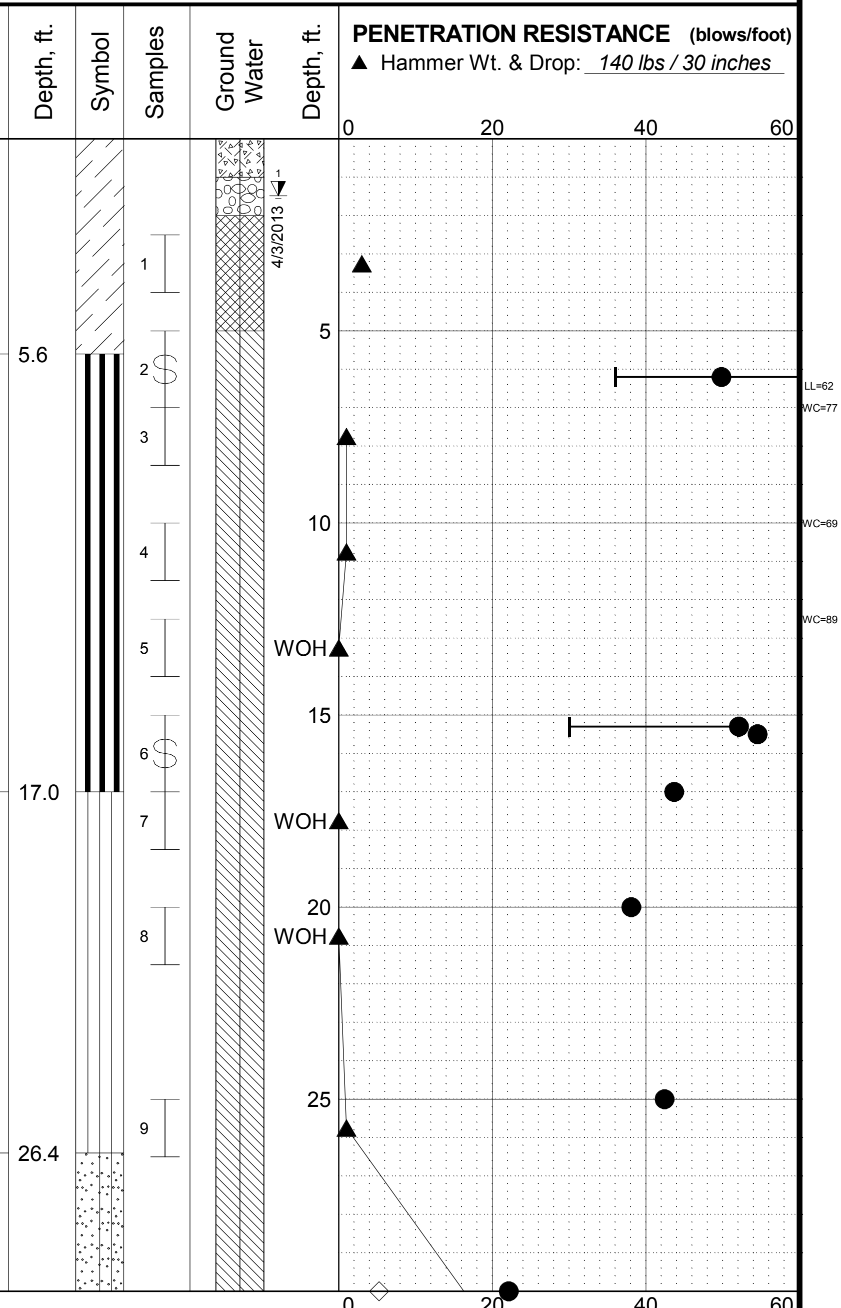
17.0

Very soft, gray, trace of fine sand to slightly fine sandy, slightly clayey SILT; wet; scattered organics; (He_2) ML.

26.4

Medium dense, gray, trace of silt to slightly silty SAND; wet; locally trace of fine gravel, trace to scattered organics; (Ha) SP-SM/SP.

CONTINUED NEXT SHEET



LEGEND

- * Sample Not Recovered
- 2.0" O.D. Split Spoon Sample
- 3" O.D. Thin-Walled Tube
- 3.0" O.D. Osterberg Sample
- Piezometer Screen and Sand Filter
- Bentonite-Cement Grout
- Bentonite Chips/Pellets
- Bentonite Grout
- Ground Water Level in VWP

◇ % Fines (<0.075mm)
● % Water Content
Plastic Limit |—●—| Liquid Limit
Natural Water Content

NOTES

1. Refer to KEY for explanation of symbols, codes, abbreviations and definitions.
2. Groundwater level, if indicated above, is for the date specified and may vary.
3. USCS designation is based on visual-manual classification and selected lab testing.
4. The hole location was measured from existing site features and should be considered approximate.

Smith Island Site Restoration
Snohomish County, Washington

LOG OF BORING B-1-13

October 2013 21-1-12405-060

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. A-2
Sheet 1 of 4

REV 3

Total Depth:	*91.5 ft.*	Northing:	*~ 370,454 ft.*	Drilling Method:	*HSA and Mud Rotary*	Hole Diam.:	*4 in.*
Top Elevation:	*~*	Easting:	*~ 1,313,160 ft.*	Drilling Company:	*Boart Longyear*	Rod Diam.:	*NWJ*
Vert. Datum:		Station:	*~*	Drill Rig Equipment:	*CME 850*	Hammer Type:	*Automatic*
Horiz. Datum:	*NAD 83 WA STP N*	Offset:	*~*	Other Comments:			

SOIL DESCRIPTION

Refer to the report text for a proper understanding of the subsurface materials and drilling methods. The stratification lines indicated below represent the approximate boundaries between material types, and the transition may be gradual.

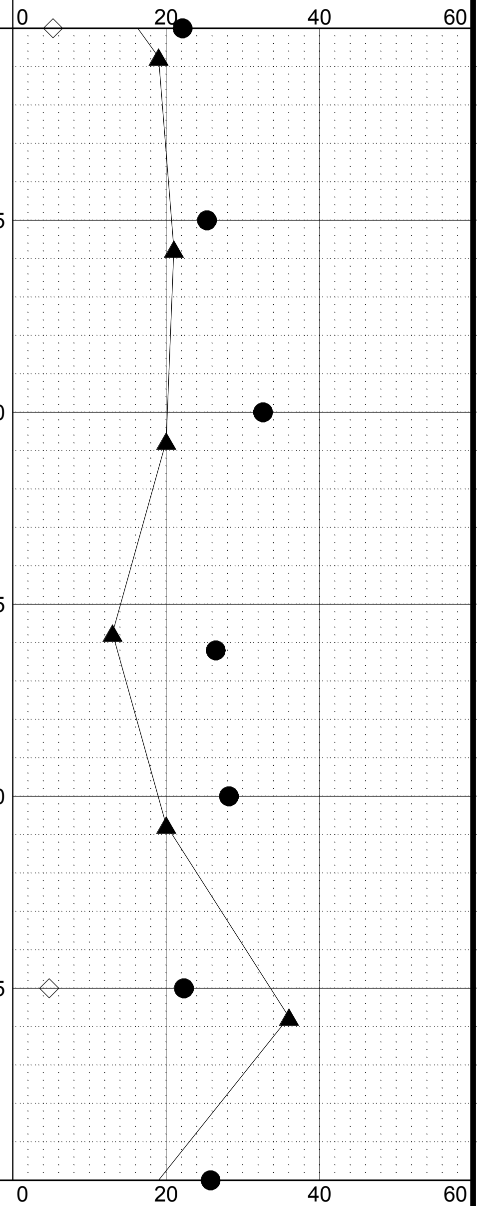
Depth, ft. | Symbol | Samples | Ground Water | Depth, ft.

PENETRATION RESISTANCE (blows/foot)

▲ Hammer Wt. & Drop: *140 lbs / 30 inches*

Depth, ft.	Soil Description
38.0	Interbedded, medium dense, gray to gray-brown, trace of silt to silty, fine to medium SAND and slightly fine sandy to fine sandy SILT, trace of clay; moist to wet; scattered organics, trace to scattered shell fragments; (Ha/He_3) SM/ML/SP-SM/SP.
	- Laminated at about 50 feet.
53.0	Dense, gray, fine to medium SAND, trace of silt; wet; (Ha) SP.
59.0	

Samples: 10, 11, 12, 13, 14, 15



CONTINUED NEXT SHEET

LEGEND

- * Sample Not Recovered
- 2.0" O.D. Split Spoon Sample
- 3" O.D. Thin-Walled Tube
- 3.0" O.D. Osterberg Sample
- Piezometer Screen and Sand Filter
- Bentonite-Cement Grout
- Bentonite Chips/Pellets
- Bentonite Grout
- Ground Water Level in VWP

◇ % Fines (<0.075mm)

● % Water Content

Plastic Limit ├─●─┤ Liquid Limit

Natural Water Content

NOTES

1. Refer to KEY for explanation of symbols, codes, abbreviations and definitions.
2. Groundwater level, if indicated above, is for the date specified and may vary.
3. USCS designation is based on visual-manual classification and selected lab testing.
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Smith Island Site Restoration
Snohomish County, Washington

LOG OF BORING B-1-13

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SHANNON & WILSON, INC.
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FIG. A-2
Sheet 2 of 4

REV 3

Total Depth:	91.5 ft.	Northing:	~ 370,454 ft.	Drilling Method:	HSA and Mud Rotary	Hole Diam.:	4 in.
Top Elevation:	~	Easting:	~ 1,313,160 ft.	Drilling Company:	Boart Longyear	Rod Diam.:	NWJ
Vert. Datum:		Station:	~	Drill Rig Equipment:	CME 850	Hammer Type:	Automatic
Horiz. Datum:	NAD 83 WA STP N	Offset:	~	Other Comments:			

SOIL DESCRIPTION

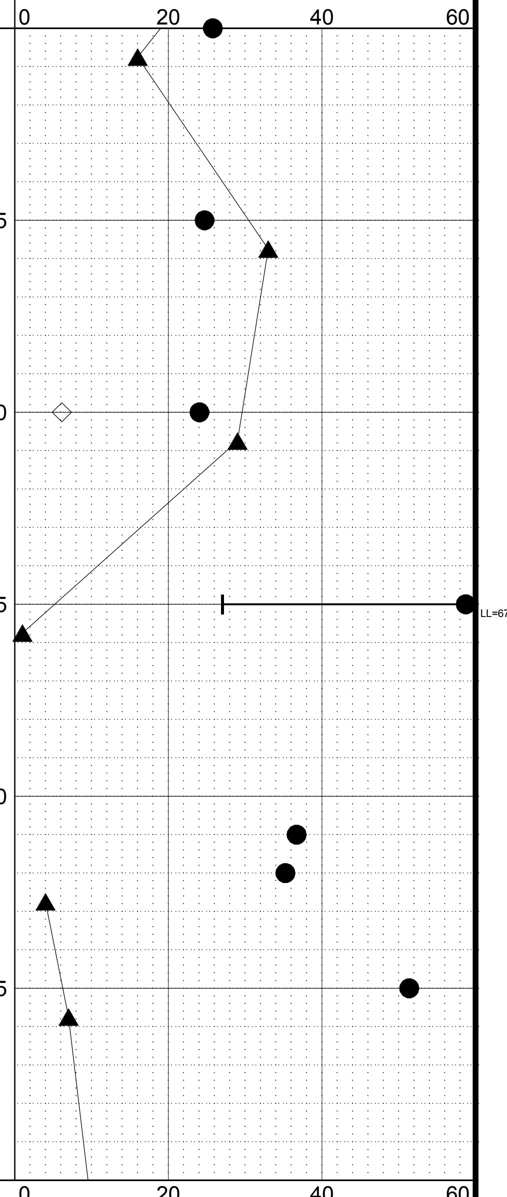
Refer to the report text for a proper understanding of the subsurface materials and drilling methods. The stratification lines indicated below represent the approximate boundaries between material types, and the transition may be gradual.

Soil Description	Depth, ft.	Samples
Interbedded, medium dense, gray, fine sandy SILT, silty, fine SAND and very stiff, trace to slightly fine sandy, slightly clayey SILT; wet; trace of organics; (He_3) ML/SM.		16
Medium dense to dense, gray, trace of silt to slightly silty, fine to medium SAND; wet; trace of organics, scattered shell fragments; (Ha) SP/SP-SM.	63.5	17, 18
Very soft, gray, silty CLAY; wet; scattered organics; (He_3) CH.	73.5	19
Medium stiff, gray, slightly clayey to clayey SILT, trace of fine sand; wet; locally slightly fine sandy, trace to abundant organics; (He_3) ML.	78.0	20, 21, 22
Interbedded, stiff, gray and brown, silty CLAY and organic SILT; wet; abundant fibrous	88.0	

CONTINUED NEXT SHEET

PENETRATION RESISTANCE (blows/foot)

▲ Hammer Wt. & Drop: 140 lbs / 30 inches



◇ % Fines (<0.075mm)
● % Water Content
Plastic Limit ├─●─┤ Liquid Limit
Natural Water Content

LEGEND

- * Sample Not Recovered
- 2.0" O.D. Split Spoon Sample
- 3" O.D. Thin-Walled Tube
- 3.0" O.D. Osterberg Sample
- Piezometer Screen and Sand Filter
- Bentonite-Cement Grout
- Bentonite Chips/Pellets
- Bentonite Grout
- Ground Water Level in VWP

NOTES

1. Refer to KEY for explanation of symbols, codes, abbreviations and definitions.
2. Groundwater level, if indicated above, is for the date specified and may vary.
3. USCS designation is based on visual-manual classification and selected lab testing.
4. The hole location was measured from existing site features and should be considered approximate.

Smith Island Site Restoration
Snohomish County, Washington

LOG OF BORING B-1-13

October 2013 21-1-12405-060

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. A-2
Sheet 3 of 4

REV 3

Total Depth:	*91.5 ft.*	Northing:	*~ 370,454 ft.*	Drilling Method:	*HSA and Mud Rotary*	Hole Diam.:	*4 in.*
Top Elevation:	*~*	Easting:	*~ 1,313,160 ft.*	Drilling Company:	*Boart Longyear*	Rod Diam.:	*NWJ*
Vert. Datum:		Station:	*~*	Drill Rig Equipment:	*CME 850*	Hammer Type:	*Automatic*
Horiz. Datum:	*NAD 83 WA STP N*	Offset:	*~*	Other Comments:			

SOIL DESCRIPTION

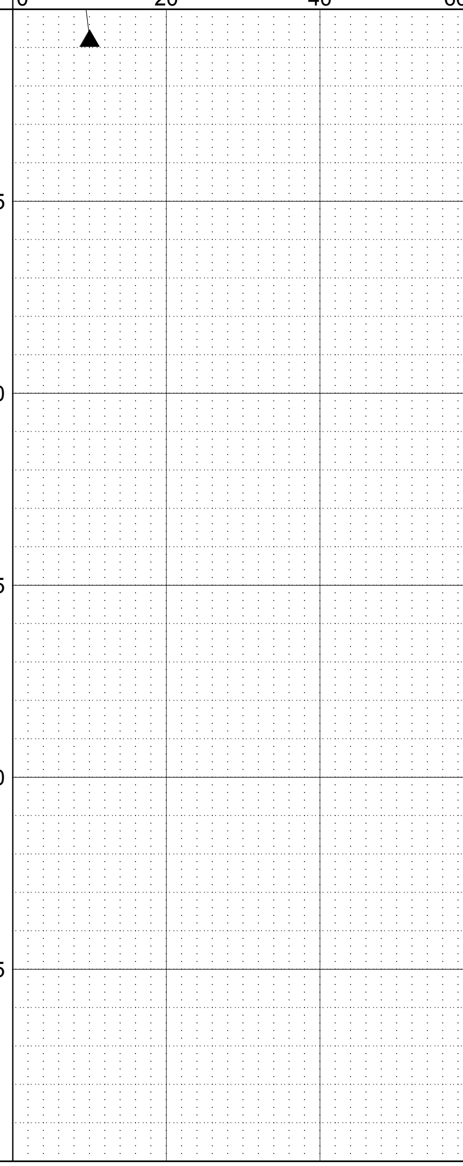
Refer to the report text for a proper understanding of the subsurface materials and drilling methods. The stratification lines indicated below represent the approximate boundaries between material types, and the transition may be gradual.

Soil Description	Depth, ft.	Samples
organics, laminated; (He_3) CL/OH/OL.	91.0	23
Medium dense, gray-brown, silty, fine to medium SAND; wet; scattered organics; (Ha) SM.	91.5	

BOTTOM OF BORING
COMPLETED 1/8/2013

Note: Drilled using hollow stem auger from the surface to 10 feet below ground surface and mud rotary from 10 feet to the bottom of the boring.

PENETRATION RESISTANCE (blows/foot)
▲ Hammer Wt. & Drop: *140 lbs / 30 inches*



◇ % Fines (<0.075mm)
● % Water Content
Plastic Limit ├─●─┤ Liquid Limit
Natural Water Content

LEGEND

- * Sample Not Recovered
- 2.0" O.D. Split Spoon Sample
- 3" O.D. Thin-Walled Tube
- 3.0" O.D. Osterberg Sample
- Piezometer Screen and Sand Filter
- Bentonite-Cement Grout
- Bentonite Chips/Pellets
- Bentonite Grout
- Ground Water Level in VWP

NOTES

1. Refer to KEY for explanation of symbols, codes, abbreviations and definitions.
2. Groundwater level, if indicated above, is for the date specified and may vary.
3. USCS designation is based on visual-manual classification and selected lab testing.
4. The hole location was measured from existing site features and should be considered approximate.

Smith Island Site Restoration
Snohomish County, Washington

LOG OF BORING B-1-13

October 2013 | 21-1-12405-060

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. A-2

REV 3

Total Depth:	41.5 ft.	Northing:	~ 371,258 ft.	Drilling Method:	HSA and Mud Rotary	Hole Diam.:	7 in.
Top Elevation:	~	Easting:	~ 1,313,561 ft.	Drilling Company:	Boart Longyear	Rod Diam.:	NWJ
Vert. Datum:		Station:	~	Drill Rig Equipment:	CME 850	Hammer Type:	Automatic
Horiz. Datum:	NAD 83 WA STP N	Offset:	~	Other Comments:			

SOIL DESCRIPTION

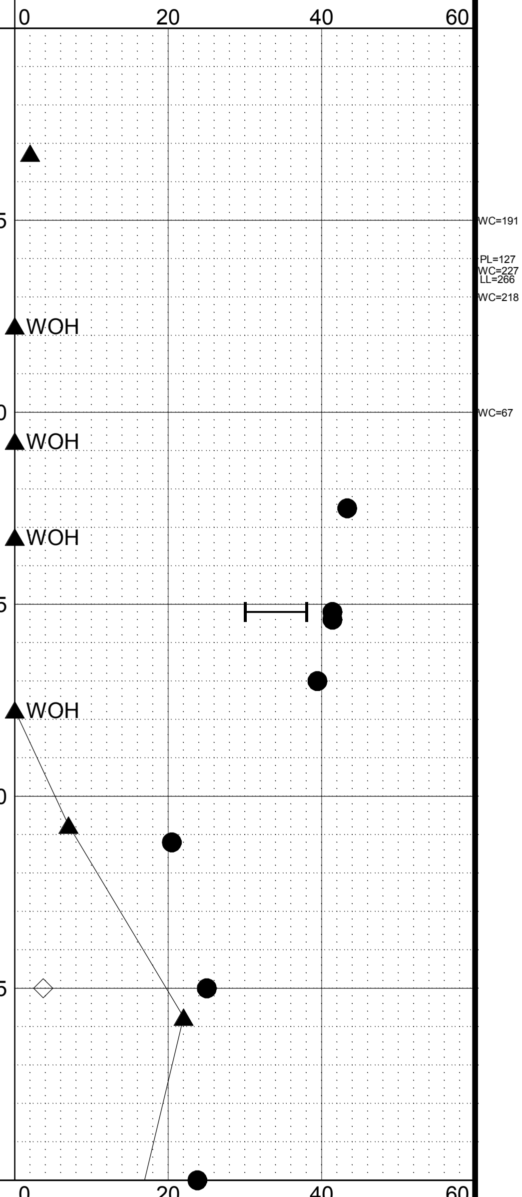
Refer to the report text for a proper understanding of the subsurface materials and drilling methods. The stratification lines indicated below represent the approximate boundaries between material types, and the transition may be gradual.

SOIL DESCRIPTION	Depth, ft.	Samples
Soft, brown, clayey SILT and organic SILT; wet; abundant organics, locally laminated with gray, clayey silt, slight sulfur odor; (He_1) ML/OH.		1 E, 2
Very soft, gray-brown to gray, slightly clayey SILT, trace of fine sand; wet; scattered organics and wood fragments, locally abundant fibrous organics above 12 feet; (He_2) ML. - Trace to slightly silty, fine to medium sand seams below about 12.5 feet. - Trace of clay below about 17 feet.	7.0	3, 4 E, 5, 6, 7, 8
Loose, gray, silty, fine to medium SAND; wet; trace of organics; (Ha) SM.	21.2	
Medium dense, gray, fine to medium SAND, trace of silt; wet; trace to scattered organics; (Ha) SP.	23.0	9

CONTINUED NEXT SHEET

Symbol | Ground Water | Depth, ft.

PENETRATION RESISTANCE (blows/foot)
▲ Hammer Wt. & Drop: 140 lbs / 30 inches



◇ % Fines (<0.075mm)
● % Water Content
Plastic Limit ├─●─┤ Liquid Limit
Natural Water Content

LEGEND

- * Sample Not Recovered
- E Environmental Sample Obtained
- 2.0" O.D. Split Spoon Sample
- 3" O.D. Thin-Walled Tube
- 3.0" O.D. Osterberg Sample

NOTES

1. Refer to KEY for explanation of symbols, codes, abbreviations and definitions.
2. Groundwater level, if indicated above, is for the date specified and may vary.
3. USCS designation is based on visual-manual classification and selected lab testing.
4. The hole location was measured from existing site features and should be considered approximate.

Log: EAS Rev: EAS Typ: LKN

MASTER_LOG_E 21-12405.GPJ SHAN_WIL.GDT 12/3/13

Smith Island Site Restoration
Snohomish County, Washington

LOG OF BORING B-2-13

October 2013 21-1-12405-060

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

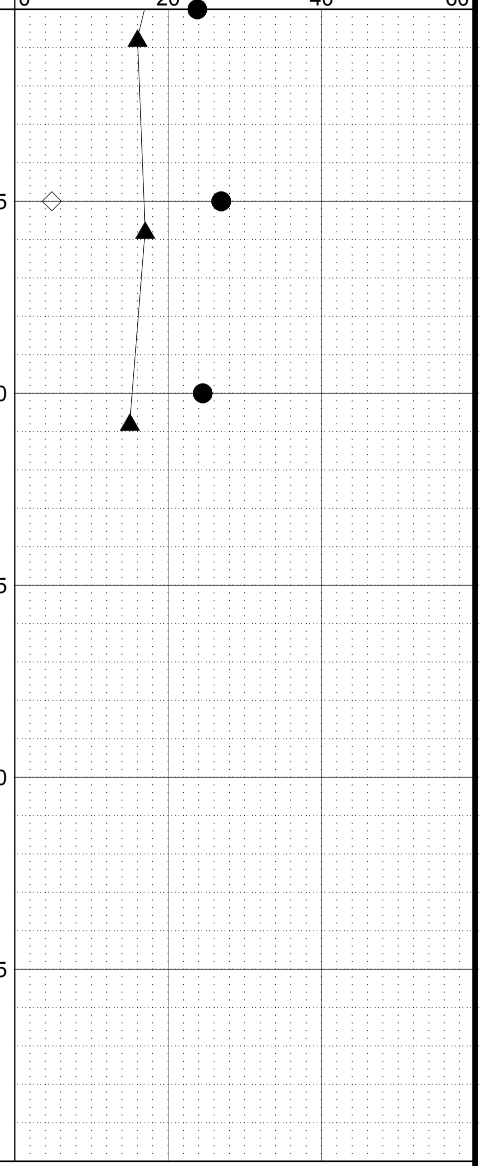
FIG. A-3
Sheet 1 of 2

REV 3

Total Depth:	41.5 ft.	Northing:	~ 371,258 ft.	Drilling Method:	HSA and Mud Rotary	Hole Diam.:	7 in.
Top Elevation:	~	Easting:	~ 1,313,561 ft.	Drilling Company:	Boart Longyear	Rod Diam.:	NWJ
Vert. Datum:		Station:	~	Drill Rig Equipment:	CME 850	Hammer Type:	Automatic
Horiz. Datum:	NAD 83 WA STP N	Offset:	~	Other Comments:			

SOIL DESCRIPTION *Refer to the report text for a proper understanding of the subsurface materials and drilling methods. The stratification lines indicated below represent the approximate boundaries between material types, and the transition may be gradual.*	Depth, ft.	Symbol	Samples	Ground Water	Depth, ft.
			10		
			11		35
			12		40
BOTTOM OF BORING COMPLETED 1/4/2013 Note: Drilled using hollow stem auger from the surface to 10 feet below ground surface and mud rotary from 10 feet to the bottom of the boring.	41.5				45
					50
					55

PENETRATION RESISTANCE (blows/foot)
▲ Hammer Wt. & Drop: 140 lbs / 30 inches



◇ % Fines (<0.075mm)
● % Water Content
Plastic Limit ├─●─┤ Liquid Limit
Natural Water Content

LEGEND
* Sample Not Recovered
E Environmental Sample Obtained
2.0" O.D. Split Spoon Sample
3" O.D. Thin-Walled Tube
3.0" O.D. Osterberg Sample

NOTES
1. Refer to KEY for explanation of symbols, codes, abbreviations and definitions.
2. Groundwater level, if indicated above, is for the date specified and may vary.
3. USCS designation is based on visual-manual classification and selected lab testing.
4. The hole location was measured from existing site features and should be considered approximate.

Smith Island Site Restoration
Snohomish County, Washington

LOG OF BORING B-2-13

October 2013 21-1-12405-060

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. A-3
Sheet 2 of 2

REV 3

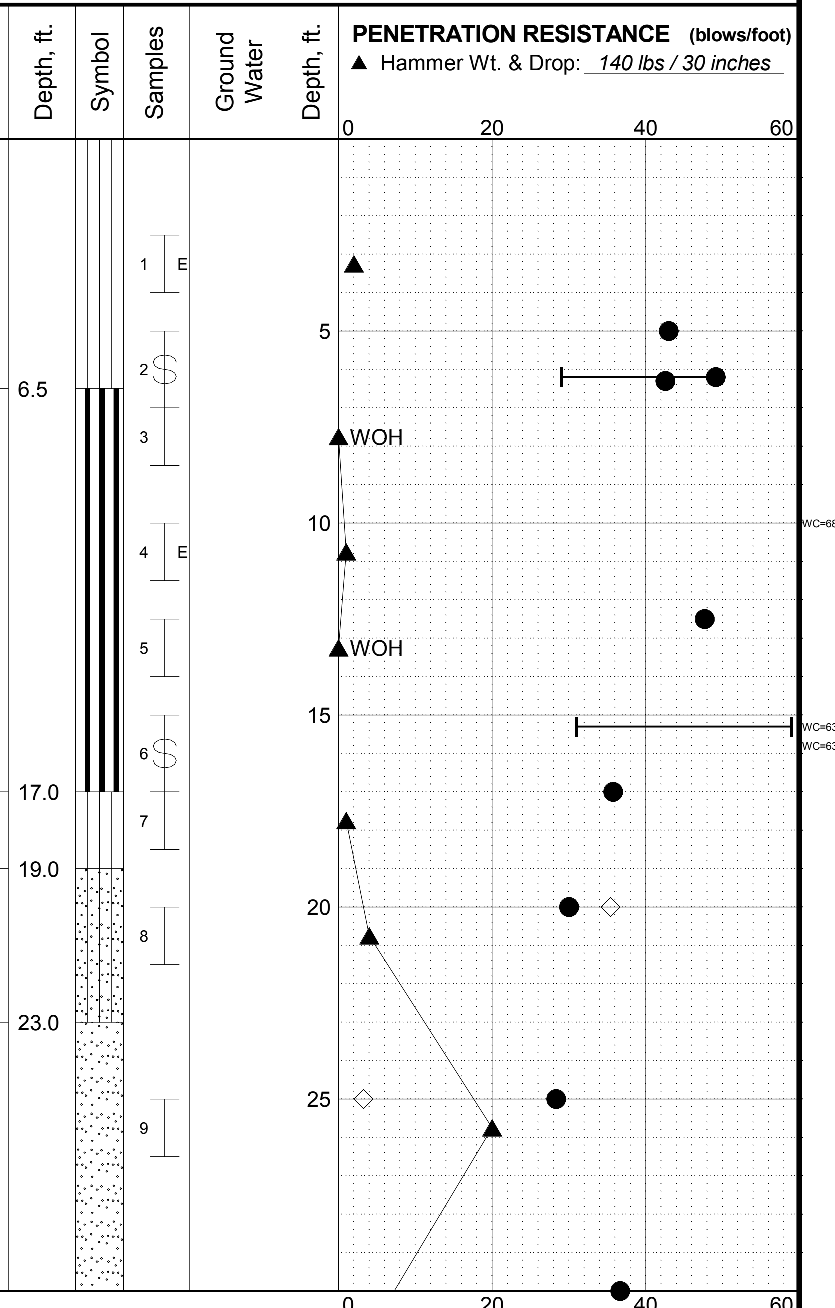
MASTER_LOG_E 21-12405.GPJ SHAN_WIL.GDT 12/3/13 Log: EAS Rev: EAS Typ: LKN

Total Depth:	41.5 ft.	Northing:	~ 372,384 ft.	Drilling Method:	HSA and Mud Rotary	Hole Diam.:	7 in.
Top Elevation:	~	Easting:	~ 1,313,753 ft.	Drilling Company:	Boart Longyear	Rod Diam.:	NWJ
Vert. Datum:		Station:	~	Drill Rig Equipment:	CME 850	Hammer Type:	Automatic
Horiz. Datum:	NAD 83 WA STP N	Offset:	~	Other Comments:			

SOIL DESCRIPTION

Refer to the report text for a proper understanding of the subsurface materials and drilling methods. The stratification lines indicated below represent the approximate boundaries between material types, and the transition may be gradual.

SOIL DESCRIPTION	Depth, ft.
Soft, brown, clayey SILT to organic SILT; moist; iron-oxide staining, abundant organics, laminated; (He_1) ML/OL/OH. - Trace of gravel above 5 feet. - Abundant iron-oxide mottles at 5.5 feet.	6.5
Very soft, gray-brown to gray, clayey SILT, trace of sand; wet; organic silt layers, scattered to abundant organics, slight sulfur odor; (He_2) MH. - Scattered charcoal fragments at about 16 feet.	17.0
Very soft, gray-brown, trace to slightly fine sandy, slightly clayey SILT; wet; scattered organics; (He_2) ML.	19.0
Very loose, gray-brown, silty, fine to medium SAND; wet; trace of organics; (Ha) SM.	23.0
Loose to medium dense, gray, fine to medium SAND, trace of silt; wet; trace of organics; (Ha) SP. - Trace of slightly clayey silt layers below approximately 27 feet.	



CONTINUED NEXT SHEET

LEGEND

- * Sample Not Recovered
- E Environmental Sample Obtained
- 2.0" O.D. Split Spoon Sample
- 3" O.D. Thin-Walled Tube

◇ % Fines (<0.075mm)
● % Water Content
Plastic Limit ├─●─┤ Liquid Limit
Natural Water Content

NOTES

1. Refer to KEY for explanation of symbols, codes, abbreviations and definitions.
2. Groundwater level, if indicated above, is for the date specified and may vary.
3. USCS designation is based on visual-manual classification and selected lab testing.
4. The hole location was measured from existing site features and should be considered approximate.

Smith Island Site Restoration
Snohomish County, Washington

LOG OF BORING B-3-13

October 2013 21-1-12405-060

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. A-4
Sheet 1 of 2

REV 3

Total Depth:	41.5 ft.	Northing:	~ 372,384 ft.	Drilling Method:	HSA and Mud Rotary	Hole Diam.:	7 in.
Top Elevation:	~	Easting:	~ 1,313,753 ft.	Drilling Company:	Boart Longyear	Rod Diam.:	NWJ
Vert. Datum:		Station:	~	Drill Rig Equipment:	CME 850	Hammer Type:	Automatic
Horiz. Datum:	NAD 83 WA STP N	Offset:	~	Other Comments:			

SOIL DESCRIPTION

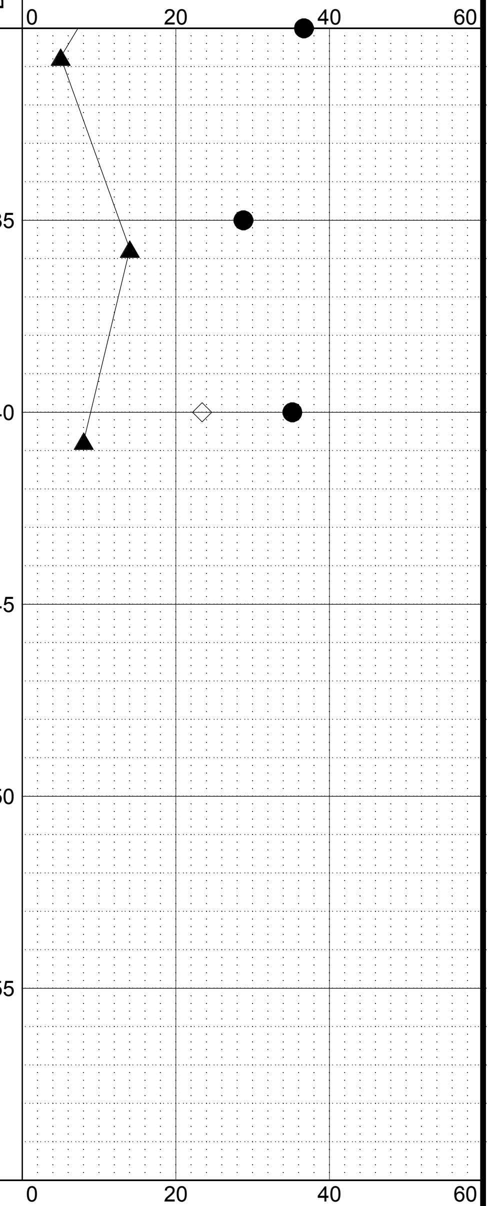
Refer to the report text for a proper understanding of the subsurface materials and drilling methods. The stratification lines indicated below represent the approximate boundaries between material types, and the transition may be gradual.

Soil Description	Depth, ft.	Samples
Interbedded, loose to medium dense, gray, fine to medium sandy SILT, trace of clay and slightly silty and silty, fine to medium SAND; wet; scattered organics; (He_2/Ha) ML/SM/SP-SM.	30.5	10, 11
Loose to medium dense, gray, silty, fine to medium SAND; wet; scattered slightly clayey silt seams, trace of organics; (Ha) SM.	36.0	12
BOTTOM OF BORING COMPLETED 1/3/2013 Note: Drilled using hollow stem auger from the surface to 10 feet below ground surface and mud rotary from 10 feet to the bottom of the boring.	41.5	

Symbol | Samples | Ground Water

PENETRATION RESISTANCE (blows/foot)

▲ Hammer Wt. & Drop: 140 lbs / 30 inches



◇ % Fines (<0.075mm)

● % Water Content

Plastic Limit ├─●─┤ Liquid Limit

Natural Water Content

LEGEND

* Sample Not Recovered

E Environmental Sample Obtained

2.0" O.D. Split Spoon Sample

3" O.D. Thin-Walled Tube

NOTES

1. Refer to KEY for explanation of symbols, codes, abbreviations and definitions.
2. Groundwater level, if indicated above, is for the date specified and may vary.
3. USCS designation is based on visual-manual classification and selected lab testing.
4. The hole location was measured from existing site features and should be considered approximate.

Smith Island Site Restoration
Snohomish County, Washington

LOG OF BORING B-3-13

October 2013 21-1-12405-060

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. A-4
Sheet 2 of 2

REV 3

Total Depth:	41.5 ft.	Northing:	~ 373,793 ft.	Drilling Method:	HSA and Mud Rotary	Hole Diam.:	7 in.
Top Elevation:	~	Easting:	~ 1,313,203 ft.	Drilling Company:	Boart Longyear	Rod Diam.:	NWJ
Vert. Datum:		Station:	~	Drill Rig Equipment:	CME 850	Hammer Type:	Automatic
Horiz. Datum:	NAD 83 WA STP N	Offset:	~	Other Comments:			

SOIL DESCRIPTION

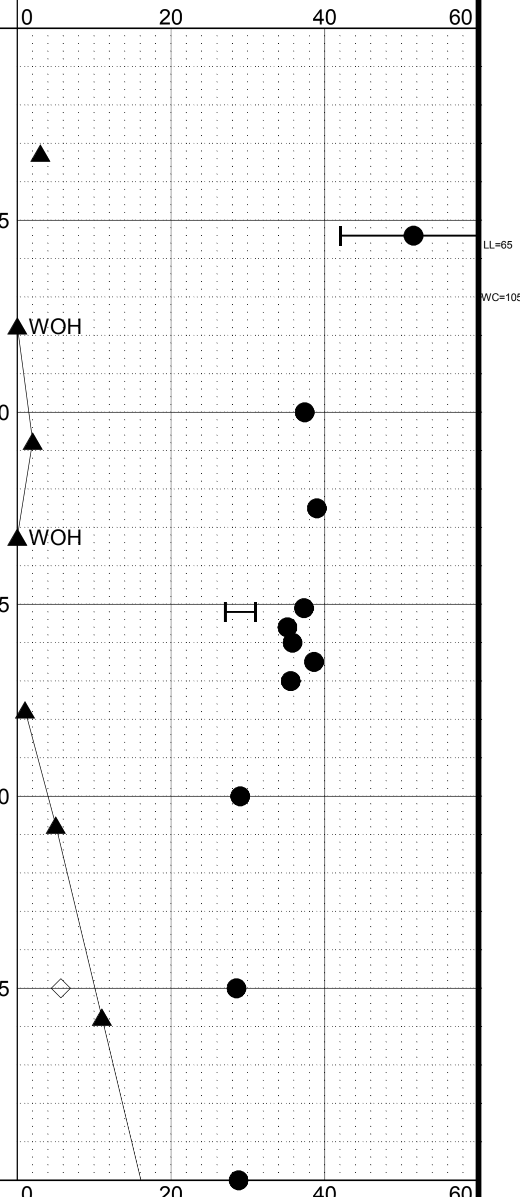
Refer to the report text for a proper understanding of the subsurface materials and drilling methods. The stratification lines indicated below represent the approximate boundaries between material types, and the transition may be gradual.

Soil Description	Depth, ft.	Samples
Soft, brown, clayey, organic SILT; moist; abundant organics; (He_1) OH.		1 E, 2, 3
Very soft, gray-brown to gray, slightly clayey SILT; moist; abundant fibrous organics, laminated; (He_2) ML.	7.0	
Interbedded, very loose, gray, slightly silty, fine to medium SAND and soft, slightly clayey SILT; wet; abundant organics in silt layers; (Ha/He_2) SP-SM/ML.	9.0	4 E
Very soft, gray, slightly clayey SILT, trace of fine sand; moist to wet; trace to scattered organics, silty, fine to medium sand layers; (He_2) ML.	12.0	5, 6, 7
Loose, gray, fine to medium sandy SILT; wet; (He_2) ML.	19.0	8
Medium dense, slightly silty, fine to medium SAND; wet; trace of organics; (Ha) SP-SM.	23.0	9

CONTINUED NEXT SHEET

PENETRATION RESISTANCE (blows/foot)

▲ Hammer Wt. & Drop: 140 lbs / 30 inches



LEGEND

- * Sample Not Recovered
- E Environmental Sample Obtained
- 2.0" O.D. Split Spoon Sample
- 3" O.D. Thin-Walled Tube

◇ % Fines (<0.075mm)

● % Water Content

Plastic Limit |—●—| Liquid Limit
Natural Water Content

NOTES

1. Refer to KEY for explanation of symbols, codes, abbreviations and definitions.
2. Groundwater level, if indicated above, is for the date specified and may vary.
3. USCS designation is based on visual-manual classification and selected lab testing.
4. The hole location was measured from existing site features and should be considered approximate.

Smith Island Site Restoration
Snohomish County, Washington

LOG OF BORING B-4-12

October 2013 21-1-12405-060

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. A-5
Sheet 1 of 2

REV 3

Log: EAS Rev: EAS Typ: CLP

MASTER LOG E 21-12405.GPJ SHAN WIL.GDT 12/3/13

Total Depth: 41.5 ft.	Northing: ~ 373,793 ft.	Drilling Method: HSA and Mud Rotary	Hole Diam.: 7 in.
Top Elevation: ~	Easting: ~ 1,313,203 ft.	Drilling Company: Boart Longyear	Rod Diam.: NWJ
Vert. Datum:	Station: ~	Drill Rig Equipment: CME 850	Hammer Type: Automatic
Horiz. Datum: NAD 83 WA STP N	Offset: ~	Other Comments:	

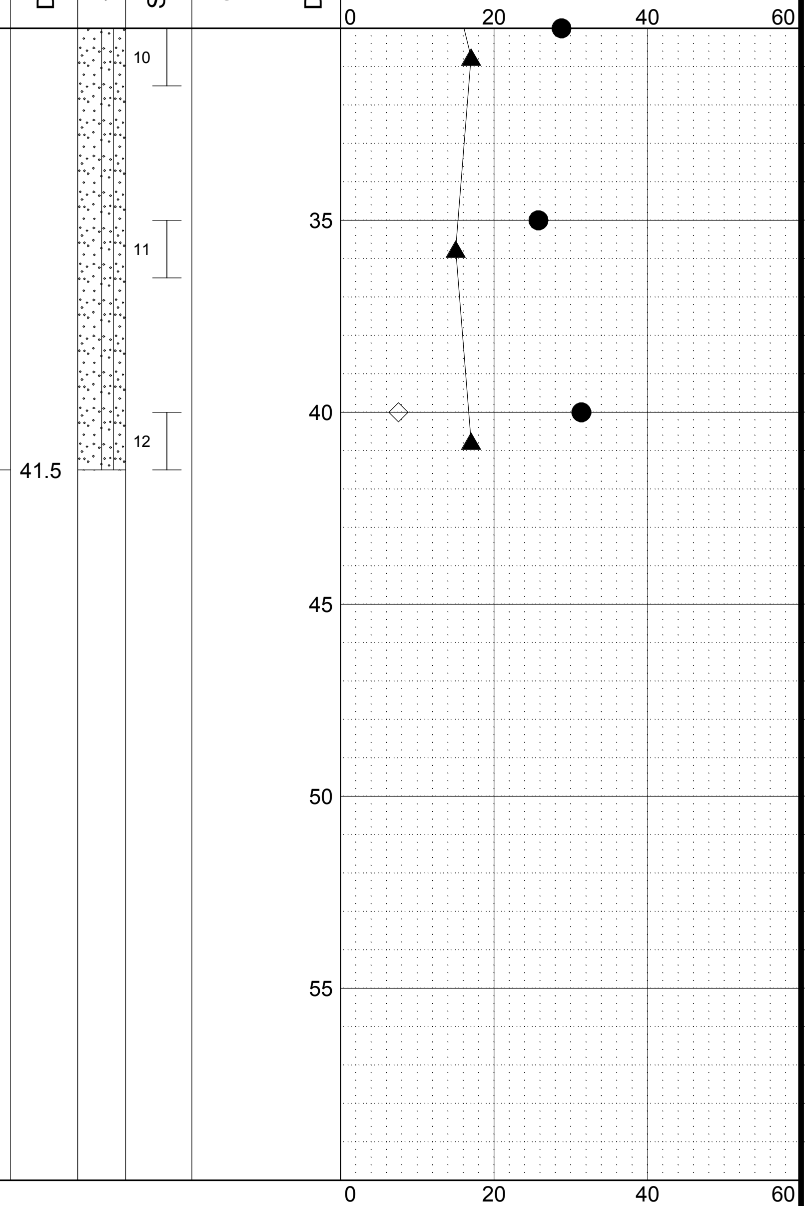
SOIL DESCRIPTION

Refer to the report text for a proper understanding of the subsurface materials and drilling methods. The stratification lines indicated below represent the approximate boundaries between material types, and the transition may be gradual.

Depth, ft. | Symbol | Samples | Ground Water | Depth, ft.

PENETRATION RESISTANCE (blows/foot)

▲ Hammer Wt. & Drop: 140 lbs / 30 inches



- Wood fragments at about 40 feet.

41.5

BOTTOM OF BORING
COMPLETED 12/28/2012

Note: Drilled using hollow stem auger from the surface to 10 feet below ground surface and mud rotary from 10 feet to the bottom of the boring.

LEGEND

* Sample Not Recovered
E Environmental Sample Obtained
2.0" O.D. Split Spoon Sample
3" O.D. Thin-Walled Tube

◇ % Fines (<0.075mm)
● % Water Content
Plastic Limit ├─●─┤ Liquid Limit
Natural Water Content

NOTES

1. Refer to KEY for explanation of symbols, codes, abbreviations and definitions.
2. Groundwater level, if indicated above, is for the date specified and may vary.
3. USCS designation is based on visual-manual classification and selected lab testing.
4. The hole location was measured from existing site features and should be considered approximate.

Smith Island Site Restoration
Snohomish County, Washington

LOG OF BORING B-4-12

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SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. A-5
Sheet 2 of 2

REV 3

Log: EAS Rev: EAS Typ: CLP

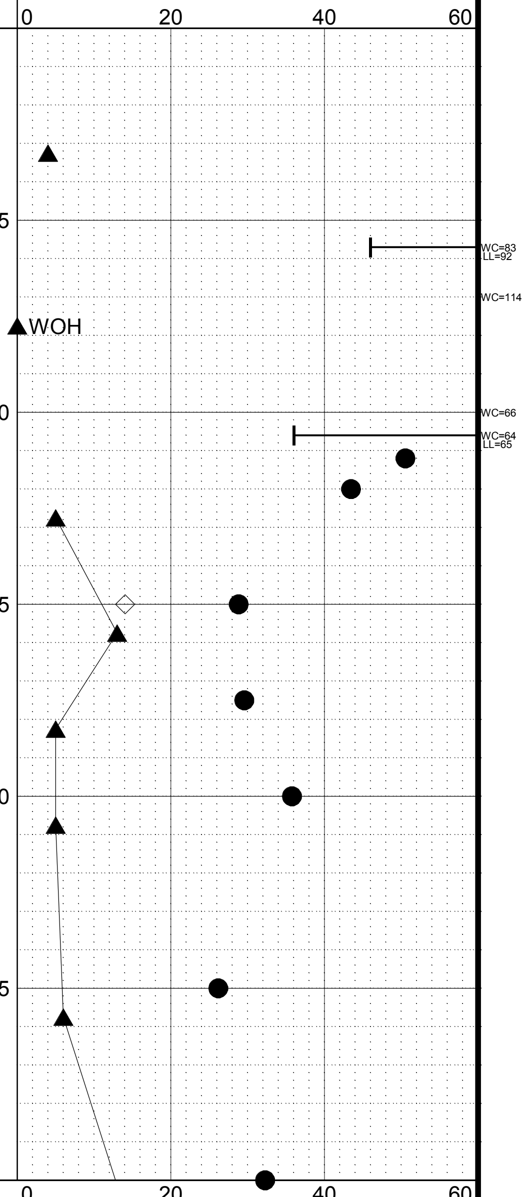
MASTER_LOG_E 21-12405.GPJ SHAN_WIL.GDT 12/3/13

Total Depth:	51.5 ft.	Northing:	~ 375,519 ft.	Drilling Method:	HSA and Mud Rotary	Hole Diam.:	7 in.
Top Elevation:	~	Easting:	~ 1,313,288 ft.	Drilling Company:	Boart Longyear	Rod Diam.:	NWJ
Vert. Datum:		Station:	~	Drill Rig Equipment:	CME 850	Hammer Type:	Automatic
Horiz. Datum:	NAD 83 WA STP N	Offset:	~	Other Comments:			

SOIL DESCRIPTION *Refer to the report text for a proper understanding of the subsurface materials and drilling methods. The stratification lines indicated below represent the approximate boundaries between material types, and the transition may be gradual.*	Depth, ft.	Samples
Interbedded, soft, brown to gray-brown, organic SILT and clayey SILT; moist; abundant organics, sulfur odor, peat seams, locally laminated; (He_1) OH/MH/ML.		1 E, 2, 3
Very soft, gray and gray-brown, slightly clayey SILT; moist; scattered to abundant organics, scattered wood fragments, sulfur odor; (He_2) ML. - Interbedded with fine sandy SILT, trace of clay below 12 feet.	7.0	4, 5 E
Loose to medium dense, gray, silty SAND; wet; scattered organics, locally trace of clay, scattered slightly silty sand layers; (Ha) SM. - Scattered layers of fine sandy silt, trace of clay and slightly clayey silt, trace of fine sand above 15 feet. - Abundant layers of trace to slightly clayey, sandy silt at about 20 feet.	12.8	6, 7, 8
Loose to medium dense, gray, slightly silty, fine to medium SAND; wet; trace to scattered organics; (Ha) SP-SM.	23.0	9

CONTINUED NEXT SHEET

PENETRATION RESISTANCE (blows/foot)
▲ Hammer Wt. & Drop: 140 lbs / 30 inches



LEGEND
* Sample Not Recovered
E Environmental Sample Obtained
2.0" O.D. Split Spoon Sample
3" O.D. Thin-Walled Tube

◇ % Fines (<0.075mm)
● % Water Content
Plastic Limit ├─●─┤ Liquid Limit
Natural Water Content

NOTES
1. Refer to KEY for explanation of symbols, codes, abbreviations and definitions.
2. Groundwater level, if indicated above, is for the date specified and may vary.
3. USCS designation is based on visual-manual classification and selected lab testing.
4. The hole location was measured from existing site features and should be considered approximate.

Smith Island Site Restoration
Snohomish County, Washington

LOG OF BORING B-5-12

October 2013 21-1-12405-060

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. A-6
Sheet 1 of 2

REV 3

Total Depth:	51.5 ft.	Northing:	~ 375,519 ft.	Drilling Method:	HSA and Mud Rotary	Hole Diam.:	7 in.
Top Elevation:	~	Easting:	~ 1,313,288 ft.	Drilling Company:	Boart Longyear	Rod Diam.:	NWJ
Vert. Datum:		Station:	~	Drill Rig Equipment:	CME 850	Hammer Type:	Automatic
Horiz. Datum:	NAD 83 WA STP N	Offset:	~	Other Comments:			

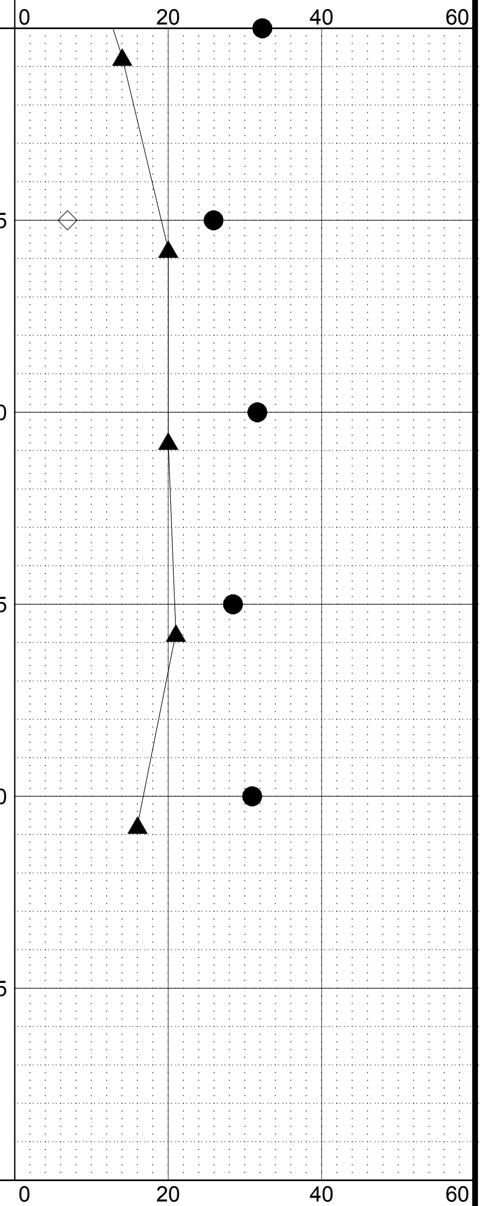
SOIL DESCRIPTION

Refer to the report text for a proper understanding of the subsurface materials and drilling methods. The stratification lines indicated below represent the approximate boundaries between material types, and the transition may be gradual.

Soil Description	Depth, ft.	Samples
- Seams with trace of silt at 30 feet.		10
		11
		12
		13
- Trace of shell fragments and scattered silt seams at 50 feet.		14
BOTTOM OF BORING COMPLETED 12/27/2012 Note: Drilled using hollow stem auger from the surface to 10 feet below ground surface and mud rotary from 10 feet to the bottom of the boring.	51.5	

PENETRATION RESISTANCE (blows/foot)

▲ Hammer Wt. & Drop: 140 lbs / 30 inches



◇ % Fines (<0.075mm)
● % Water Content
Plastic Limit ├─●─┤ Liquid Limit
Natural Water Content

LEGEND

- * Sample Not Recovered
- E Environmental Sample Obtained
- 2.0" O.D. Split Spoon Sample
- 3" O.D. Thin-Walled Tube

NOTES

1. Refer to KEY for explanation of symbols, codes, abbreviations and definitions.
2. Groundwater level, if indicated above, is for the date specified and may vary.
3. USCS designation is based on visual-manual classification and selected lab testing.
4. The hole location was measured from existing site features and should be considered approximate.

Smith Island Site Restoration
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LOG OF BORING B-5-12

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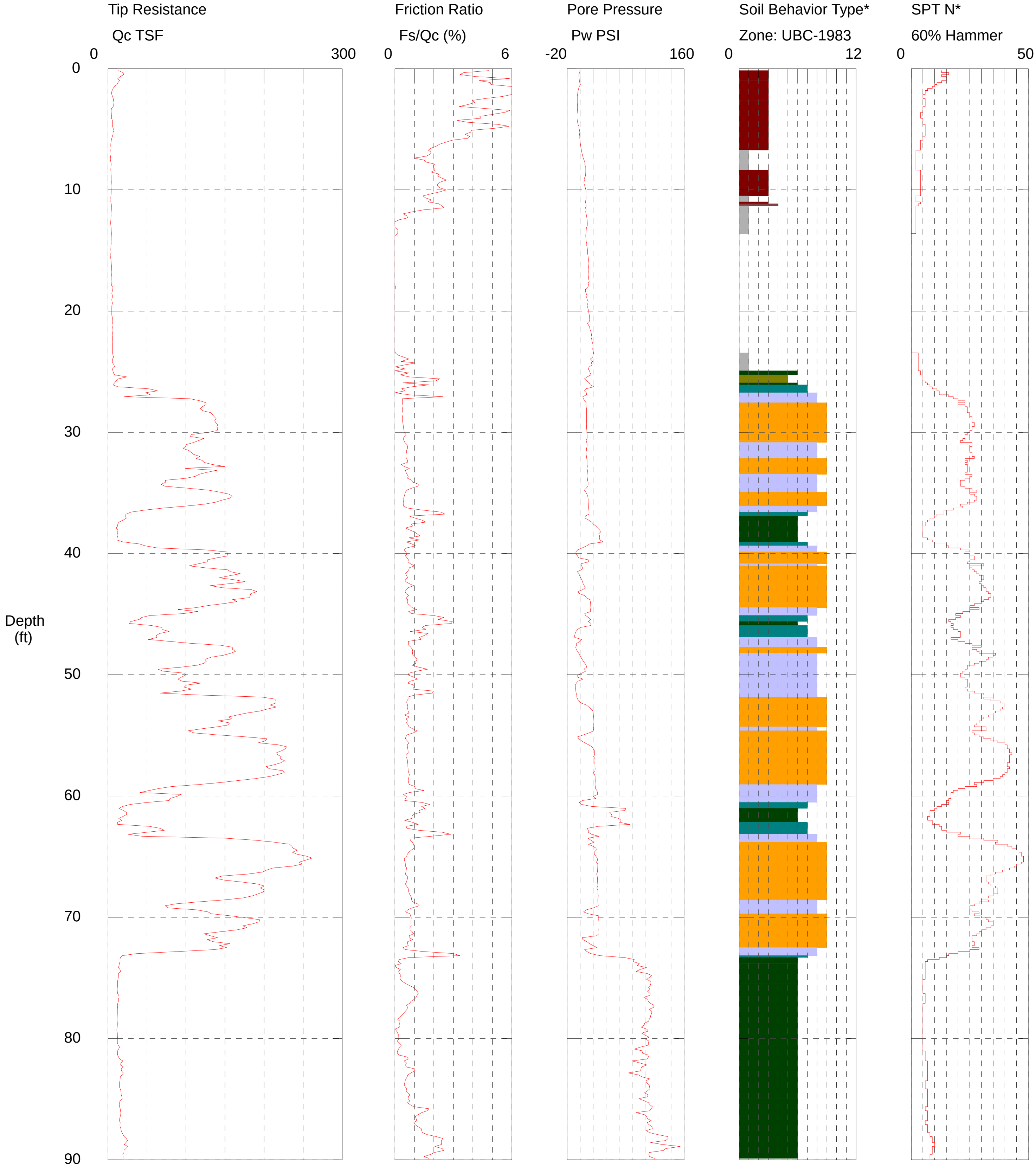
FIG. A-6
Sheet 2 of 2

REV 3

Shannon & Wilson

Operator: Gerdes
Sounding: CPT-01-13
Cone Used: DPG1015

CPT Date/Time: 1/17/2013 11:19:28 AM
Location: Smith Island
Job Number: 21-1-12405-030



Maximum Depth = 90.22 feet

Depth Increment = 0.164 feet

1 sensitive fine grained	4 silty clay to clay	7 silty sand to sandy silt	10 gravelly sand to sand
2 organic material	5 clayey silt to silty clay	8 sand to silty sand	11 very stiff fine grained (*)
3 clay	6 sandy silt to clayey silt	9 sand	12 sand to clayey sand (*)

InSitu Engineering

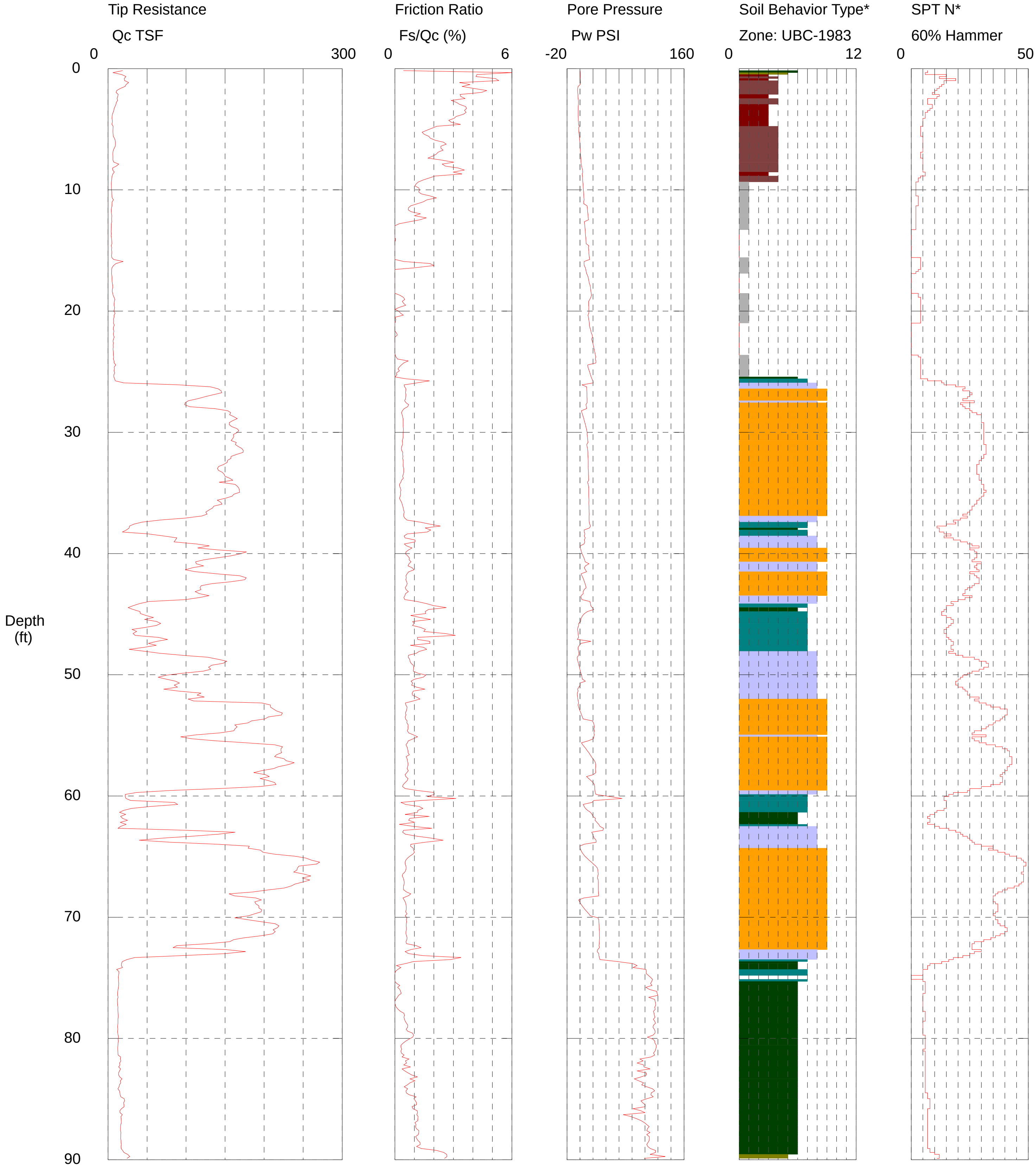
*Soil behavior type and SPT based on data from UBC-1983

Figure A-7

Shannon & Wilson

Operator: Gerdes
Sounding: CPT-02-13
Cone Used: DPG1015

CPT Date/Time: 1/17/2013 1:43:08 PM
Location: Smith Island
Job Number: 21-1-12405-030



Maximum Depth = 90.06 feet

Depth Increment = 0.164 feet

1 sensitive fine grained	4 silty clay to clay	7 silty sand to sandy silt	10 gravelly sand to sand
2 organic material	5 clayey silt to silty clay	8 sand to silty sand	11 very stiff fine grained (*)
3 clay	6 sandy silt to clayey silt	9 sand	12 sand to clayey sand (*)

InSitu Engineering

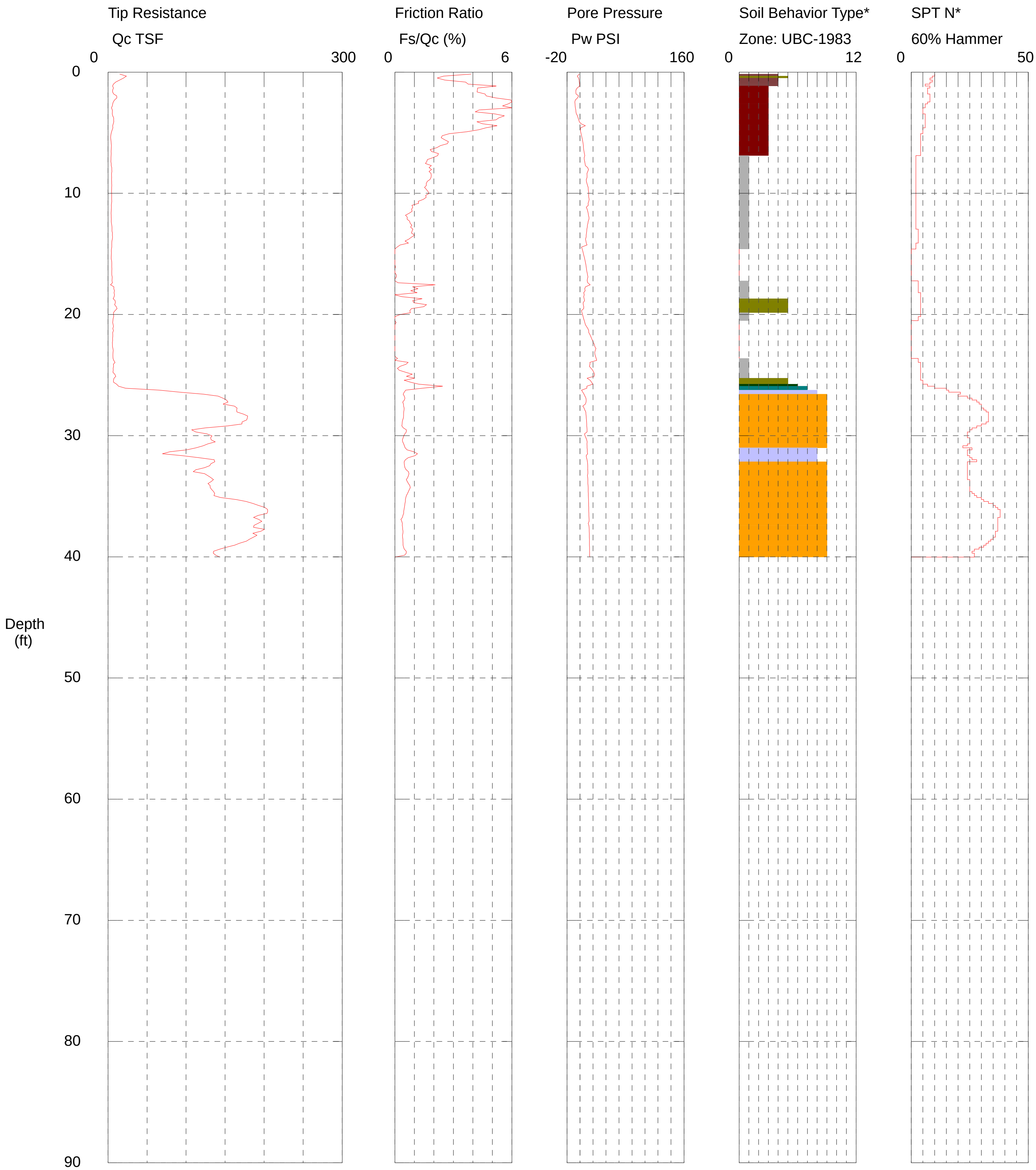
Figure A-8

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

Shannon & Wilson

Operator: Gerdes
Sounding: CPT-03-13
Cone Used: DPG1015

CPT Date/Time: 1/18/2013 10:07:54 AM
Location: Smith Island
Job Number: 21-1-12405-030



Maximum Depth = 40.03 feet

Depth Increment = 0.164 feet

1 sensitive fine grained
2 organic material
3 clay
4 silty clay to clay
5 clayey silt to silty clay
6 sandy silt to clayey silt
7 silty sand to sandy silt
8 sand to silty sand
9 sand
10 gravelly sand to sand
11 very stiff fine grained (*)
12 sand to clayey sand (*)

InSitu Engineering

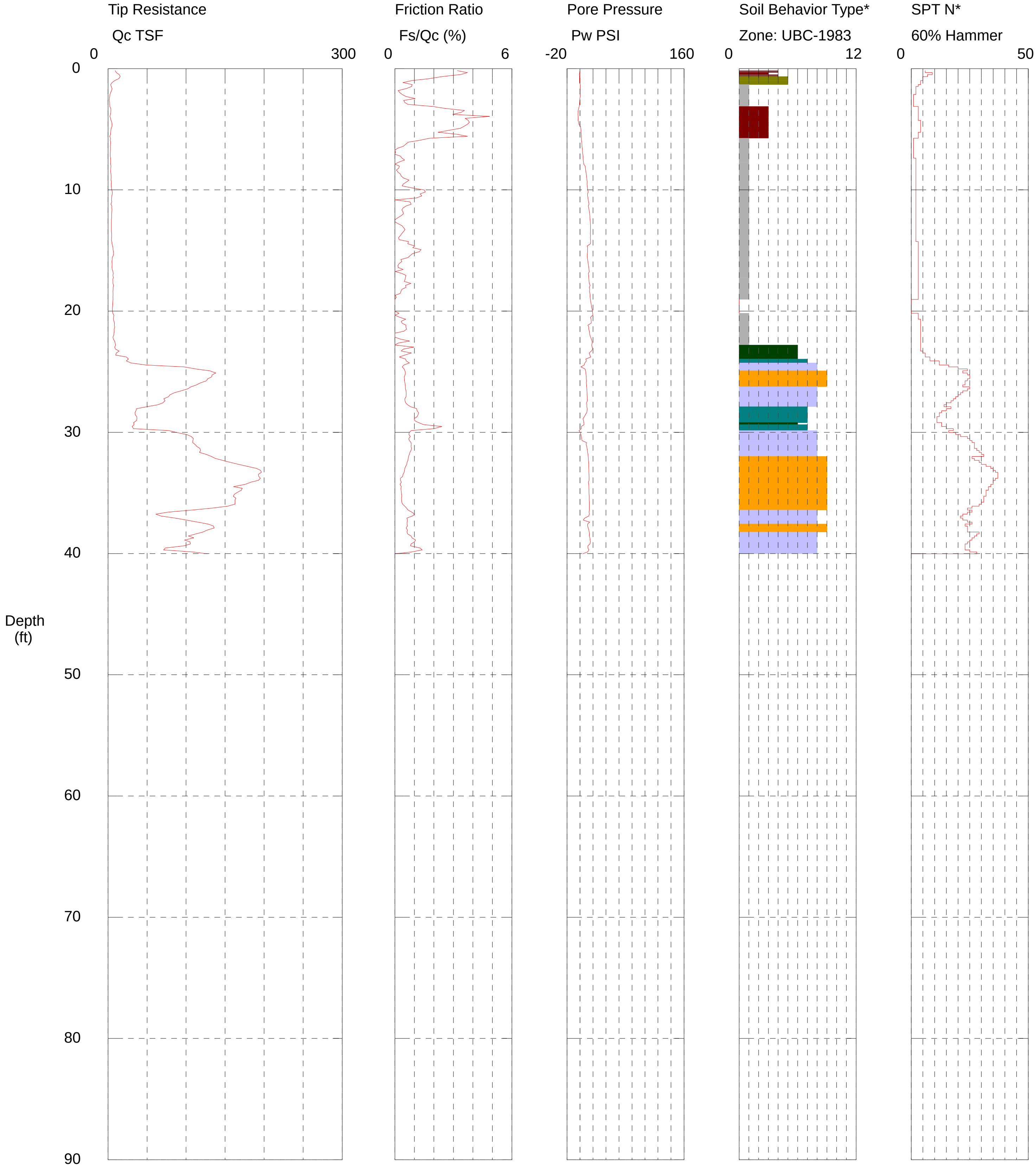
*Soil behavior type and SPT based on data from UBC-1983

Figure A-9

Shannon & Wilson

Operator: Gerdes
Sounding: CPT-04-13
Cone Used: DPG1015

CPT Date/Time: 1/18/2013 12:29:36 PM
Location: Smith Island
Job Number: 21-1-12405-030



Maximum Depth = 40.03 feet

Depth Increment = 0.164 feet

1 sensitive fine grained
2 organic material
3 clay
4 silty clay to clay
5 clayey silt to silty clay
6 sandy silt to clayey silt
7 silty sand to sandy silt
8 sand to silty sand
9 sand
10 gravelly sand to sand
11 very stiff fine grained (*)
12 sand to clayey sand (*)

InSitu Engineering

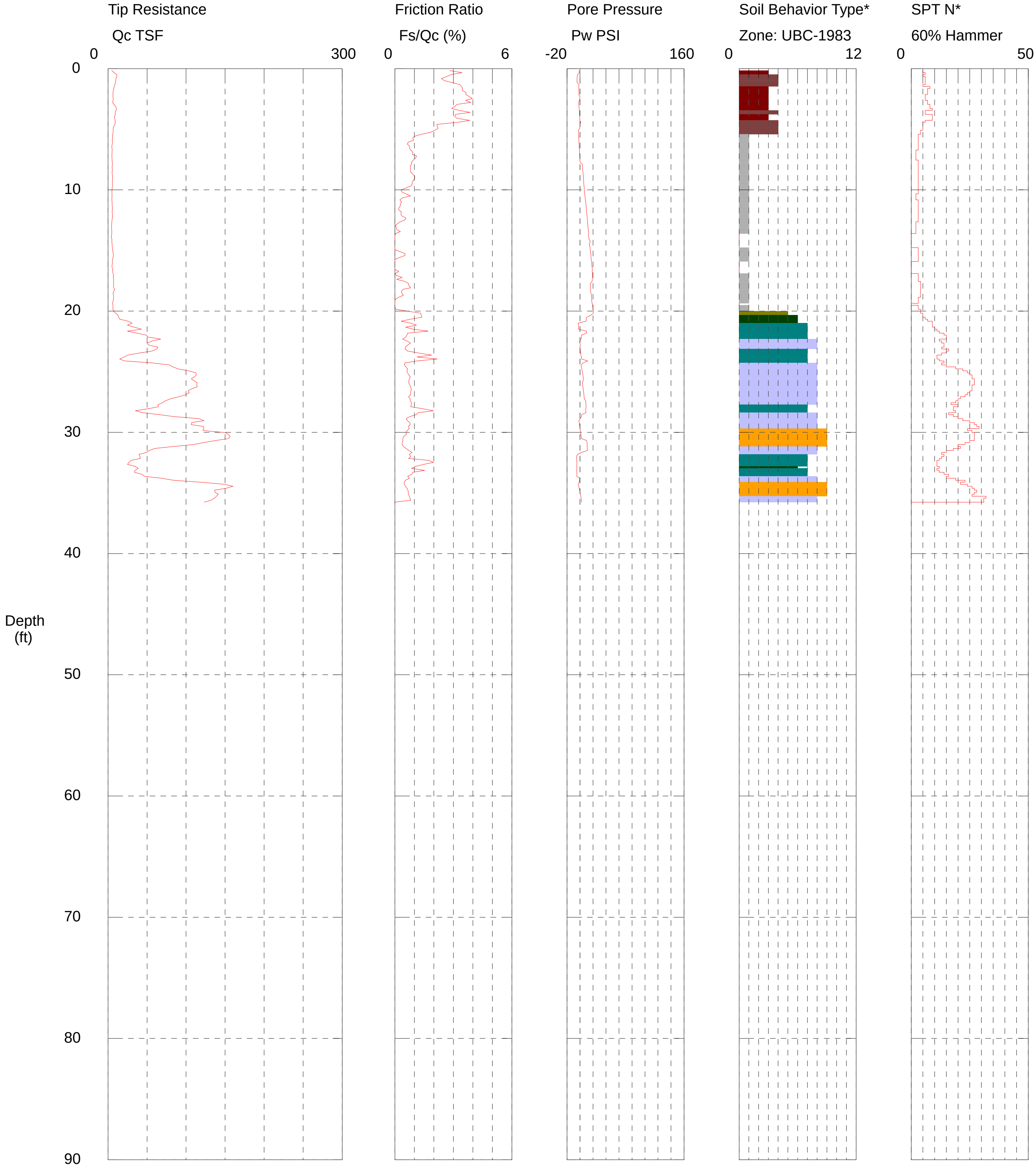
*Soil behavior type and SPT based on data from UBC-1983

Figure A-10

Shannon & Wilson

Operator: Gerdes
Sounding: CPT-05-13
Cone Used: DPG1015

CPT Date/Time: 1/18/2013 2:54:28 PM
Location: Smith Island
Job Number: 21-1-12405-030



Maximum Depth = 35.76 feet

Depth Increment = 0.164 feet

1	sensitive fine grained
2	organic material
3	clay
4	silty clay to clay
5	clayey silt to silty clay
6	sandy silt to clayey silt
7	silty sand to sandy silt
8	sand to silty sand
9	sand
10	gravelly sand to sand
11	very stiff fine grained (*)
12	sand to clayey sand (*)

InSitu Engineering

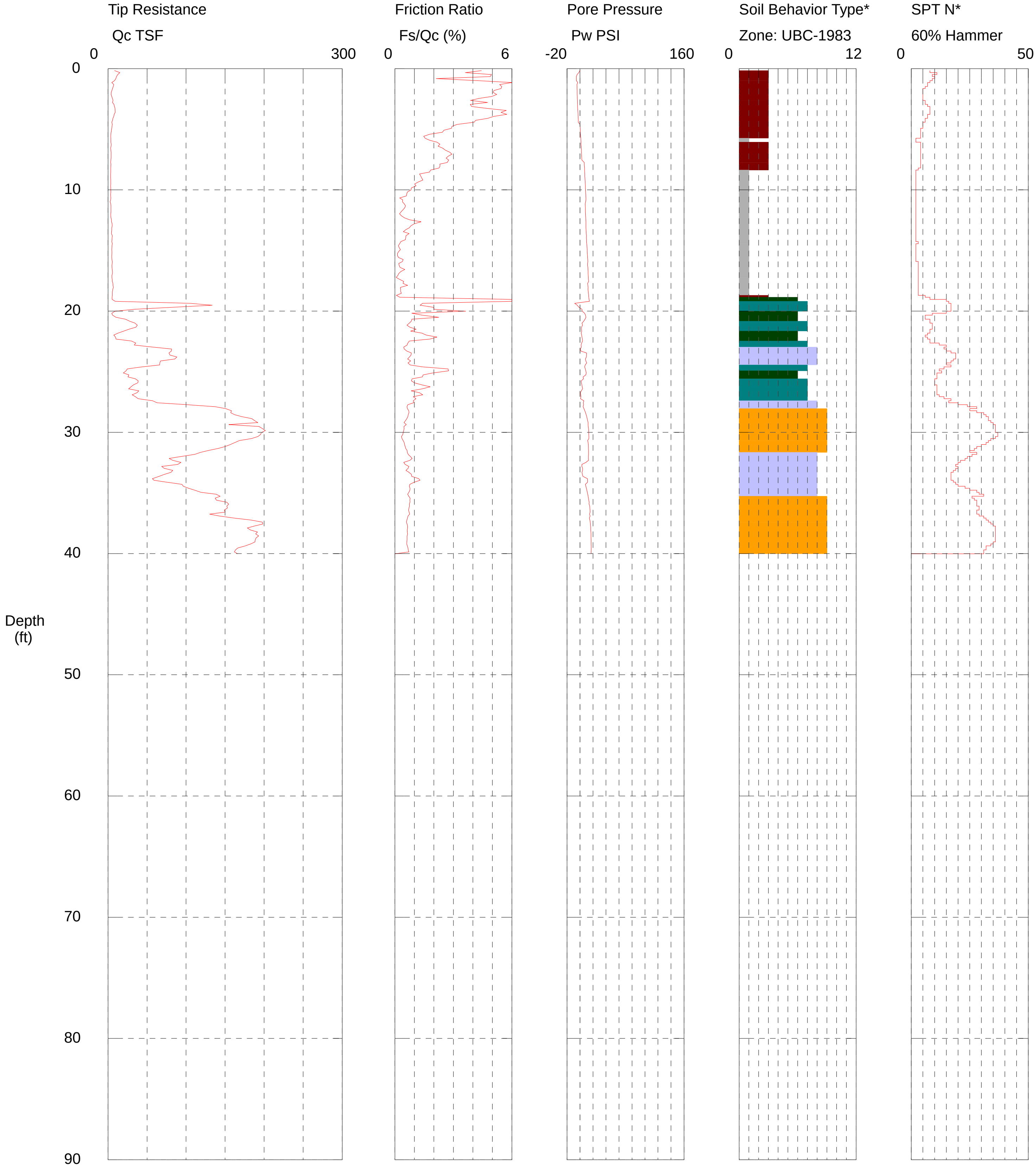
Figure A-11

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

Shannon & Wilson

Operator: Gerdes
Sounding: CPT-06-13
Cone Used: DPG1015

CPT Date/Time: 1/18/2013 4:00:22 PM
Location: Smith Island
Job Number: 21-1-12405-030



Maximum Depth = 40.03 feet

Depth Increment = 0.164 feet

1 sensitive fine grained
2 organic material
3 clay
4 silty clay to clay
5 clayey silt to silty clay
6 sandy silt to clayey silt
7 silty sand to sandy silt
8 sand to silty sand
9 sand
10 gravelly sand to sand
11 very stiff fine grained (*)
12 sand to clayey sand (*)

InSitu Engineering

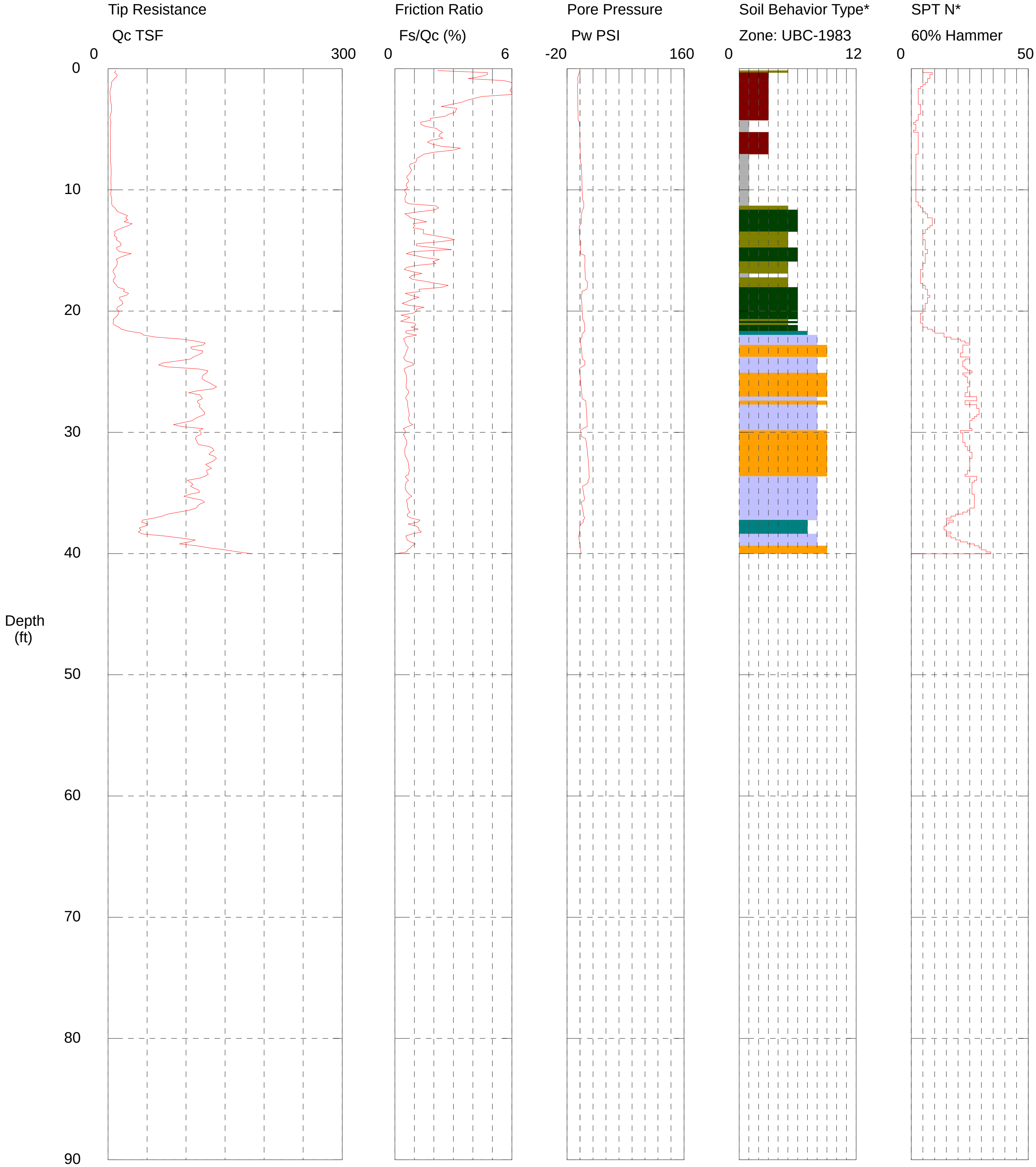
*Soil behavior type and SPT based on data from UBC-1983

Figure A-12

Shannon & Wilson

Operator: Gerdes
Sounding: CPT-07-13
Cone Used: DPG1015

CPT Date/Time: 1/18/2013 5:09:44 PM
Location: Smith Island
Job Number: 21-1-12405-030



Maximum Depth = 40.03 feet

Depth Increment = 0.164 feet

1 sensitive fine grained	4 silty clay to clay	7 silty sand to sandy silt	10 gravelly sand to sand
2 organic material	5 clayey silt to silty clay	8 sand to silty sand	11 very stiff fine grained (*)
3 clay	6 sandy silt to clayey silt	9 sand	12 sand to clayey sand (*)

InSitu Engineering

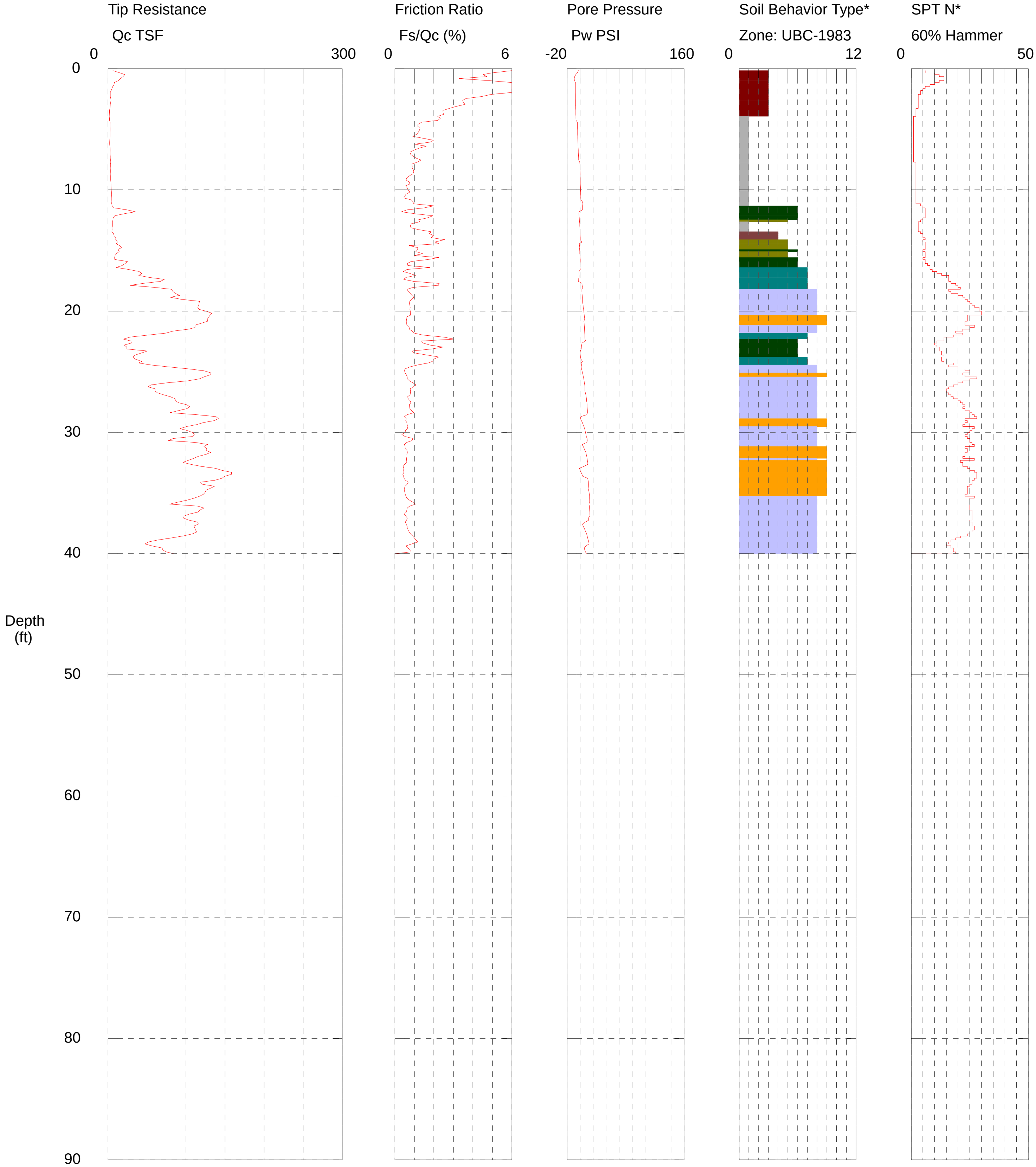
Figure A-13

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

Shannon & Wilson

Operator: Gerdes
Sounding: CPT-08-13
Cone Used: DPG1015

CPT Date/Time: 1/18/2013 6:09:10 PM
Location: Smith Island
Job Number: 21-1-12405-030



Maximum Depth = 40.03 feet

Depth Increment = 0.197 feet

1 sensitive fine grained	4 silty clay to clay	7 silty sand to sandy silt	10 gravelly sand to sand
2 organic material	5 clayey silt to silty clay	8 sand to silty sand	11 very stiff fine grained (*)
3 clay	6 sandy silt to clayey silt	9 sand	12 sand to clayey sand (*)

InSitu Engineering

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

Figure A-14

Shannon & Wilson

Operator Gerdes
Sounding: CPT-01-13
Cone Used: DPG1015

CPT Date/Time: 1/17/2013 11:19:28 AM
Location: Smith Island
Job Number: 21-1-12405-030

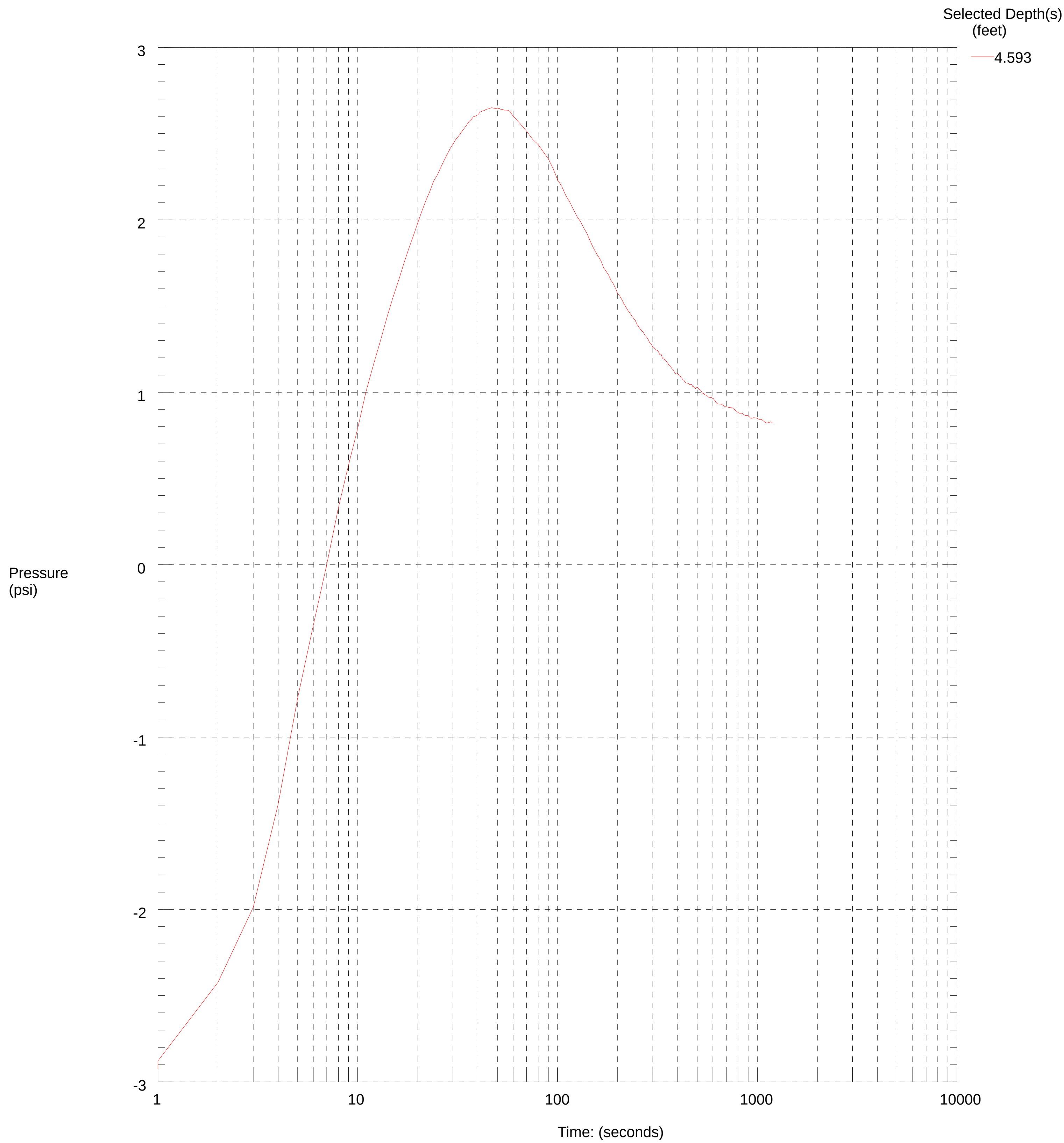


Figure A-15

Shannon & Wilson

Operator Gerdes
Sounding: CPT-02-13
Cone Used: DPG1015

CPT Date/Time: 1/17/2013 1:43:08 PM
Location: Smith Island
Job Number: 21-1-12405-030

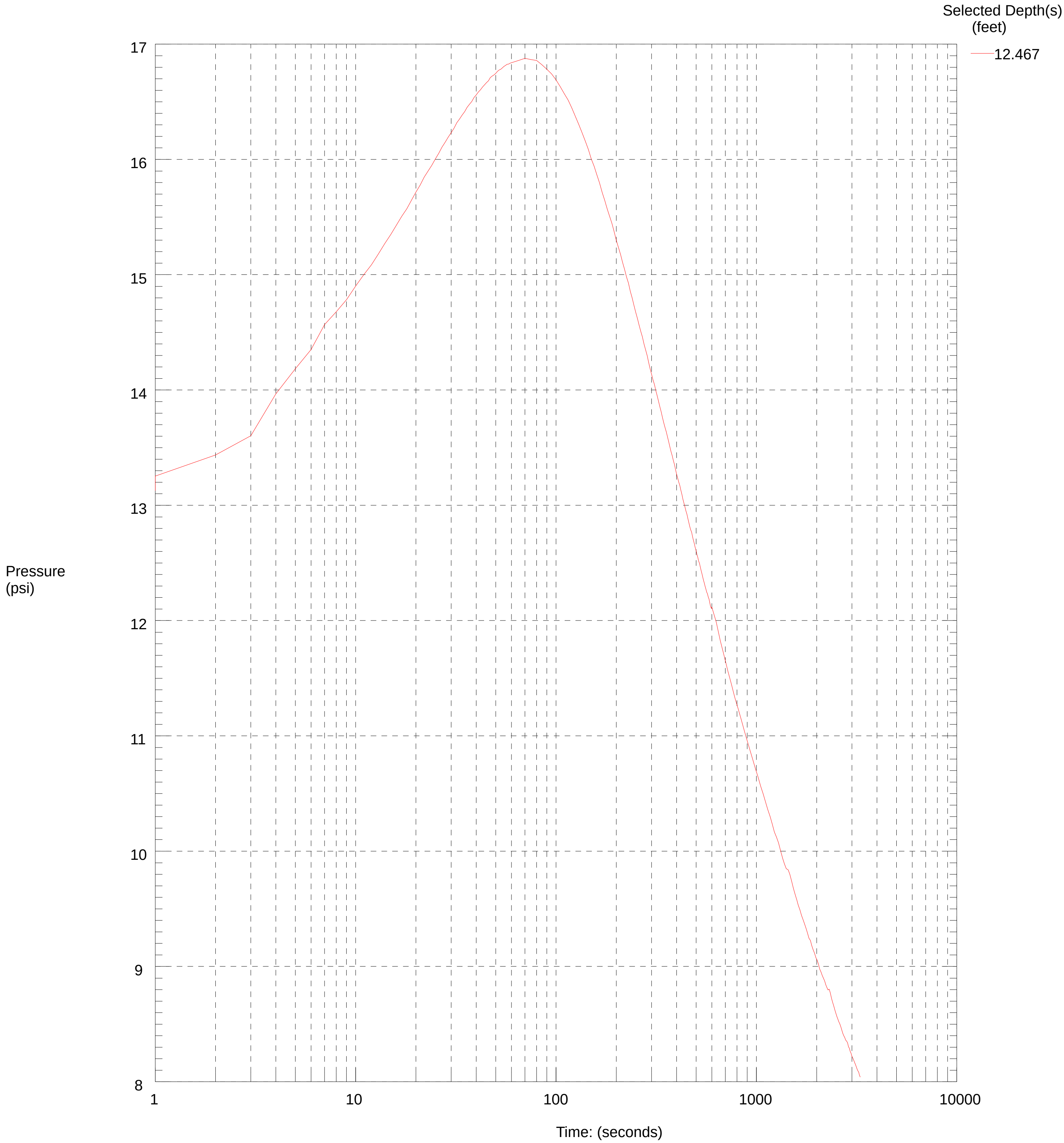


Figure A-16

Shannon & Wilson

Operator Gerdes
Sounding: CPT-03-13
Cone Used: DPG1015

CPT Date/Time: 1/18/2013 10:07:54 AM
Location: Smith Island
Job Number: 21-1-12405-030

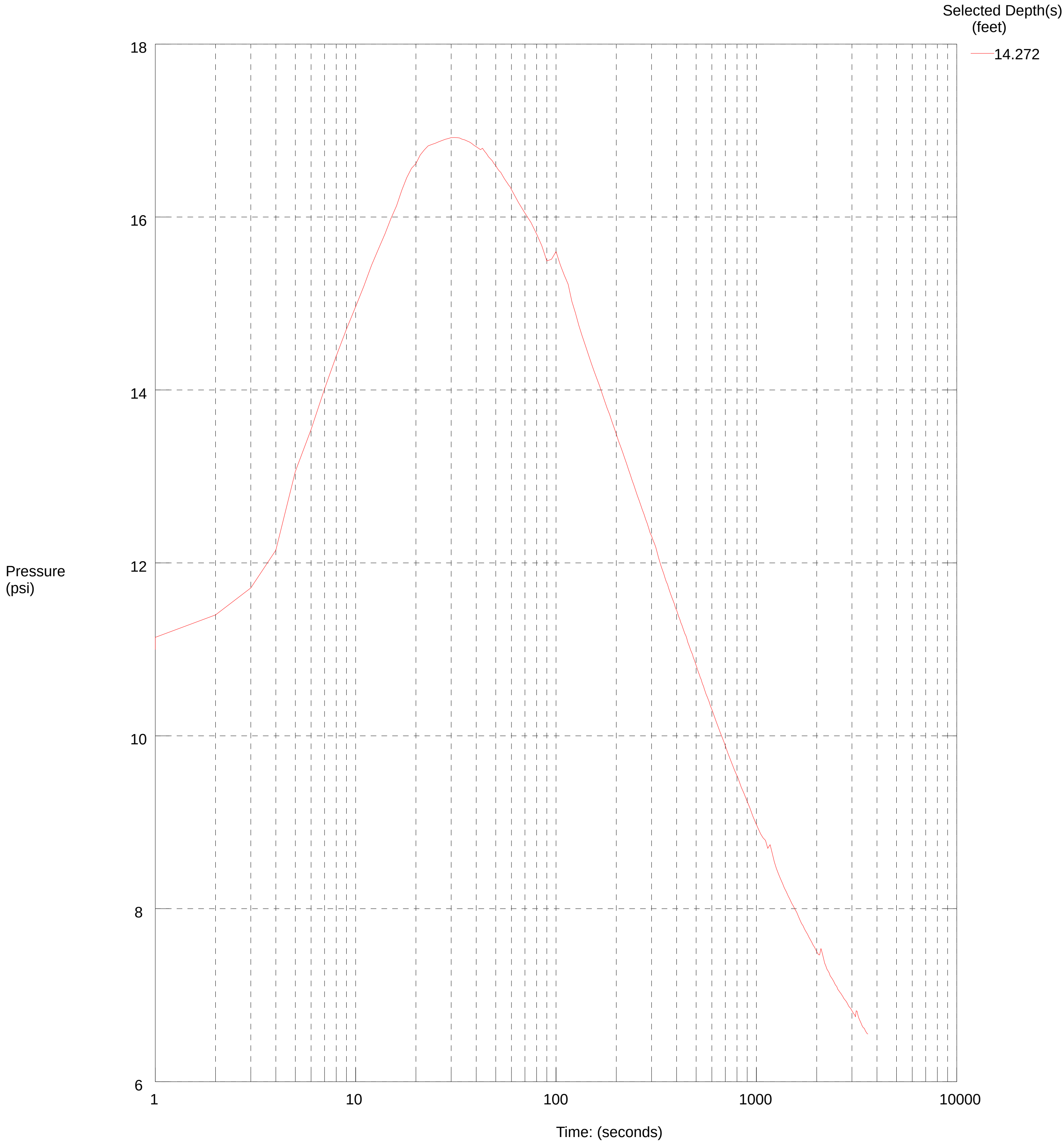


Figure A-17

Shannon & Wilson

Operator Gerdes
Sounding: CPT-03-13
Cone Used: DPG1015

CPT Date/Time: 1/18/2013 10:07:54 AM
Location: Smith Island
Job Number: 21-1-12405-030

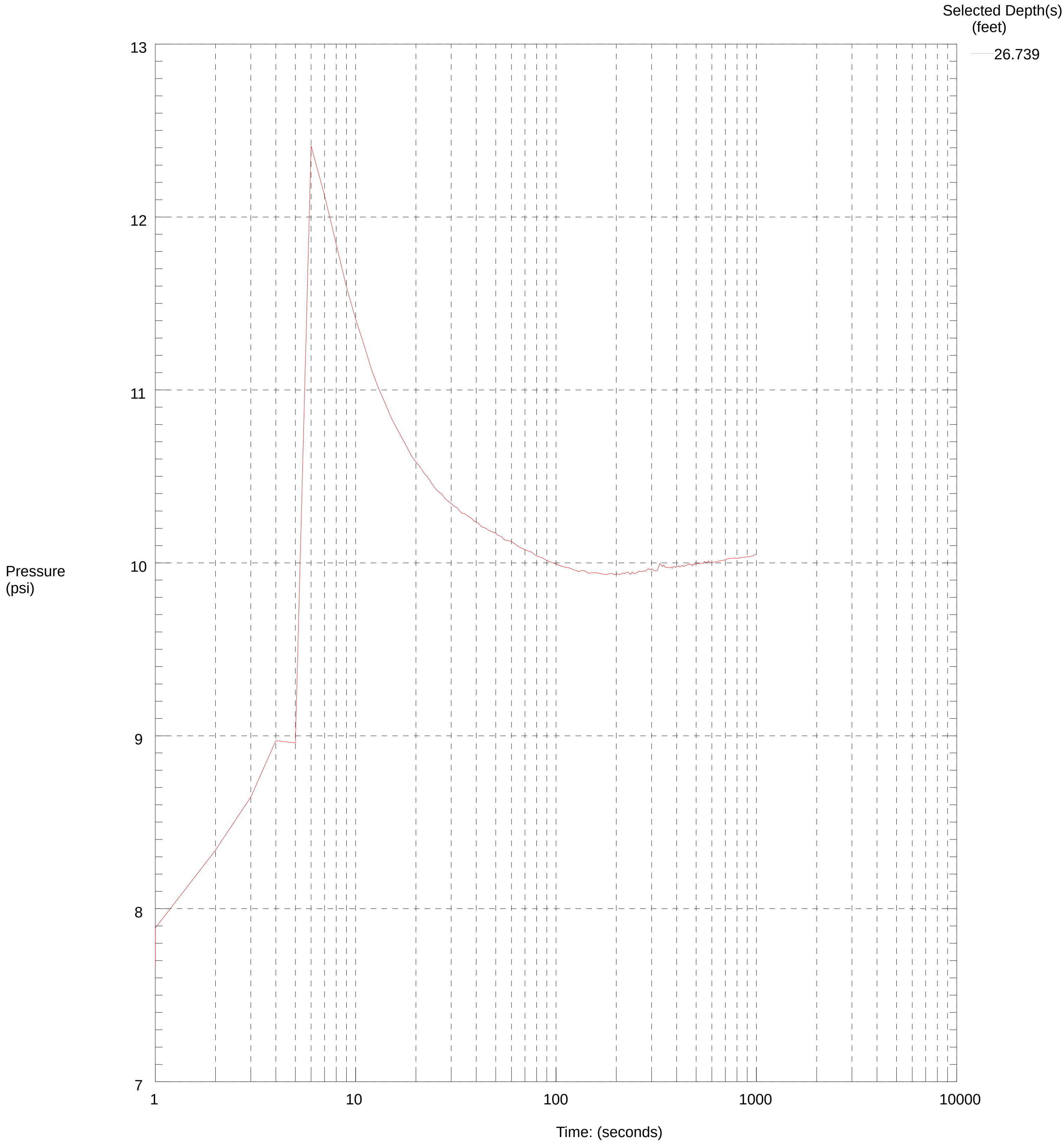


Figure A-18

Shannon & Wilson

Operator Gerdes
Sounding: CPT-04-13
Cone Used: DPG1015

CPT Date/Time: 1/18/2013 12:29:36 PM
Location: Smith Island
Job Number: 21-1-12405-030

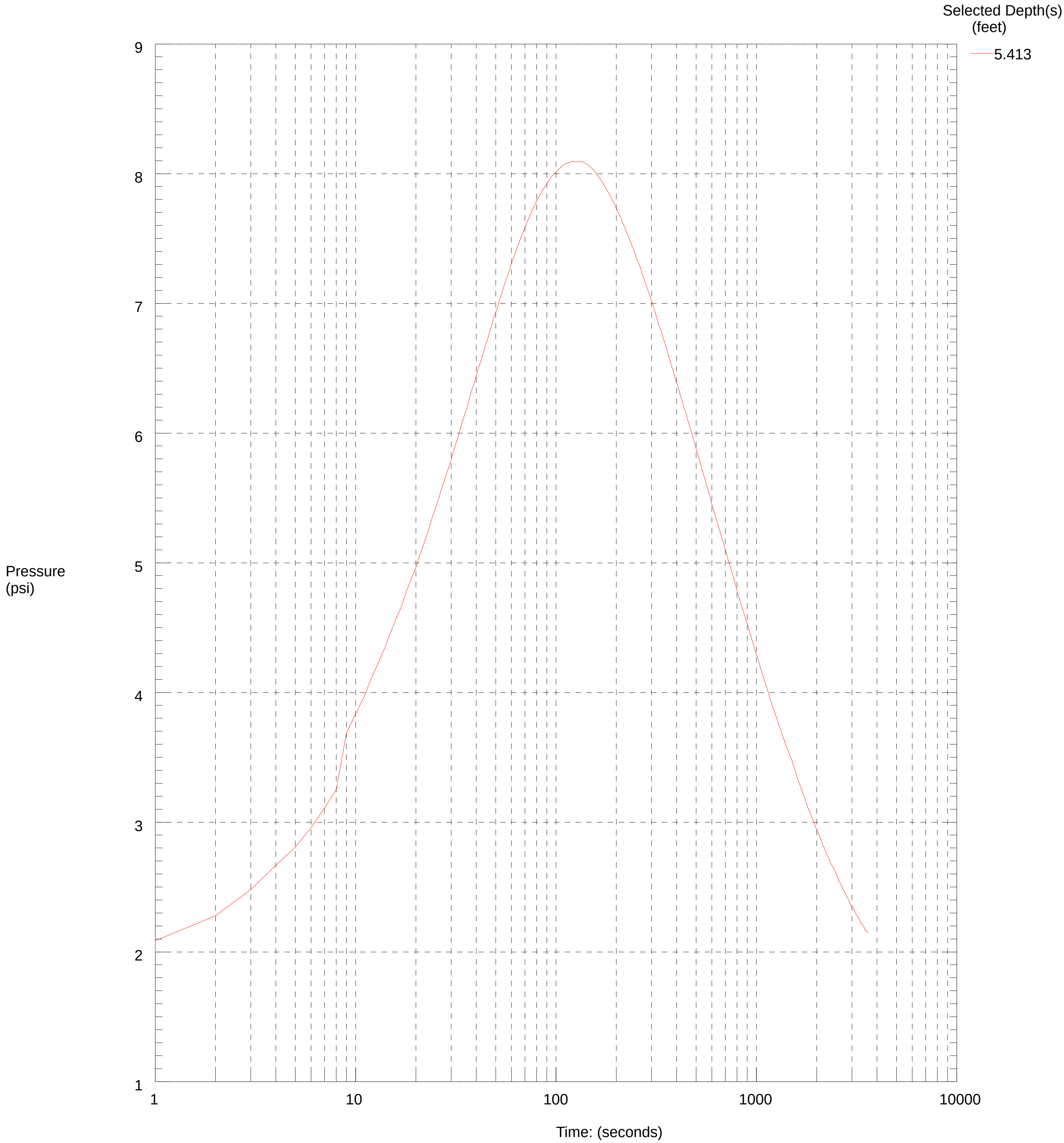


Figure A-19

Shannon & Wilson

Operator Gerdes
Sounding: CPT-04-13
Cone Used: DPG1015

CPT Date/Time: 1/18/2013 12:29:36 PM
Location: Smith Island
Job Number: 21-1-12405-030

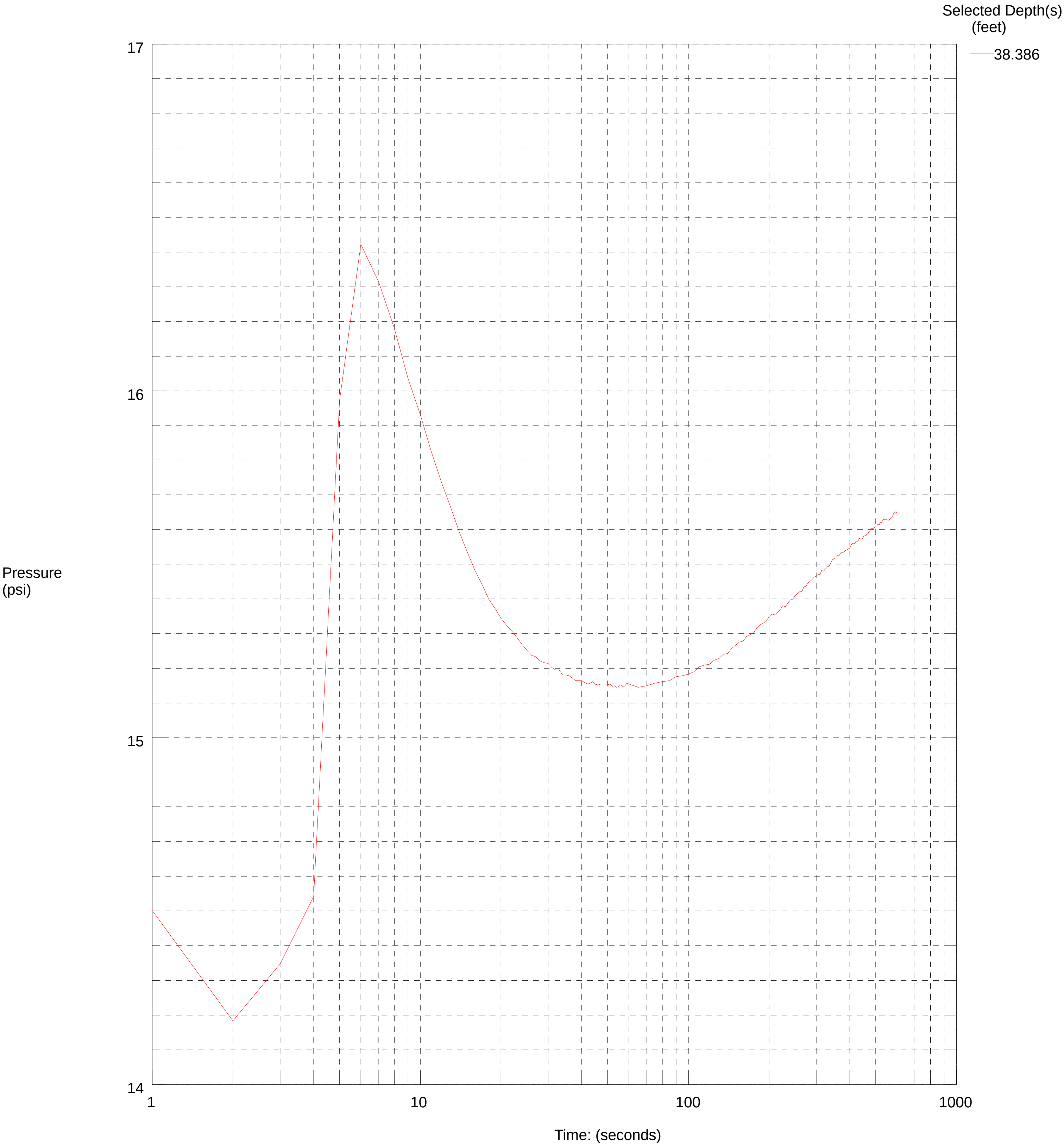


Figure A-20

APPENDIX B

GEOTECHNICAL LABORATORY TESTING AND RESULTS

APPENDIX B

GEOTECHNICAL LABORATORY TESTING AND RESULTS

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TABLE

FIGURES

FIGURES (cont.)

FIGURES (cont.)

REPORT

APPENDIX B

GEOTECHNICAL LABORATORY TESTING AND RESULTS

We performed geotechnical laboratory testing on select soil samples retrieved from the five borings completed under this work order. The laboratory testing program included tests to classify the soil and provide data for engineering studies. Visual classification was performed on all retrieved samples. Index testing, including water content determinations, grain size distribution analyses, Atterberg Limits tests, and organic content determinations were completed on select samples. One-dimensional consolidation and triaxial compression tests were performed on select relatively undisturbed samples.

The following sections describe the laboratory test procedures.

B-1 VISUAL CLASSIFICATION

Soil samples retrieved from the borings were visually classified in the laboratory using a system based on ASTM 2487, Standard Test Method for Classification of Soil for Engineering Purposes, and ASTM D 2488, Standard Recommended Practice for Description of Soils (Visual-Manual Procedure) (ASTM, 2012). The soil units encountered were described using the Shannon & Wilson, Inc. standardized field classification system, which is modeled after the Unified Soil Classification System (USCS). The system used is summarized in Figure A-1. Visual classifications were checked using index testing as discussed in the next sections.

B-2 WATER CONTENT DETERMINATIONS

The water content of select samples were estimated in accordance with ASTM D 2216, Standard Method for Laboratory Determination of Water (Moisture) Content of Soil, Rock, and Soil-Aggregate Mixtures (ASTM, 2012). Comparison of the water content of a soil with its index properties can be useful in characterizing soil unit weight, consistency, compressibility, and strength. The water content test results are shown graphically on the boring logs presented in Appendix A.

B-3 GRAIN SIZE DISTRIBUTION ANALYSES

The grain size distribution of select soil samples were measured in accordance with ASTM D 422, Standard Test Method for Particle-Size Analysis of Soils, and ASTM D 1140, Standard Test Methods for Amount of Material in Soils Finer than No. 200 (0.075 millimeter) Sieve (ASTM, 2012). Grain size distribution is used to assist in classifying soils and to provide correlation with soil properties, including permeability, shear strength, liquefaction potential, capillary action, and sensitivity to moisture. The grain size distribution analyses results are plotted as gradation curves presented in Figures B-1 through B-5. The gradation plots provide the USCS group symbols, sample descriptions, and water contents.

B-4 ATTERBERG LIMITS DETERMINATIONS

The soil plasticity of select fine-grained samples was determined by performing Atterberg Limits tests. The tests were performed in accordance with ASTM D 4318, Standard Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils (ASTM, 2012). The Atterberg Limits include Liquid Limit (LL), Plastic Limit (PL), and Plasticity Index (PI = LL - PL). They are used to assist in classifying soils, to indicate soil consistency (when compared with natural water content), and to provide correlation with soil properties including compressibility and strength. The Atterberg Limits are shown graphically on the boring logs presented in Appendix A, and are plotted on the plasticity charts presented in Figures B-6 through B-10. The plasticity charts provide USCS group symbols, sample descriptions, and water contents.

B-5 ORGANIC LIQUID LIMIT DETERMINATIONS

Organic liquid limits (OLL) were estimated by performing LL tests on select, organic-rich, fine-grained soil samples. The samples were oven dried prior to testing to evaluate the organic classification of the soil in accordance with ASTM D2487, Standard Test Method for Classification of Soil for Engineering Purposes (ASTM, 2012). The soil was classified as an organic soil if the OLL was 75 percent or less of the LL performed on the same soil during the Atterberg Limits test. The OLL results are presented in tabular form on the plasticity charts presented as Figures B-6 through B-10.

B-6 ORGANIC CONTENT

Organic contents were evaluated on select soil samples. First, the moisture content of the samples was measured by drying the soil in an oven at 105 degrees Celsius (°C). Second, the organic content of the sample was tested by igniting the oven-dried soil in a muffle furnace at 440 °C. Results of the organic content analyses are presented in Table B-1.

B-7 ONE-DIMENSIONAL CONSOLIDATION

One-dimensional consolidation tests were performed on six relatively undisturbed samples in general accordance with ASTM D 2435, Standard Test Methods for One-Dimensional Consolidation Properties of Soils Using Incremental Loading (ASTM, 2012). The samples were incrementally loaded in a fixed-ring consolidometer. During each load increment, the change in sample height with time was recorded. Each load increment approximately doubled the previous load, to a preselected maximum consolidation pressure. The samples were inundated with distilled water after the first load increment. Drainage was allowed from both the top and bottom of the sample. Once the void ratio, e, versus consolidation pressure curve had past a clear yield point (i.e., stressed beyond its past maximum vertical effective stress, or preconsolidation pressure), an unload-reload loop was performed so that the recompression behavior could be observed. Upon reaching the maximum test load, the sample was unloaded in steps of about one-fourth the previous load. Test summaries and output plots are presented in Figures B-11 to B-34.

B-8 CONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION TESTS

Consolidated-undrained triaxial compression tests with pore pressure measurements were performed on five relatively undisturbed samples in general accordance with ASTM D 4767, Standard Test Method for Consolidated-Undrained Triaxial (CUTX) Compression Test for Cohesive Soils (ASTM, 2012). To expedite the laboratory testing process, three CUTX tests were performed by HWA GeoSciences Inc. (HWA) under subcontract with Shannon & Wilson and two were performed in our laboratory. Prior to consolidation and shearing, each sample was saturated using back pressure. The degree of saturation was estimated by measuring the pore pressure coefficient B. Displacement-controlled testing machines were used to perform the tests.

All samples were sheared once except for Boring B-3-13, Sample S-2, which was sheared twice using a multi-stage procedure (see Report B-1). Effective horizontal confining (or consolidating) pressures for the CUTX tests were selected in the anticipated range of stresses that the soil will be subjected to under the proposed levee load. These stresses ranged between about one-half the estimated final (after embankment-induced consolidation) horizontal in situ stress, σ'_{hf}, and twice σ'_{hf}. Initial consolidation of the sample was performed incrementally by doubling the effective confining pressure until the desired value was reached. During each test, the sample was strained to produce a peak shear stress ratio, or to achieve a maximum 5 percent strain, whichever occurred first.

Summaries of the two Shannon & Wilson test results (Boring B-4-12, Sample S-6, at 16.0 feet and 16.5 feet) are presented as Figures B-35 through B-38. The three tests performed by HWA are presented in Report B-1.

TABLE B-1
LABORATORY TESTING SUMMARY

Boring	Sample Number	Top Depth (feet)	Water Content (%)	Organic Content (%)	Percent Gravel	Percent Sand	Percent Fines[1]	LL[2]	PL[3]	PI[4]	OLL[5]	OLL/LL (%)[2,5]	CU[6] Test Performed	Consolidation[7] Test Performed	USCS[8]	Interpreted Geologic Unit[9]	Soil Description[10]
B-1-13	2	6.2	49.8					62	36	26				X	MH	He	Gray, clayey SILT; scattered organics
B-1-13	3	7	76.6												MH	He	
B-1-13	4	10	69.1												MH	He	
B-1-13	5	12.5	89.3	7.7											MH	He	
B-1-13	6	15.3	52.1					52	30	22					MH	He	Gray, clayey SILT; scattered organics
B-1-13	6	15.5	54.5										X		MH	He	
B-1-13	7	17	43.7												ML	He	
B-1-13	8	20	38.1												ML	He	
B-1-13	9	25	42.4												ML	He	
B-1-13	10	30	22.1		0.9	93.9	5.2								SP-SM	Ha	Gray, slightly silty SAND, trace of fine gravel
B-1-13	11	35	25.3												SP-SM	Ha	
B-1-13	12	40	32.6												SM	Ha	
B-1-13	13	46.2	26.5												SM	Ha	
B-1-13	14	50	28.2												SM	Ha	
B-1-13	15	55	22.3				4.7								SP	Ha	Gray, fine to medium SAND, trace of silt
B-1-13	16	60	25.8												ML	He	
B-1-13	17	65	24.7												SP	Ha	
B-1-13	18	70	24.1				6.1								SP-SM	Ha	Gray, slightly silty, fine to medium SAND
B-1-13	19	75	58.7					67	27	40					CH	He	Gray, silty CLAY; scattered organics
B-1-13	20	81	36.7												ML	He	
B-1-13	21	82	35.2												ML	He	
B-1-13	22	85	51.4												ML	He	
B-2-13	2	5	191.2	19.4											ML	He	
B-2-13	2	6.3	226.9					266	127	139	100	38		X	OH	He	Brown, organic SILT
B-2-13	3	7	217.6												ML	He	
B-2-13	4	10	66.7												ML	He	
B-2-13	5	12.5	43.3												ML	He	
B-2-13	6	15.2	41.4					38	30	8					ML	He	Gray, slightly clayey SILT, trace of fine sand; scattered organics
B-2-13	6	15.4	41.4												ML	He	
B-2-13	7	17	39.4												ML	He	
B-2-13	8	21.2	20.5												SM	Ha	
B-2-13	9	25	25		0	96.3	3.7								SP	Ha	Gray, fine to medium SAND, trace of silt; trace of fine organics
B-2-13	10	30	23.8												SP	Ha	
B-2-13	11	35	26.9				4.8								SP	Ha	Gray, fine to medium SAND, trace of silt; trace of organics

(see Page 3 for Notes)

TABLE B-1
LABORATORY TESTING SUMMARY

Boring	Sample Number	Top Depth (feet)	Water Content (%)	Organic Content (%)	Percent Gravel	Percent Sand	Percent Fines[1]	LL[2]	PL[3]	PI[4]	OLL[5]	OLL/LL (%)[2,5]	CU[6] Test Performed	Consolidation[7] Test Performed	USCS[8]	Interpreted Geologic Unit[9]	Soil Description[10]
B-2-13	12	40	24.5												SP	Ha	
B-3-13	2	5	43										X		ML	He	
B-3-13	2	6.2	49.1					49	29	20	34	69			OL	He	Gray-brown, organic SILT
B-3-13	2	6.3	42.6	2.8										X	ML	He	
B-3-13	4	10	68												MH	He	
B-3-13	5	12.5	47.7												MH	He	
B-3-13	6	15.3	62.6					59	31	28					MH	He	Gray, clayey SILT; abundant organics
B-3-13	6	15.8	62.6										X		MH	He	
B-3-13	7	17	35.8												ML	He	
B-3-13	8	20	30		0	64.6	35.4								SM	Ha	Gray-brown, silty, fine to medium SAND
B-3-13	9	25	28.3				3.2								SP	Ha	Gray, fine to medium SAND, trace of silt; trace of organics
B-3-13	10	30	36.7												SP	Ha	
B-3-13	11	35	28.8												ML	He	
B-3-13	12	40	35.2				23.4								SM	Ha	Gray, silty, fine to medium SAND; trace of organics
B-4-12	2	5.4	51.5					65	42	23	46	71		X	OH	He	Brown, clayey, organic SILT
B-4-12	3	7	105.3	9.4											ML	He	
B-4-12	4	10	37.4												SP-SM	Ha	
B-4-12	5	12.5	39												ML	He	
B-4-12	6	15.1	37.3												ML	He	
B-4-12	6	15.2						31	27	4					ML	He	Gray, slightly clayey SILT, trace of fine sand; trace of fine organics
B-4-12	6	15.6	35.1											X	ML	He	
B-4-13	6	16											X		ML	He	
B-4-14	6	16.5											X		ML	He	
B-4-12	7	17	35.6												ML	He	
B-4-12	8	20	29												ML	He	
B-4-12	9	25	28.5		0	94.3	5.7								SP-SM	Ha	Gray, slightly silty, fine to medium SAND; trace of organics
B-4-12	10	30	28.8												SP-SM	Ha	
B-4-12	11	35	25.8												SP-SM	Ha	
B-4-12	12	40	31.4				7.5								SP-SM	Ha	Gray, slightly silty, fine to medium SAND; trace of organics
B-5-12	2	5.7	82.5					92	46	46	46	50		X	OH	He	Gray-brown, organic SILT
B-5-12	3	7	114	10.8											ML	He	
B-5-12	4	10	65.6												ML	He	

(see Page 3 for Notes)

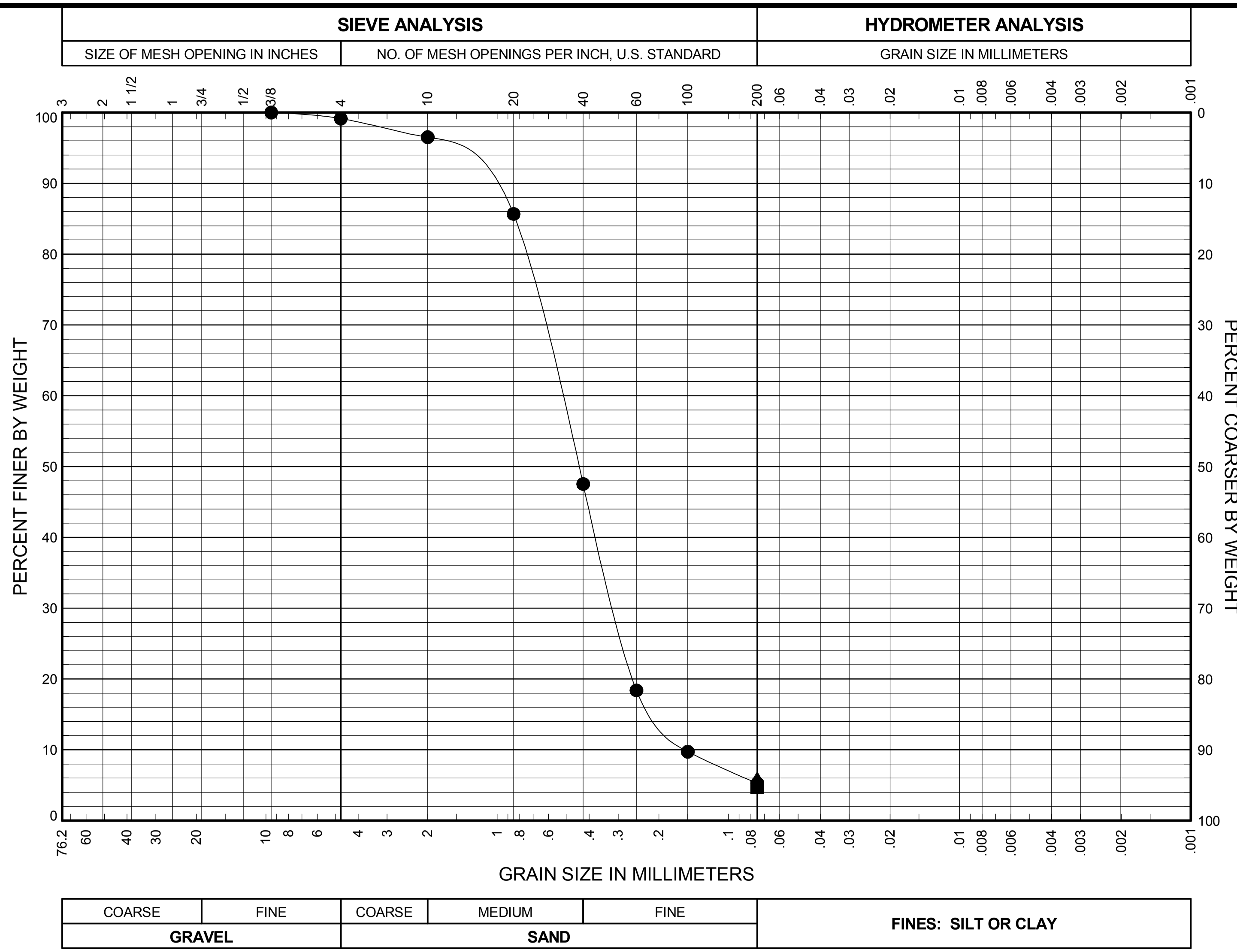
TABLE B-1
LABORATORY TESTING SUMMARY

Boring	Sample Number	Top Depth (feet)	Water Content (%)	Organic Content (%)	Percent Gravel	Percent Sand	Percent Fines[1]	LL[2]	PL[3]	PI[4]	OLL[5]	OLL/LL (%)[2,5]	CU[6] Test Performed	Consolidation[7] Test Performed	USCS[8]	Interpreted Geologic Unit[9]	Soil Description[10]
B-5-12	4	10.6						65	36	29					MH	He	Gray-brown, clayey SILT; abundant organics
B-5-12	5	12	43.5												ML	He	
B-5-12	6	15	28.8		0	86	14								SM	Ha	Gray, silty, fine SAND; scattered organics
B-5-12	7	17.5	29.6												SM	Ha	
B-5-12	8	20	35.8												SM	Ha	
B-5-12	9	25	26.2												SP-SM	Ha	
B-5-12	10	30	32.3												SP-SM	Ha	
B-5-12	11	35	25.9				6.9								SP-SM	Ha	Gray, slightly silty, fine to medium SAND; trace to scattered organics
B-5-12	12	40	31.6												SP-SM	Ha	
B-5-12	13	45	28.4												SP-SM	Ha	
B-5-12	14	50	30.9												SP-SM	Ha	

Notes:
1. Fines are defined as particle size smaller than 0.075 millimeter (mm).
2. LL = Liquid Limit
3. PL = Plastic Limit
4. PI = Plasticity Index
5. OLL = Organic Liquid Limit
6. CU = Consolidated-Undrained Triaxial Compression Test
7. Consolidation = One-Dimensional Consolidation Test
8. USCS = Unified Soil Classification System
9. Brief descriptions of the interpreted geologic units can be found in the Site Subsurface Conditions and Geology section in the main report text.
10. Soil descriptions have been abbreviated and simplified; more complete descriptions can be found in the borings logs in Appendix A.

% = percent

(see Page 3 for Notes)



LEGEND

USCS: Unified Soil Classification System

COBBLE REM %: Percentage of cobbles removed from specimen; based on pre-removal total dry mass

SG: Specific gravity of soil solids < No. 4 sieve per ASTM D854

NAT WC %: Natural water content

Cu: Coefficient of uniformity

Cc: Coefficient of curvature

ASTM DES: ASTM International test standard designation

BORING AND SAMPLE NO.	DEPTH (feet)	U.S.C.S. SYMBOL	SOIL CLASSIFICATION	GRAVEL %	SAND %	FINES %	COBBLE REM %	SG	NAT WC %	Cu	Cc	TEST BY	REVIEW BY	ASTM DES
● B-1-13, S-10	30.0	SP-SM	Gray, slightly silty SAND, trace of fine gravel	1	94	5.2			22.1	3.5	1.2	AKV	JFL	D422
■ B-1-13, S-15	55.0	SP	Gray, fine to medium SAND, trace of silt			4.7			22.3			AKV	JFL	D1140
▲ B-1-13, S-18	70.0	SP-SM	Gray, slightly silty, fine to medium SAND			6.1			24.1			AKV	JFL	D1140

Smith Island Site Restoration
Snohomish County, Washington

GRAIN SIZE DISTRIBUTION
BORING B-1-13

October 2013 21-1-12405-060

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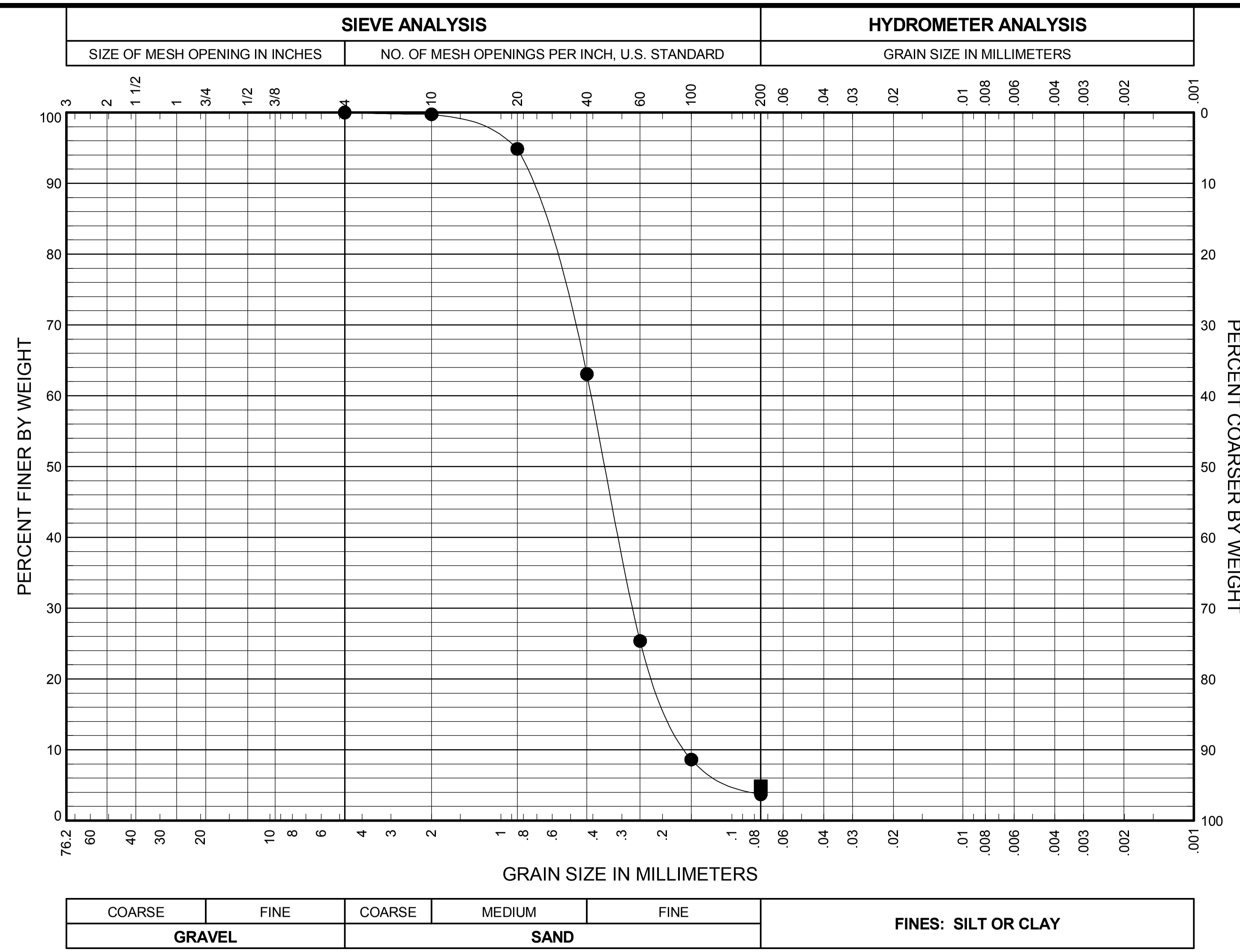
FIG. B-1
Sheet 1 of 1



LEGEND

USCS: Unified Soil Classification System

COBBLE REM %: Percentage of cobbles removed from specimen; based on pre-removal total dry mass

SG: Specific gravity of soil solids < No. 4 sieve per ASTM D854

NAT WC %: Natural water content

Cu: Coefficient of uniformity

Cc: Coefficient of curvature

ASTM DES: ASTM International test standard designation

BORING AND SAMPLE NO.	DEPTH (feet)	U.S.C.S. SYMBOL	SOIL CLASSIFICATION	GRAVEL %	SAND %	FINES %	COBBLE REM %	SG	NAT WC %	Cu	Cc	TEST BY	REVIEW BY	ASTM DES
● B-2-13, S-9	25.0	SP	Gray, fine to medium SAND, trace of silt; trace of fine organics		96	3.7			25.0	2.6	1.1	AKV	JFL	D422
■ B-2-13, S-11	35.0	SP	Gray, fine to medium SAND, trace of silt; trace of organics			4.8			26.9			AKV	JFL	D1140

Smith Island Site Restoration
Snohomish County, Washington

GRAIN SIZE DISTRIBUTION
BORING B-2-13

October 2013 21-1-12405-060

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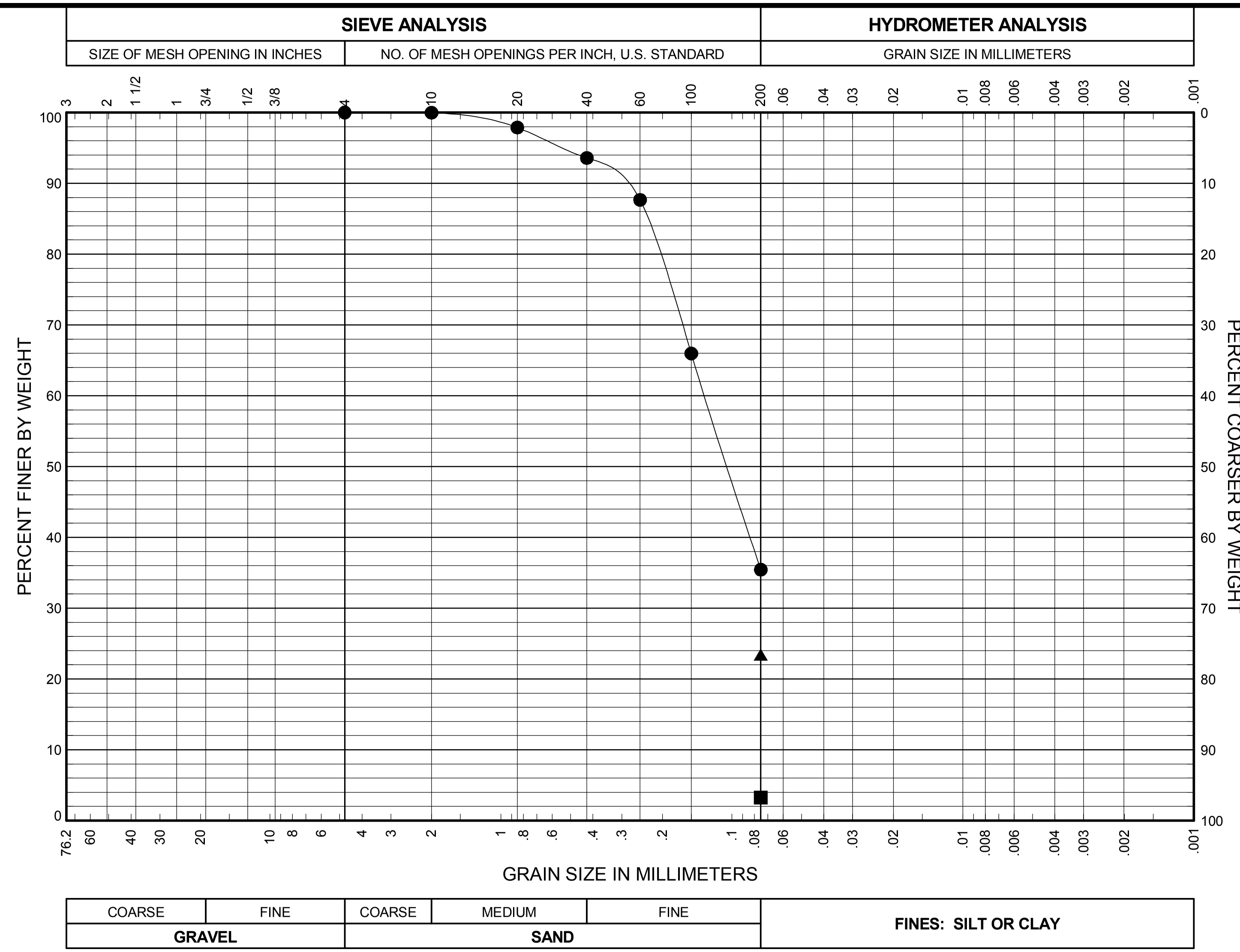
FIG. B-2
Sheet 1 of 1

FIG. B-2



LEGEND

USCS: Unified Soil Classification System

COBBLE REM %: Percentage of cobbles removed from specimen; based on pre-removal total dry mass

SG: Specific gravity of soil solids < No. 4 sieve per ASTM D854

NAT WC %: Natural water content

Cu: Coefficient of uniformity

Cc: Coefficient of curvature

ASTM DES: ASTM International test standard designation

BORING AND SAMPLE NO.	DEPTH (feet)	U.S.C.S. SYMBOL	SOIL CLASSIFICATION	GRAVEL %	SAND %	FINES %	COBBLE REM %	SG	NAT WC %	Cu	Cc	TEST BY	REVIEW BY	ASTM DES
● B-3-13, S-8	20.0	SM	Gray-brown, silty, fine to medium SAND		65	35.4			30.0			AXT	JFL	D422
■ B-3-13, S-9	25.0	SP	Gray, fine to medium SAND, trace of silt; trace of organics			3.2			28.3			AXT	JFL	D1140
▲ B-3-13, S-12	40.0	SM	Gray, silty, fine to medium SAND; trace of organics			23.4			35.2			AXT	JFL	D1140

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Snohomish County, Washington

GRAIN SIZE DISTRIBUTION
BORING B-3-13

October 2013 21-1-12405-060

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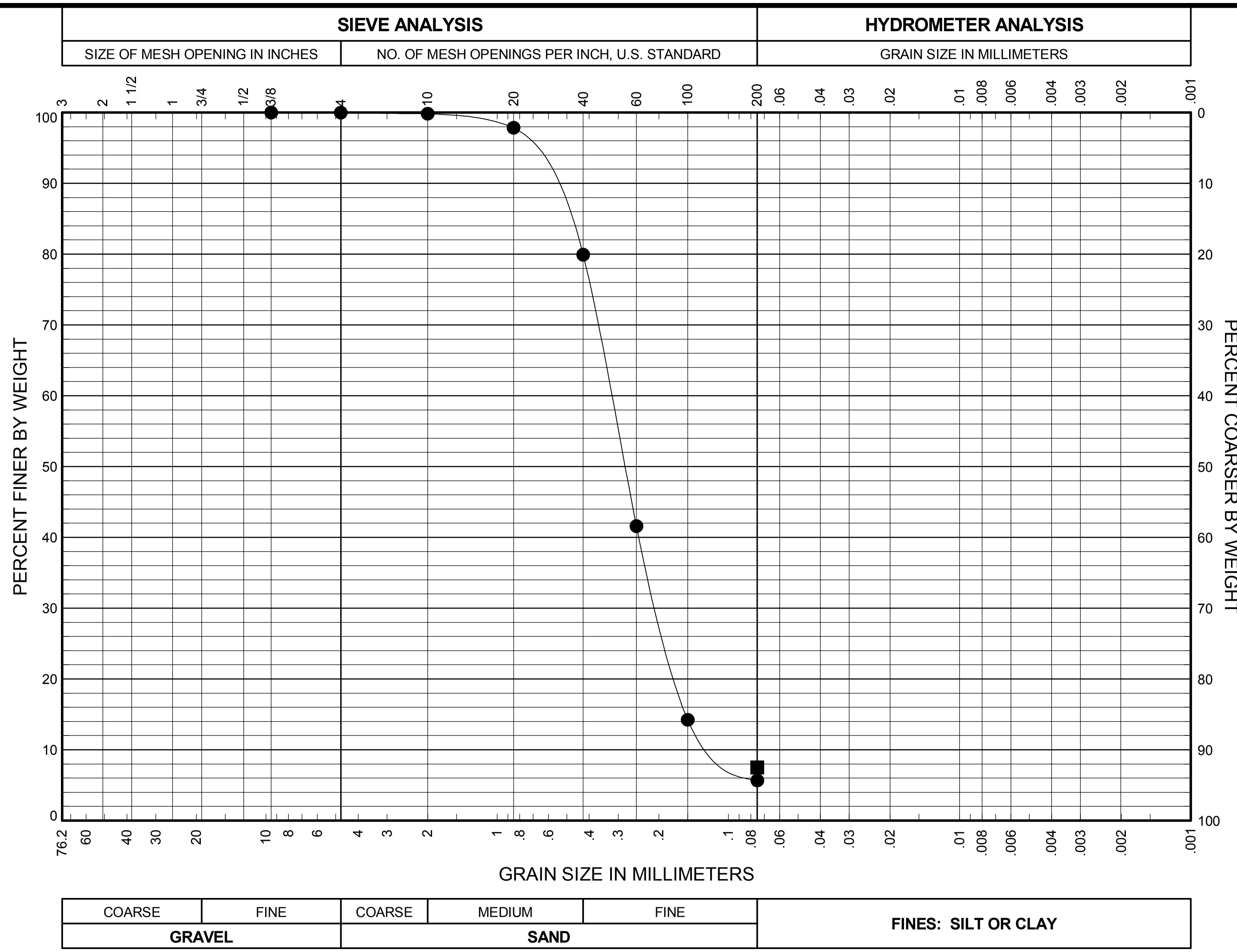
FIG. B-3
Sheet 1 of 1

FIG. B-3



LEGEND

USCS: Unified Soil Classification System

COBBLE REM %: Percentage of cobbles removed from specimen; based on pre-removal total dry mass

SG: Specific gravity of soil solids < No. 4 sieve per ASTM D854

NAT WC %: Natural water content

Cu: Coefficient of uniformity

Cc: Coefficient of curvature

ASTM DES: ASTM International test standard designation

BORING AND SAMPLE NO.	DEPTH (feet)	U.S.C.S. SYMBOL	SOIL CLASSIFICATION	GRAVEL %	SAND %	FINES %	COBBLE REM %	SG	NAT WC %	Cu	Cc	TEST BY	REVIEW BY	ASTM DES
● B-4-12, S-9	25.0	SP-SM	Gray, slightly silty, fine to medium SAND; trace of organics	0	94	5.7			28.5	3.0	1.2	AXT	JFL	D422
■ B-4-12, S-12	40.0	SP-SM	Gray, slightly silty, fine to medium SAND; trace of organics			7.5			31.4			AXT	JFL	D1140

Smith Island Site Restoration
Snohomish County, Washington

GRAIN SIZE DISTRIBUTION
BORING B-4-12

October 2013 21-1-12405-060

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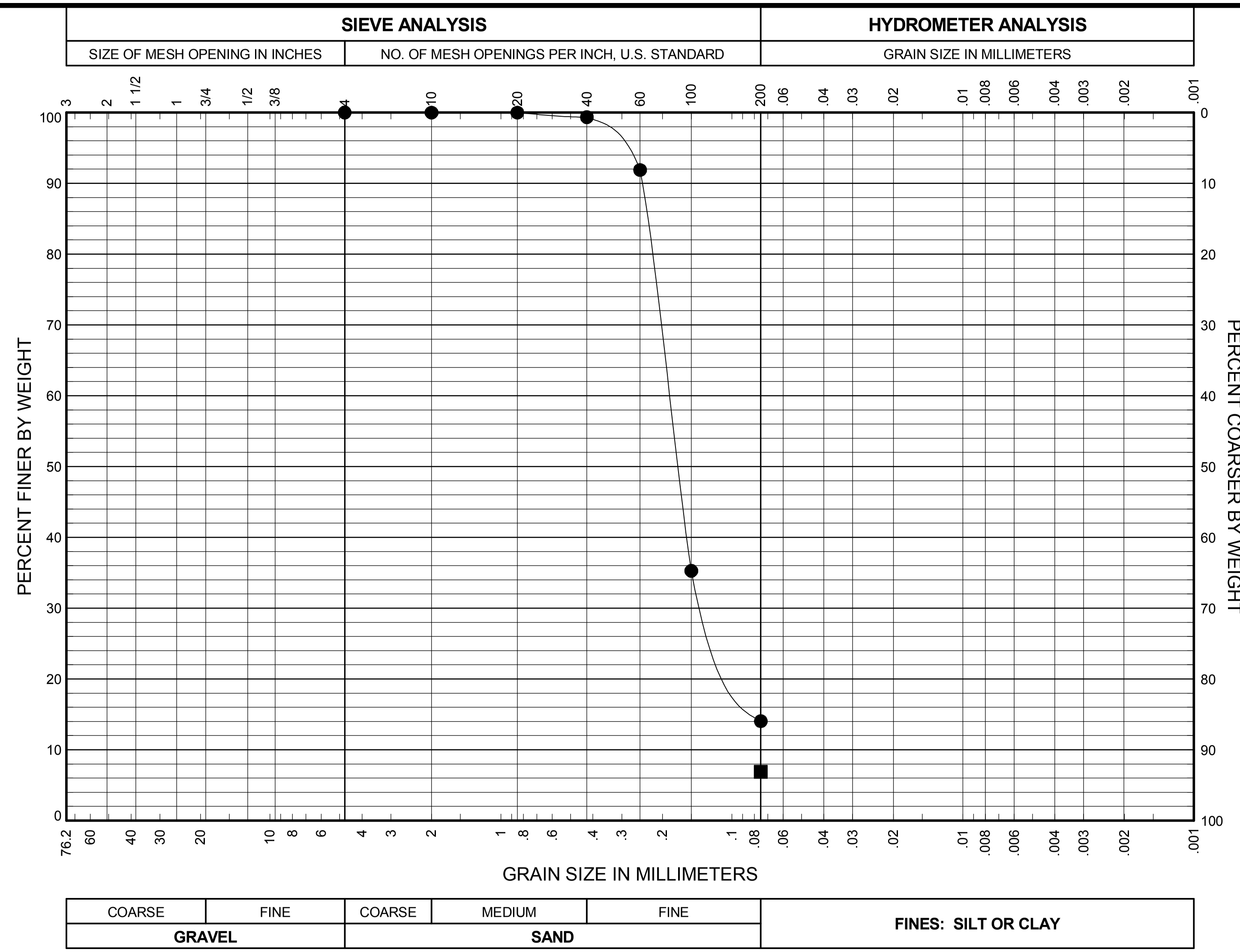
FIG. B-4
Sheet 1 of 1

FIG. B-4



LEGEND

USCS: Unified Soil Classification System

COBBLE REM %: Percentage of cobbles removed from specimen; based on pre-removal total dry mass

SG: Specific gravity of soil solids < No. 4 sieve per ASTM D854

NAT WC %: Natural water content

Cu: Coefficient of uniformity

Cc: Coefficient of curvature

ASTM DES: ASTM International test standard designation

BORING AND SAMPLE NO.	DEPTH (feet)	U.S.C.S. SYMBOL	SOIL CLASSIFICATION	GRAVEL %	SAND %	FINES %	COBBLE REM %	SG	NAT WC %	Cu	Cc	TEST BY	REVIEW BY	ASTM DES
● B-5-12, S-6	15.0	SM	Gray, silty, fine SAND; scattered organics		86	14.0			28.8			AXT	JFL	D422
■ B-5-12, S-11	35.0	SP-SM	Gray, slightly silty, fine to medium SAND; trace to scattered organics			6.9			25.9			AXT	JFL	D1140

Smith Island Site Restoration
Snohomish County, Washington

GRAIN SIZE DISTRIBUTION
BORING B-5-12

October 2013 21-1-12405-060

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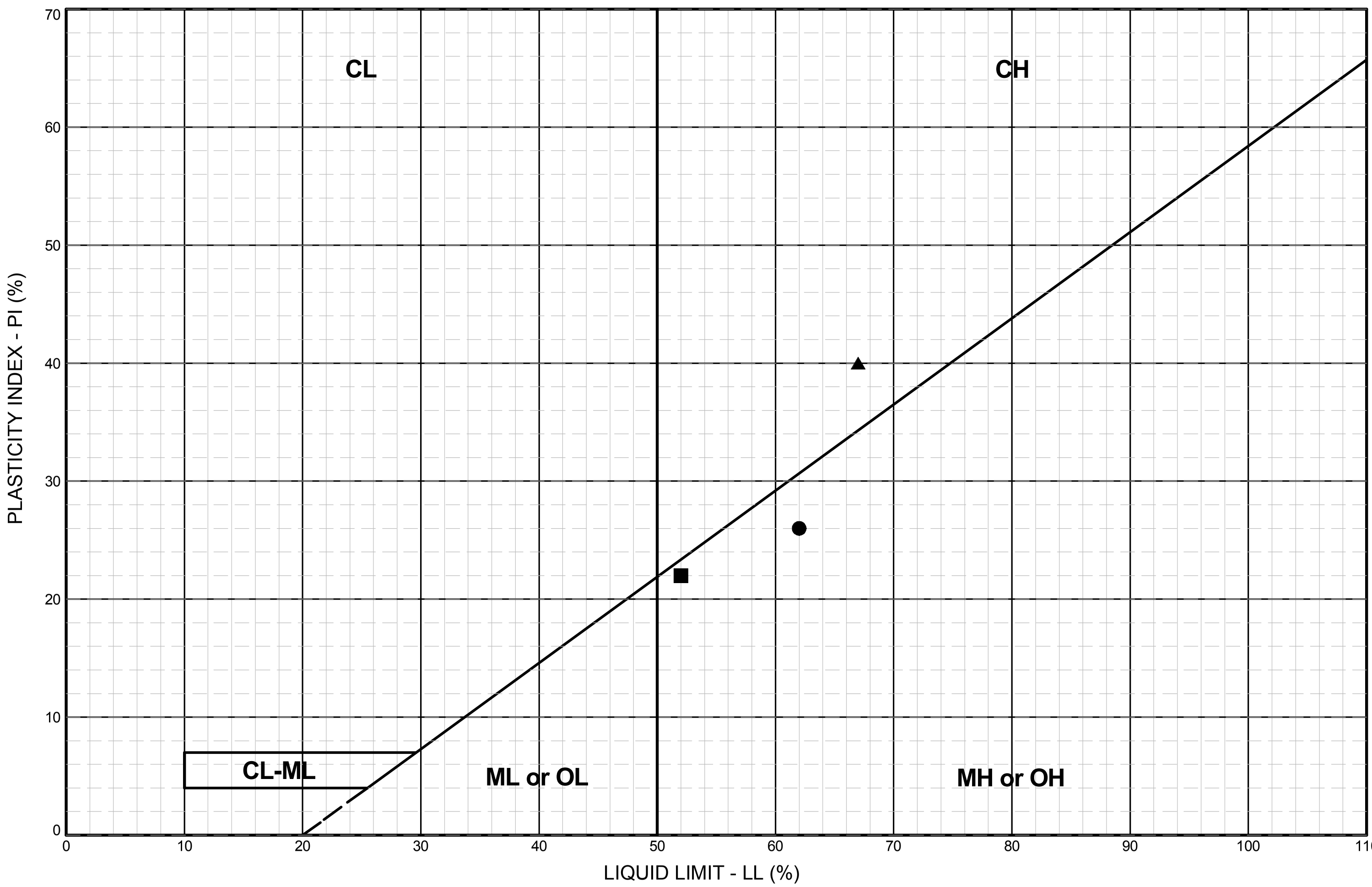
FIG. B-5
Sheet 1 of 1

FIG. B-5



LEGEND

CL: Low plasticity inorganic clays; sandy and silty clays

CH: High plasticity inorganic clays

ML: Inorganic silts and clayey silts of low plasticity

MH: Inorganic silts and clayey silts of high plasticity

CL-ML: Silty clays and clayey silts

OL: Organic silts and clays of low plasticity

OH: Organic silts and clays of high plasticity

LL: Liquid limit

PL: Plastic limit

PI: Plasticity index; PI=LL-PL

OLL: Organic liquid limit; oven-dried prior to testing, in accordance with the ASTM D2487 definition of organic soils

OLL/LL: Ratio of OLL to LL; considered organic when the ratio is less than 75%

NP: Nonplastic

NV: No value

BORING AND SAMPLE NO.	DEPTH (feet)	U.S.C.S. SYMBOL	SOIL CLASSIFICATION	LL %	PL %	PI %	OLL %	OLL/LL %	NAT. W.C. %	PASS. #200,%	TEST BY	CKD BY	ASTM STD
● B-1-13, S-2	6.2	MH	Gray, clayey SILT; scattered organics	62	36	26			49.8		AKV	JFL	D4318
■ B-1-13, S-6	15.3	MH	Gray, clayey SILT; scattered organics	52	30	22			52.1		AKV	JFL	D4318
▲ B-1-13, S-19	75.0	CH	Gray, silty CLAY; scattered organics	67	27	40			58.7		AKV	JFL	D4318

Smith Island Site Restoration
Snohomish County, Washington

PLASTICITY CHART
BORING B-1-13

October 2013

21-1-12405-060

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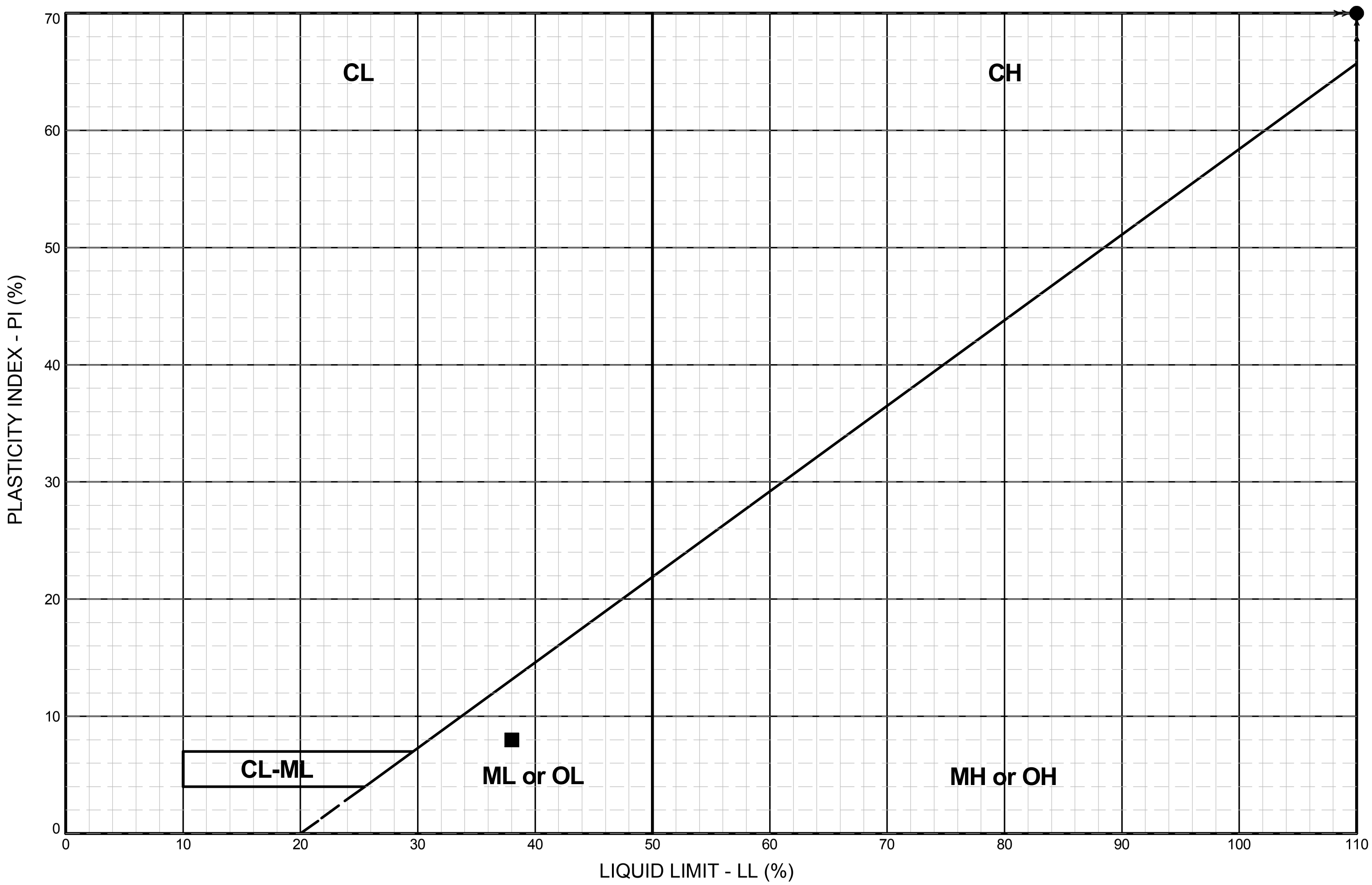
FIG. B-6
Sheet 1 of 1

FIG. B-6



LEGEND

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MH: Inorganic silts and clayey silts of high plasticity

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OH: Organic silts and clays of high plasticity

LL: Liquid limit

PL: Plastic limit

PI: Plasticity index; PI=LL-PL

OLL: Organic liquid limit; oven-dried prior to testing, in accordance with the ASTM D2487 definition of organic soils

OLL/LL: Ratio of OLL to LL; considered organic when the ratio is less than 75%

NP: Nonplastic

NV: No value

AASHTO_ATT_MAIN_OLL 21-12405.GPJ SHAN_WIL.GDT 12/2/13

BORING AND SAMPLE NO.	DEPTH (feet)	U.S.C.S. SYMBOL	SOIL CLASSIFICATION	LL %	PL %	PI %	OLL %	OLL/LL %	NAT. W.C. %	PASS. #200,%	TEST BY	CKD BY	ASTM STD
● B-2-13, S-2	6.3	OH	Brown, organic SILT	266	127	139	100	38	226.9		AKV	JFL	D4318
■ B-2-13, S-6	15.2	ML	Gray, slightly clayey SILT, trace of fine sand; scattered organics	38	30	8			41.4		AKV	JFL	D4318

Smith Island Site Restoration
Snohomish County, Washington

PLASTICITY CHART
BORING B-2-13

October 2013 — 21-1-12405-060

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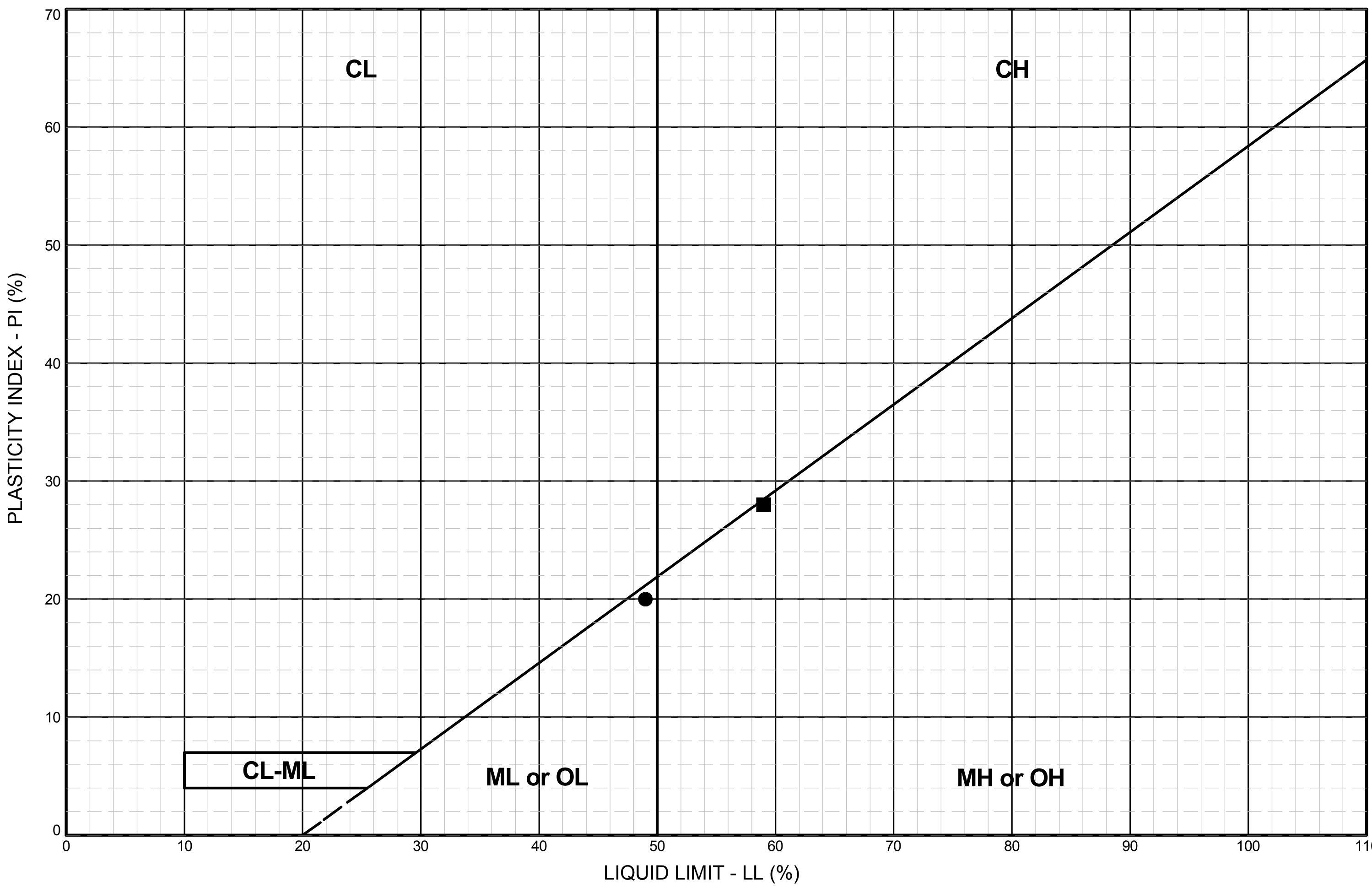
FIG. B-7
Sheet 1 of 1

FIG. B-7



LEGEND

CL: Low plasticity inorganic clays; sandy and silty clays

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OL: Organic silts and clays of low plasticity

OH: Organic silts and clays of high plasticity

LL: Liquid limit

PL: Plastic limit

PI: Plasticity index; PI=LL-PL

OLL: Organic liquid limit; oven-dried prior to testing, in accordance with the ASTM D2487 definition of organic soils

OLL/LL: Ratio of OLL to LL; considered organic when the ratio is less than 75%

NP: Nonplastic

NV: No value

BORING AND SAMPLE NO.	DEPTH (feet)	U.S.C.S. SYMBOL	SOIL CLASSIFICATION	LL %	PL %	PI %	OLL %	OLL/LL %	NAT. W.C. %	PASS. #200,%	TEST BY	CKD BY	ASTM STD
● B-3-13, S-2	6.2	OL	Gray-brown, organic SILT	49	29	20	34	69	49.1		AKV	JFL	D4318
■ B-3-13, S-6	15.3	MH	Gray, clayey SILT; abundant organics	59	31	28			62.6		AKV	JFL	D4318

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Snohomish County, Washington

PLASTICITY CHART
BORING B-3-13

October 2013 — 21-1-12405-060

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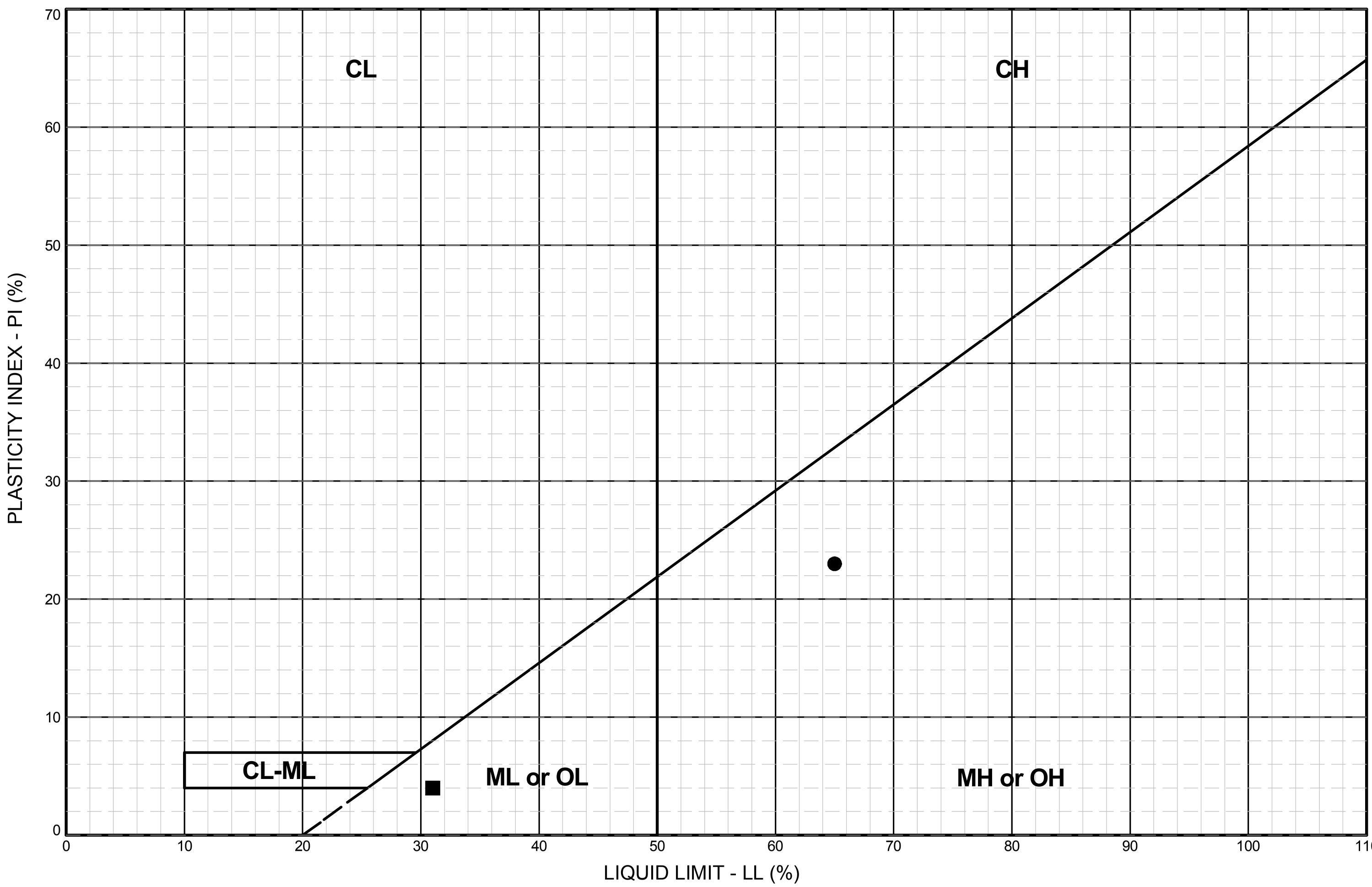
FIG. B-8
Sheet 1 of 1

FIG. B-8



LEGEND

CL: Low plasticity inorganic clays; sandy and silty clays

CH: High plasticity inorganic clays

ML: Inorganic silts and clayey silts of low plasticity

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OH: Organic silts and clays of high plasticity

LL: Liquid limit

PL: Plastic limit

PI: Plasticity index; PI=LL-PL

OLL: Organic liquid limit; oven-dried prior to testing, in accordance with the ASTM D2487 definition of organic soils

OLL/LL: Ratio of OLL to LL; considered organic when the ratio is less than 75%

NP: Nonplastic

NV: No value

BORING AND SAMPLE NO.	DEPTH (feet)	U.S.C.S. SYMBOL	SOIL CLASSIFICATION	LL %	PL %	PI %	OLL %	OLL/LL %	NAT. W.C. %	PASS. #200,%	TEST BY	CKD BY	ASTM STD
● B-4-12, S-2	5.4	OH	Brown, clayey, organic SILT	65	42	23	46	71	51.5		AKV	JFL	D4318
■ B-4-12, S-6	15.2	ML	Gray, slightly clayey SILT, trace of fine sand; trace of fine organics	31	27	4					AKV	JFL	D4318

Smith Island Site Restoration
Snohomish County, Washington

PLASTICITY CHART
BORING B-4-12

October 2013 21-1-12405-060

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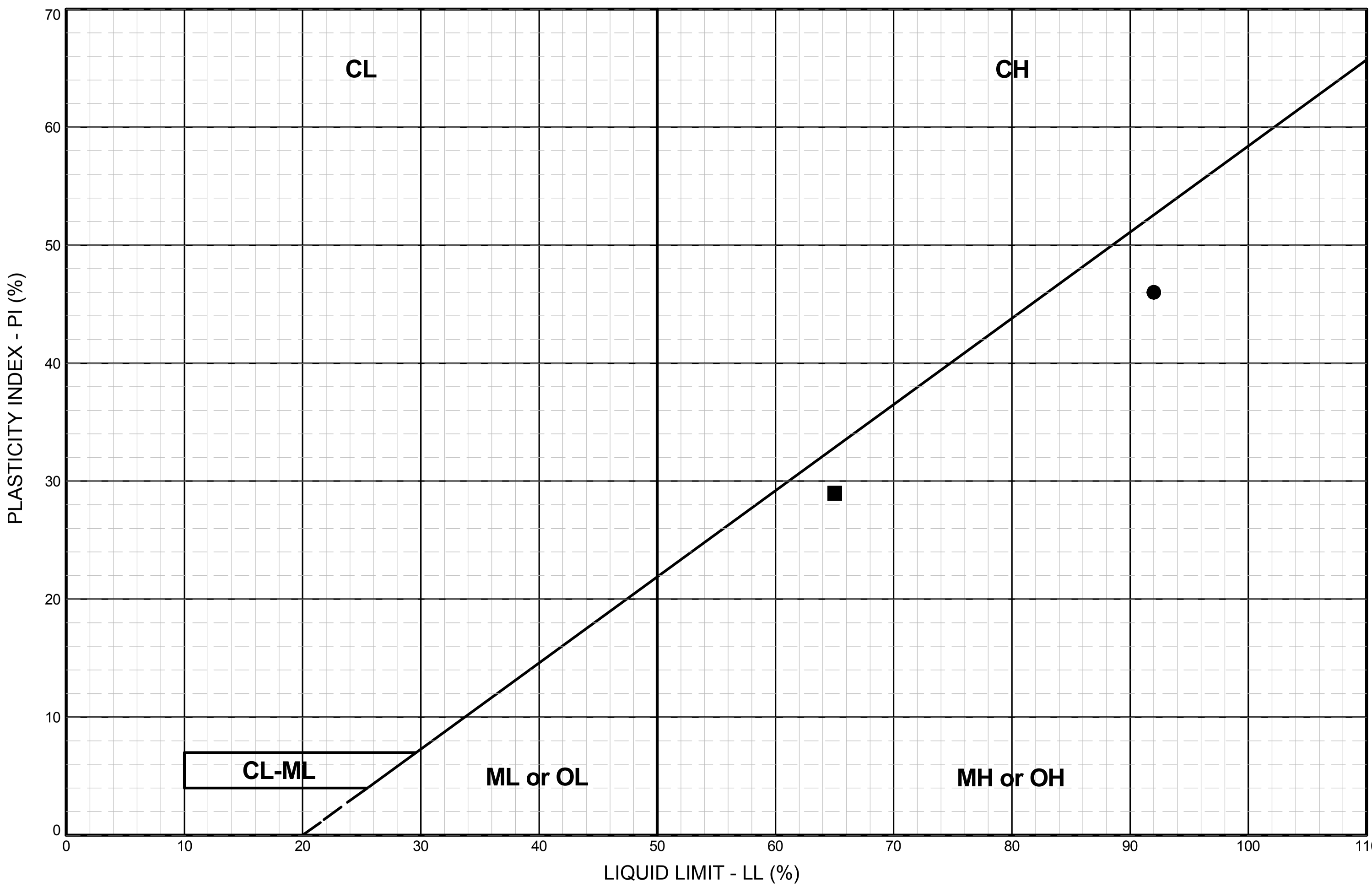
FIG. B-9
Sheet 1 of 1



LEGEND

CL: Low plasticity inorganic clays; sandy and silty clays

CH: High plasticity inorganic clays

ML: Inorganic silts and clayey silts of low plasticity

MH: Inorganic silts and clayey silts of high plasticity

CL-ML: Silty clays and clayey silts

OL: Organic silts and clays of low plasticity

OH: Organic silts and clays of high plasticity

LL: Liquid limit

PL: Plastic limit

PI: Plasticity index; PI=LL-PL

OLL: Organic liquid limit; oven-dried prior to testing, in accordance with the ASTM D2487 definition of organic soils

OLL/LL: Ratio of OLL to LL; considered organic when the ratio is less than 75%

NP: Nonplastic

NV: No value

BORING AND SAMPLE NO.	DEPTH (feet)	U.S.C.S. SYMBOL	SOIL CLASSIFICATION	LL %	PL %	PI %	OLL %	OLL/LL %	NAT. W.C. %	PASS. #200,%	TEST BY	CKD BY	ASTM STD
● B-5-12, S-2	5.7	OH	Gray-brown, organic SILT	92	46	46	46	50	82.5		AKV	JFL	D4318
■ B-5-12, S-4	10.6	MH	Gray-brown, clayey SILT; abundant organics	65	36	29			64.4		AKV	JFL	D4318

Smith Island Site Restoration
Snohomish County, Washington

PLASTICITY CHART
BORING B-5-12

October 2013 21-1-12405-060

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FIG. B-10
Sheet 1 of 1

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-1-13	Tested By/Date	AKV 1/10/2013
Sample	S-2	Calculated By/Date	JFL 2/4/2013
Depth, ft	6.2	Checked By/Date	JFL 2/19/2013

SAMPLE CLASSIFICATION:
Gray, clayey SILT; scattered organics; MH

SAMPLE DATA:

Specific Gravity (estimated)	2.7
Liquid Limit	62
Plastic Limit	36
Plasticity Index	26

SPECIMEN DATA:

	Before Inundation	First Load	Final Load
Height, inches	0.786	0.786	0.580
Diameter, inches	2.502	2.502	2.502
Sample Volume, cuin	3.865	3.865	2.853
Wet Density, pcf	101.9	101.9	120.3
Dry Density, pcf	67.0	67.0	90.8
Water Content, %	52%	52%	32%
Void Ratio	1.52	1.52	0.86
Saturation, %	93%	93%	100%

Increment	Applied Stress, tsf	ΔH at t_{100}, in	ΔH / H_o	Void Ratio	$t_{50,}$ min	Coeff. of Comp., MPa^{-1}	Coeff. of Consol., cm^2/sec	Coeff. of Perm., cm/sec
1	0.08	0.001	0.1%	1.513	0.9	0.34	4.2E-03	5.6E-08
2	0.16	0.005	0.6%	1.501	0.5	1.57	6.7E-03	4.1E-07
3	0.32	0.012	1.6%	1.476	0.6	1.61	5.4E-03	3.4E-07
4	0.64	0.024	3.0%	1.440	0.4	1.16	6.4E-03	3.0E-07
5	1.29	0.041	5.3%	1.383	0.4	0.93	5.6E-03	2.1E-07
6	2.58	0.071	9.0%	1.289	0.5	0.76	4.7E-03	1.5E-07
7	5.15	0.115	14.7%	1.146	0.6	0.58	2.5E-03	6.2E-08
8	1.29	0.127	16.1%	1.110	0.3	-0.10	9.2E-03	4.1E-08
9	0.32	0.116	14.8%	1.144	1.0	0.37	2.1E-03	3.7E-08
10	0.08	0.100	12.7%	1.197	2.3	2.29	9.5E-04	9.9E-08
11	0.32	0.093	11.8%	1.219	0.7	-0.94	3.3E-03	1.4E-07
12	1.29	0.107	13.6%	1.174	0.6	0.48	4.2E-03	9.0E-08
13	5.15	0.130	16.5%	1.100	0.3	0.20	8.2E-03	7.4E-08
14	10.31	0.159	20.2%	1.008	0.5	0.19	4.1E-03	3.6E-08
15	20.61	0.197	25.1%	0.885	0.4	0.12	4.3E-03	2.6E-08
16	41.22	0.235	29.9%	0.765	0.4	0.06	4.3E-03	1.4E-08
17	10.31	0.2470	31.44%	0.725	0.0	-0.013	4.1E-02	3.0E-08
18	2.58	0.2383	30.33%	0.753	1.5	0.038	8.8E-04	1.9E-09
19	0.64	0.2283	29.06%	0.785	0.2	0.172	1.4E-03	1.3E-08
20	0.16	0.2152	27.39%	0.827	7.2	0.907	2.3E-04	1.1E-08

NOTES:

1. Abbreviations:
   - cm = centimeter
   - cm^2 = square centimeter
   - Coeff. = Coefficient
   - Comp. = Compressibility
   - Consol. = Consolidation
   - cu in = cubic inch
   - ft = feet
   - H_o = initial height
   - ΔH = change in height
   - in = inch
   - min = minute
   - MPa = megapascal
   - pcf = pounts per cubic foot
   - Perm. = Permeability
   - sec = second
   - t_n = time at n% of primary consolidation
   - tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST SUMMARY
BORING B-1-13, SAMPLE S-2 @6.2ft

October 2013 21-1-12405-060

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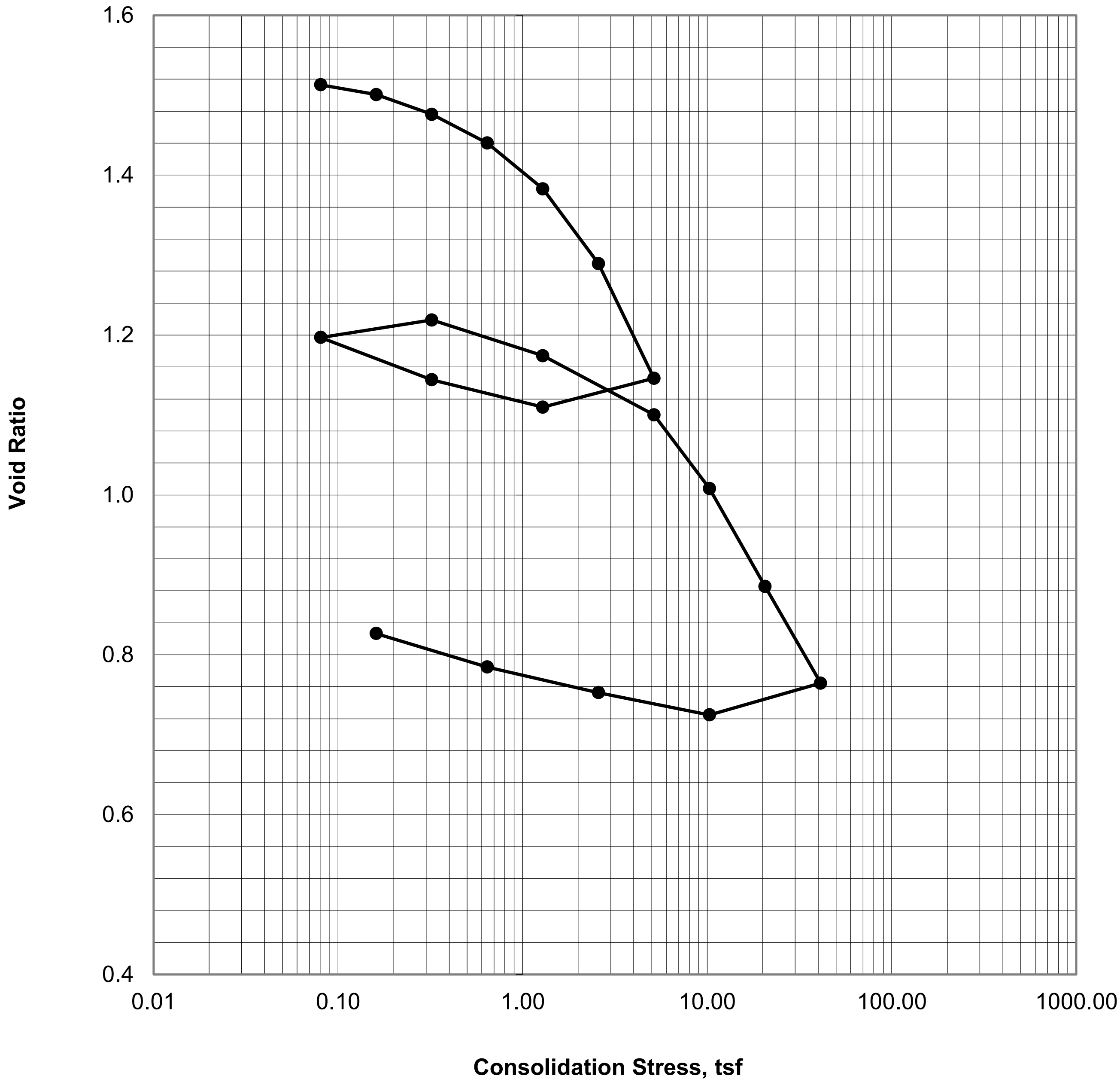
Geotechnical and Environmental Consultants

FIG. B-11

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-1-13	Tested By/Date	AKV 1/10/2013
Sample	S-2	Calculated By/Date	JFL 2/4/2013
Depth, ft	6.2	Checked By/Date	JFL 2/19/2013



Maximum Load, tsf 41.22

NOTES:
1. Abbreviations:
ft = feet
tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION VOID RATIO vs STRESS PLOT BORING B-1-13, SAMPLE S-2 @6.2ft

October 2013 21-1-12405-060

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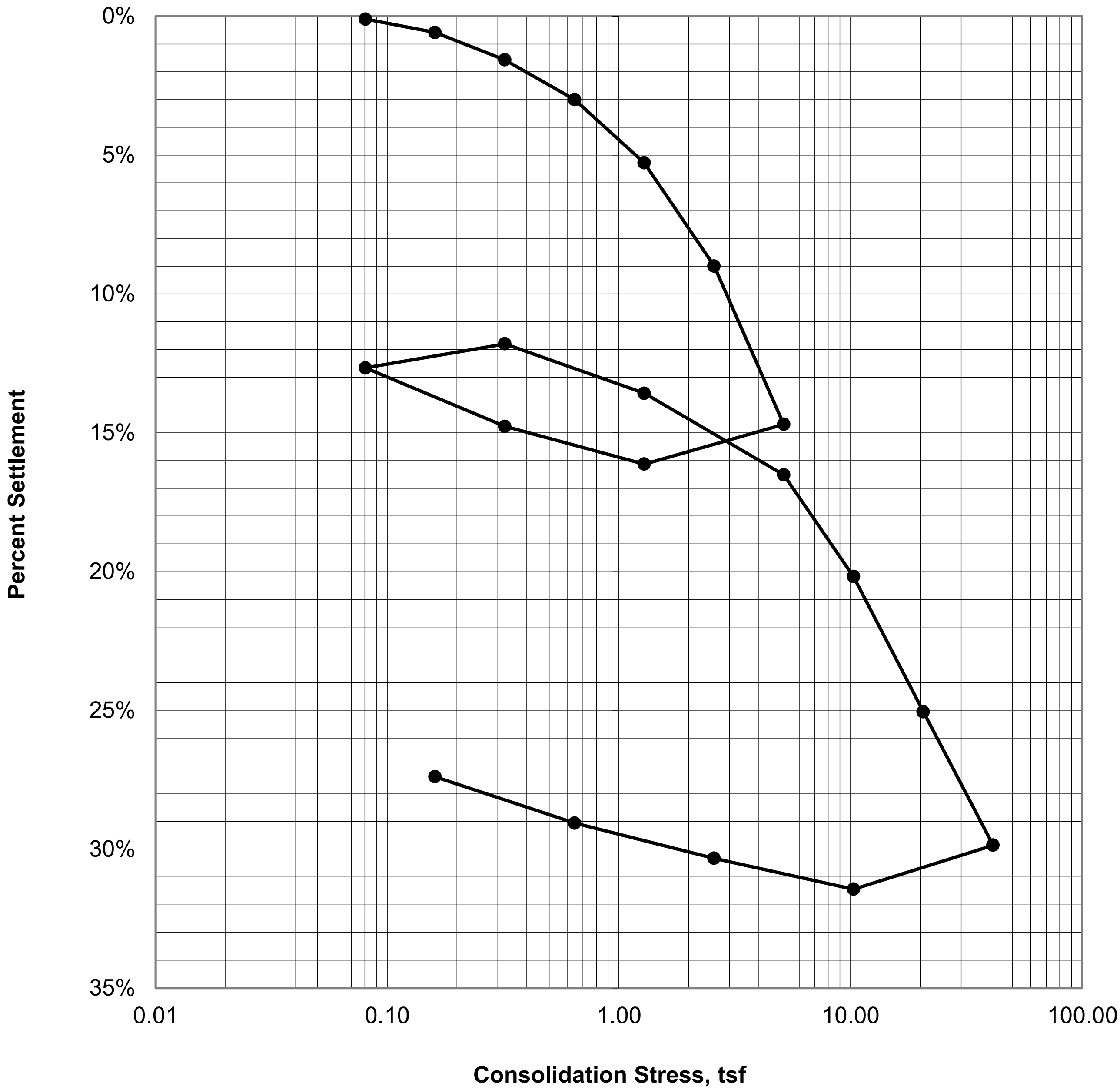
FIG. B-12

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-1-13	Tested By/Date	AKV 1/10/2013
Sample	S-2	Calculated By/Date	JFL 2/4/2013
Depth, ft	6.2	Checked By/Date	JFL 2/19/2013



Maximum Load, tsf 41.22

NOTES:
1. Abbreviations:
ft = feet
tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION PERCENT SETTLEMENT vs STRESS PLOT BORING B-1-13, SAMPLE S-2 @6.2ft

October 2013 21-1-12405-060

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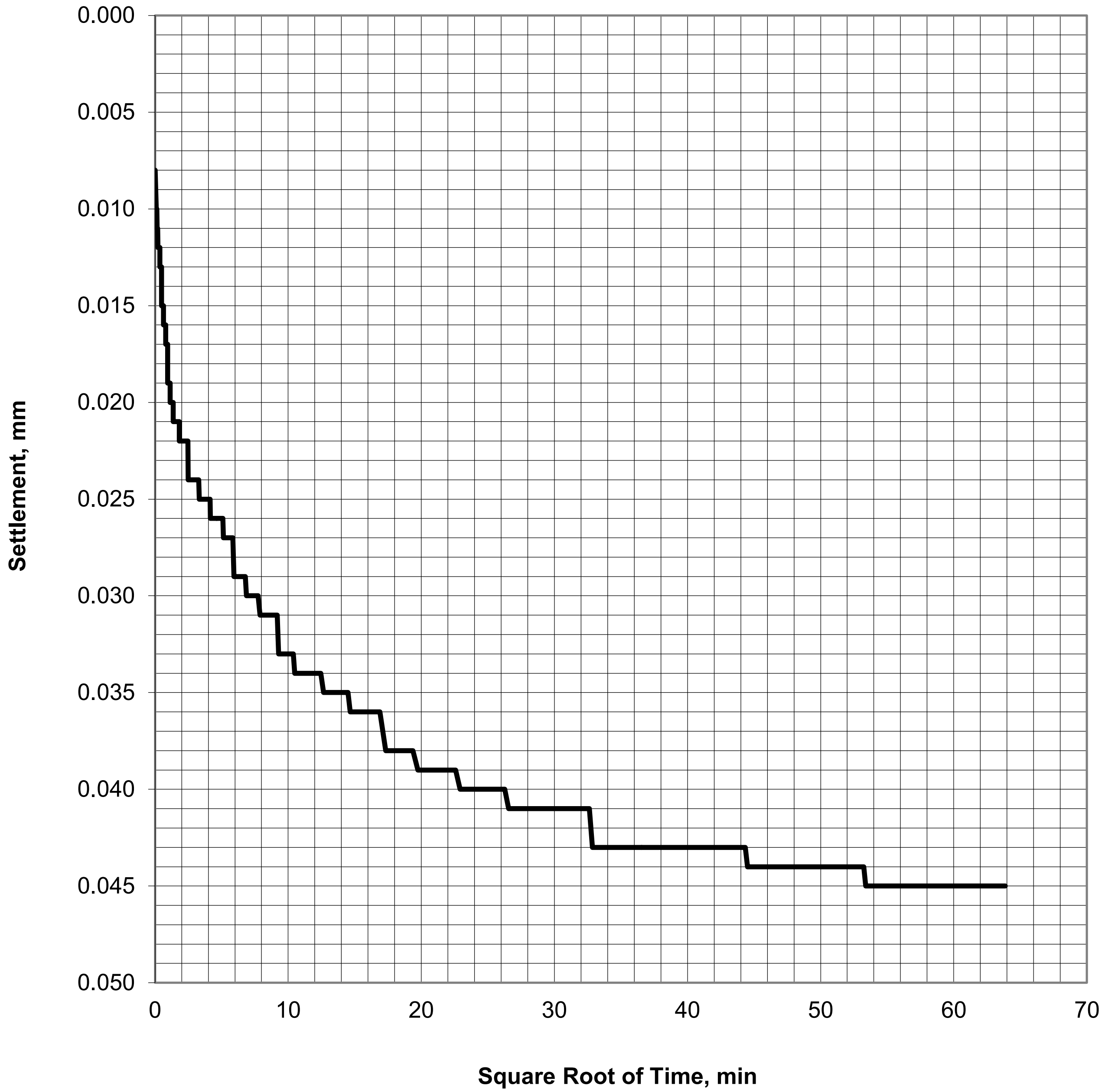
FIG. B-13

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-1-13	Tested By/Date	AKV 1/10/2013
Sample	S-2	Calculated By/Date	JFL 2/4/2013
Depth, ft	6.2	Checked By/Date	JFL 2/19/2013



Increment Number 1

Applied Stress, tsf 0.08

NOTES:
1. Abbreviations:
   ft = feet
   min = minutes
   mm = mimilimeters
   tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-1-13, SAMPLE S-2 @6.2ft

October 2013 21-1-12405-060

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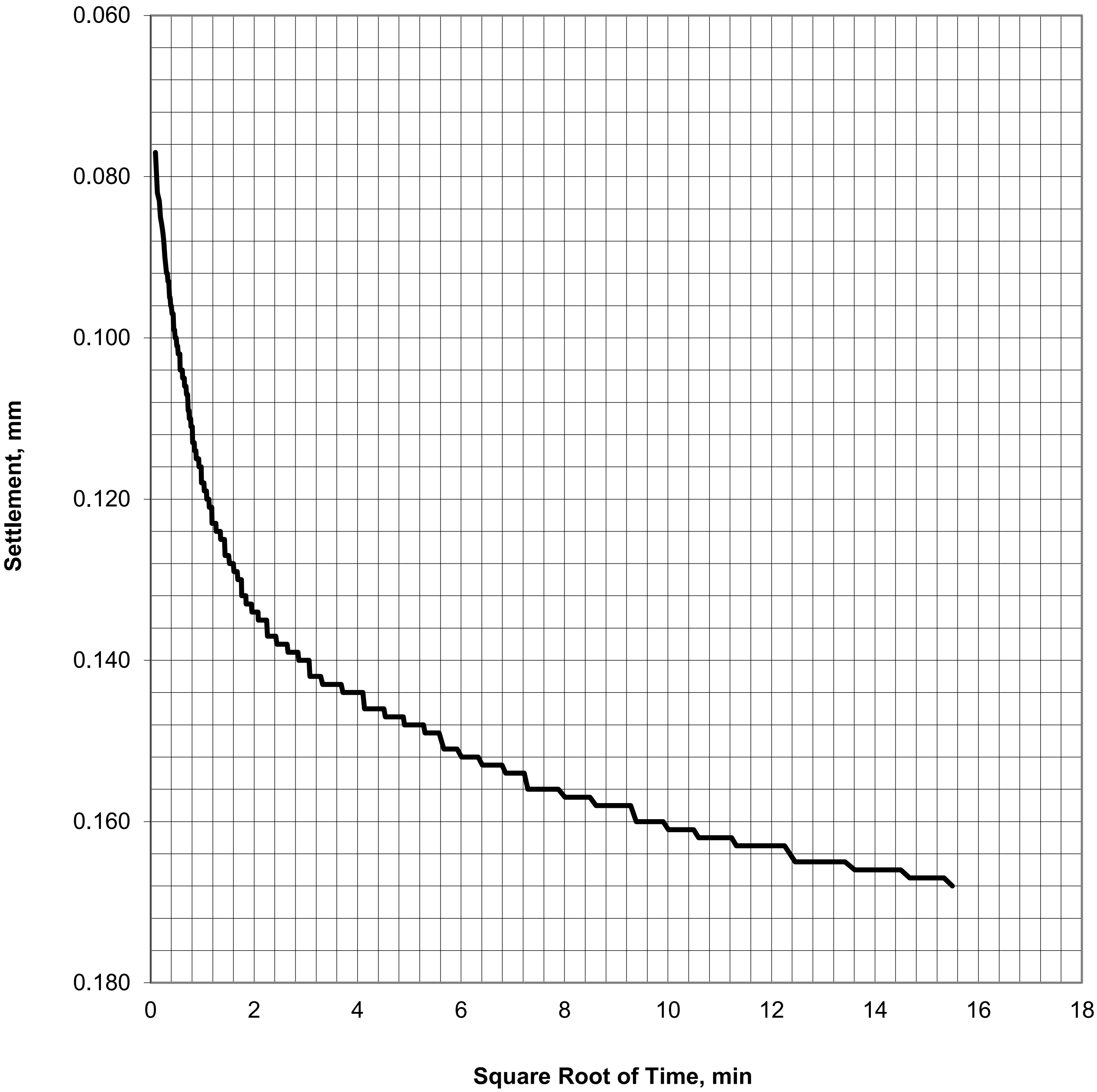
FIG. B-14
Sheet 1 of 20

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-1-13	Tested By/Date	AKV 1/10/2013
Sample	S-2	Calculated By/Date	JFL 2/4/2013
Depth, ft	6.2	Checked By/Date	JFL 2/19/2013



Increment Number 2

Applied Stress, tsf 0.16

NOTES:
1. Abbreviations:
ft = feet
min = minutes
mm = mimilimeters
tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-1-13, SAMPLE S-2 @6.2ft

October 2013 21-1-12405-060

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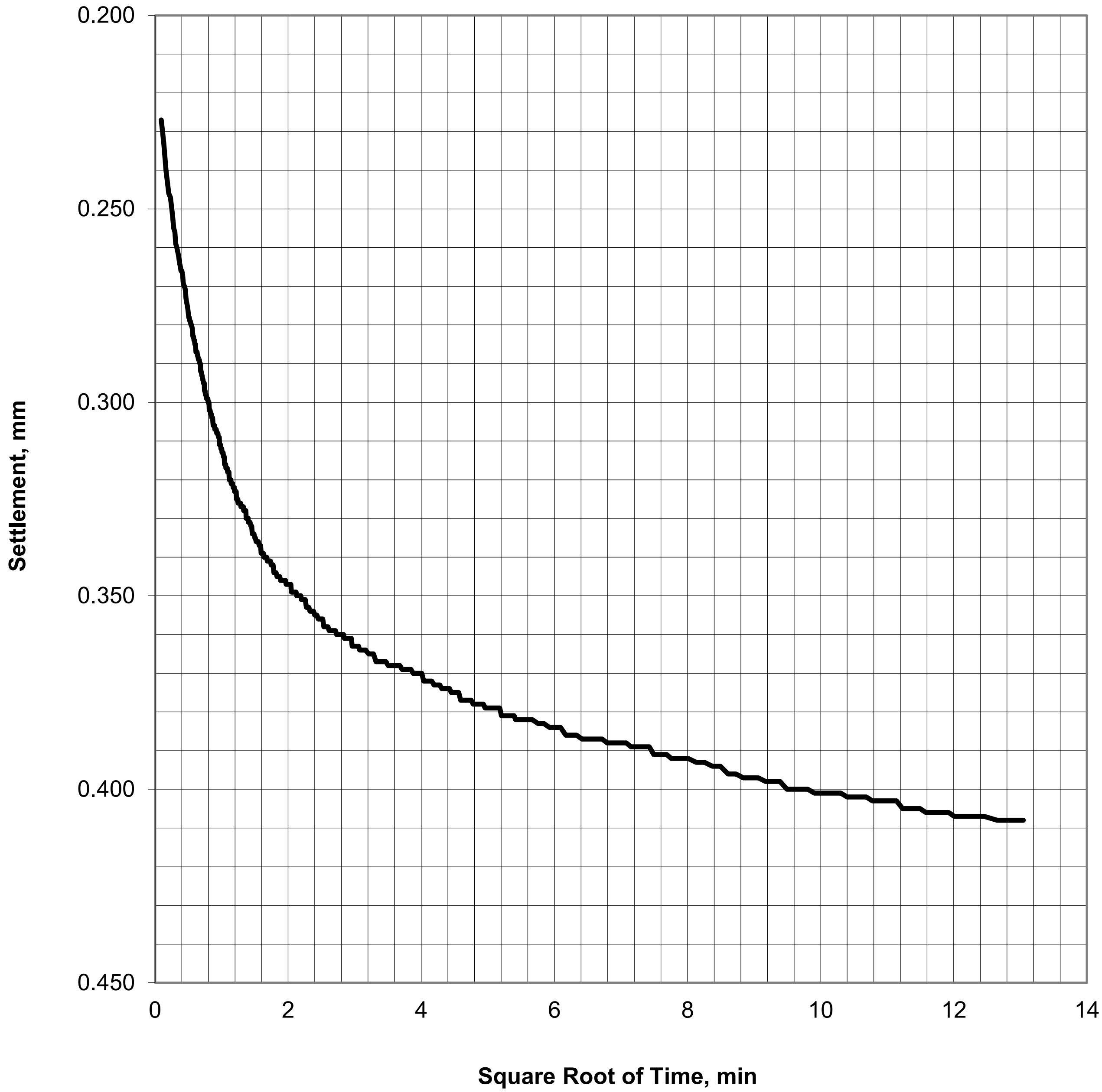
FIG. B-14
Sheet 2 of 20

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-1-13	Tested By/Date	AKV 1/10/2013
Sample	S-2	Calculated By/Date	JFL 2/4/2013
Depth, ft	6.2	Checked By/Date	JFL 2/19/2013



Increment Number 3

Applied Stress, tsf 0.32

NOTES:
1. Abbreviations:
ft = feet
min = minutes
mm = mimilimeters
tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-1-13, SAMPLE S-2 @6.2ft

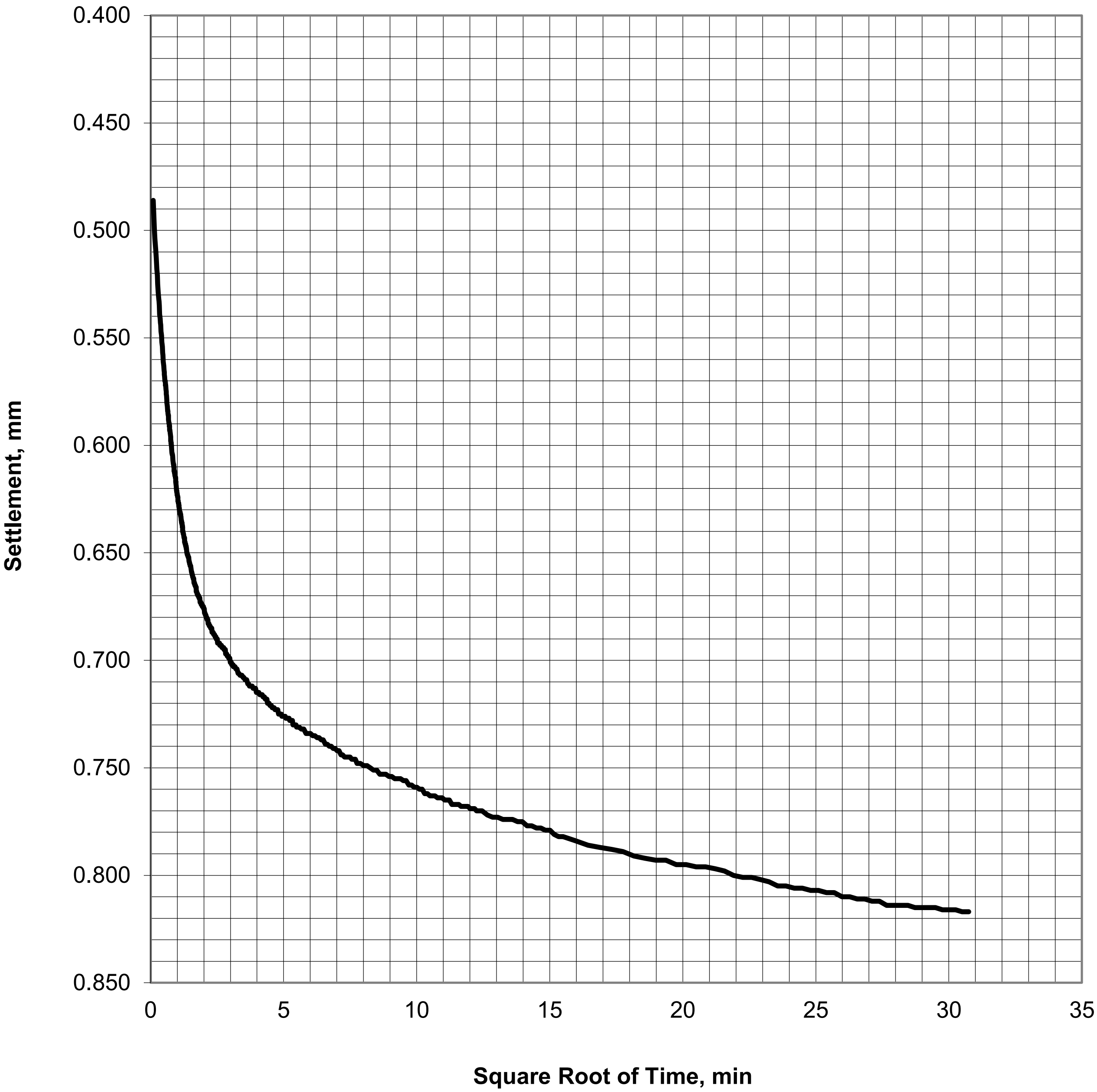
October 2013 21-1-12405-060

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B-14

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-1-13	Tested By/Date	AKV 1/10/2013
Sample	S-2	Calculated By/Date	JFL 2/4/2013
Depth, ft	6.2	Checked By/Date	JFL 2/19/2013



Increment Number 4

Applied Stress, tsf 0.64

NOTES:
1. Abbreviations:
ft = feet
min = minutes
mm = mimilimeters
tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-1-13, SAMPLE S-2 @6.2ft

October 2013 21-1-12405-060

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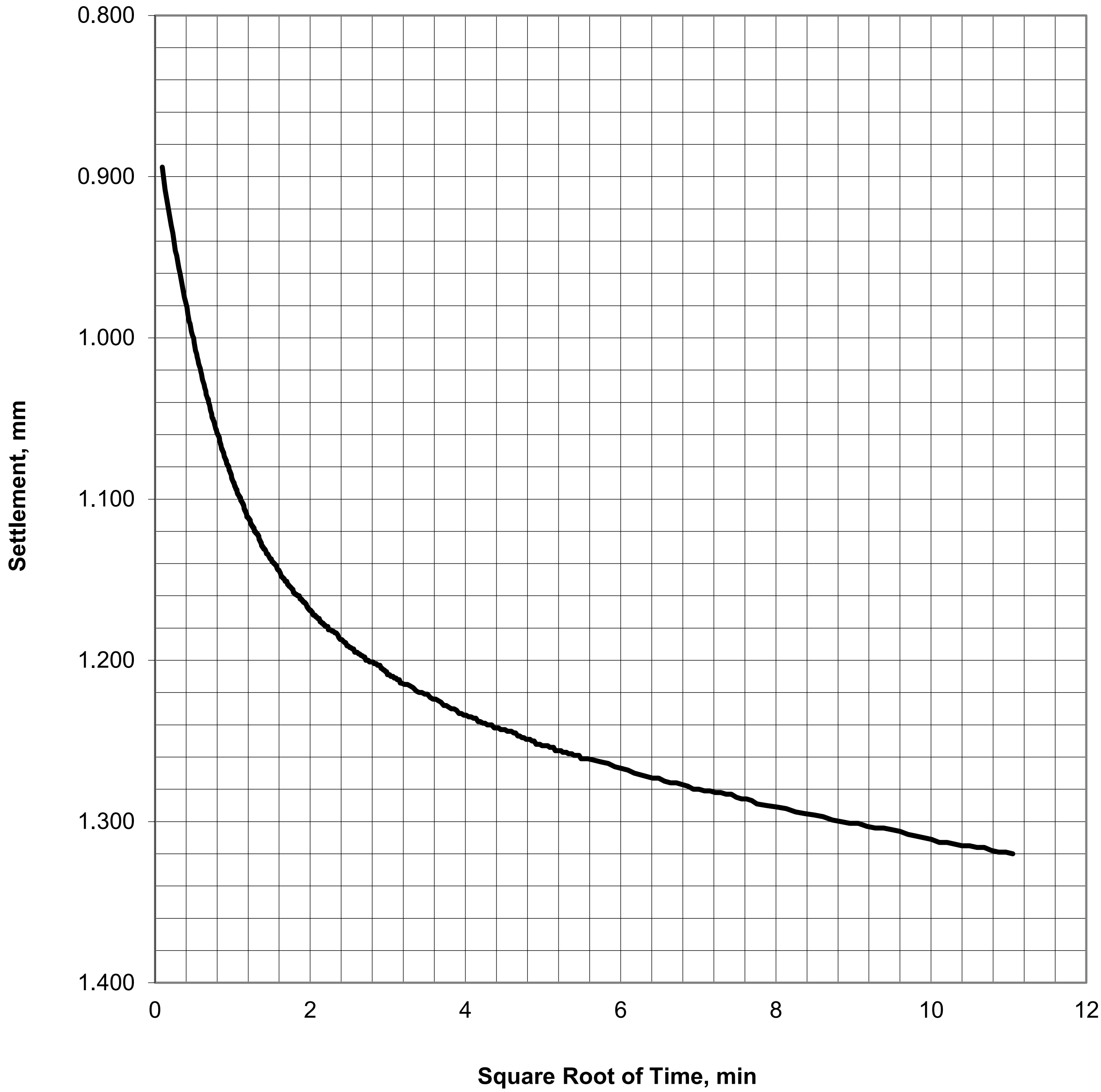
FIG. B-14

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-1-13	Tested By/Date	AKV 1/10/2013
Sample	S-2	Calculated By/Date	JFL 2/4/2013
Depth, ft	6.2	Checked By/Date	JFL 2/19/2013



Increment Number 5

Applied Stress, tsf 1.29

NOTES:
1. Abbreviations:
ft = feet
min = minutes
mm = mimilimeters
tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-1-13, SAMPLE S-2 @6.2ft

October 2013 21-1-12405-060

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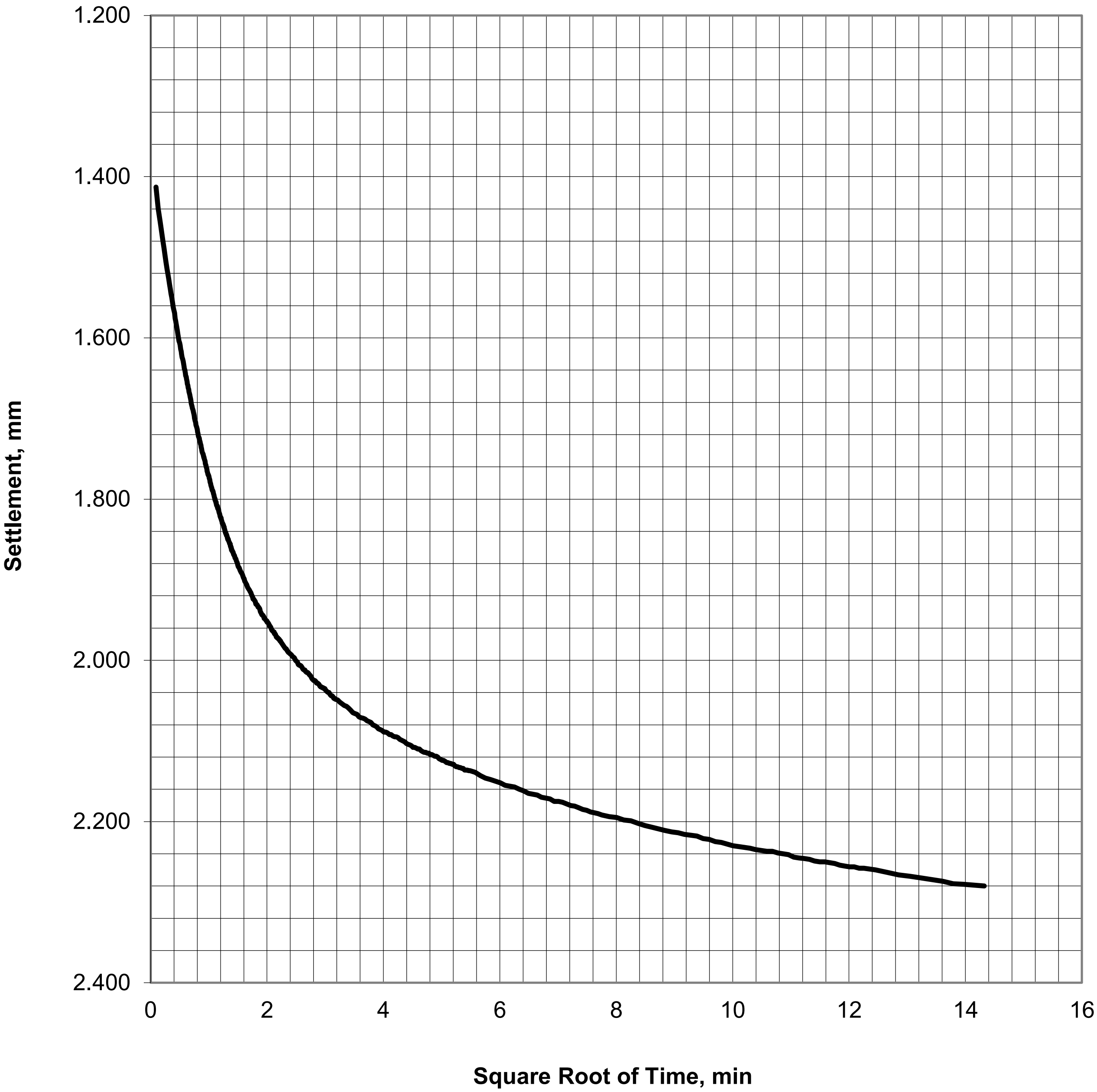
FIG. B-14

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-1-13	Tested By/Date	AKV 1/10/2013
Sample	S-2	Calculated By/Date	JFL 2/4/2013
Depth, ft	6.2	Checked By/Date	JFL 2/19/2013



Increment Number 6

Applied Stress, tsf 2.58

NOTES:
1. Abbreviations:
ft = feet
min = minutes
mm = mimilimeters
tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-1-13, SAMPLE S-2 @6.2ft

October 2013 21-1-12405-060

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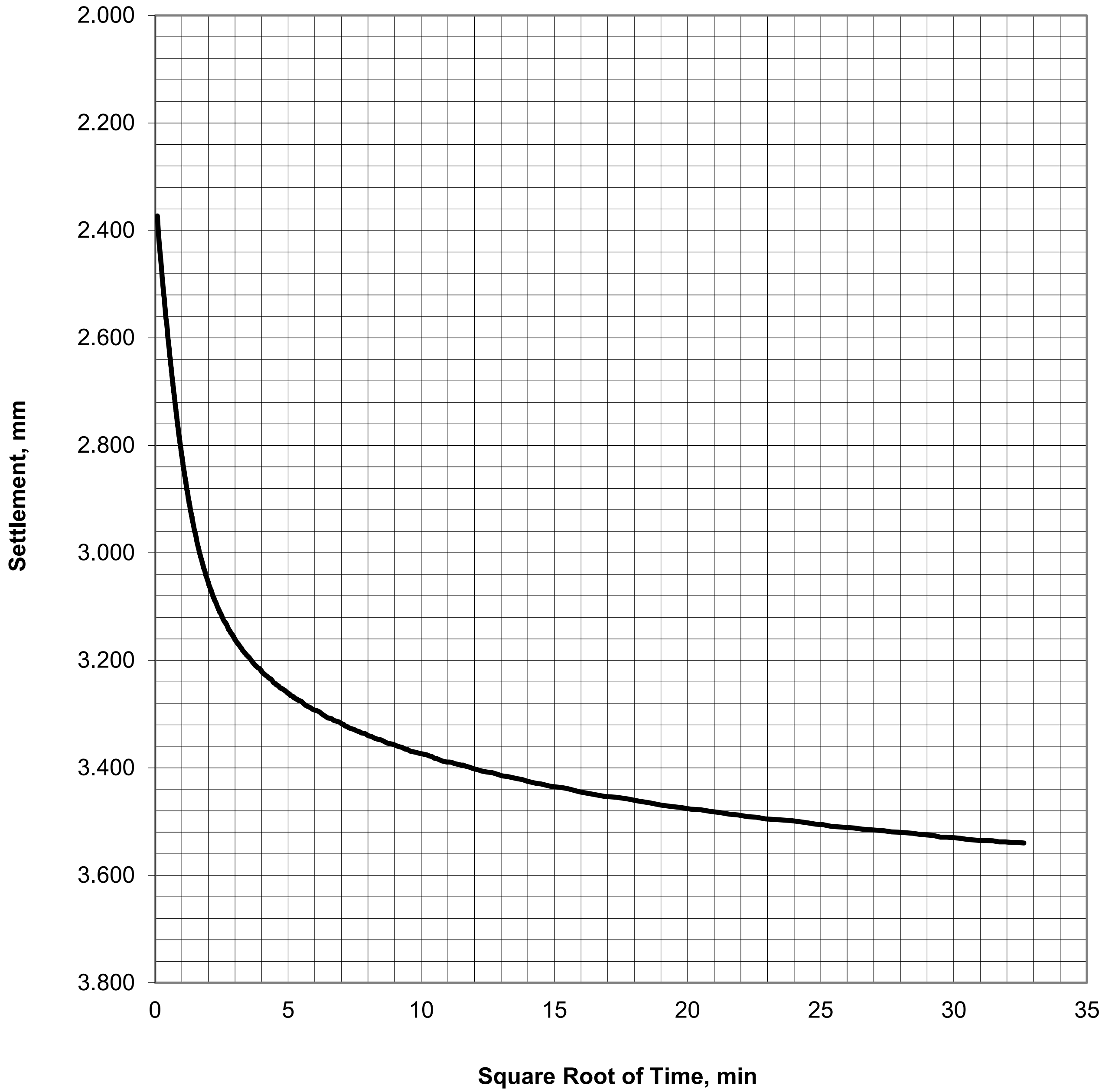
FIG. B-14

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-1-13	Tested By/Date	AKV 1/10/2013
Sample	S-2	Calculated By/Date	JFL 2/4/2013
Depth, ft	6.2	Checked By/Date	JFL 2/19/2013



Increment Number 7

Applied Stress, tsf 5.15

NOTES:
1. Abbreviations:
ft = feet
min = minutes
mm = mimilimeters
tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-1-13, SAMPLE S-2 @6.2ft

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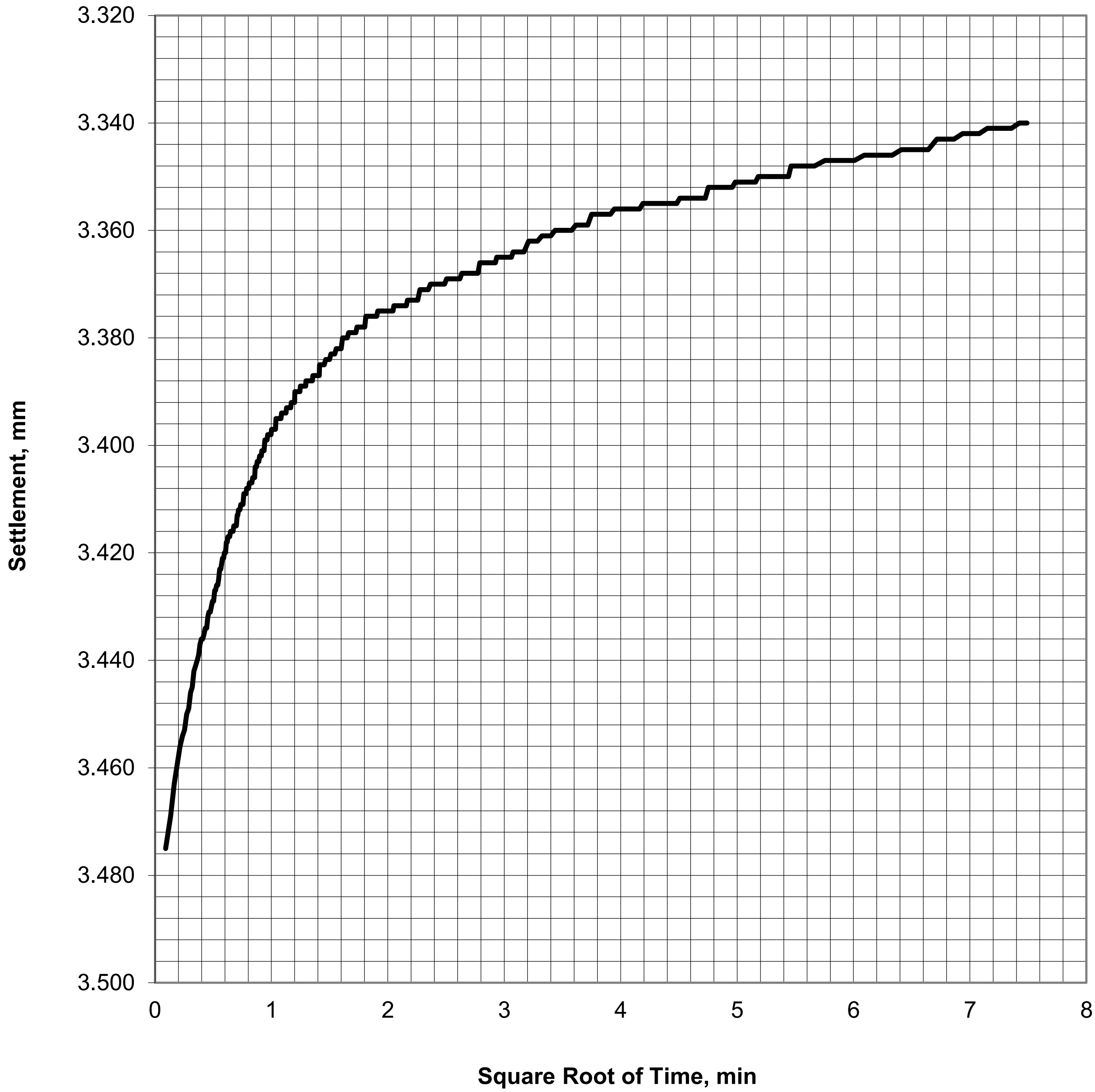
SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B-14

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-1-13	Tested By/Date	AKV 1/10/2013
Sample	S-2	Calculated By/Date	JFL 2/4/2013
Depth, ft	6.2	Checked By/Date	JFL 2/19/2013



Increment Number 8

Applied Stress, tsf 1.29

NOTES:
1. Abbreviations:
ft = feet
min = minutes
mm = mimilimeters
tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-1-13, SAMPLE S-2 @6.2ft

October 2013 21-1-12405-060

SHANNON & WILSON, INC.
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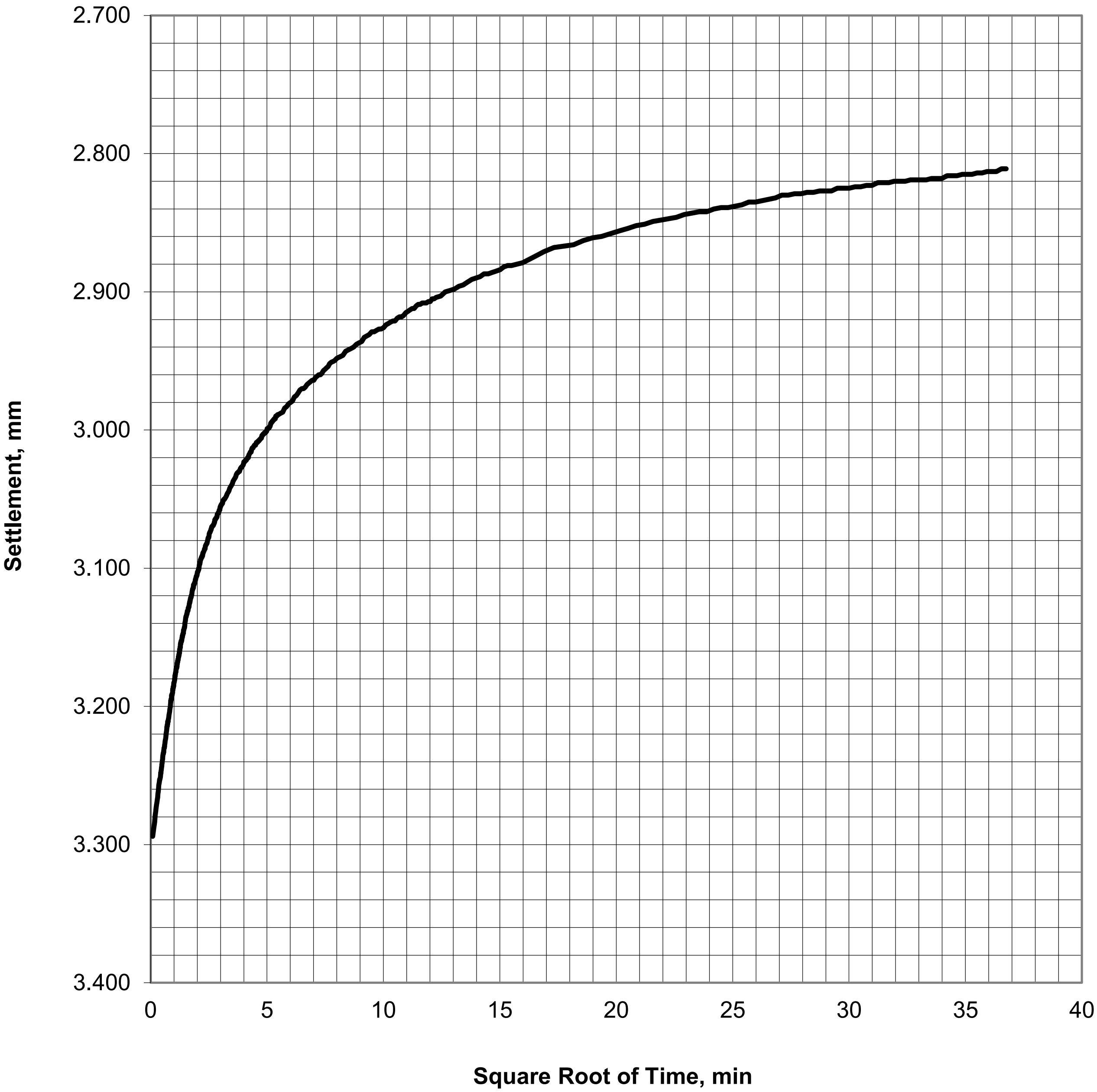
FIG. B-14

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-1-13	Tested By/Date	AKV 1/10/2013
Sample	S-2	Calculated By/Date	JFL 2/4/2013
Depth, ft	6.2	Checked By/Date	JFL 2/19/2013



Increment Number 9

Applied Stress, tsf 0.32

NOTES:
1. Abbreviations:
   ft = feet
   min = minutes
   mm = mimilimeters
   tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-1-13, SAMPLE S-2 @6.2ft

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SHANNON & WILSON, INC.
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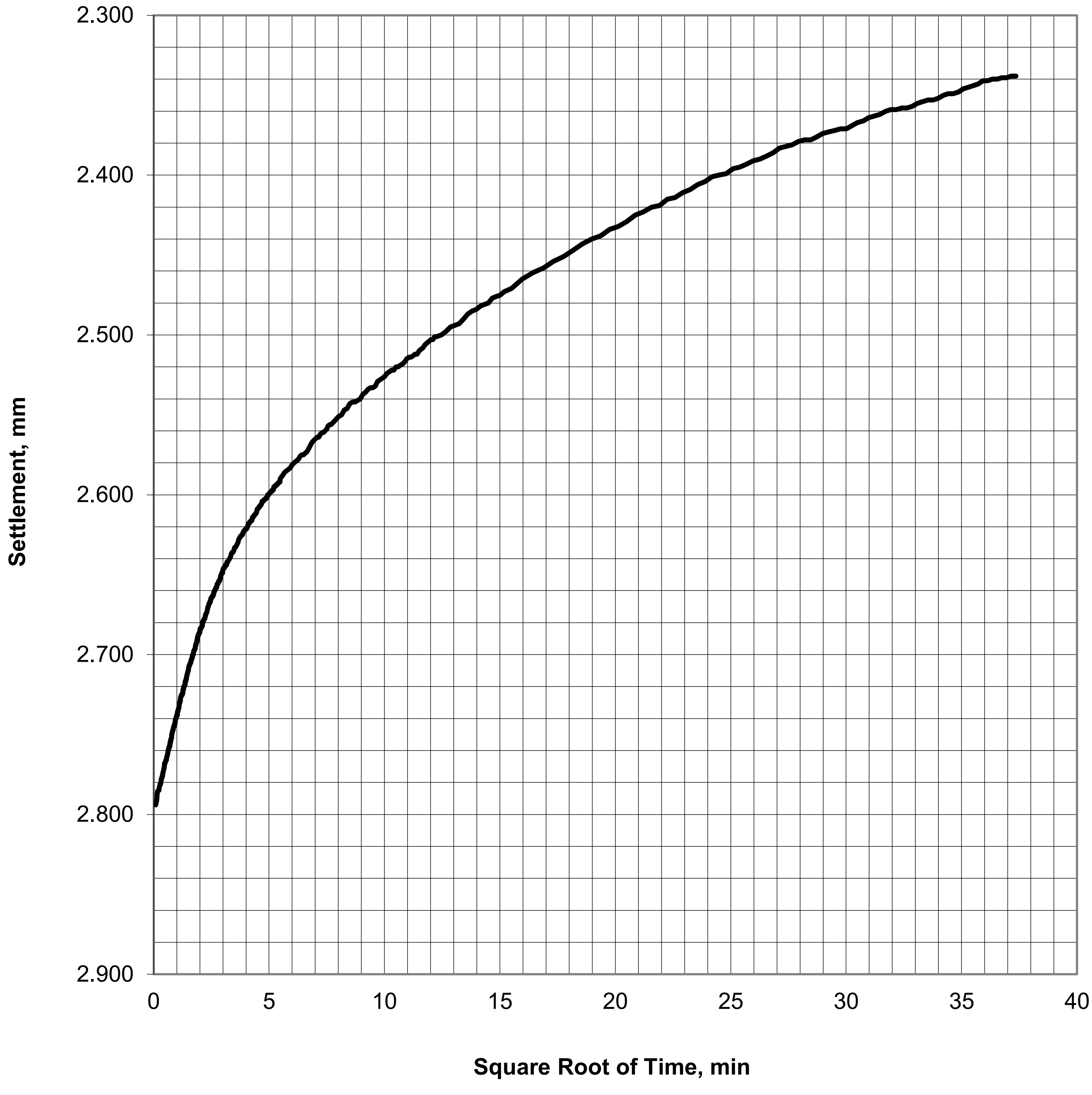
FIG. B-14

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-1-13	Tested By/Date	AKV 1/10/2013
Sample	S-2	Calculated By/Date	JFL 2/4/2013
Depth, ft	6.2	Checked By/Date	JFL 2/19/2013



Increment Number 10

Applied Stress, tsf 0.08

NOTES:
1. Abbreviations:
ft = feet
min = minutes
mm = mimilimeters
tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-1-13, SAMPLE S-2 @6.2ft

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SHANNON & WILSON, INC.
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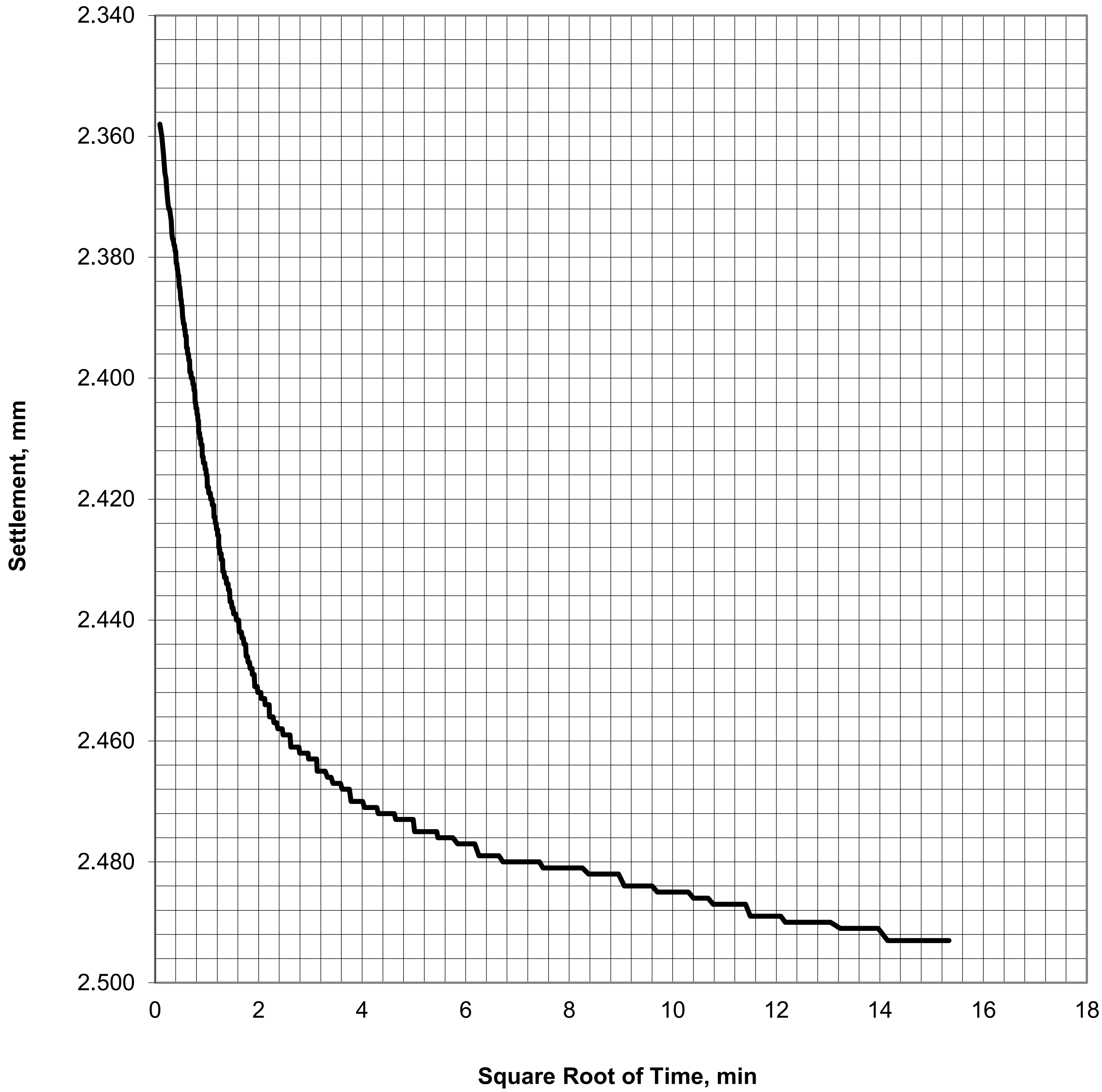
FIG. B-14
Sheet 10 of 20

ONE DIMENSIONAL CONSOLIDATION TEST

Boring B-1-13
Sample S-2
Depth, ft 6.2

Tested By/Date AKV 1/10/2013
Calculated By/Date JFL 2/4/2013
Checked By/Date JFL 2/19/2013



Increment Number 11
Applied Stress, tsf 0.32

NOTES:
1. Abbreviations:
ft = feet
min = minutes
mm = mimilimeters
tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-1-13, SAMPLE S-2 @6.2ft

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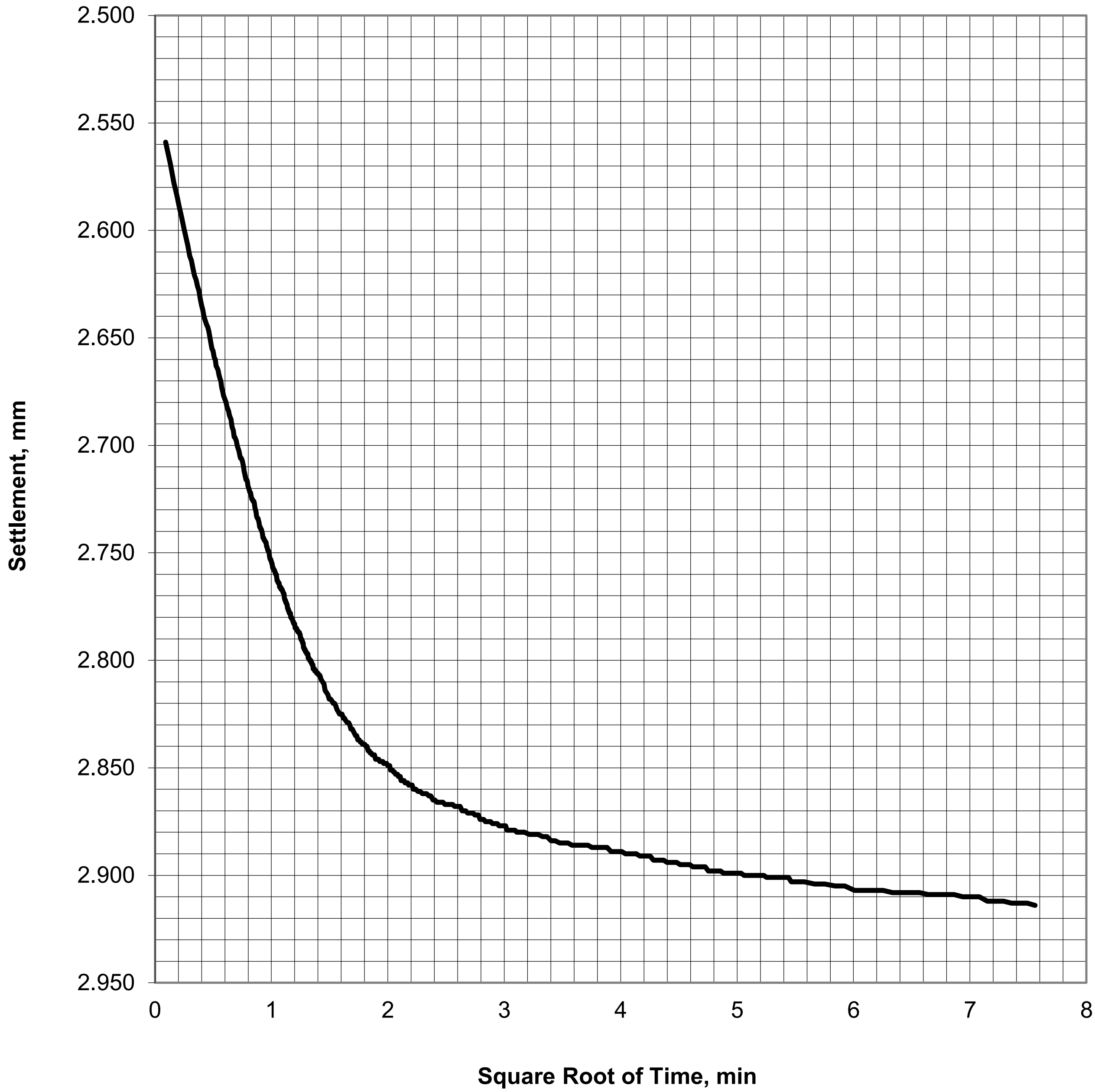
SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B-14

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-1-13	Tested By/Date	AKV 1/10/2013
Sample	S-2	Calculated By/Date	JFL 2/4/2013
Depth, ft	6.2	Checked By/Date	JFL 2/19/2013



Increment Number 12

Applied Stress, tsf 1.29

NOTES:
1. Abbreviations:
ft = feet
min = minutes
mm = mimilimeters
tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-1-13, SAMPLE S-2 @6.2ft

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SHANNON & WILSON, INC.
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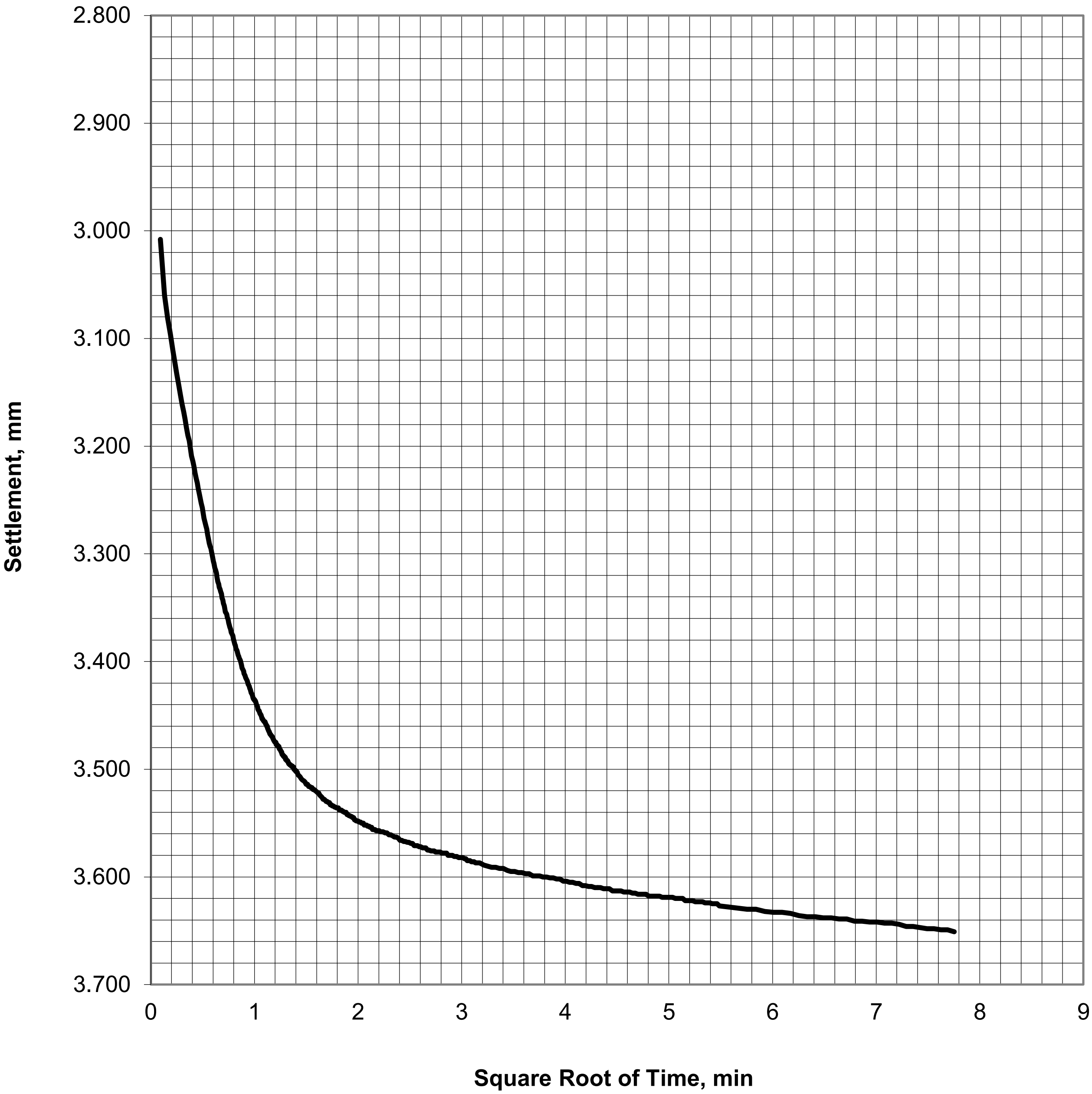
FIG. B-14

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-1-13	Tested By/Date	AKV 1/10/2013
Sample	S-2	Calculated By/Date	JFL 2/4/2013
Depth, ft	6.2	Checked By/Date	JFL 2/19/2013



Increment Number 13

Applied Stress, tsf 5.15

NOTES:
1. Abbreviations:
ft = feet
min = minutes
mm = mimilimeters
tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-1-13, SAMPLE S-2 @6.2ft

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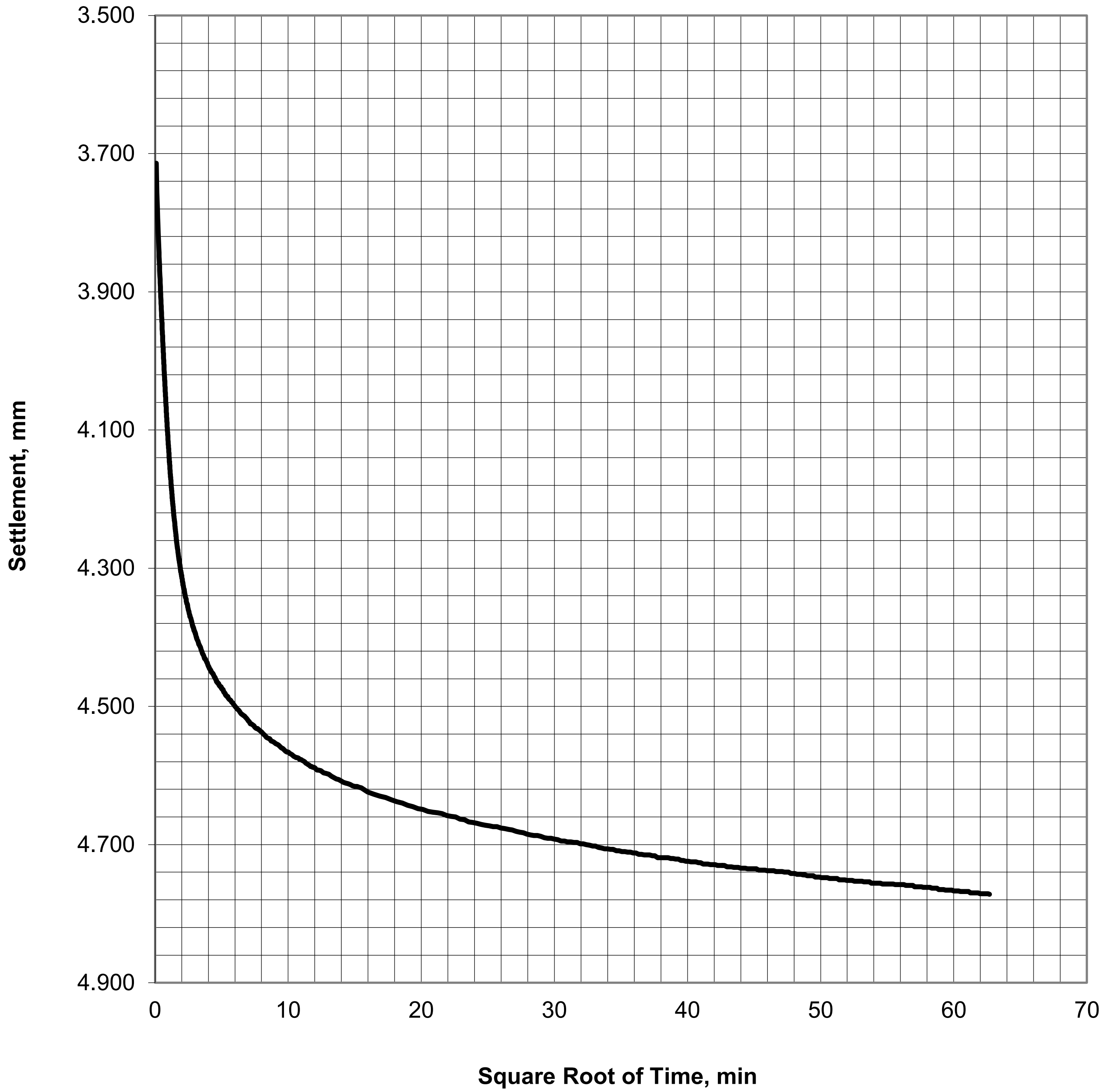
SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B-14

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-1-13	Tested By/Date	AKV 1/10/2013
Sample	S-2	Calculated By/Date	JFL 2/4/2013
Depth, ft	6.2	Checked By/Date	JFL 2/19/2013



Increment Number 14

Applied Stress, tsf 10.31

NOTES:
1. Abbreviations:
 ft = feet
 min = minutes
 mm = mimilimeters
 tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-1-13, SAMPLE S-2 @6.2ft

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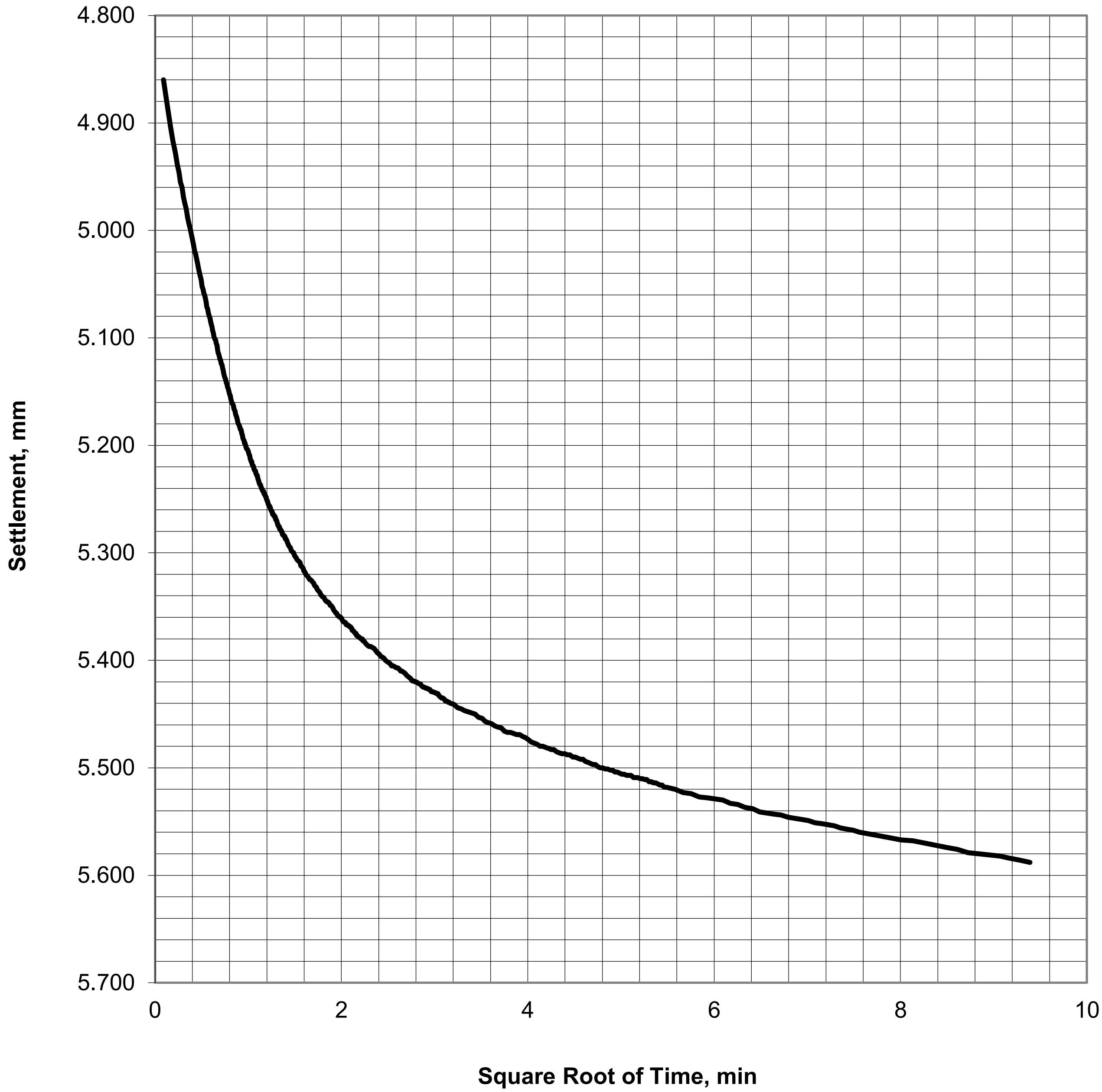
SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B-14

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-1-13	Tested By/Date	AKV 1/10/2013
Sample	S-2	Calculated By/Date	JFL 2/4/2013
Depth, ft	6.2	Checked By/Date	JFL 2/19/2013



Increment Number 15

Applied Stress, tsf 20.61

NOTES:
1. Abbreviations:
   ft = feet
   min = minutes
   mm = mimilimeters
   tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-1-13, SAMPLE S-2 @6.2ft

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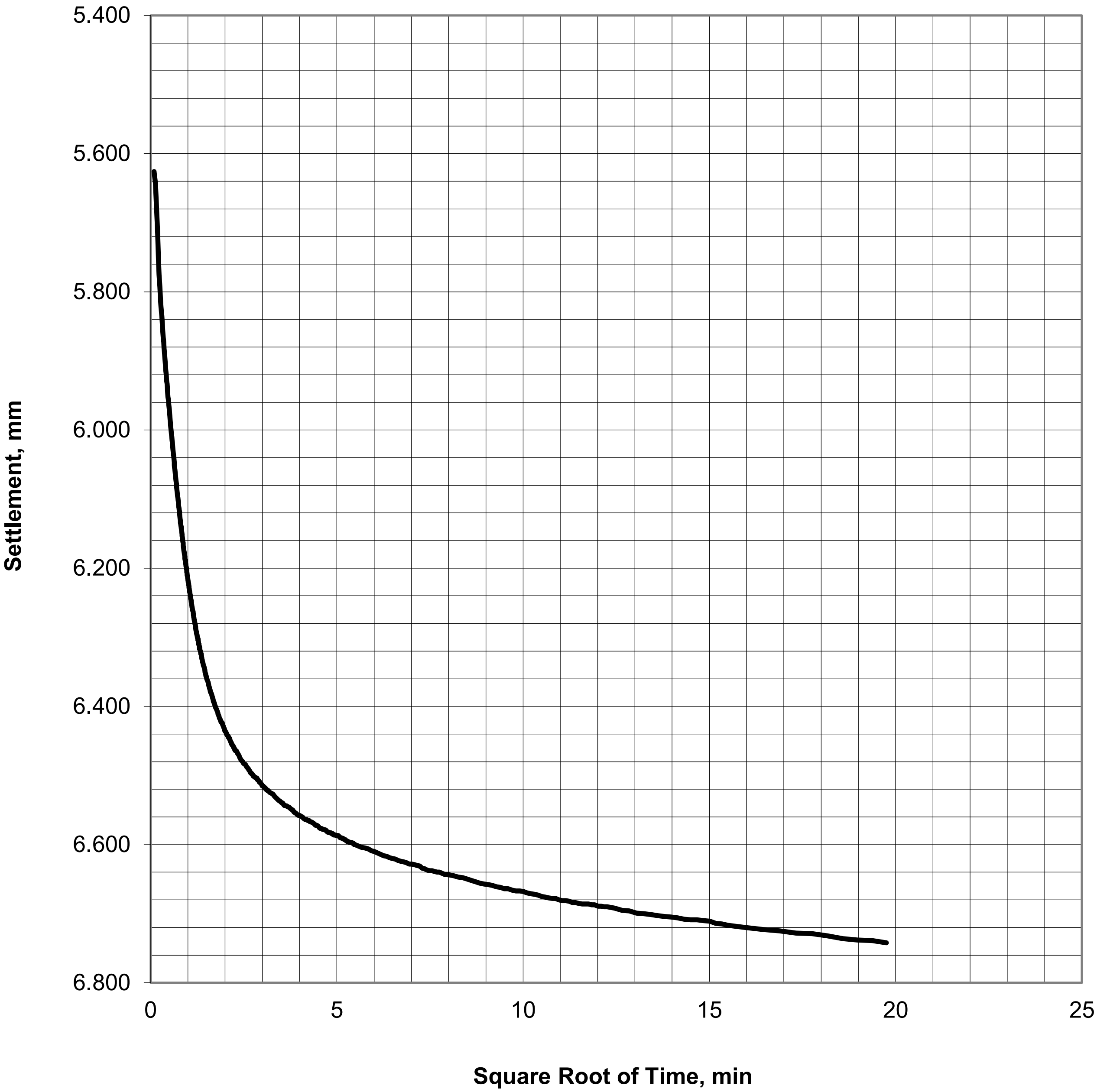
FIG. B-14

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-1-13	Tested By/Date	AKV 1/10/2013
Sample	S-2	Calculated By/Date	JFL 2/4/2013
Depth, ft	6.2	Checked By/Date	JFL 2/19/2013



Increment Number 16

Applied Stress, tsf 41.22

NOTES:
1. Abbreviations:
ft = feet
min = minutes
mm = mimilimeters
tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-1-13, SAMPLE S-2 @6.2ft

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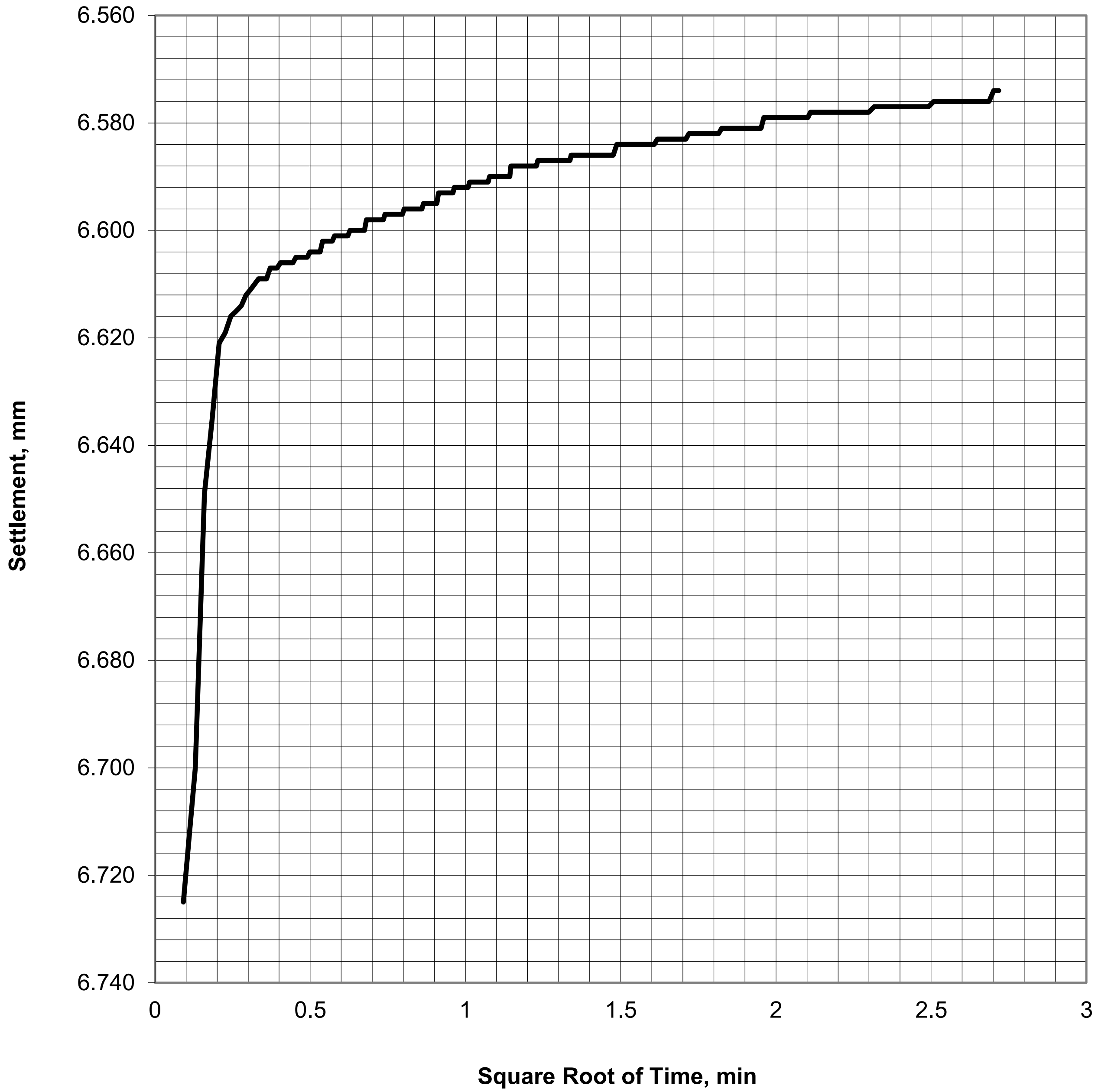
SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B-14
Sheet 16 of 20

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-1-13	Tested By/Date	AKV 1/10/2013
Sample	S-2	Calculated By/Date	JFL 2/4/2013
Depth, ft	6.2	Checked By/Date	JFL 2/19/2013



Increment Number 17

Applied Stress, tsf 10.31

NOTES:
1. Abbreviations:
   ft = feet
   min = minutes
   mm = mimilimeters
   tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-1-13, SAMPLE S-2 @6.2ft

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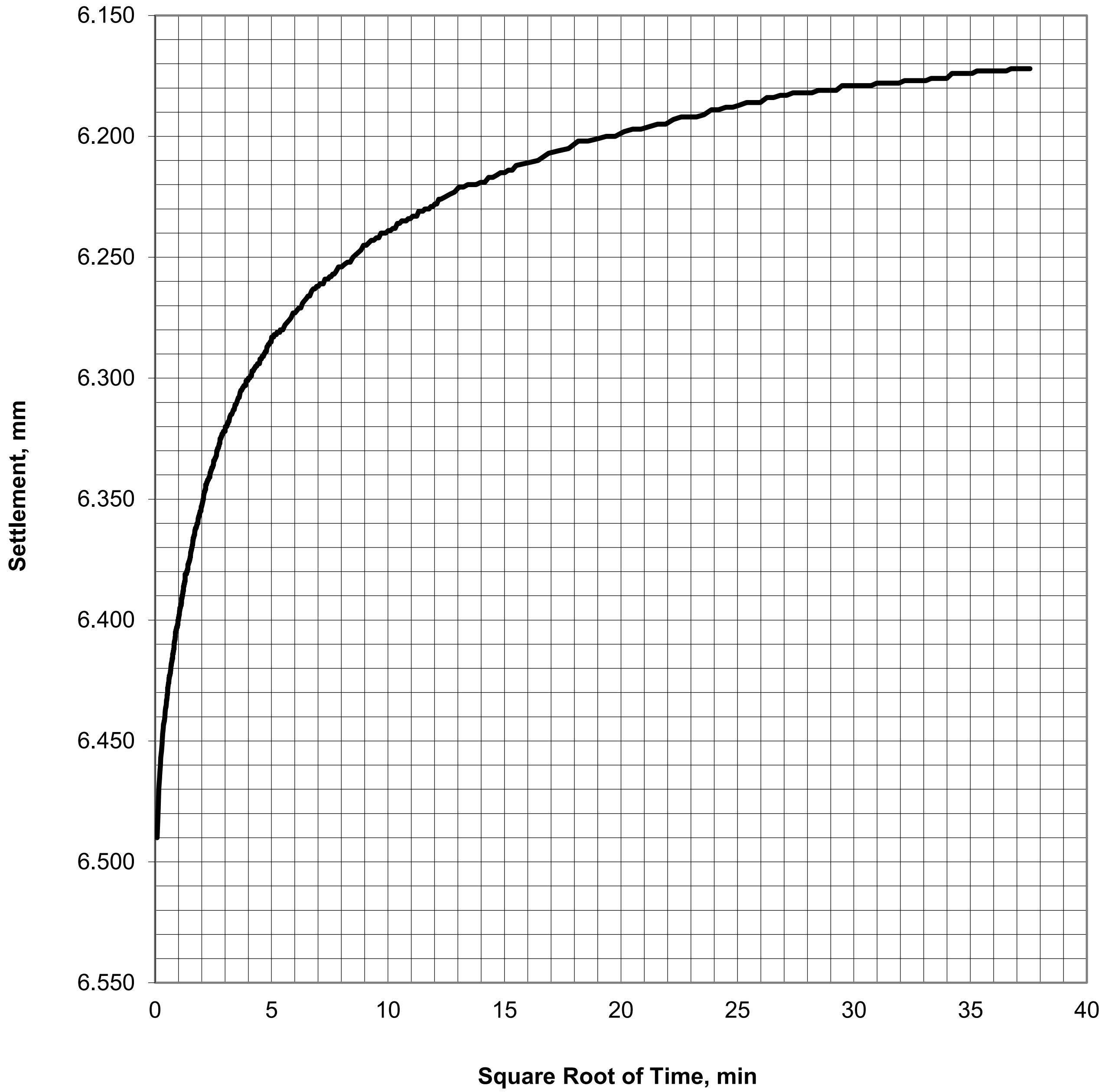
FIG. B-14

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-1-13	Tested By/Date	AKV 1/10/2013
Sample	S-2	Calculated By/Date	JFL 2/4/2013
Depth, ft	6.2	Checked By/Date	JFL 2/19/2013



Increment Number 18

Applied Stress, tsf 2.58

NOTES:
1. Abbreviations:
ft = feet
min = minutes
mm = mimilimeters
tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-1-13, SAMPLE S-2 @6.2ft

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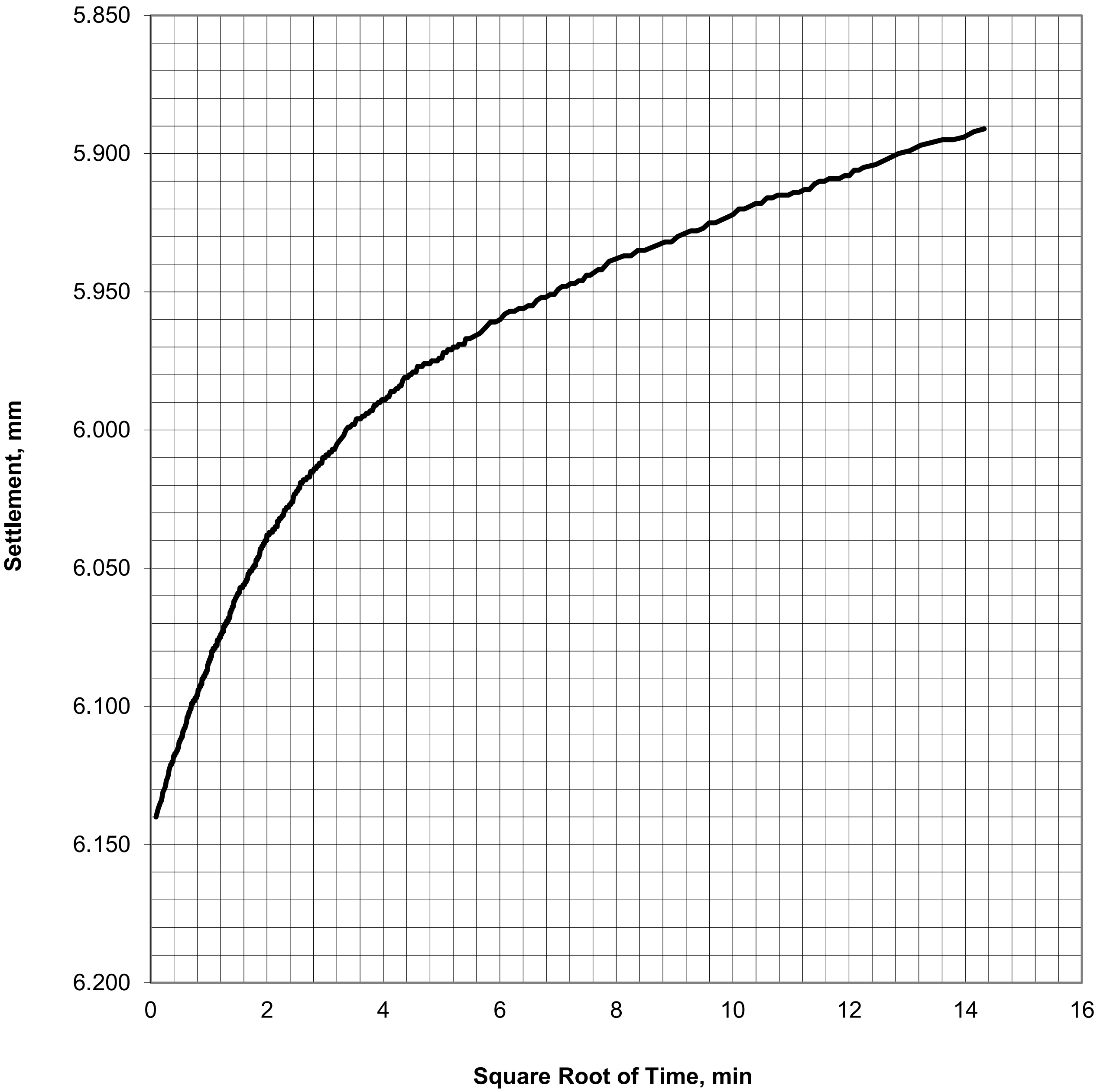
FIG. B-14

ONE DIMENSIONAL CONSOLIDATION TEST

Boring B-1-13
Sample S-2
Depth, ft 6.2

Tested By/Date AKV 1/10/2013
Calculated By/Date JFL 2/4/2013
Checked By/Date JFL 2/19/2013



Increment Number 19
Applied Stress, tsf 0.64

NOTES:
1. Abbreviations:
ft = feet
min = minutes
mm = mimilimeters
tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-1-13, SAMPLE S-2 @6.2ft

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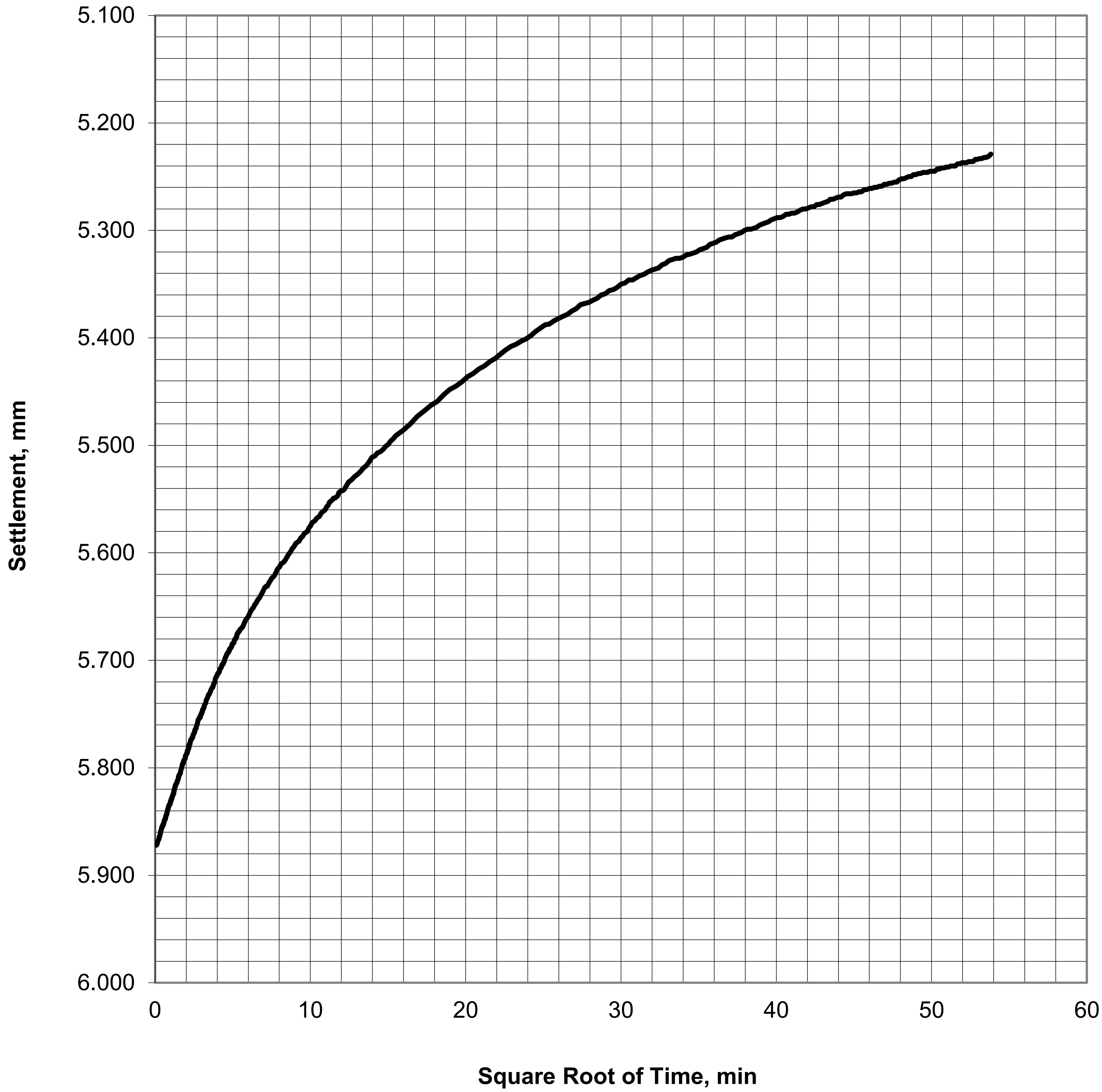
FIG. B-14
Sheet 19 of 20

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-1-13	Tested By/Date	AKV 1/10/2013
Sample	S-2	Calculated By/Date	JFL 2/4/2013
Depth, ft	6.2	Checked By/Date	JFL 2/19/2013



Increment Number 20

Applied Stress, tsf 0.16

NOTES:

1. Abbreviations:
   - ft = feet
   - min = minutes
   - mm = mimilimeters
   - tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-1-13, SAMPLE S-2 @6.2ft

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SHANNON & WILSON, INC.
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FIG. B-14
Sheet 20 of 20

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-2-13	Tested By/Date	AKV 1/10/2013
Sample	S-2	Calculated By/Date	JFL 2/4/2013
Depth, ft	6.3	Checked By/Date	JFL 2/27/2013

SAMPLE CLASSIFICATION:
Brown, organic SILT; OH

SAMPLE DATA:

Specific Gravity (estimated)	2.7
Liquid Limit	266
Plastic Limit	127
Plasticity Index	139

SPECIMEN DATA:	Before Inundation	First Load	Final Load
Height, inches	0.786	0.786	0.332
Diameter, inches	2.501	2.501	2.501
Sample Volume, cuin	3.863	3.863	1.630
Wet Density, pcf	68.4	68.4	82.6
Dry Density, pcf	16.2	16.2	38.4
Water Content, %	323%	323%	115%
Void Ratio	9.41	9.41	3.40
Saturation, %	93%	93%	92%

Increment	Applied Stress, tsf	ΔH at t_{100}, in	ΔH / H_o	Void Ratio	$t_{50,}$ min	Coeff. of Comp., MPa^{-1}	Coeff. of Consol., cm^2/sec	Coeff. of Perm., cm/sec
1	0.05	0.001	0.2%	9.396	0.3	3.94	9.9E-03	3.7E-07
2	0.10	0.007	0.9%	9.317	0.4	17.01	2.1E-02	3.4E-06
3	0.19	0.033	4.2%	8.982	0.9	36.23	5.2E-03	1.8E-06
4	0.39	0.104	13.2%	8.035	2.5	51.10	1.4E-03	7.0E-07
5	0.77	0.217	27.6%	6.542	5.9	40.31	4.5E-04	2.0E-07
6	1.55	0.321	40.9%	5.155	5.4	18.73	1.7E-04	4.2E-08
7	3.09	0.399	50.8%	4.127	6.8	6.94	1.2E-04	1.3E-08
8	6.19	0.454	57.8%	3.392	4.5	2.48	1.3E-04	6.0E-09
9	1.55	0.437	55.6%	3.620	4.1	0.51	1.7E-04	1.9E-09
10	0.39	0.407	51.8%	4.023	12.6	3.63	6.3E-05	4.9E-09
11	0.10	0.367	46.6%	4.556	67.3	19.19	1.5E-05	5.8E-09
12	0.39	0.361	45.9%	4.631	3.9	-2.67	2.5E-04	1.2E-08
13	1.55	0.398	50.6%	4.145	5.5	4.37	1.7E-04	1.3E-08
14	6.19	0.459	58.4%	3.331	4.7	1.83	1.3E-04	4.4E-09
15	12.38	0.510	64.8%	2.661	8.8	1.13	4.8E-05	1.2E-09
16	24.75	0.547	69.6%	2.170	9.7	0.41	3.6E-05	4.0E-10
17	6.19	0.5458	69.44%	2.182	5.0	0.007	4.2E-05	9.2E-12
18	1.55	0.5189	66.02%	2.539	41.4	0.802	8.6E-06	2.1E-10
19	0.39	0.5061	64.40%	2.708	16.8	1.521	1.8E-05	7.8E-10
20	0.10	0.4604	58.57%	3.314	529.4	21.840	9.8E-07	5.7E-10

NOTES:
1. Abbreviations:
cm = centimeter
cm^2 = square centimeter
Coeff. = Coefficient
Comp. = Compressibility
Consol. = Consolidation
cu in = cubic inch
ft = feet
H_o = initial height
ΔH = change in height
in = inch
min = minute
MPa = megapascal
pcf = pounts per cubic foot
Perm. = Permeability
sec = second
t_n = time at n% of primary consolidation
tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST SUMMARY
BORING B-2-13, SAMPLE S-2 @6.3ft

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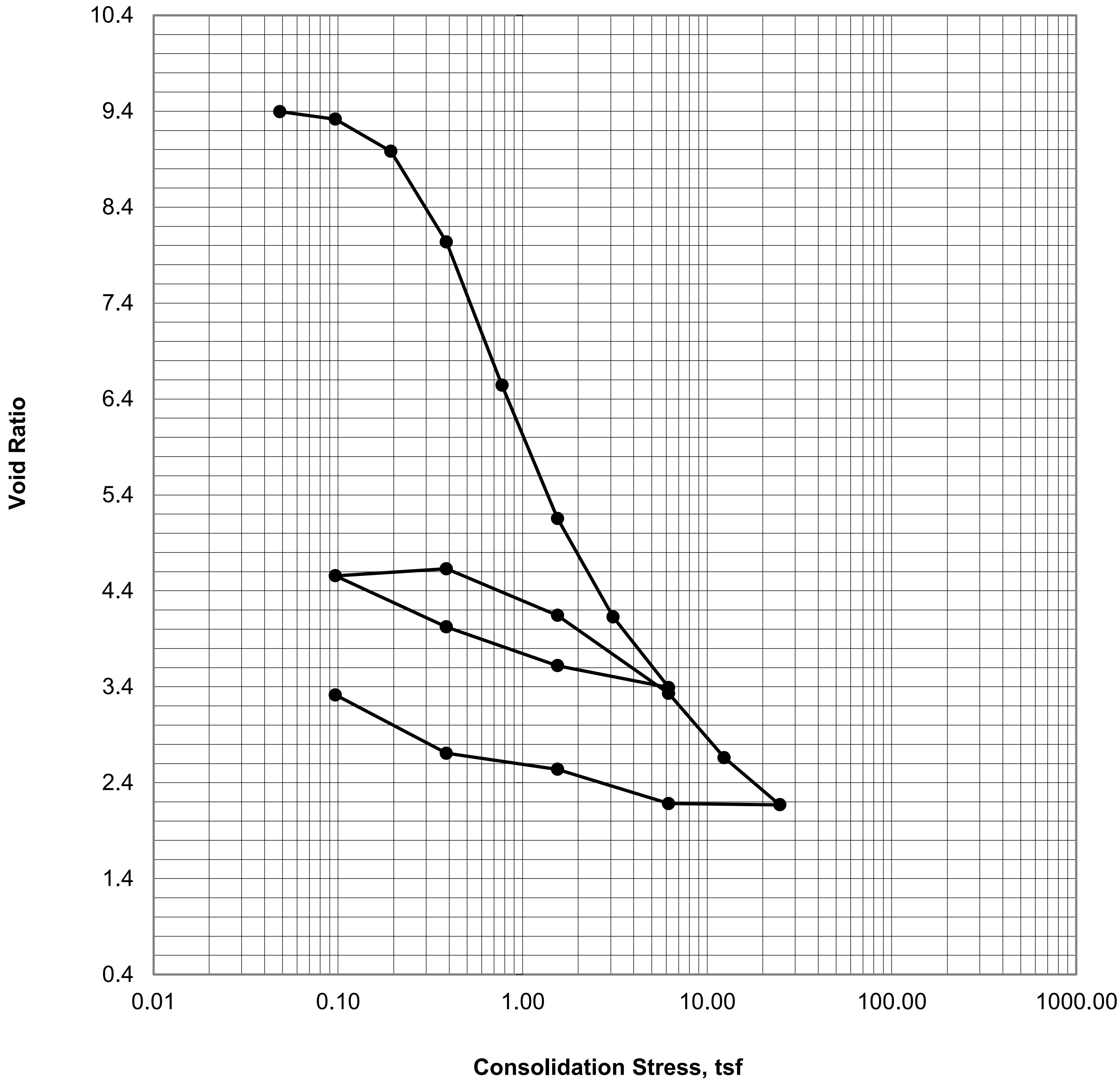
SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B-15

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-2-13	Tested By/Date	AKV 1/10/2013
Sample	S-2	Calculated By/Date	JFL 2/4/2013
Depth, ft	6.3	Checked By/Date	JFL 2/27/2013



Maximum Load, tsf 24.75

NOTES:
1. Abbreviations:
ft = feet
tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION VOID RATIO vs STRESS PLOT BORING B-2-13, SAMPLE S-2 @6.3ft

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SHANNON & WILSON, INC.
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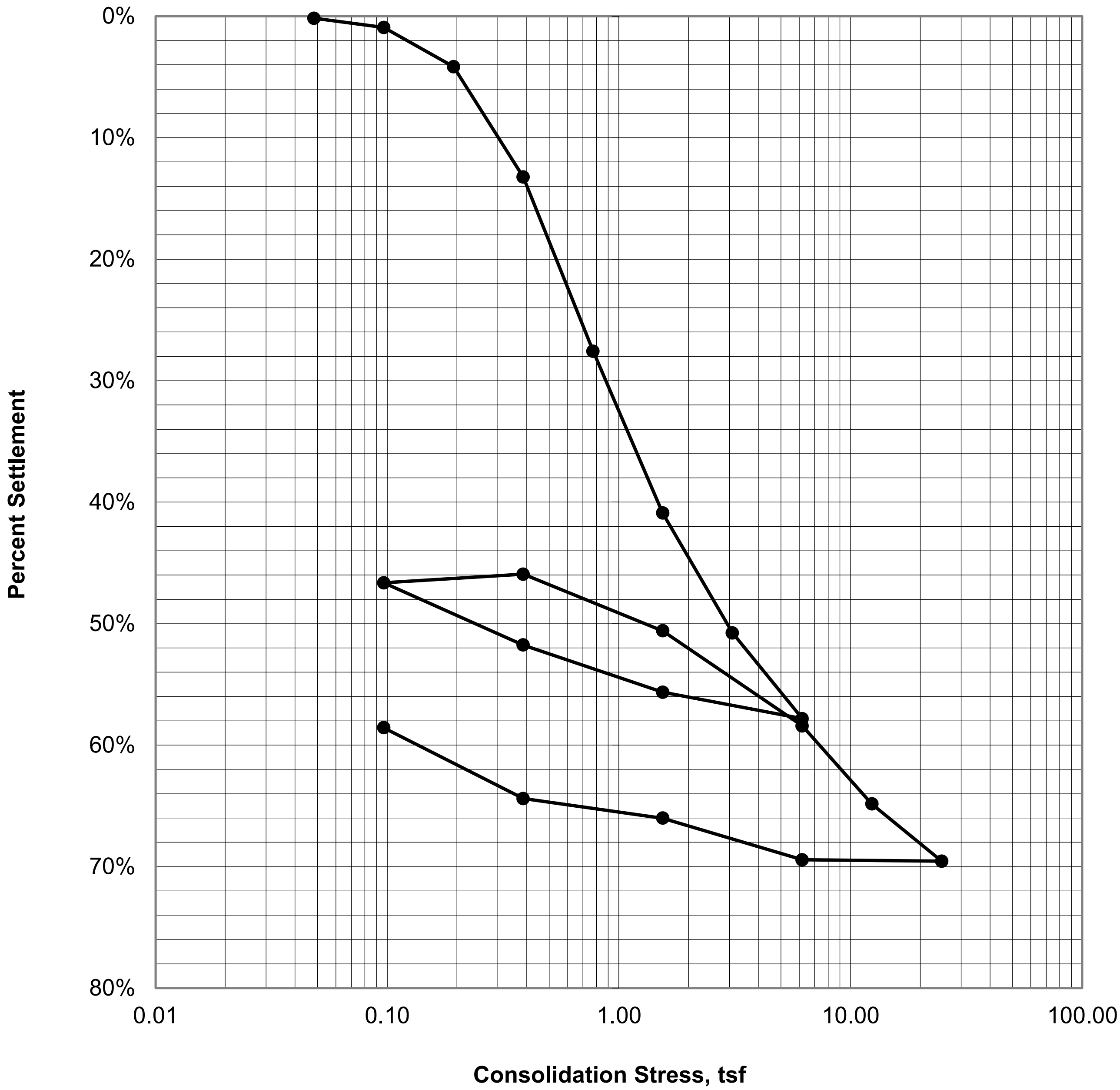
FIG. B-16

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-2-13	Tested By/Date	AKV 1/10/2013
Sample	S-2	Calculated By/Date	JFL 2/4/2013
Depth, ft	6.3	Checked By/Date	JFL 2/27/2013



Maximum Load, tsf 24.75

NOTES:
1. Abbreviations:
ft = feet
tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION PERCENT SETTLEMENT vs STRESS PLOT BORING B-2-13, SAMPLE S-2 @6.3ft

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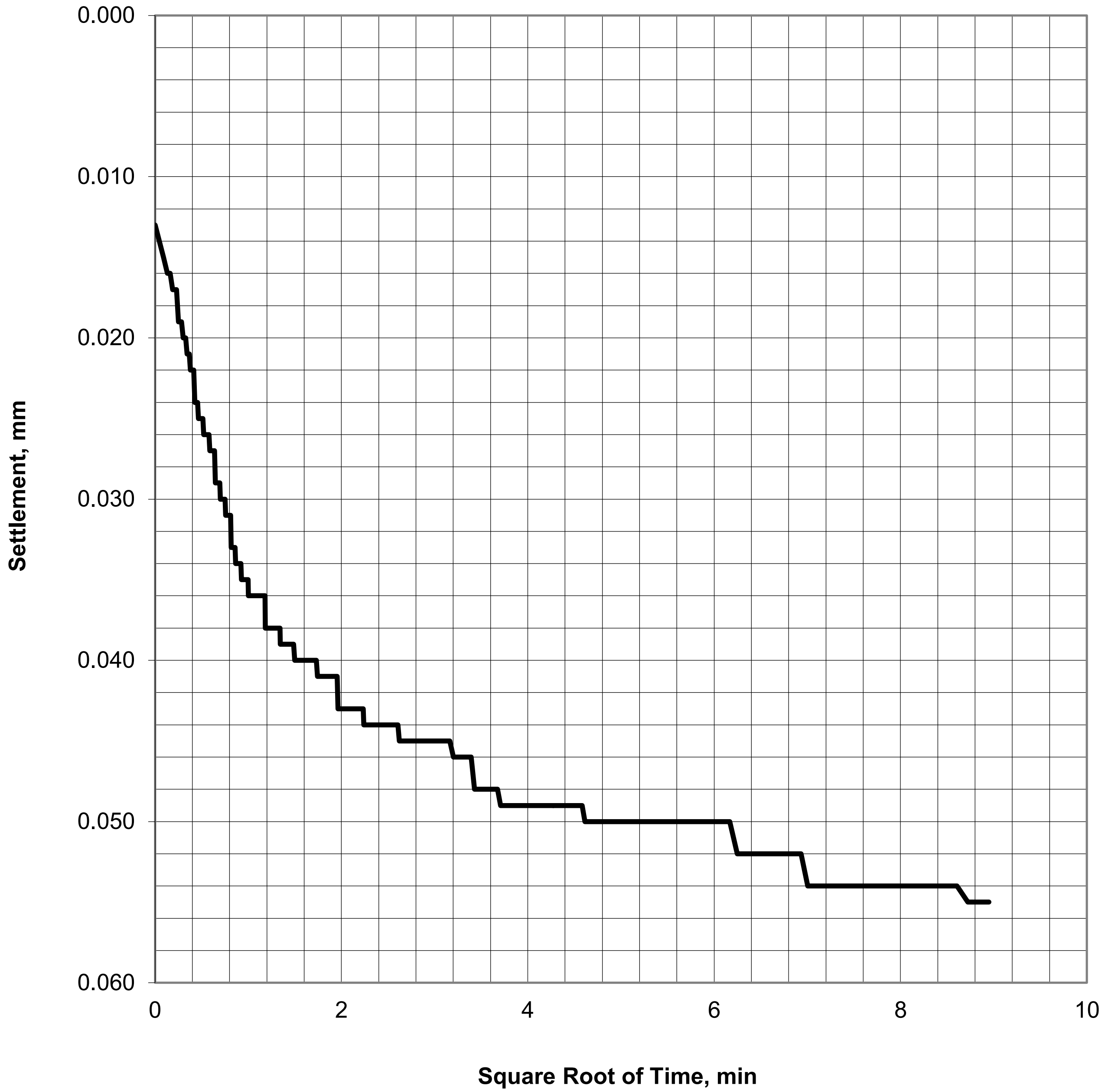
Geotechnical and Environmental Consultants

FIG. B-17

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-2-13	Tested By/Date	AKV 1/10/2013
Sample	S-2	Calculated By/Date	JFL 2/4/2013
Depth, ft	6.3	Checked By/Date	JFL 2/27/2013



Increment Number 1

Applied Stress, tsf 0.05

NOTES:
1. Abbreviations:
ft = feet
min = minutes
mm = mimilimeters
tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-2-13, SAMPLE S-2 @6.3ft

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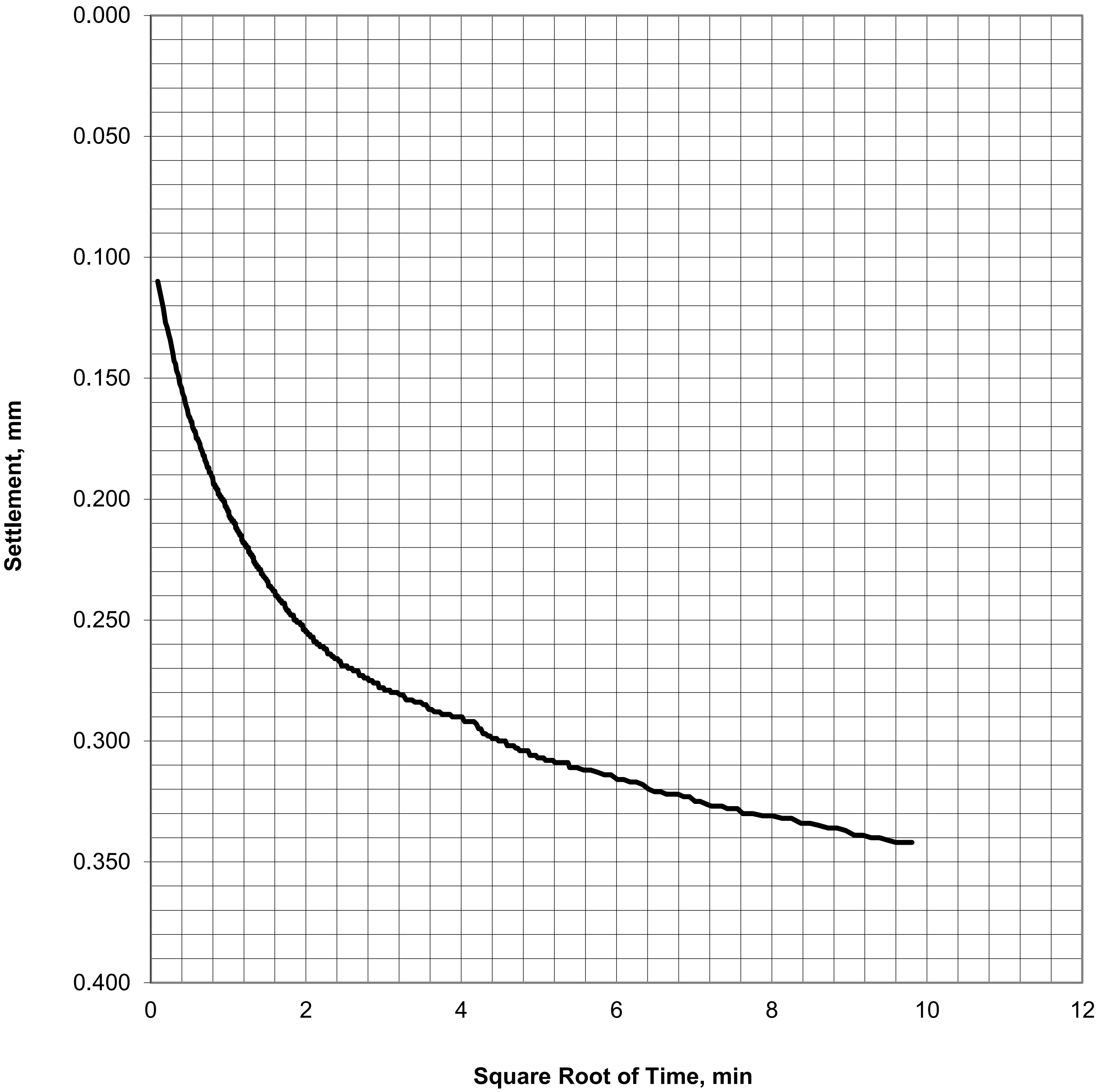
SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B-18

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-2-13	Tested By/Date	AKV 1/10/2013
Sample	S-2	Calculated By/Date	JFL 2/4/2013
Depth, ft	6.3	Checked By/Date	JFL 2/27/2013



Increment Number 2

Applied Stress, tsf 0.05

NOTES:
1. Abbreviations:
ft = feet
min = minutes
mm = mimilimeters
tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-2-13, SAMPLE S-2 @6.3ft

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SHANNON & WILSON, INC.
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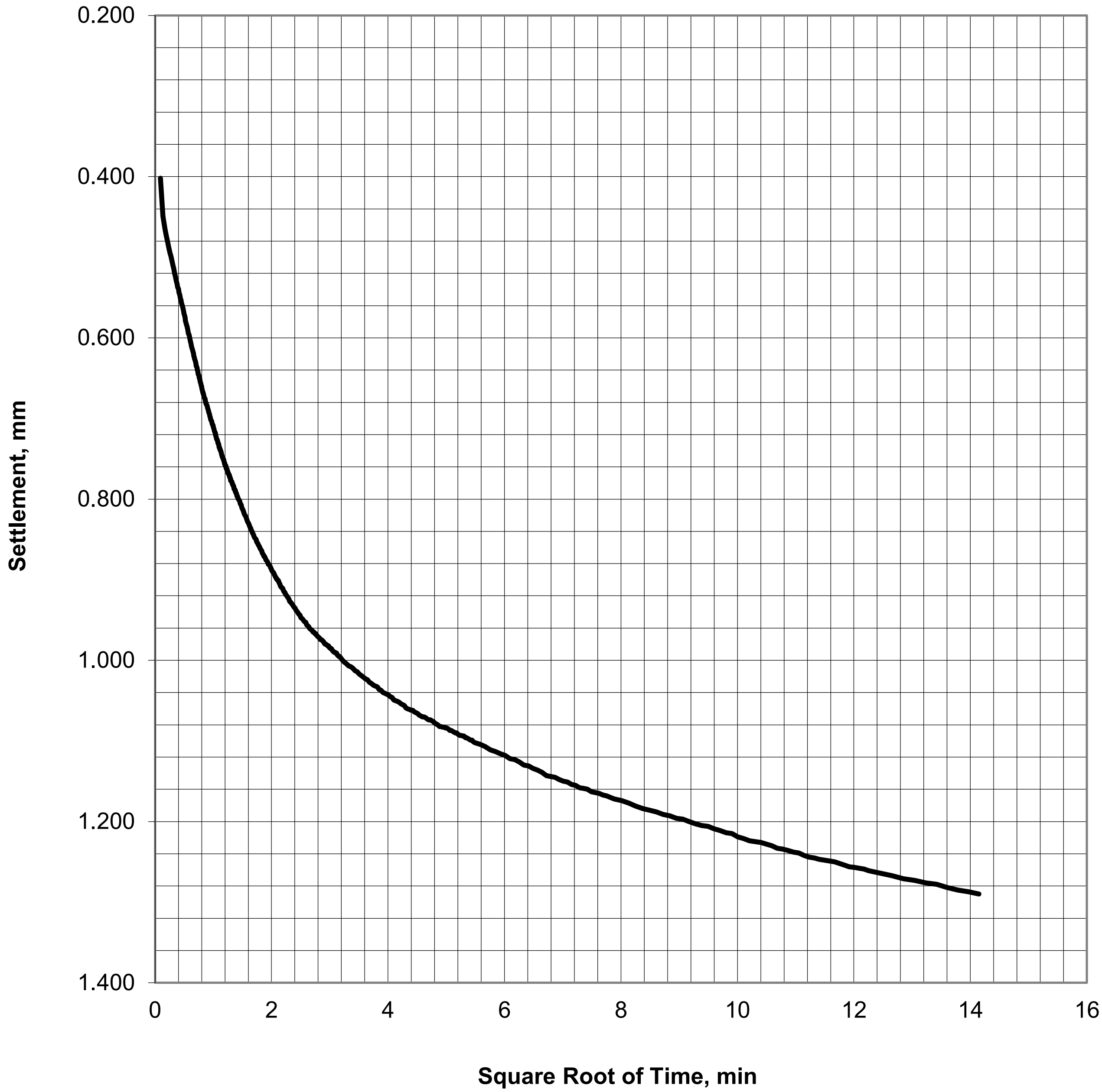
FIG. B-18
Sheet 2 of 20

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-2-13	Tested By/Date	AKV 1/10/2013
Sample	S-2	Calculated By/Date	JFL 2/4/2013
Depth, ft	6.3	Checked By/Date	JFL 2/27/2013



Increment Number 3

Applied Stress, tsf 0.05

NOTES:
1. Abbreviations:
   ft = feet
   min = minutes
   mm = mimilimeters
   tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-2-13, SAMPLE S-2 @6.3ft

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SHANNON & WILSON, INC.
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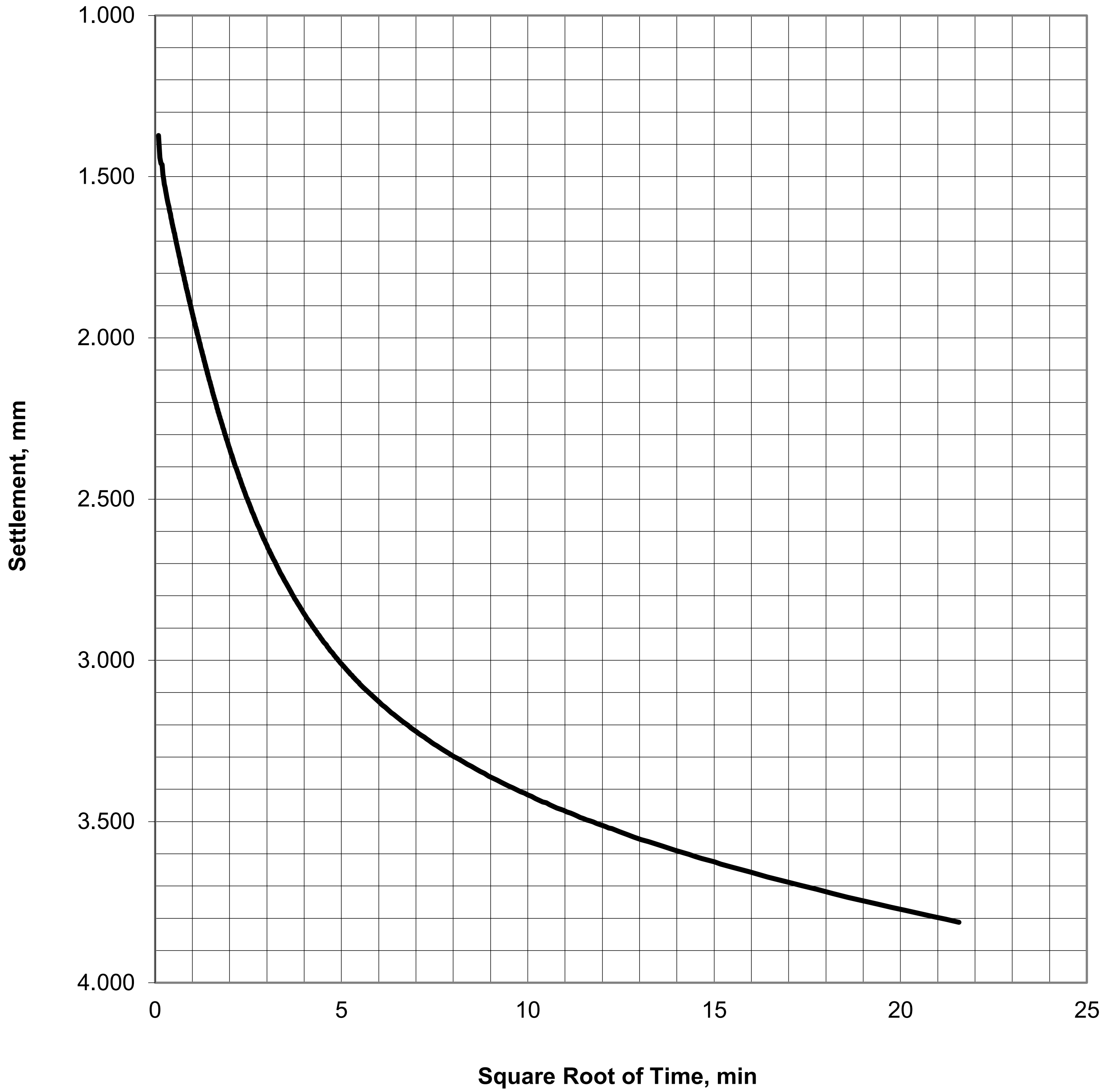
FIG. B-18

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-2-13	Tested By/Date	AKV 1/10/2013
Sample	S-2	Calculated By/Date	JFL 2/4/2013
Depth, ft	6.3	Checked By/Date	JFL 2/27/2013



Increment Number 4

Applied Stress, tsf 0.05

NOTES:
1. Abbreviations:
   ft = feet
   min = minutes
   mm = mimilimeters
   tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-2-13, SAMPLE S-2 @6.3ft

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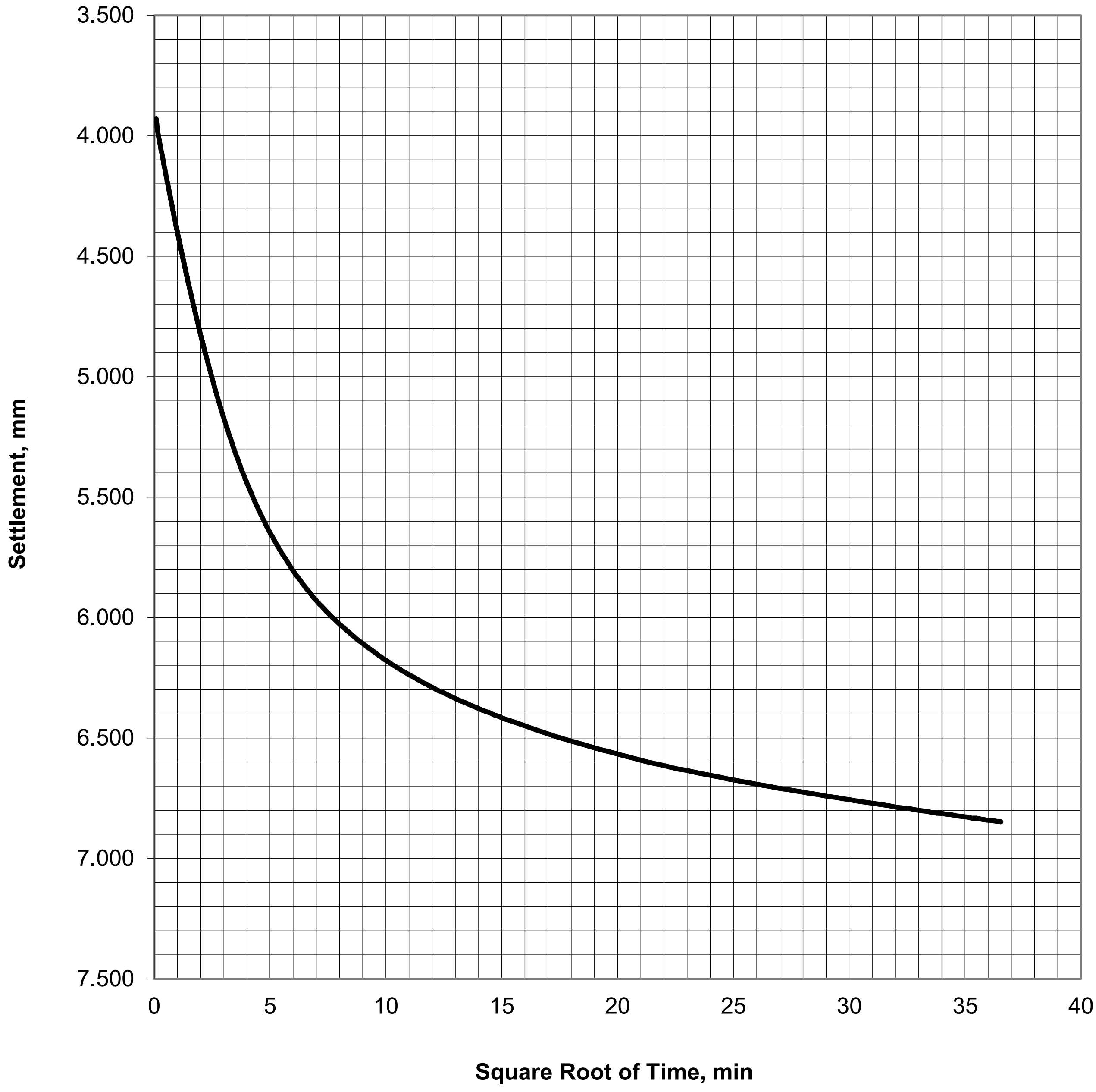
FIG. B-18
Sheet 4 of 20

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-2-13	Tested By/Date	AKV 1/10/2013
Sample	S-2	Calculated By/Date	JFL 2/4/2013
Depth, ft	6.3	Checked By/Date	JFL 2/27/2013



Increment Number 5

Applied Stress, tsf 0.05

NOTES:
1. Abbreviations:
   ft = feet
   min = minutes
   mm = mimilimeters
   tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-2-13, SAMPLE S-2 @6.3ft

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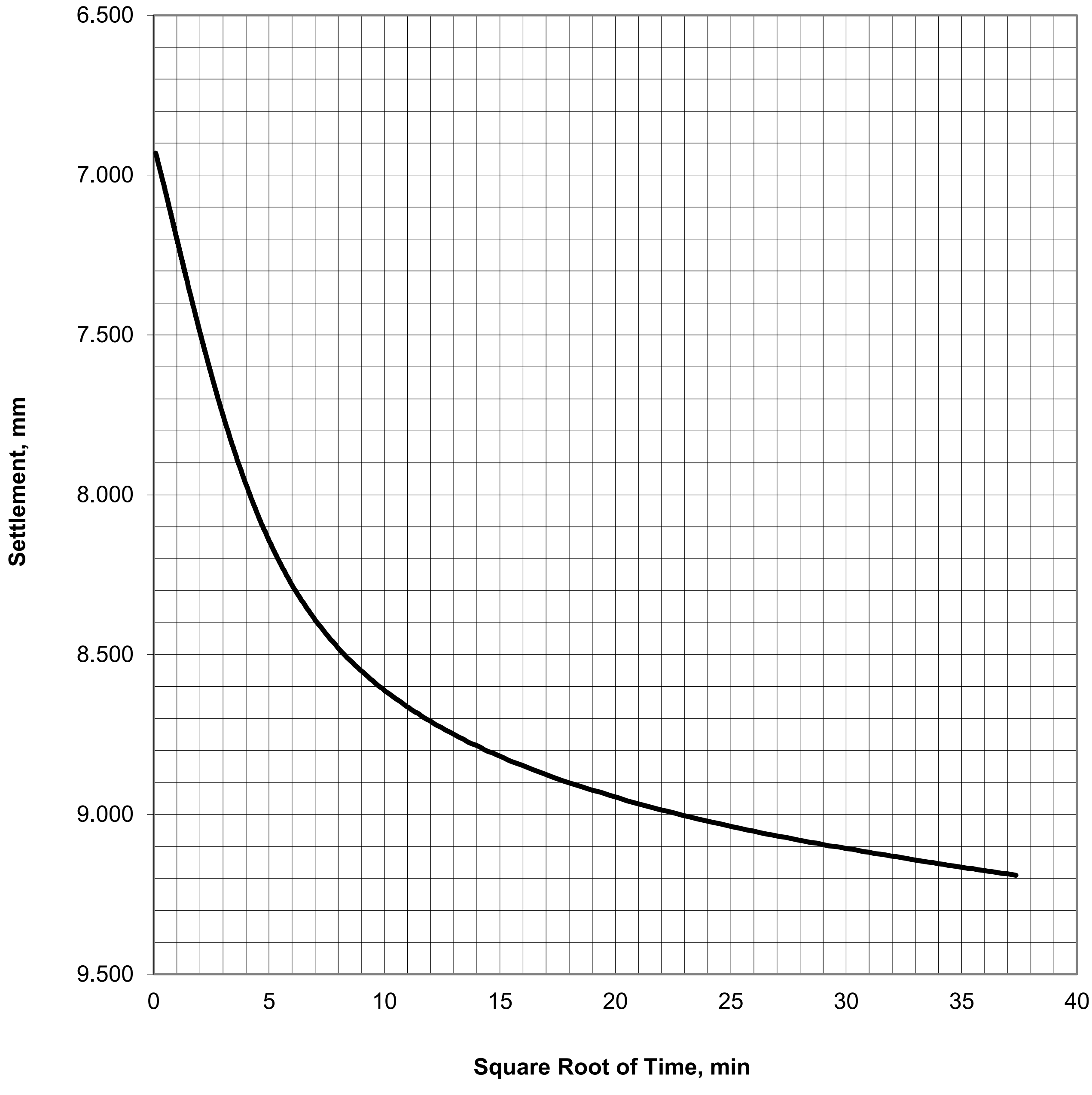
SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B-18
Sheet 5 of 20

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-2-13	Tested By/Date	AKV 1/10/2013
Sample	S-2	Calculated By/Date	JFL 2/4/2013
Depth, ft	6.3	Checked By/Date	JFL 2/27/2013



Increment Number 6

Applied Stress, tsf 0.05

NOTES:
1. Abbreviations:
ft = feet
min = minutes
mm = mimilimeters
tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-2-13, SAMPLE S-2 @6.3ft

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SHANNON & WILSON, INC.
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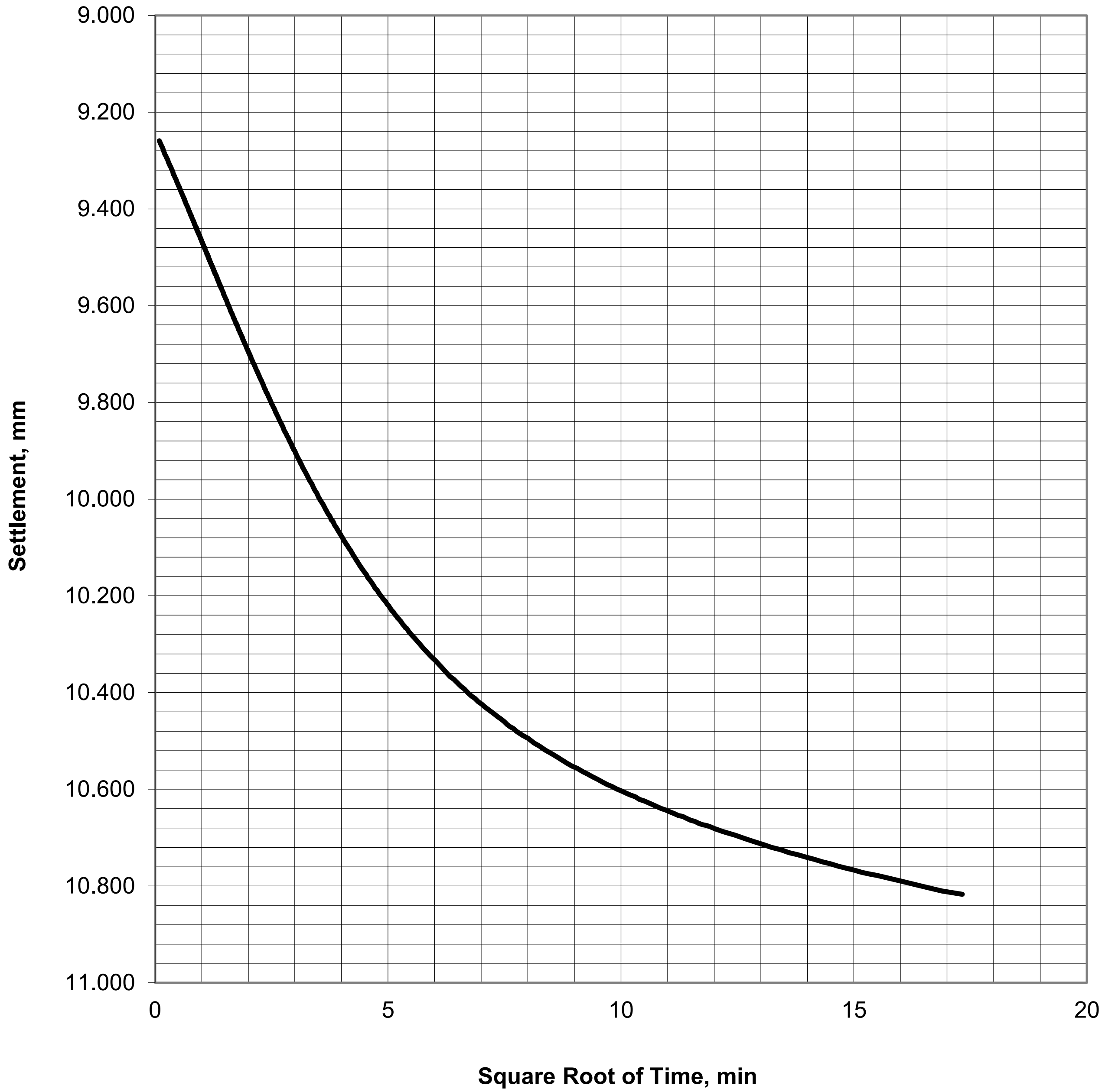
FIG. B-18

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-2-13	Tested By/Date	AKV 1/10/2013
Sample	S-2	Calculated By/Date	JFL 2/4/2013
Depth, ft	6.3	Checked By/Date	JFL 2/27/2013



Increment Number 7

Applied Stress, tsf 0.05

NOTES:
1. Abbreviations:
   - ft = feet
   - min = minutes
   - mm = mimilimeters
   - tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-2-13, SAMPLE S-2 @6.3ft

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SHANNON & WILSON, INC.
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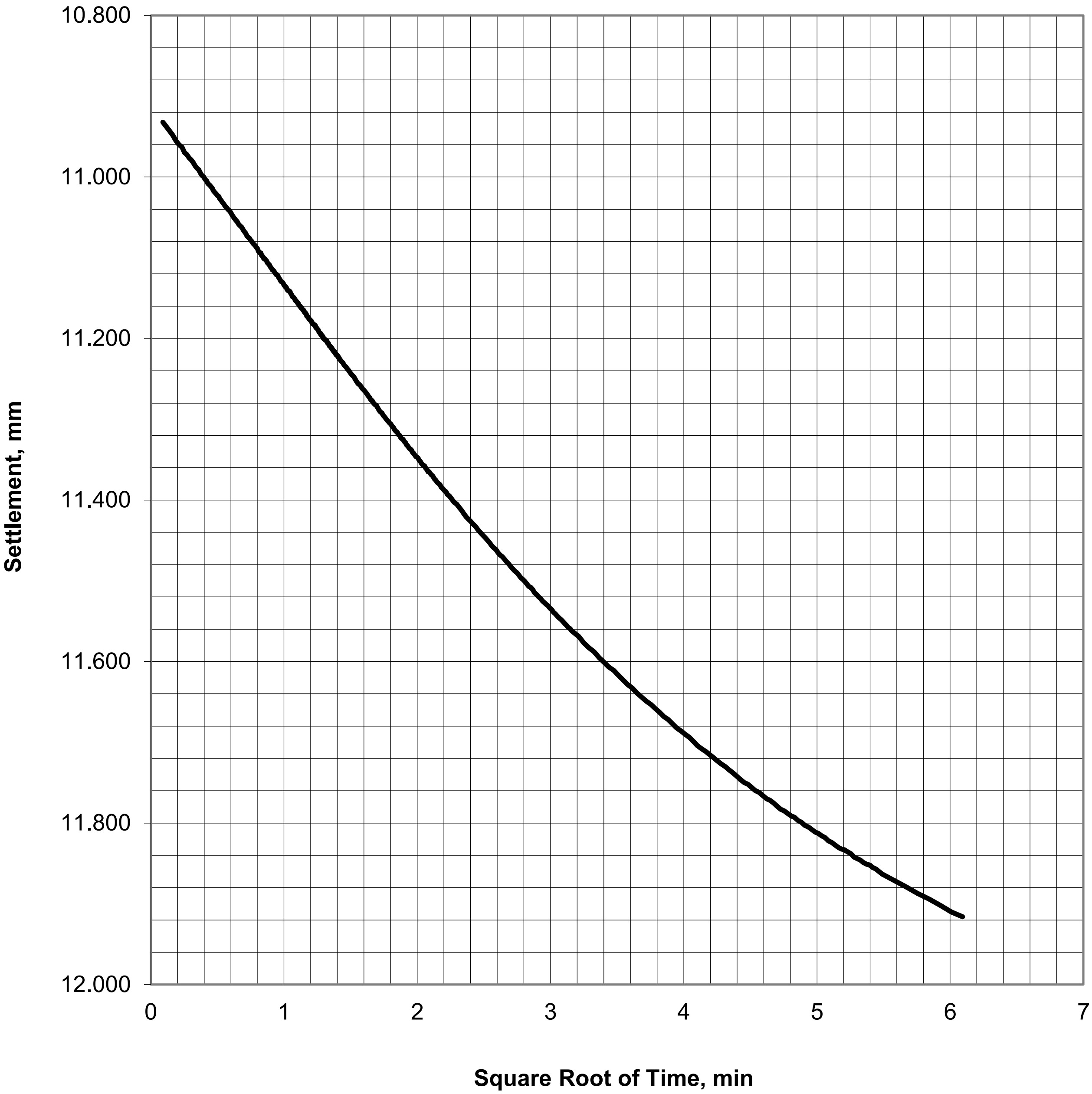
FIG. B-18

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-2-13	Tested By/Date	AKV 1/10/2013
Sample	S-2	Calculated By/Date	JFL 2/4/2013
Depth, ft	6.3	Checked By/Date	JFL 2/27/2013



Increment Number 8

Applied Stress, tsf 0.05

NOTES:
1. Abbreviations:
ft = feet
min = minutes
mm = mimilimeters
tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-2-13, SAMPLE S-2 @6.3ft

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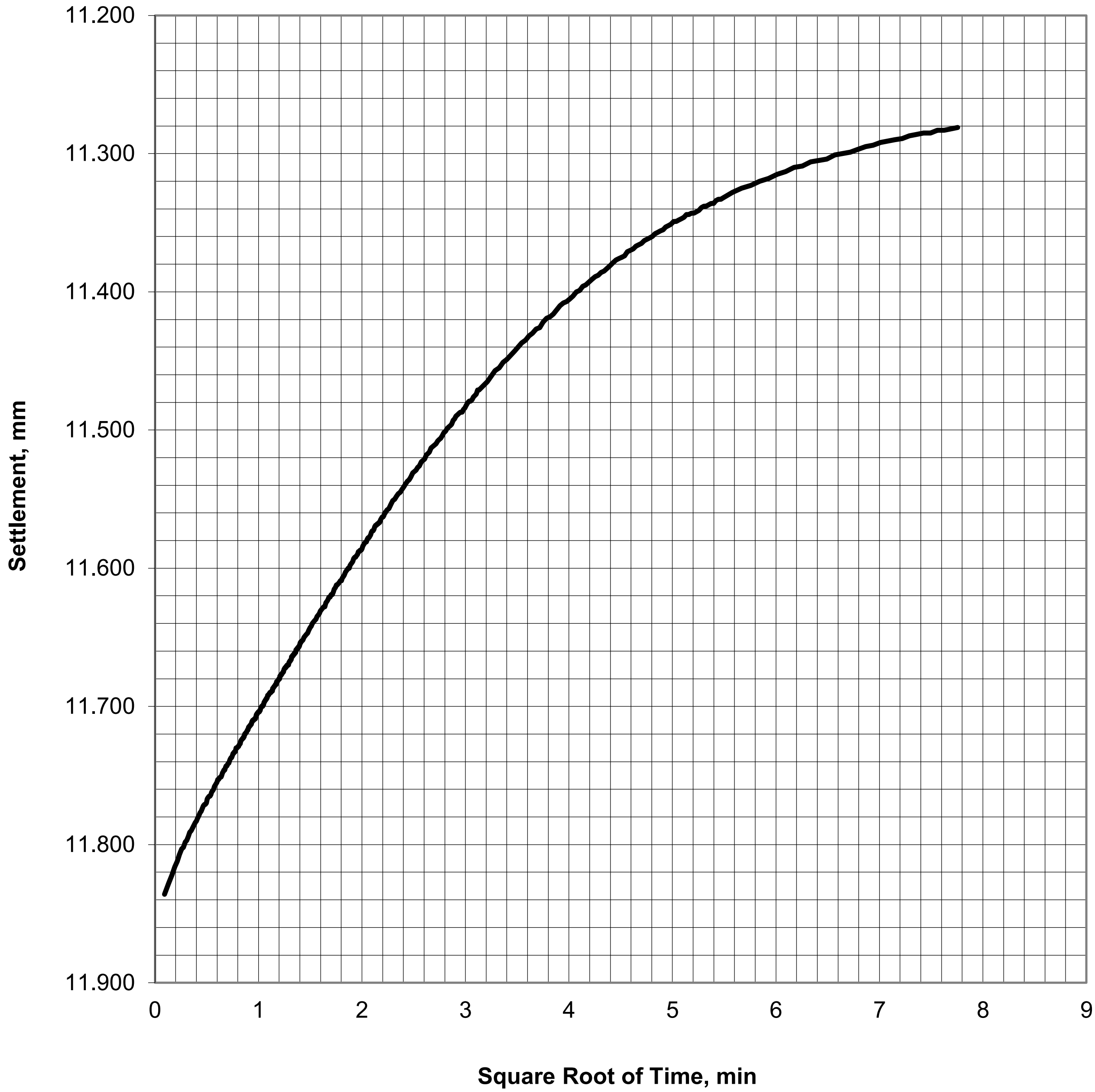
FIG. B-18

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-2-13	Tested By/Date	AKV 1/10/2013
Sample	S-2	Calculated By/Date	JFL 2/4/2013
Depth, ft	6.3	Checked By/Date	JFL 2/27/2013



Increment Number 9

Applied Stress, tsf 0.05

NOTES:
1. Abbreviations:
   ft = feet
   min = minutes
   mm = mimilimeters
   tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-2-13, SAMPLE S-2 @6.3ft

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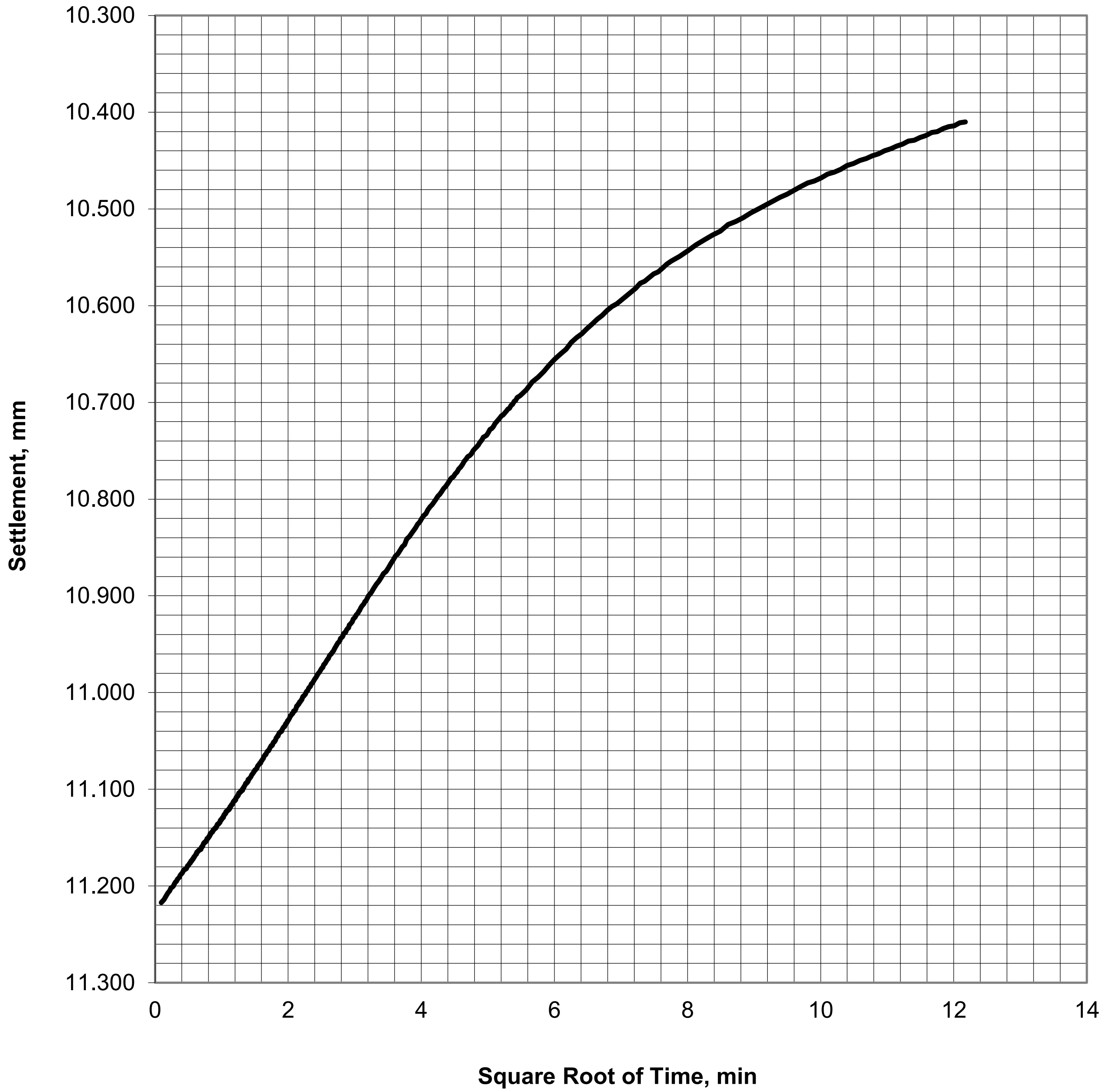
FIG. B-18

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-2-13	Tested By/Date	AKV 1/10/2013
Sample	S-2	Calculated By/Date	JFL 2/4/2013
Depth, ft	6.3	Checked By/Date	JFL 2/27/2013



Increment Number 10

Applied Stress, tsf 0.05

NOTES:
1. Abbreviations:
   - ft = feet
   - min = minutes
   - mm = mimilimeters
   - tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-2-13, SAMPLE S-2 @6.3ft

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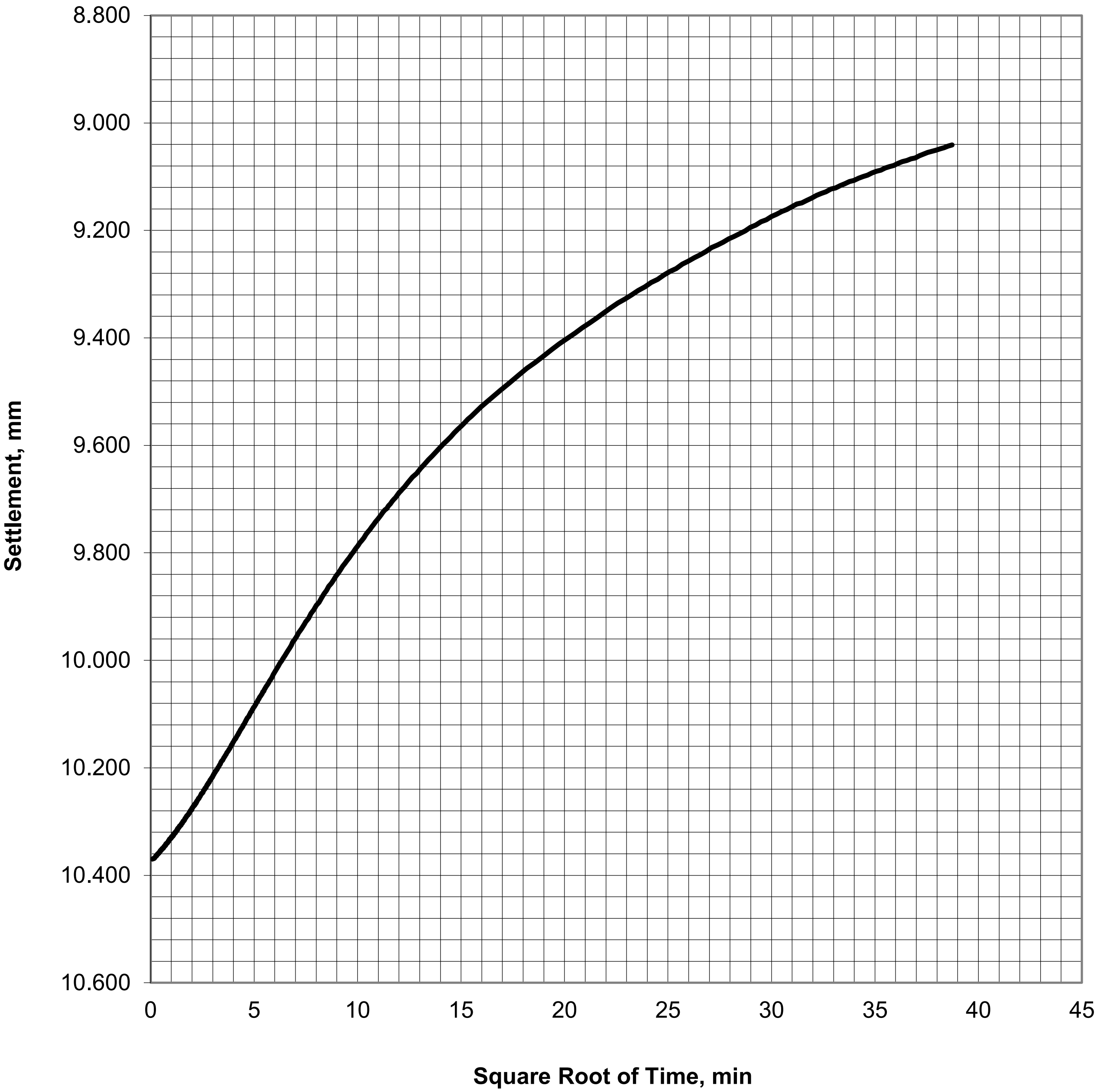
FIG. B-18
Sheet 10 of 20

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-2-13	Tested By/Date	AKV 1/10/2013
Sample	S-2	Calculated By/Date	JFL 2/4/2013
Depth, ft	6.3	Checked By/Date	JFL 2/27/2013



Increment Number 11

Applied Stress, tsf 0.05

NOTES:
1. Abbreviations:
ft = feet
min = minutes
mm = mimilimeters
tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-2-13, SAMPLE S-2 @6.3ft

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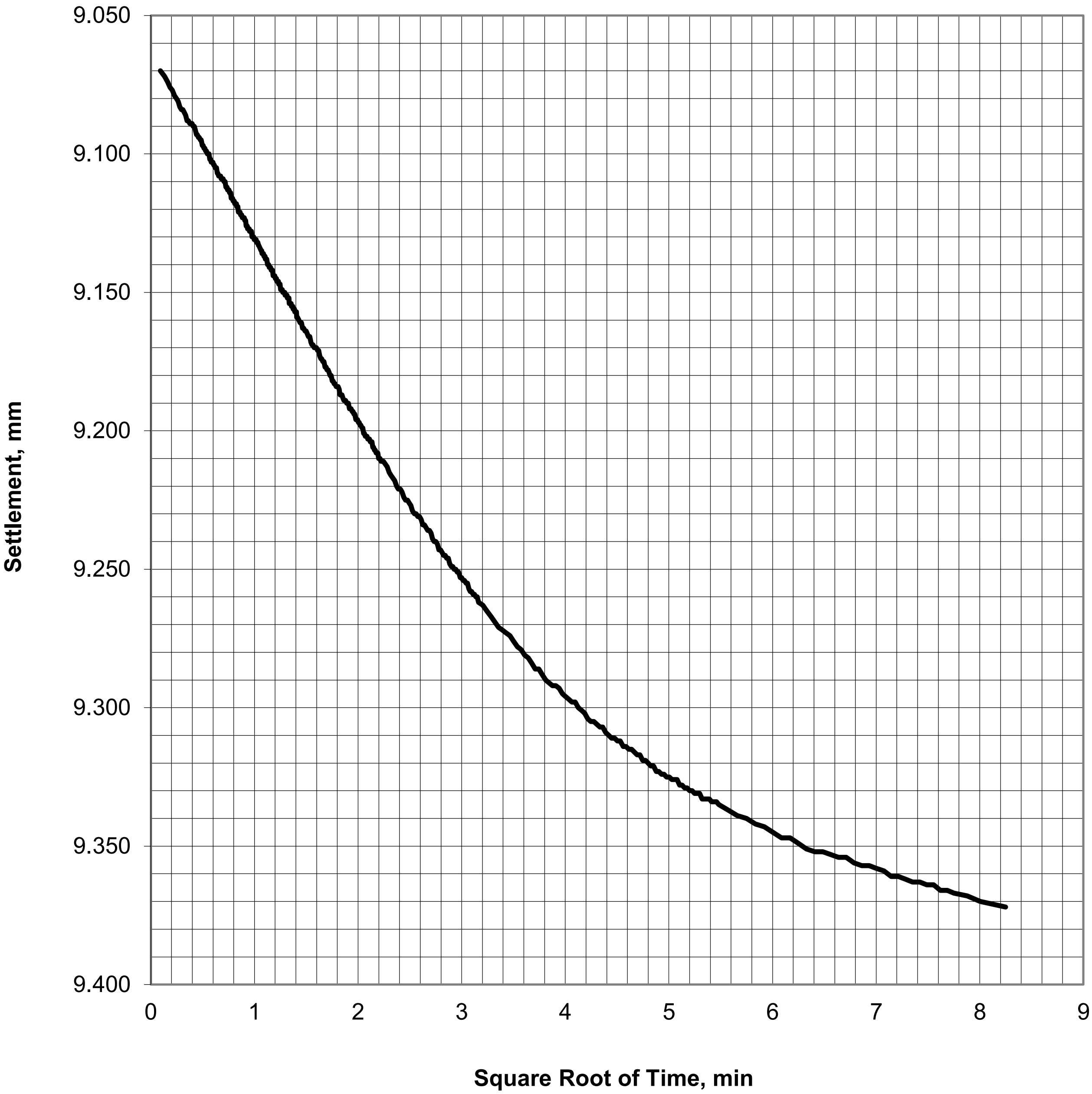
FIG. B-18

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-2-13	Tested By/Date	AKV 1/10/2013
Sample	S-2	Calculated By/Date	JFL 2/4/2013
Depth, ft	6.3	Checked By/Date	JFL 2/27/2013



Increment Number 12

Applied Stress, tsf 0.05

NOTES:
1. Abbreviations:
   ft = feet
   min = minutes
   mm = mimilimeters
   tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-2-13, SAMPLE S-2 @6.3ft

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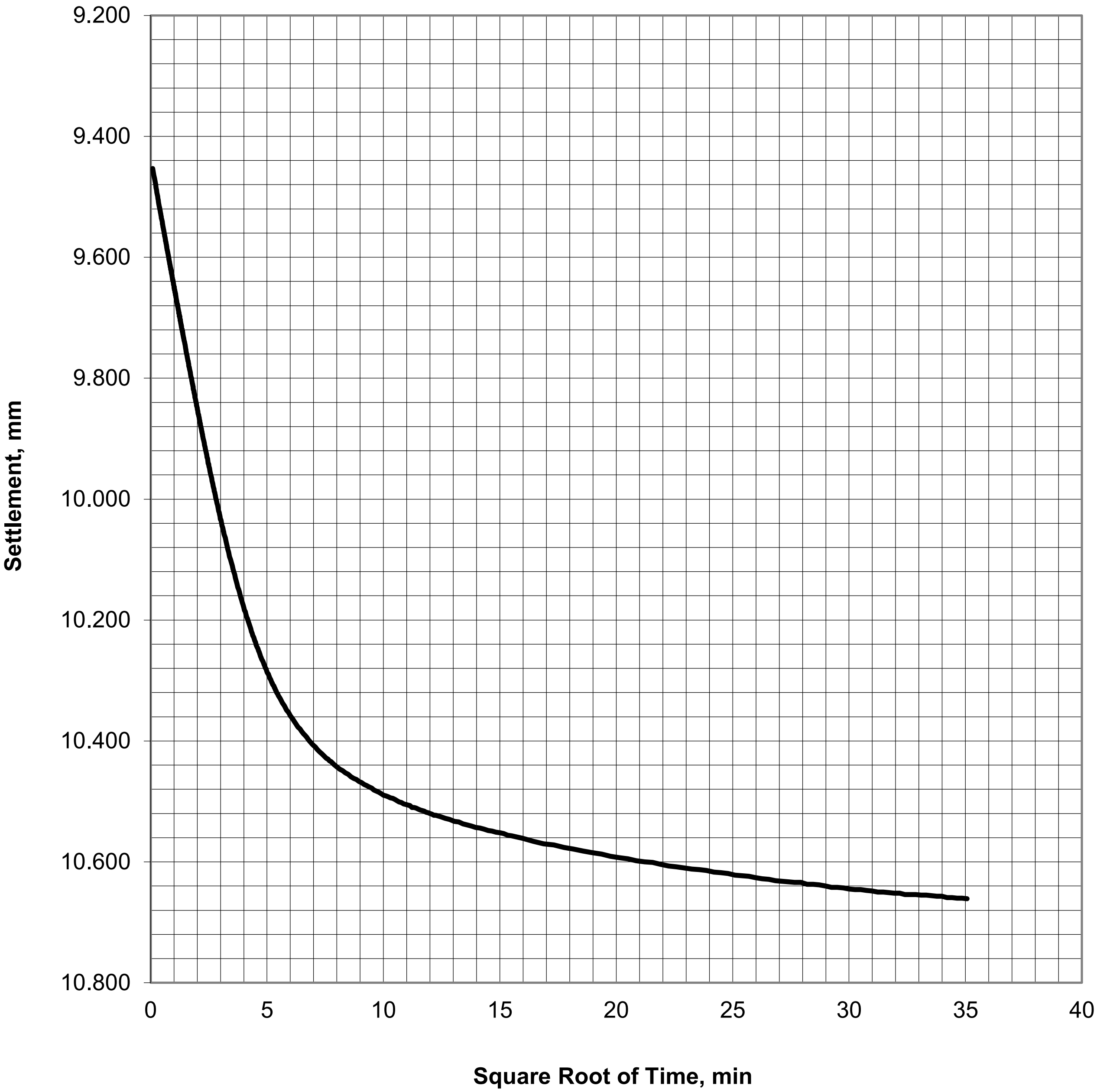
FIG. B-18
Sheet 12 of 20

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-2-13	Tested By/Date	AKV 1/10/2013
Sample	S-2	Calculated By/Date	JFL 2/4/2013
Depth, ft	6.3	Checked By/Date	JFL 2/27/2013



Increment Number 13

Applied Stress, tsf 0.05

NOTES:
1. Abbreviations:
ft = feet
min = minutes
mm = mimilimeters
tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-2-13, SAMPLE S-2 @6.3ft

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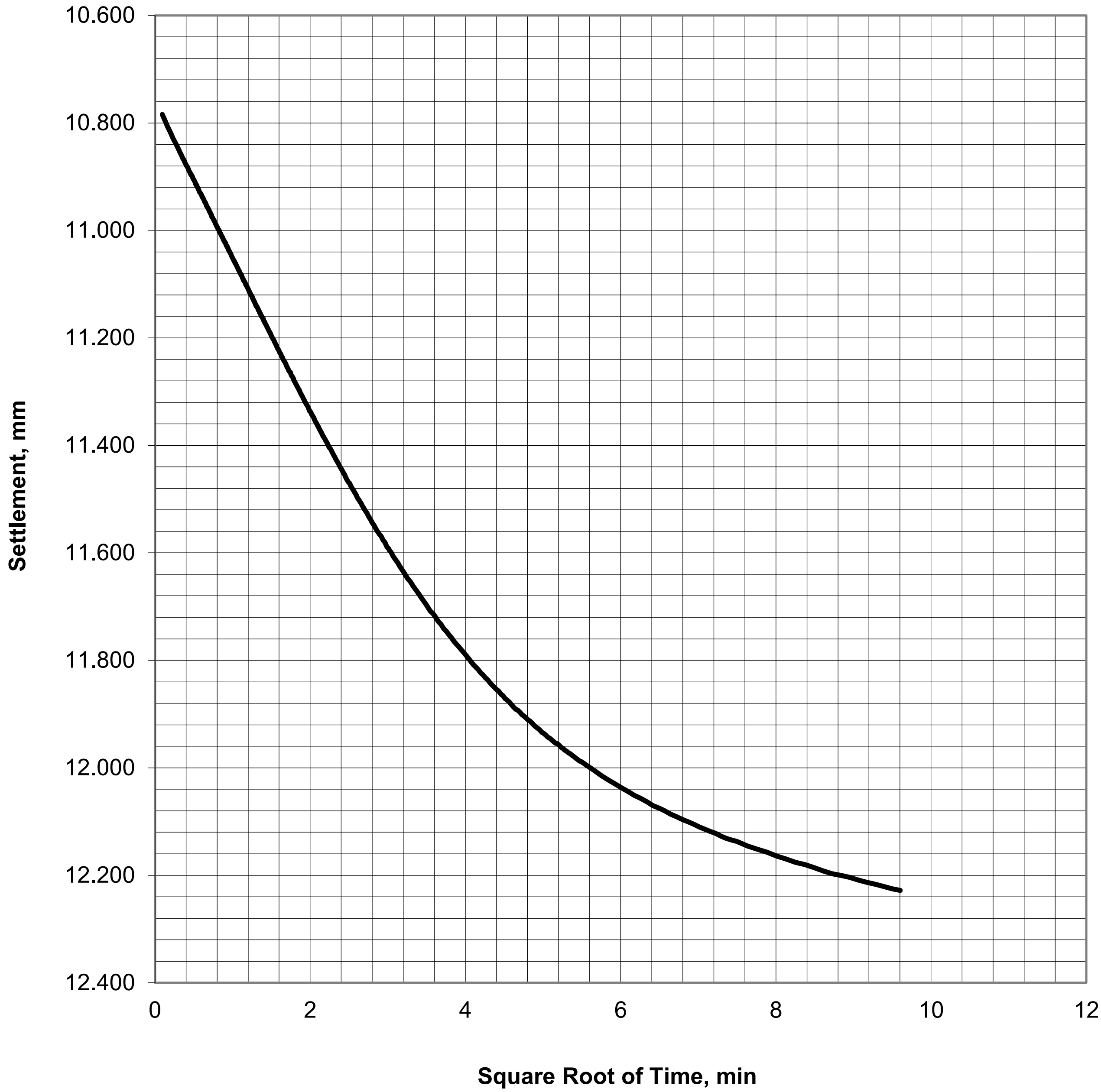
FIG. B-18

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-2-13	Tested By/Date	AKV 1/10/2013
Sample	S-2	Calculated By/Date	JFL 2/4/2013
Depth, ft	6.3	Checked By/Date	JFL 2/27/2013



Increment Number 14

Applied Stress, tsf 0.05

NOTES:
1. Abbreviations:
   ft = feet
   min = minutes
   mm = mimilimeters
   tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-2-13, SAMPLE S-2 @6.3ft

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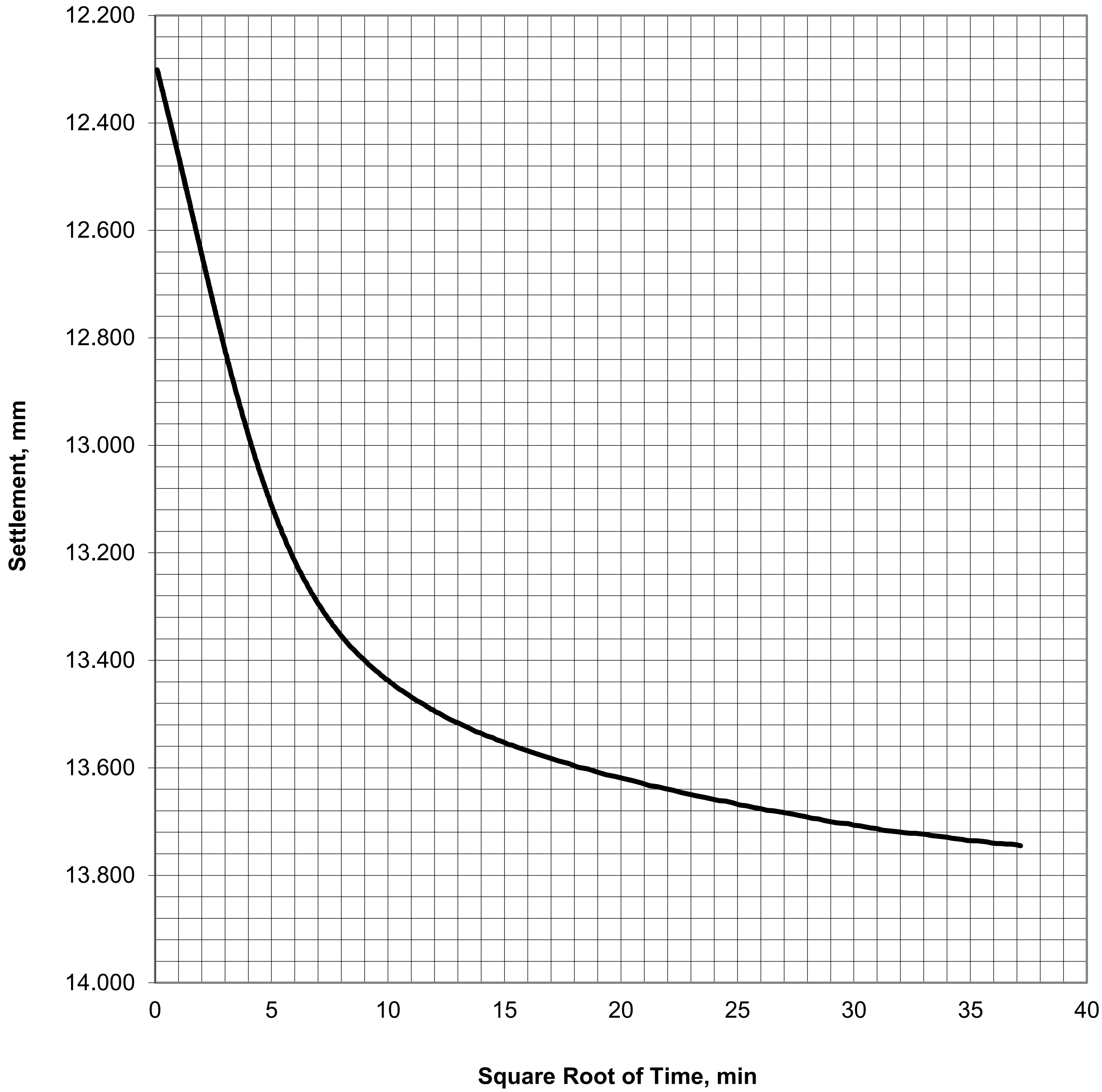
FIG. B-18

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-2-13	Tested By/Date	AKV 1/10/2013
Sample	S-2	Calculated By/Date	JFL 2/4/2013
Depth, ft	6.3	Checked By/Date	JFL 2/27/2013



Increment Number 15

Applied Stress, tsf 0.05

NOTES:
1. Abbreviations:
ft = feet
min = minutes
mm = mimilimeters
tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-2-13, SAMPLE S-2 @6.3ft

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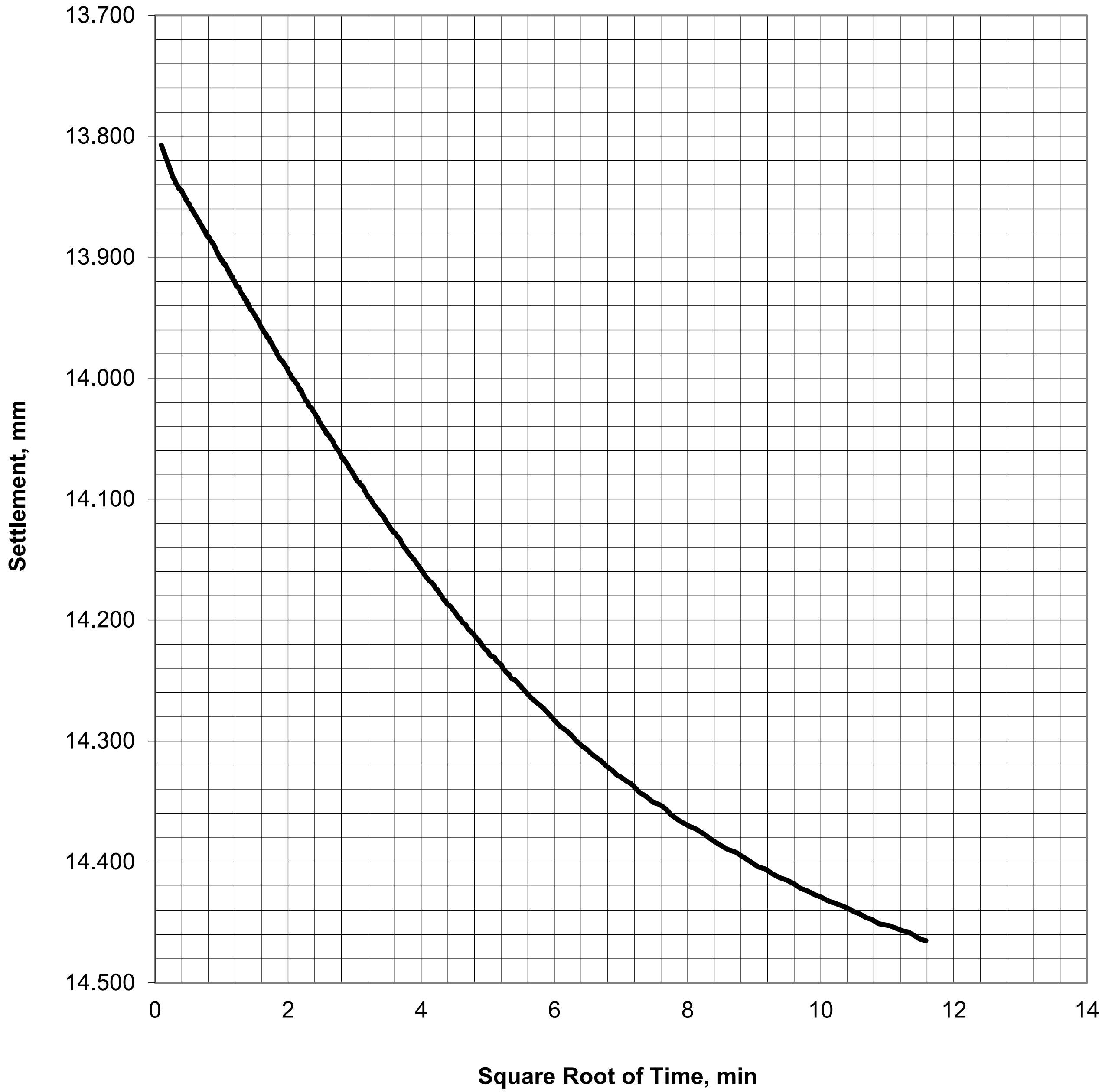
FIG. B-18

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-2-13	Tested By/Date	AKV 1/10/2013
Sample	S-2	Calculated By/Date	JFL 2/4/2013
Depth, ft	6.3	Checked By/Date	JFL 2/27/2013



Increment Number 16

Applied Stress, tsf 0.05

NOTES:
1. Abbreviations:
ft = feet
min = minutes
mm = mimilimeters
tsf = tons per square foot

Smith Island Site Restoration
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ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-2-13, SAMPLE S-2 @6.3ft

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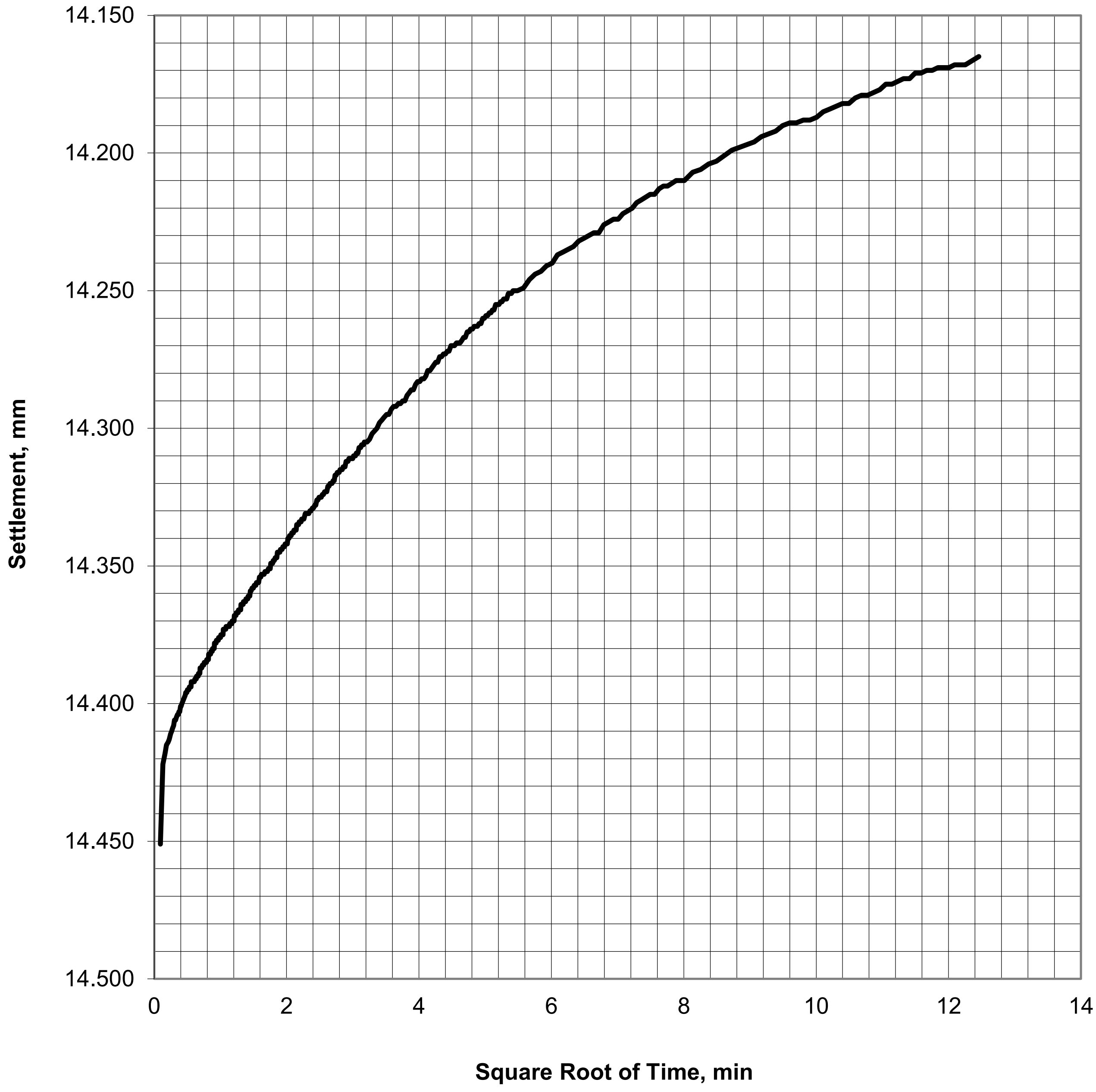
FIG. B-18

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-2-13	Tested By/Date	AKV 1/10/2013
Sample	S-2	Calculated By/Date	JFL 2/4/2013
Depth, ft	6.3	Checked By/Date	JFL 2/27/2013



Increment Number 17

Applied Stress, tsf 0.05

NOTES:
1. Abbreviations:
ft = feet
min = minutes
mm = mimilimeters
tsf = tons per square foot

Smith Island Site Restoration
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ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-2-13, SAMPLE S-2 @6.3ft

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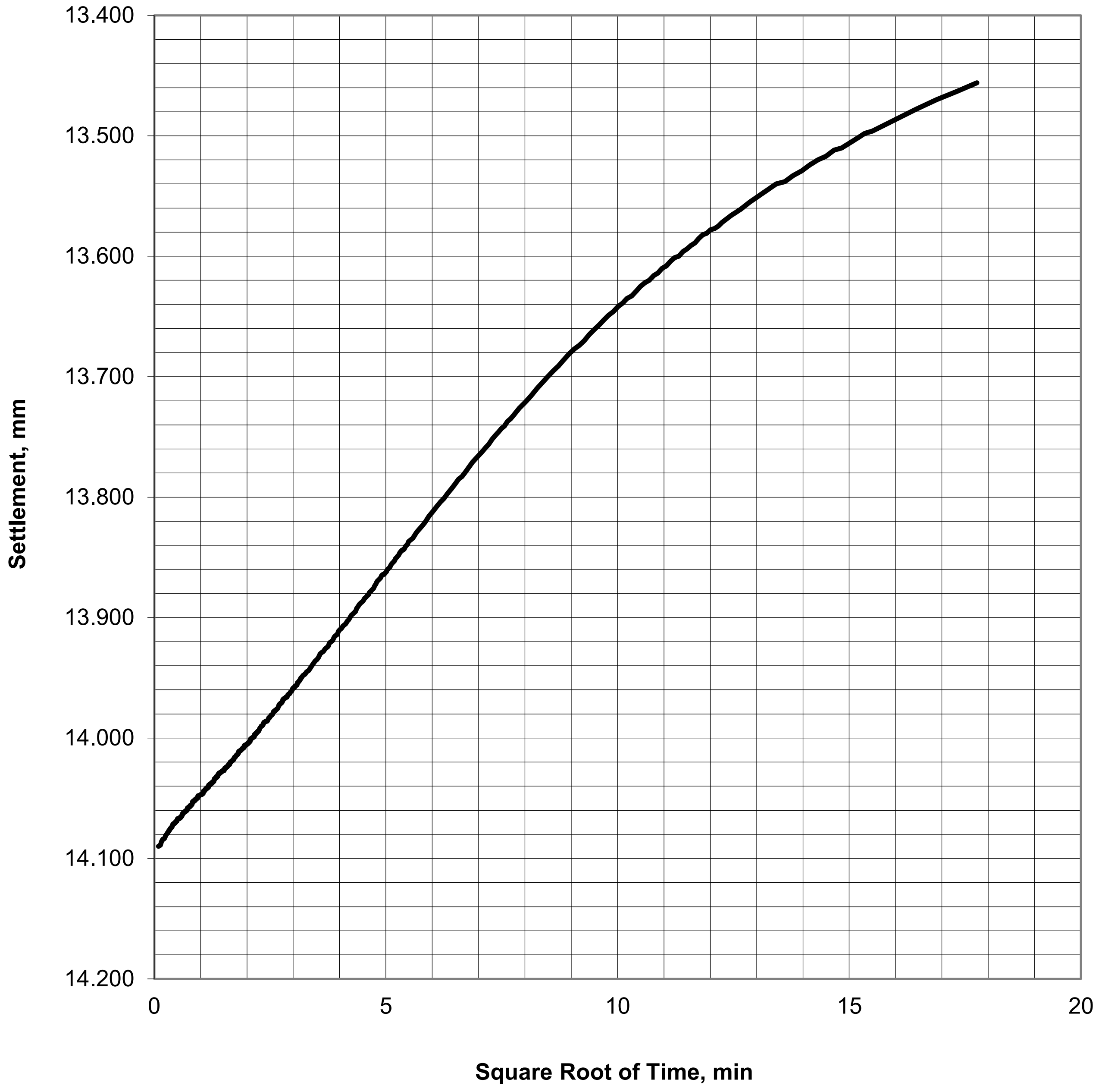
FIG. B-18

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-2-13	Tested By/Date	AKV 1/10/2013
Sample	S-2	Calculated By/Date	JFL 2/4/2013
Depth, ft	6.3	Checked By/Date	JFL 2/27/2013



Increment Number 18

Applied Stress, tsf 0.05

NOTES:
1. Abbreviations:
ft = feet
min = minutes
mm = mimilimeters
tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-2-13, SAMPLE S-2 @6.3ft

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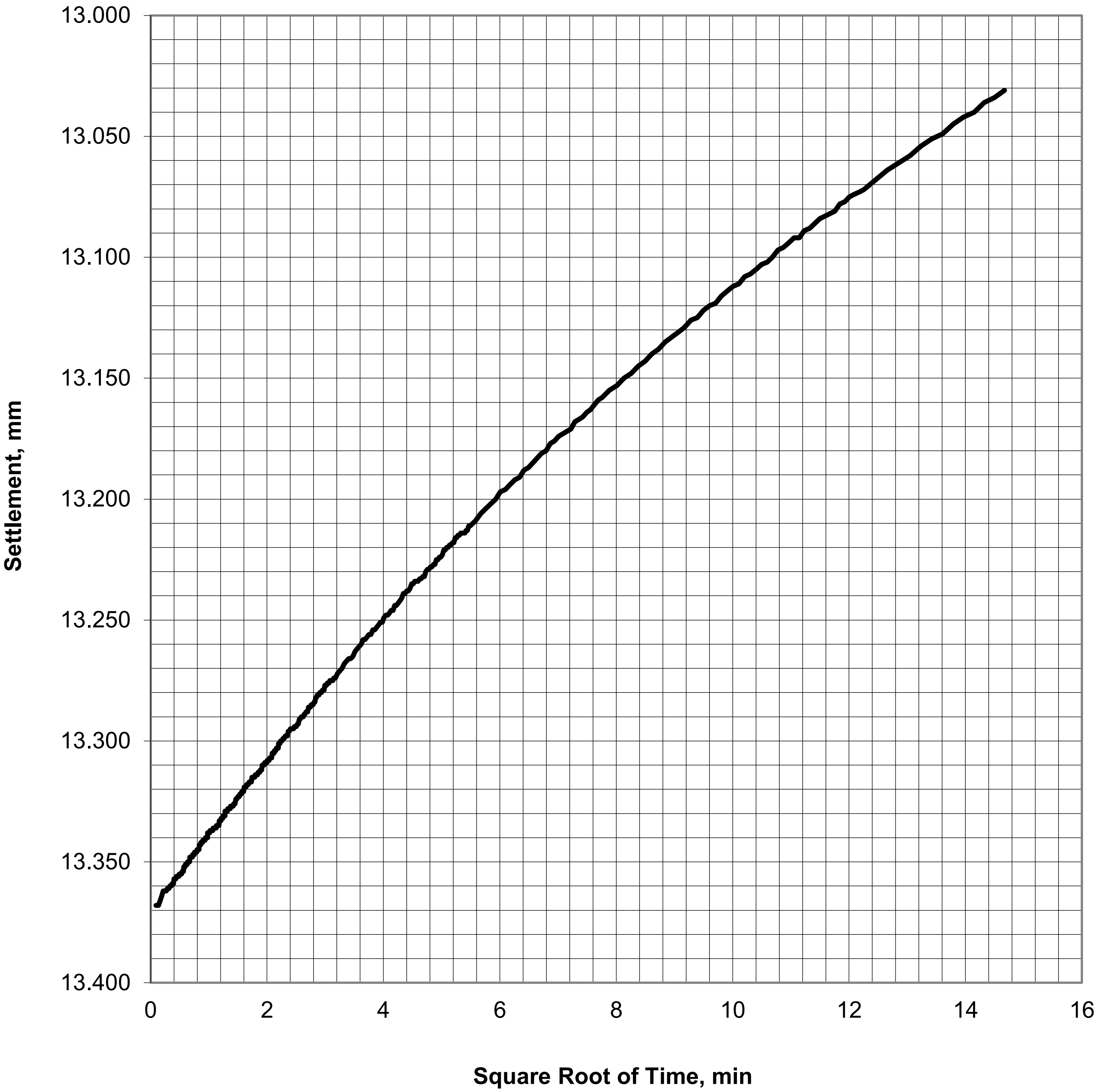
FIG. B-18
Sheet 18 of 20

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-2-13	Tested By/Date	AKV 1/10/2013
Sample	S-2	Calculated By/Date	JFL 2/4/2013
Depth, ft	6.3	Checked By/Date	JFL 2/27/2013



Increment Number 19

Applied Stress, tsf 0.05

NOTES:
1. Abbreviations:
   ft = feet
   min = minutes
   mm = mimilimeters
   tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-2-13, SAMPLE S-2 @6.3ft

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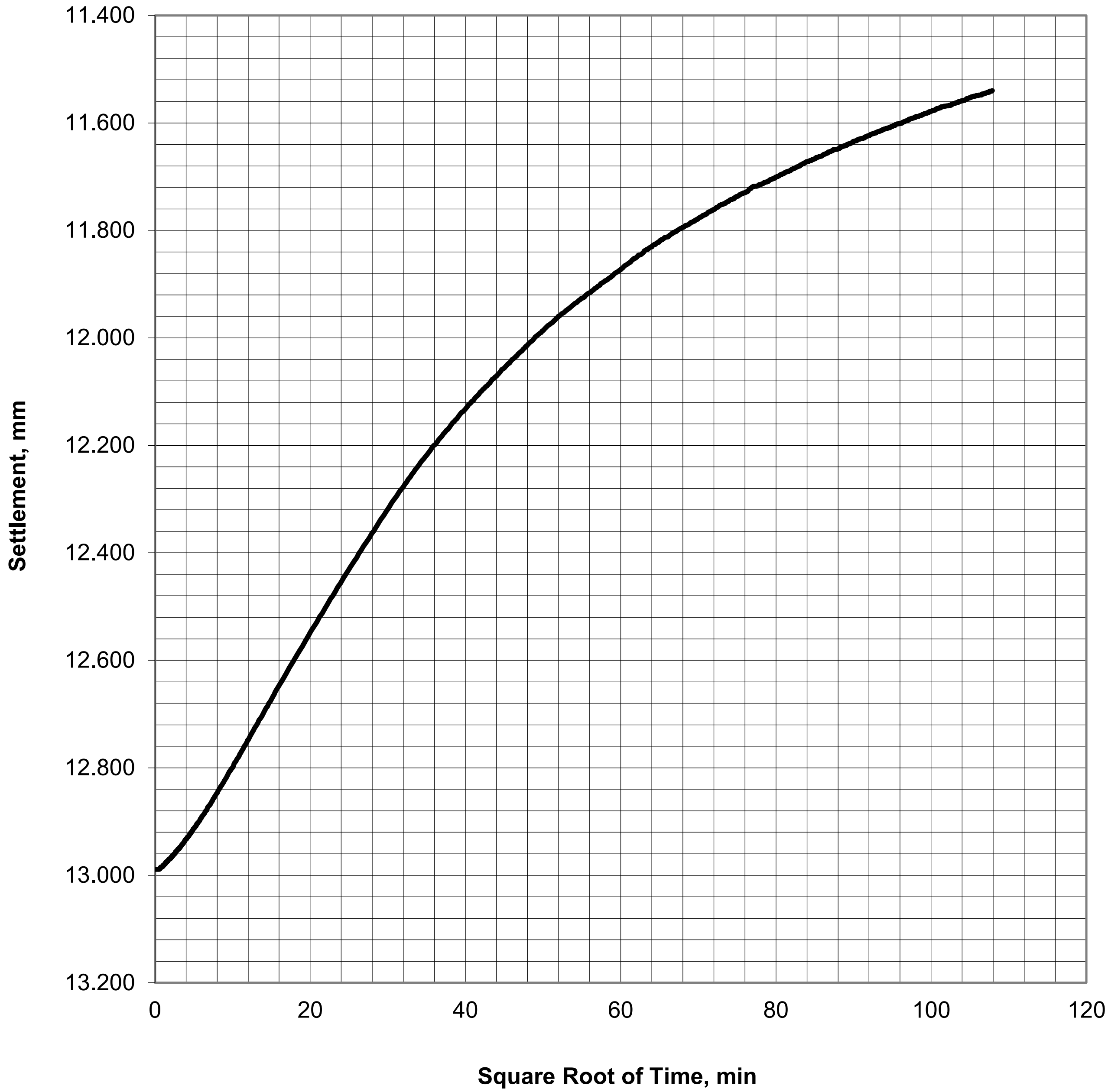
FIG. B-18

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-2-13	Tested By/Date	AKV 1/10/2013
Sample	S-2	Calculated By/Date	JFL 2/4/2013
Depth, ft	6.3	Checked By/Date	JFL 2/27/2013



Increment Number 20

Applied Stress, tsf 0.05

NOTES:
1. Abbreviations:
   ft = feet
   min = minutes
   mm = mimilimeters
   tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-2-13, SAMPLE S-2 @6.3ft

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FIG. B-18

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-3-13	Tested By/Date	AKV 1/9/2013
Sample	S-2	Calculated By/Date	JFL 2/4/2013
Depth, ft	6.3	Checked By/Date	JFL 2/26/2013

SAMPLE CLASSIFICATION:
Gray-brown, organic SILT; OL

SAMPLE DATA:

Specific Gravity (estimated)	2.7
Organic Content	2.8%
Liquid Limit	49
Plastic Limit	29
Plasticity Index	20

SPECIMEN DATA:

	Before Inundation	First Load	Final Load
Height, inches	0.787	0.787	0.559
Diameter, inches	2.815	2.815	2.815
Sample Volume, cuin	4.900	4.900	3.479
Wet Density, pcf	105.3	105.3	127.8
Dry Density, pcf	70.8	70.7	99.7
Water Content, %	49%	49%	28%
Void Ratio	1.38	1.38	0.69
Saturation, %	95%	95%	100%

Increment	Applied Stress, tsf	ΔH at t_{100}, in	ΔH / H_o	Void Ratio	t_{50}, min	Coeff. of Comp., MPa^{-1}	Coeff. of Consol., cm^2/sec	Coeff. of Perm., cm/sec
1	0.08	0.001	0.2%	1.378	1.0	0.62	2.51E-03	6.4E-08
2	0.15	0.008	1.0%	1.358	0.7	2.75	5.01E-03	5.7E-07
3	0.31	0.019	2.4%	1.326	1.2	2.18	2.12E-03	1.9E-07
4	0.61	0.033	4.2%	1.282	1.1	1.49	2.36E-03	1.5E-07
5	1.22	0.056	7.1%	1.214	0.6	1.16	3.28E-03	1.6E-07
6	2.44	0.088	11.2%	1.116	0.9	0.84	2.74E-03	1.0E-07
7	4.89	0.126	16.0%	1.002	0.6	0.49	3.51E-03	7.9E-08
8	9.77	0.169	21.4%	0.872	0.7	0.28	2.26E-03	3.1E-08
9	2.44	0.176	22.4%	0.849	0.0	-0.03	8.91E-03	1.5E-08
10	0.61	0.168	21.3%	0.875	1.2	0.15	1.47E-03	1.1E-08
11	0.15	0.159	20.2%	0.901	1.8	0.60	1.09E-03	3.4E-08
12	0.61	0.155	19.6%	0.914	0.7	-0.30	2.88E-03	4.5E-08
13	2.44	0.164	20.9%	0.885	0.4	0.17	5.32E-03	4.6E-08
14	9.77	0.180	22.9%	0.836	0.2	0.07	1.01E-02	3.6E-08
15	19.55	0.206	26.2%	0.759	0.4	0.08	3.68E-03	1.6E-08
16	29.32	0.227	28.8%	0.695	0.5	0.07	2.48E-03	9.5E-09
17	43.98	0.2454	31.18%	0.640	0.3	0.040	4.33E-03	9.9E-09
18	11.00	0.2531	32.15%	0.616	0.2	-0.007	7.39E-03	3.2E-09
19	2.75	0.2460	31.25%	0.638	0.7	0.027	1.84E-03	3.0E-09
20	0.69	0.2365	30.05%	0.666	2.8	0.145	5.28E-04	4.6E-09
21	0.17	0.2276	28.90%	0.694	3.3	0.552	3.83E-04	1.2E-08

NOTES:

1. Abbreviations:
   cm = centimeter
   cm^2 = square centimeter
   Coeff. = Coefficient
   Comp. = Compressibility
   Consol. = Consolidation
   cu in = cubic inch
   ft = feet
   H_o = initial height
   ΔH = change in height
   in = inch
   min = minute
   MPa = megapascal
   pcf = pounts per cubic foot
   Perm. = Permeability
   sec = second
   t_n = time at n% of primary consolidation
   tsf = tons per square foot

Smith Island Site Restoration
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ONE DIMENSIONAL CONSOLIDATION TEST SUMMARY
BORING B-3-13, SAMPLE S-2 @6.3ft

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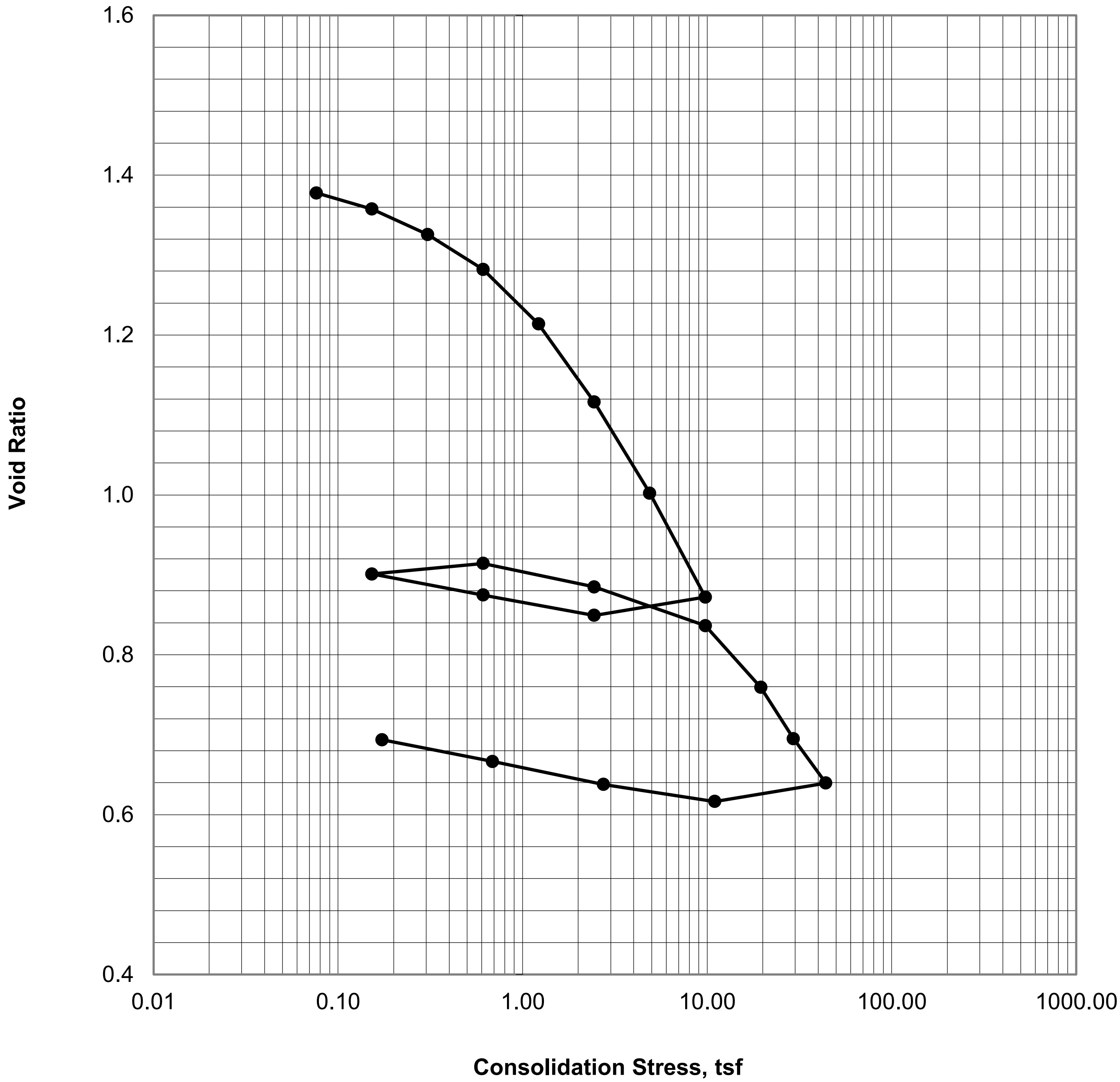
Geotechnical and Environmental Consultants

FIG. B-19

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-3-13	Tested By/Date	AKV 1/9/2013
Sample	S-2	Calculated By/Date	JFL 2/4/2013
Depth, ft	6.3	Checked By/Date	JFL 2/26/2013



Maximum Load, tsf 43.98

NOTES:
1. Abbreviations:
ft = feet
tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION VOID RATIO vs STRESS PLOT BORING B-3-13, SAMPLE S-2 @6.3ft

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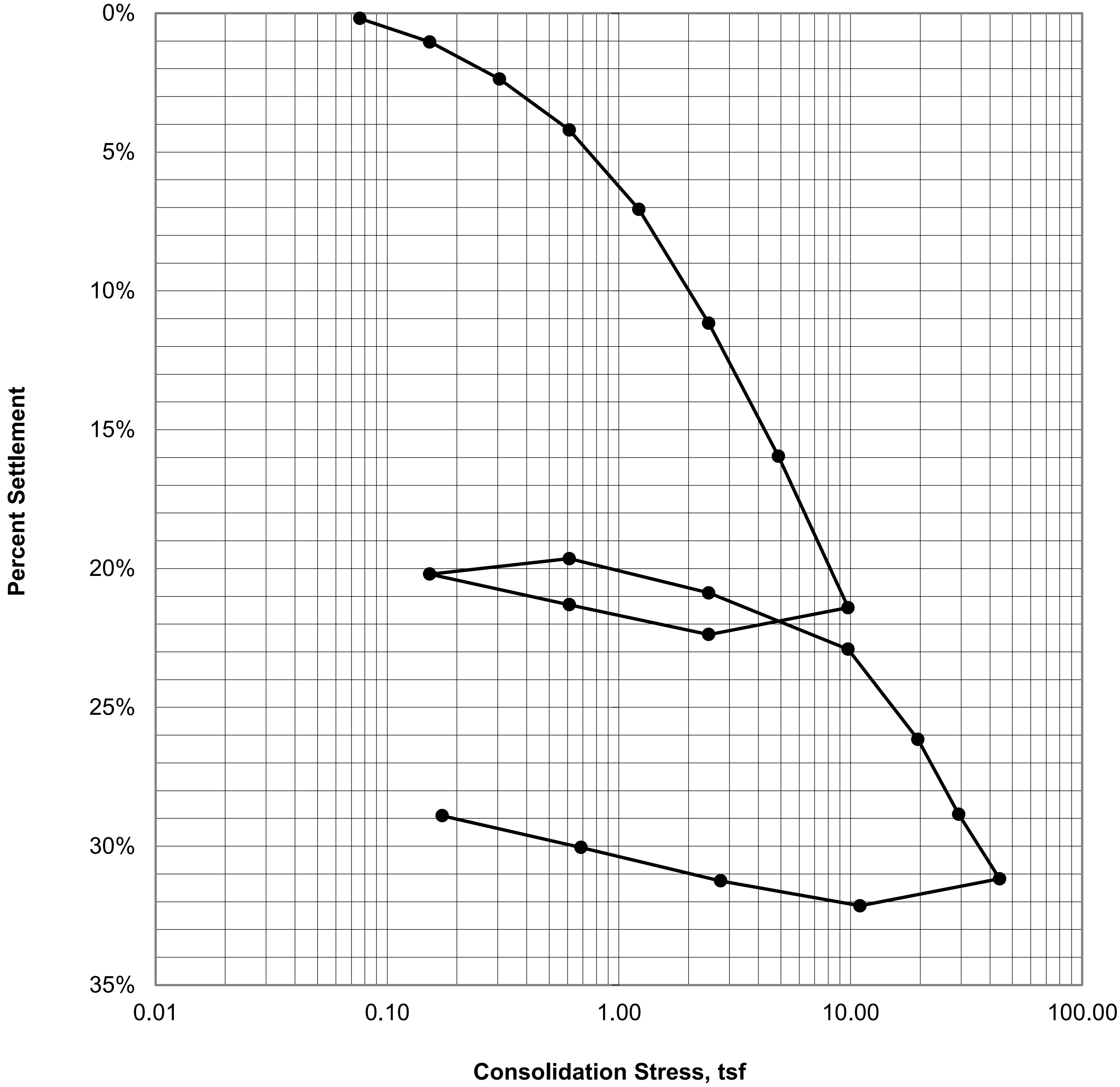
FIG. B-20

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-3-13	Tested By/Date	AKV 1/9/2013
Sample	S-2	Calculated By/Date	JFL 2/4/2013
Depth, ft	6.3	Checked By/Date	JFL 2/26/2013



Maximum Load, tsf 43.98

NOTES:
1. Abbreviations:
ft = feet
tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION PERCENT SETTLEMENT vs STRESS PLOT BORING B-3-13, SAMPLE S-2 @6.3ft

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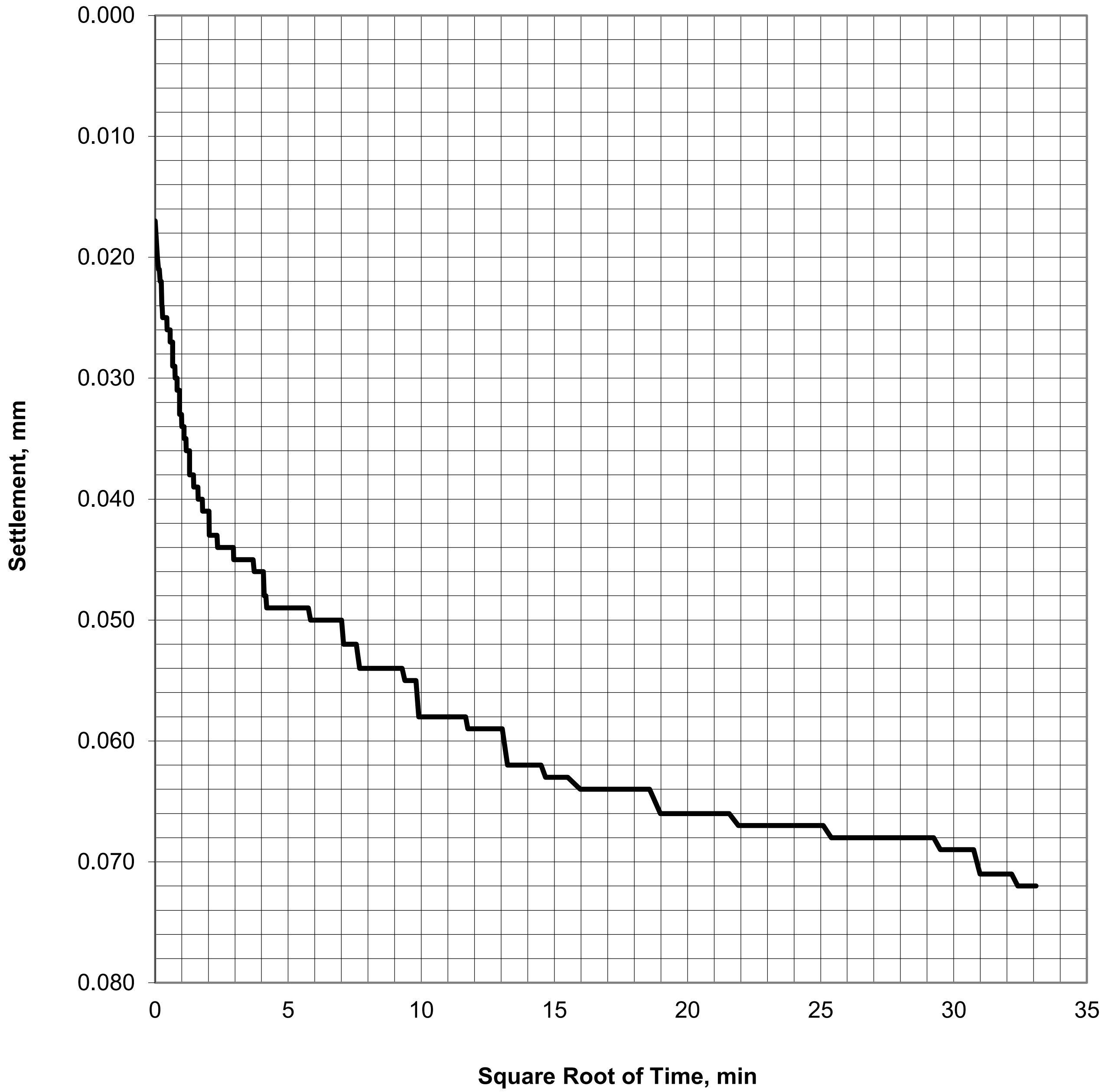
FIG. B-21

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-3-13	Tested By/Date	AKV 1/9/2013
Sample	S-2	Calculated By/Date	JFL 2/4/2013
Depth, ft	6.3	Checked By/Date	JFL 2/26/2013



Increment Number 1

Applied Stress, tsf 0.08

NOTES:
1. Abbreviations:
ft = feet
min = minutes
mm = mimilimeters
tsf = tons per square foot

Smith Island Site Restoration
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ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-3-13, SAMPLE S-2 @6.3ft

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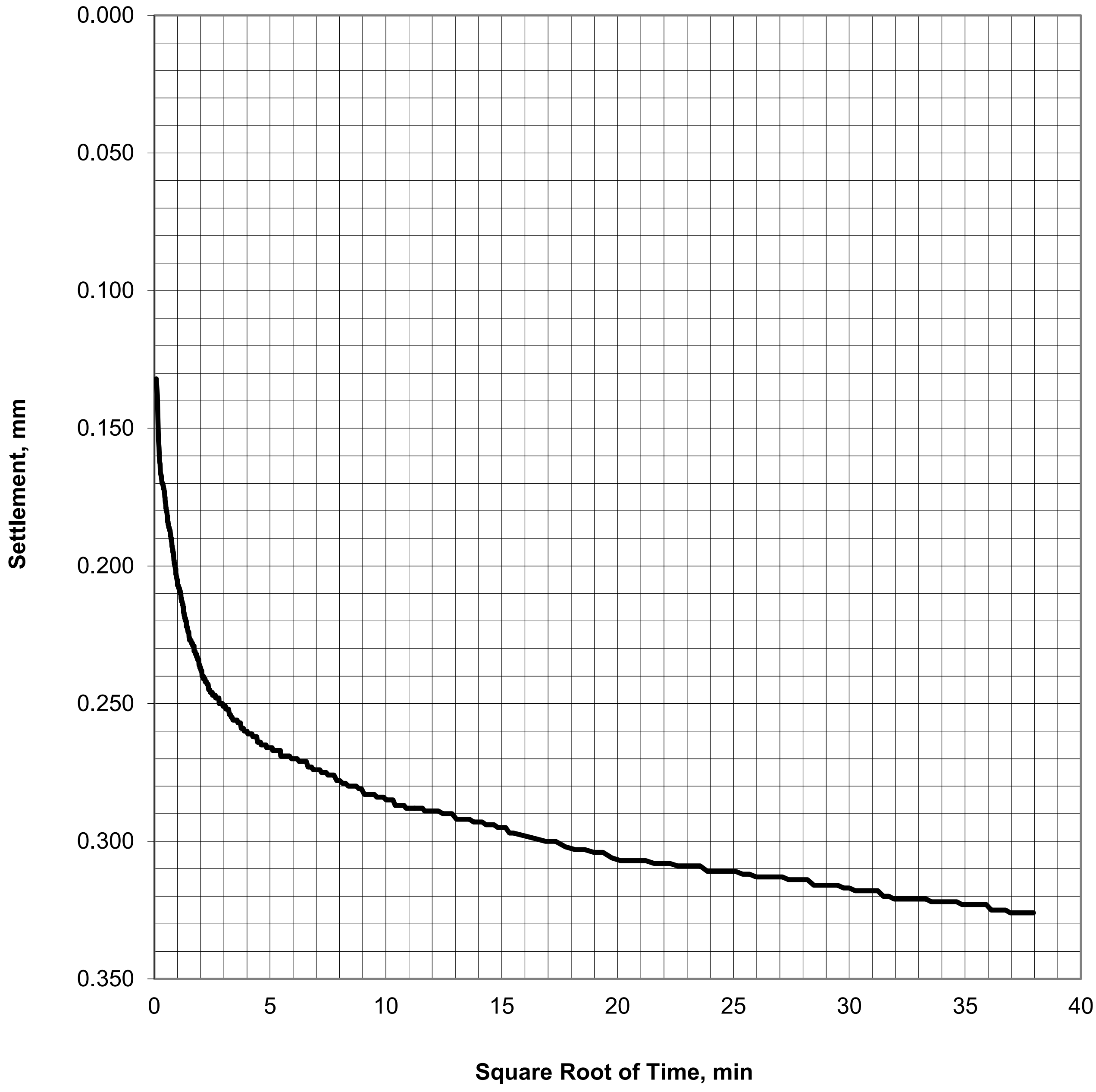
FIG. B-22
Sheet 1 of 21

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-3-13	Tested By/Date	AKV 1/9/2013
Sample	S-2	Calculated By/Date	JFL 2/4/2013
Depth, ft	6.3	Checked By/Date	JFL 2/26/2013



Increment Number 2

Applied Stress, tsf 0.15

NOTES:
1. Abbreviations:
ft = feet
min = minutes
mm = mimilimeters
tsf = tons per square foot

Smith Island Site Restoration
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ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-3-13, SAMPLE S-2 @6.3ft

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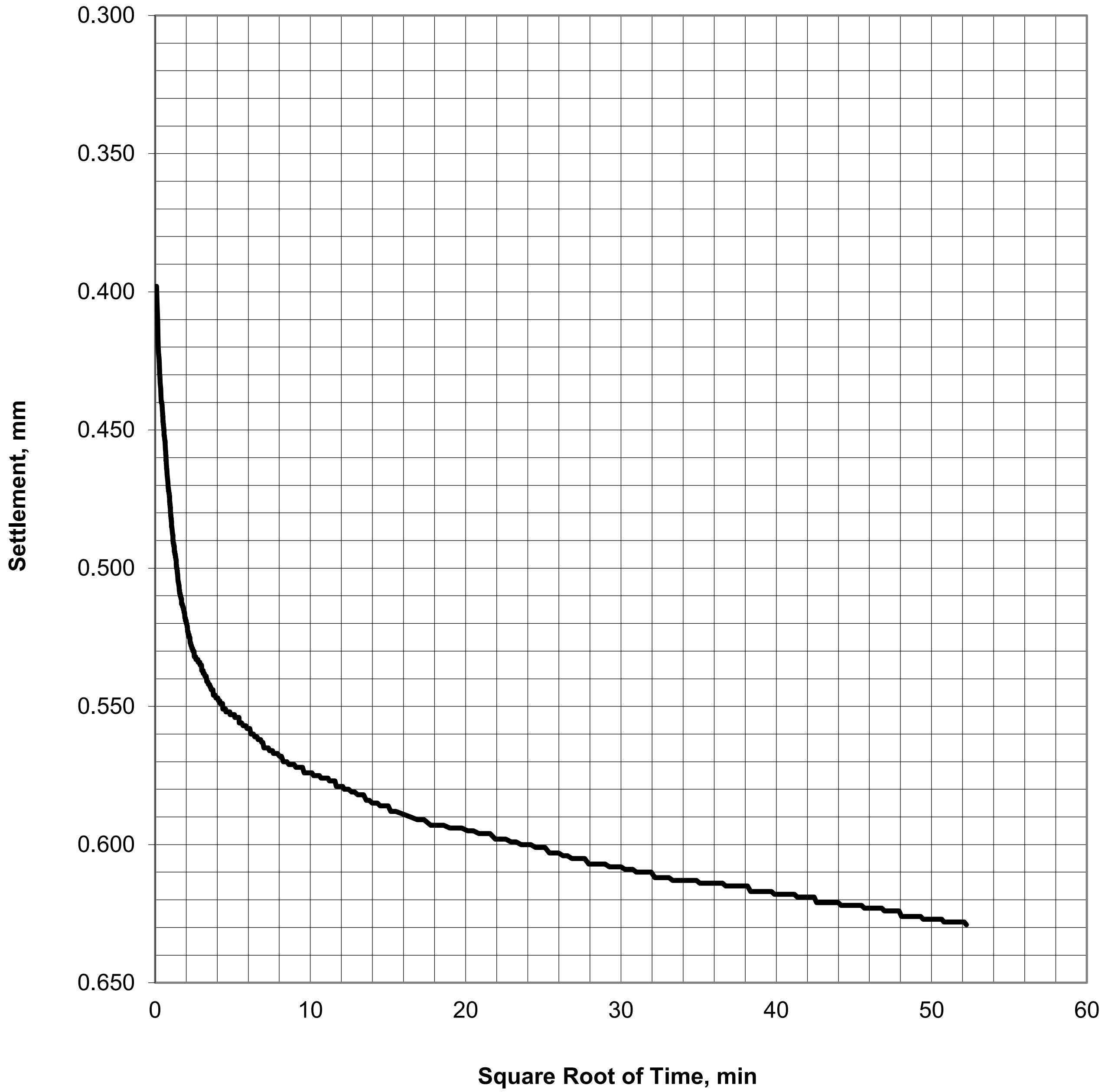
FIG. B-22
Sheet 2 of 21

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-3-13	Tested By/Date	AKV 1/9/2013
Sample	S-2	Calculated By/Date	JFL 2/4/2013
Depth, ft	6.3	Checked By/Date	JFL 2/26/2013



Increment Number 3

Applied Stress, tsf 0.31

NOTES:
1. Abbreviations:
   ft = feet
   min = minutes
   mm = mimilimeters
   tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-3-13, SAMPLE S-2 @6.3ft

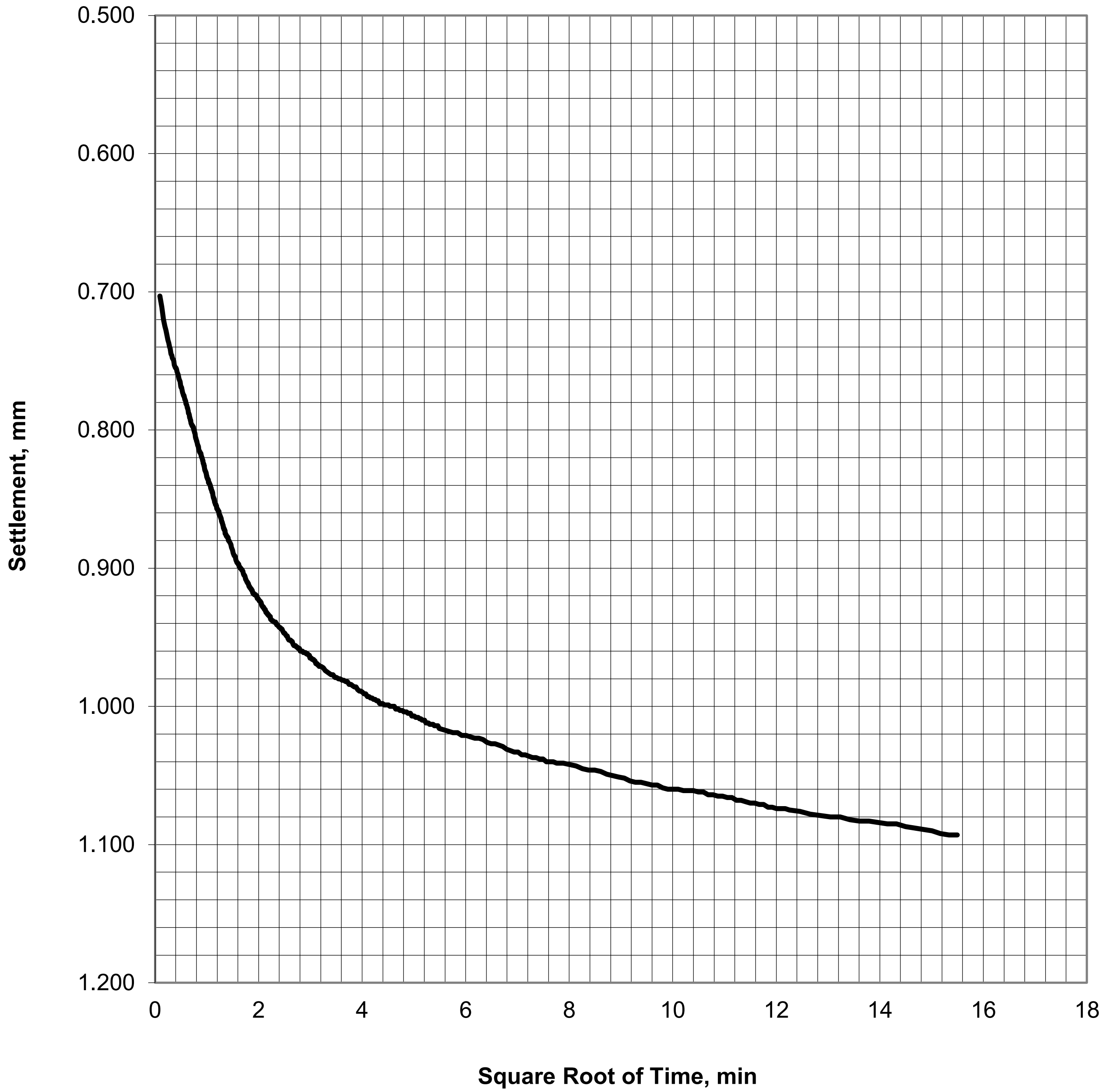
October 2013 21-1-12405-060

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B-22

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-3-13	Tested By/Date	AKV 1/9/2013
Sample	S-2	Calculated By/Date	JFL 2/4/2013
Depth, ft	6.3	Checked By/Date	JFL 2/26/2013



Increment Number 4

Applied Stress, tsf 0.61

NOTES:
1. Abbreviations:
   ft = feet
   min = minutes
   mm = mimilimeters
   tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-3-13, SAMPLE S-2 @6.3ft

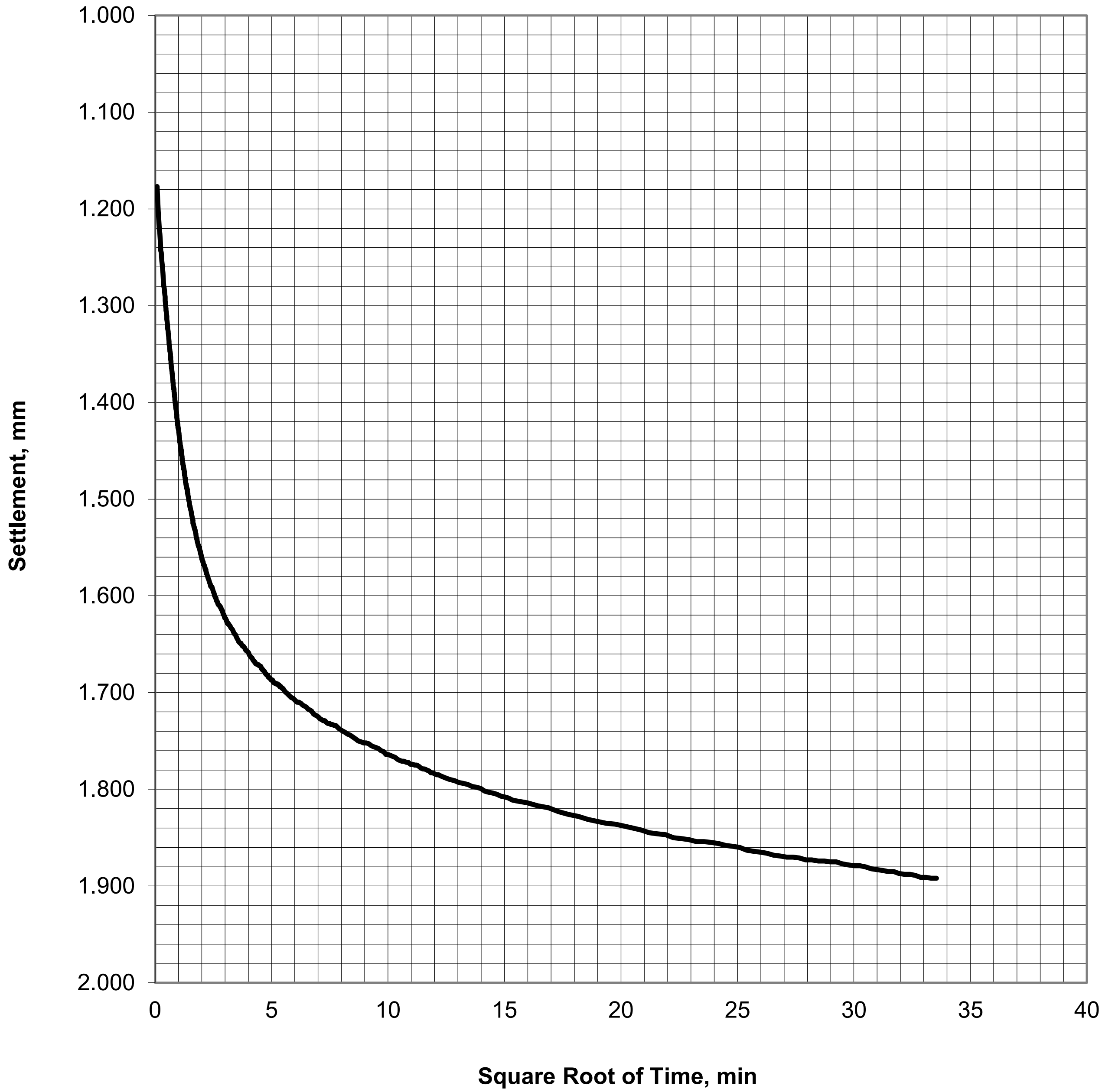
October 2013 21-1-12405-060

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B-22
Sheet 4 of 21

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-3-13	Tested By/Date	AKV 1/9/2013
Sample	S-2	Calculated By/Date	JFL 2/4/2013
Depth, ft	6.3	Checked By/Date	JFL 2/26/2013



Increment Number 5

Applied Stress, tsf 1.22

NOTES:
1. Abbreviations:
ft = feet
min = minutes
mm = mimilimeters
tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-3-13, SAMPLE S-2 @6.3ft

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SHANNON & WILSON, INC.
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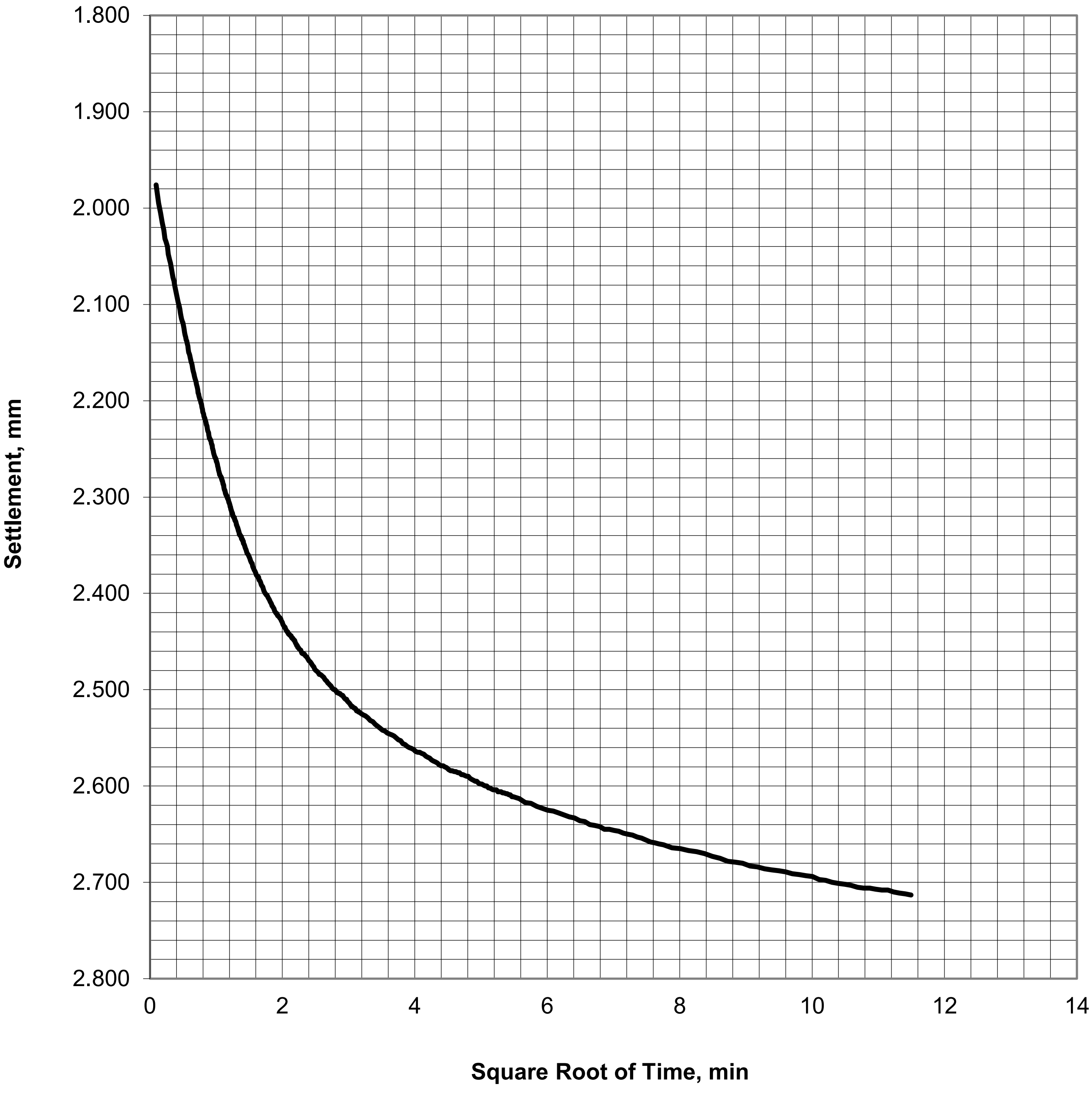
FIG. B-22

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-3-13	Tested By/Date	AKV 1/9/2013
Sample	S-2	Calculated By/Date	JFL 2/4/2013
Depth, ft	6.3	Checked By/Date	JFL 2/26/2013



Increment Number 6

Applied Stress, tsf 2.44

NOTES:
1. Abbreviations:
   ft = feet
   min = minutes
   mm = mimilimeters
   tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-3-13, SAMPLE S-2 @6.3ft

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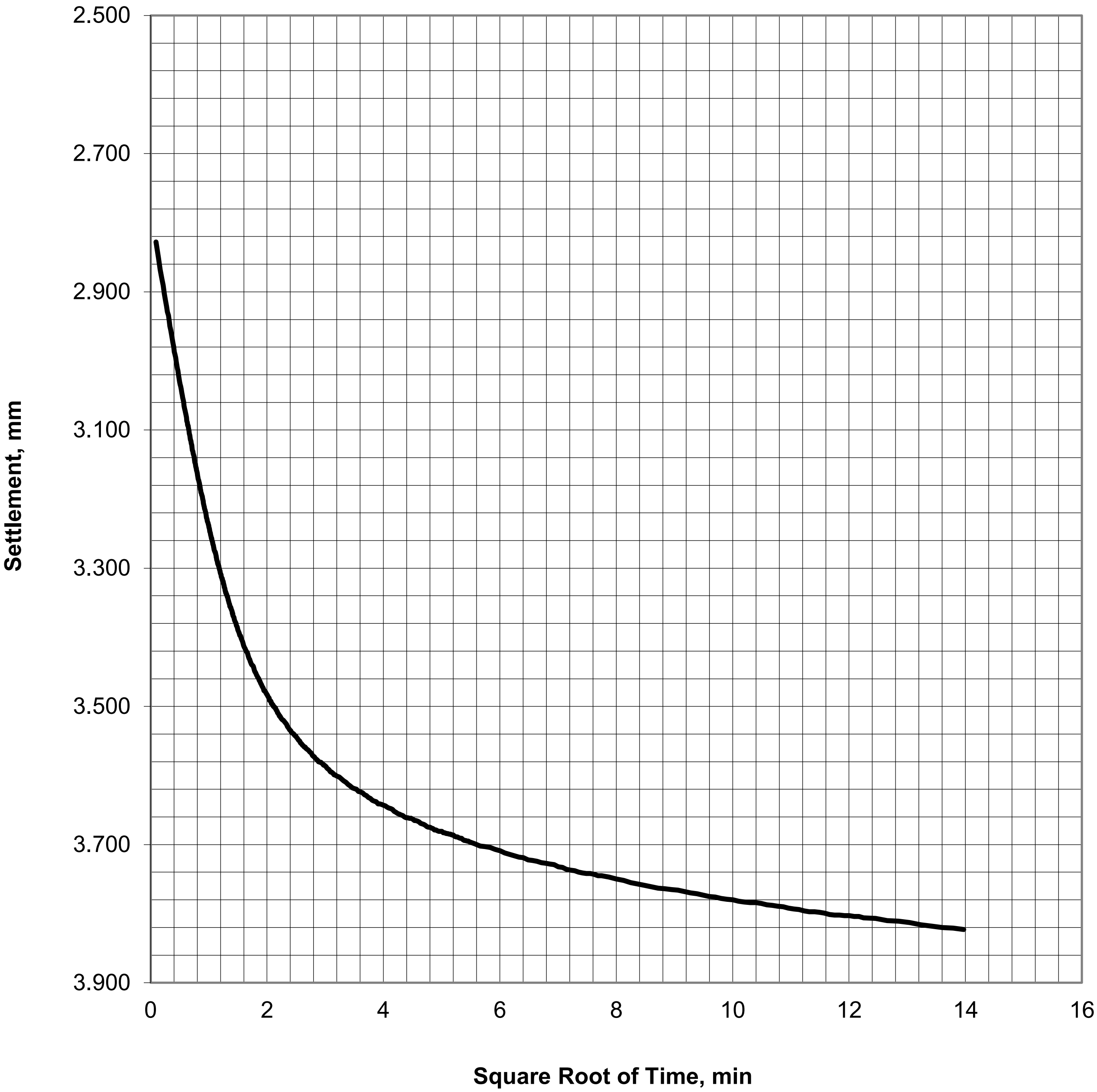
SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B-22

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-3-13	Tested By/Date	AKV 1/9/2013
Sample	S-2	Calculated By/Date	JFL 2/4/2013
Depth, ft	6.3	Checked By/Date	JFL 2/26/2013



Increment Number 7

Applied Stress, tsf 4.89

NOTES:
1. Abbreviations:
   ft = feet
   min = minutes
   mm = mimilimeters
   tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-3-13, SAMPLE S-2 @6.3ft

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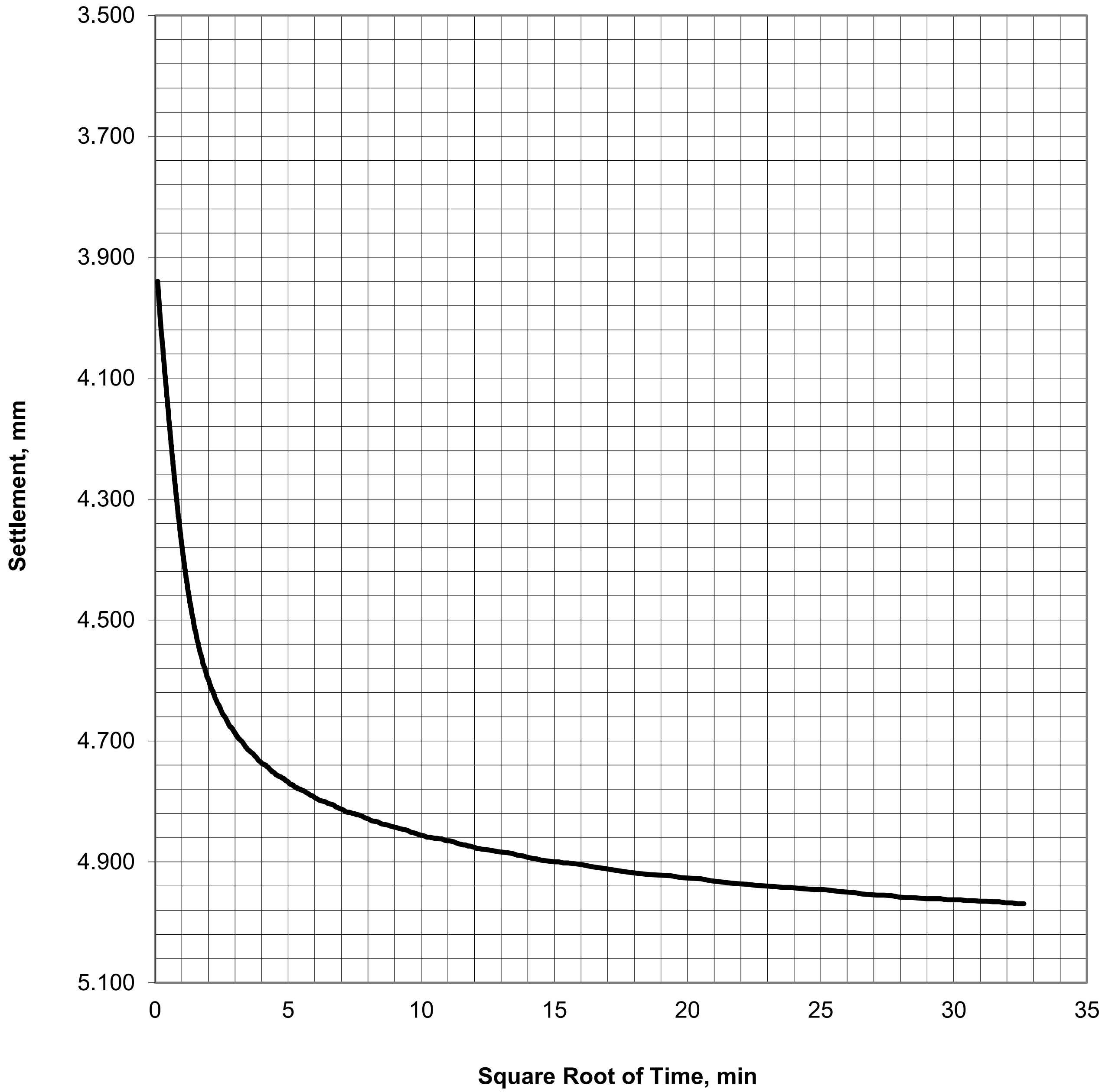
SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B-22

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-3-13	Tested By/Date	AKV 1/9/2013
Sample	S-2	Calculated By/Date	JFL 2/4/2013
Depth, ft	6.3	Checked By/Date	JFL 2/26/2013



Increment Number 8

Applied Stress, tsf 9.77

NOTES:
1. Abbreviations:
   ft = feet
   min = minutes
   mm = mimilimeters
   tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-3-13, SAMPLE S-2 @6.3ft

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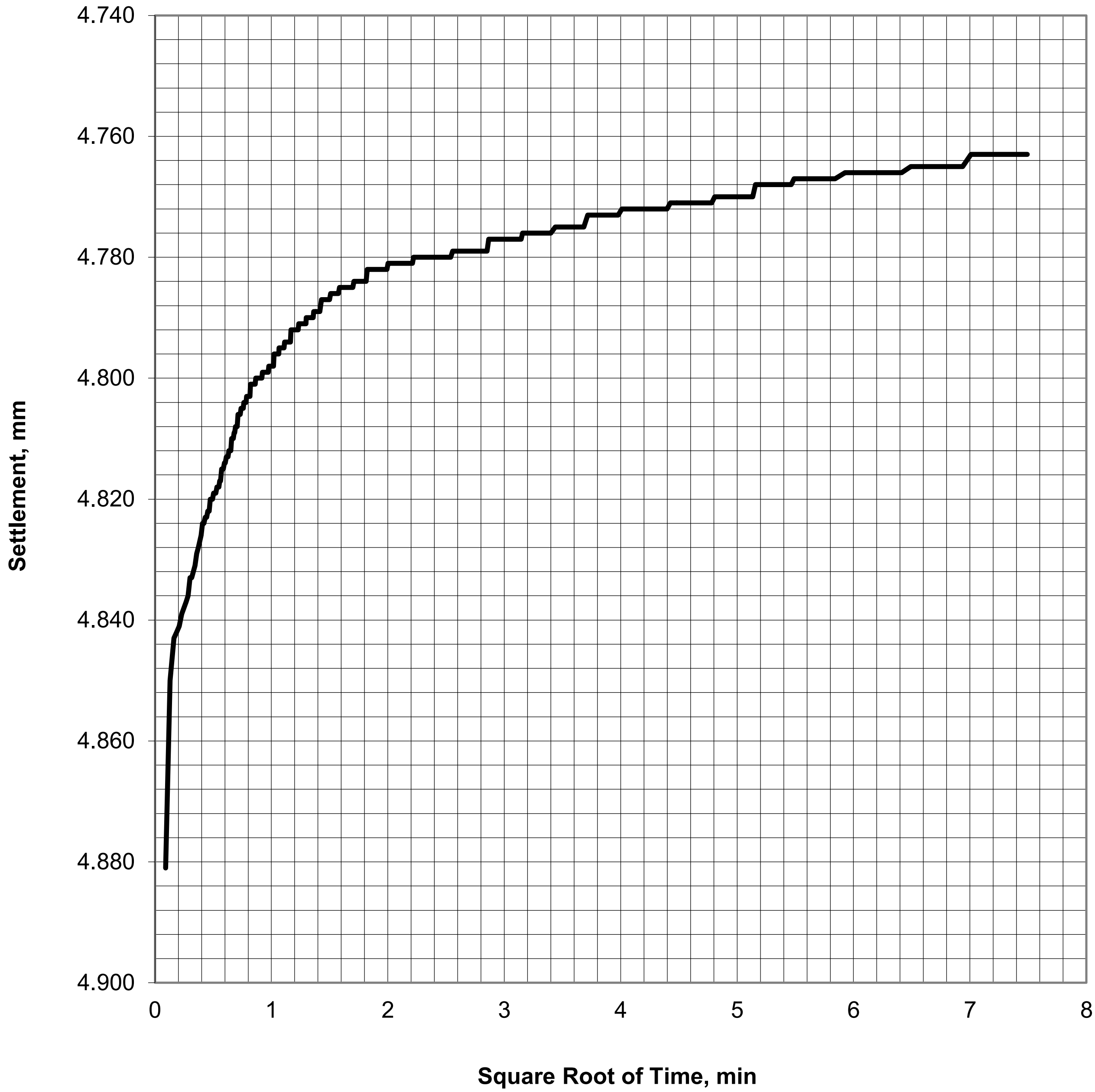
SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B-22

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-3-13	Tested By/Date	AKV 1/9/2013
Sample	S-2	Calculated By/Date	JFL 2/4/2013
Depth, ft	6.3	Checked By/Date	JFL 2/26/2013



Increment Number 9

Applied Stress, tsf 2.44

NOTES:
1. Abbreviations:
   ft = feet
   min = minutes
   mm = mimilimeters
   tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-3-13, SAMPLE S-2 @6.3ft

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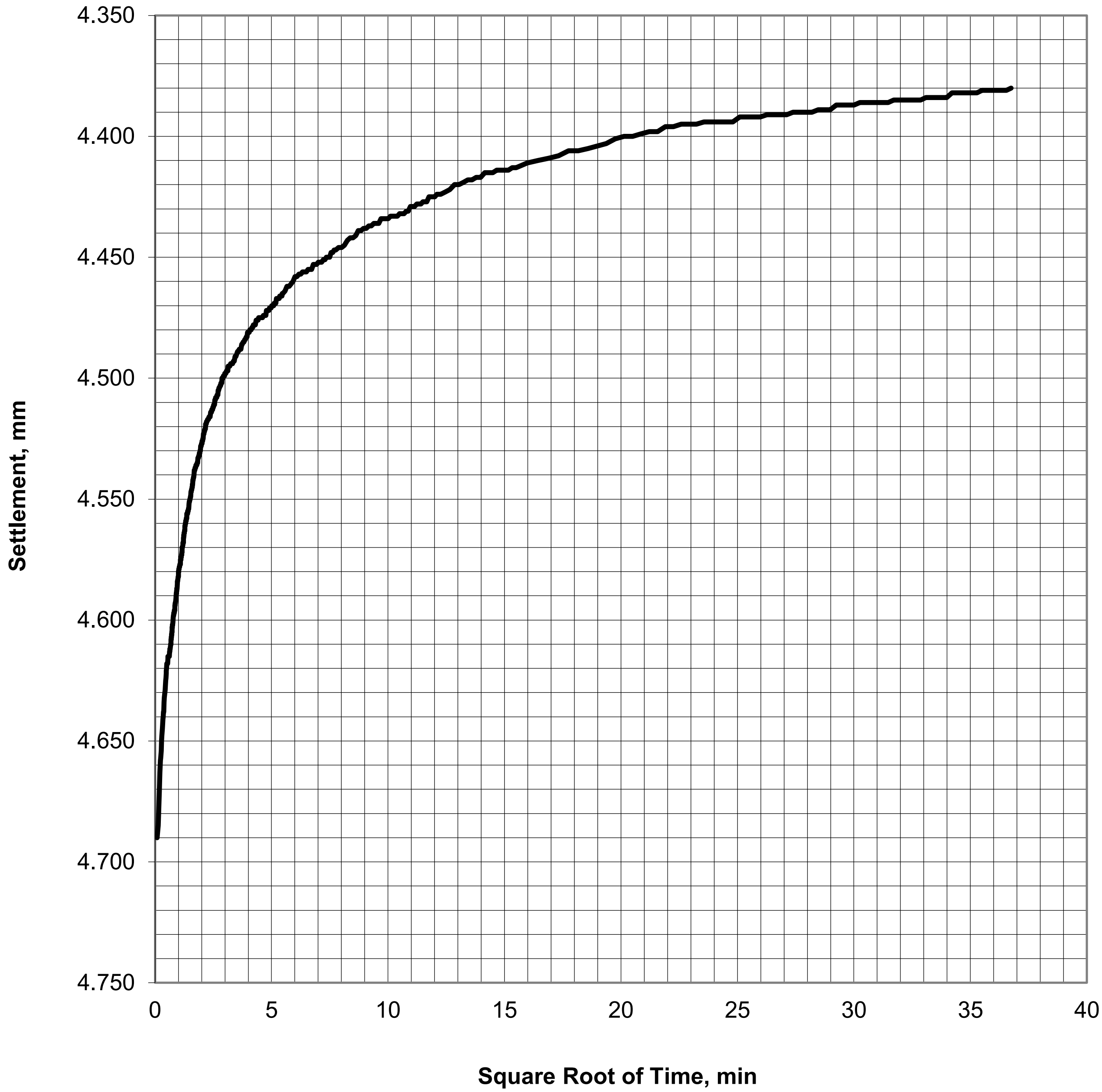
SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B-22

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-3-13	Tested By/Date	AKV 1/9/2013
Sample	S-2	Calculated By/Date	JFL 2/4/2013
Depth, ft	6.3	Checked By/Date	JFL 2/26/2013



Increment Number 10

Applied Stress, tsf 0.61

NOTES:
1. Abbreviations:
ft = feet
min = minutes
mm = mimilimeters
tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-3-13, SAMPLE S-2 @6.3ft

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SHANNON & WILSON, INC.
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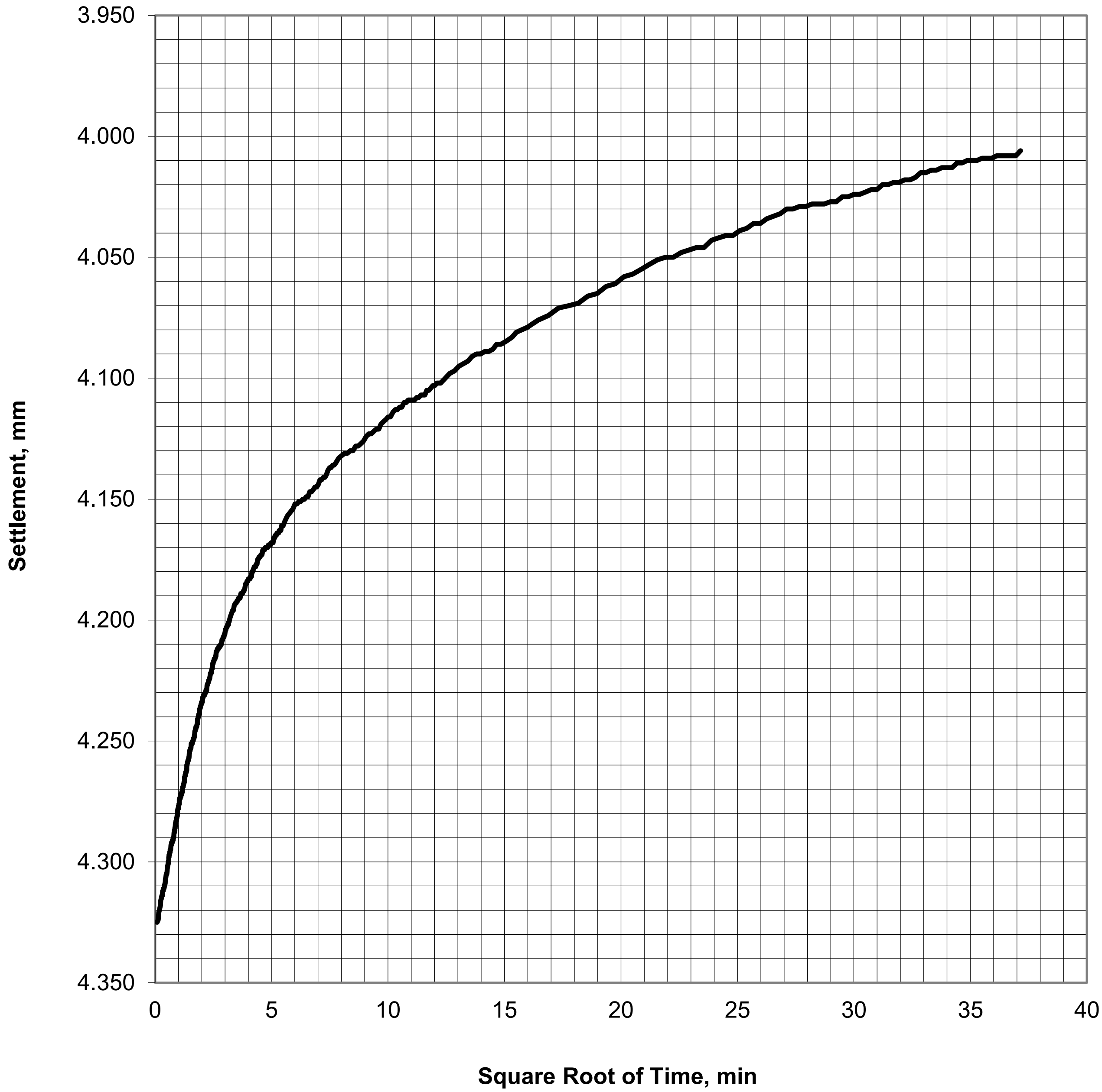
FIG. B-22

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-3-13	Tested By/Date	AKV 1/9/2013
Sample	S-2	Calculated By/Date	JFL 2/4/2013
Depth, ft	6.3	Checked By/Date	JFL 2/26/2013



Increment Number 11

Applied Stress, tsf 0.15

NOTES:
1. Abbreviations:
   ft = feet
   min = minutes
   mm = mimilimeters
   tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-3-13, SAMPLE S-2 @6.3ft

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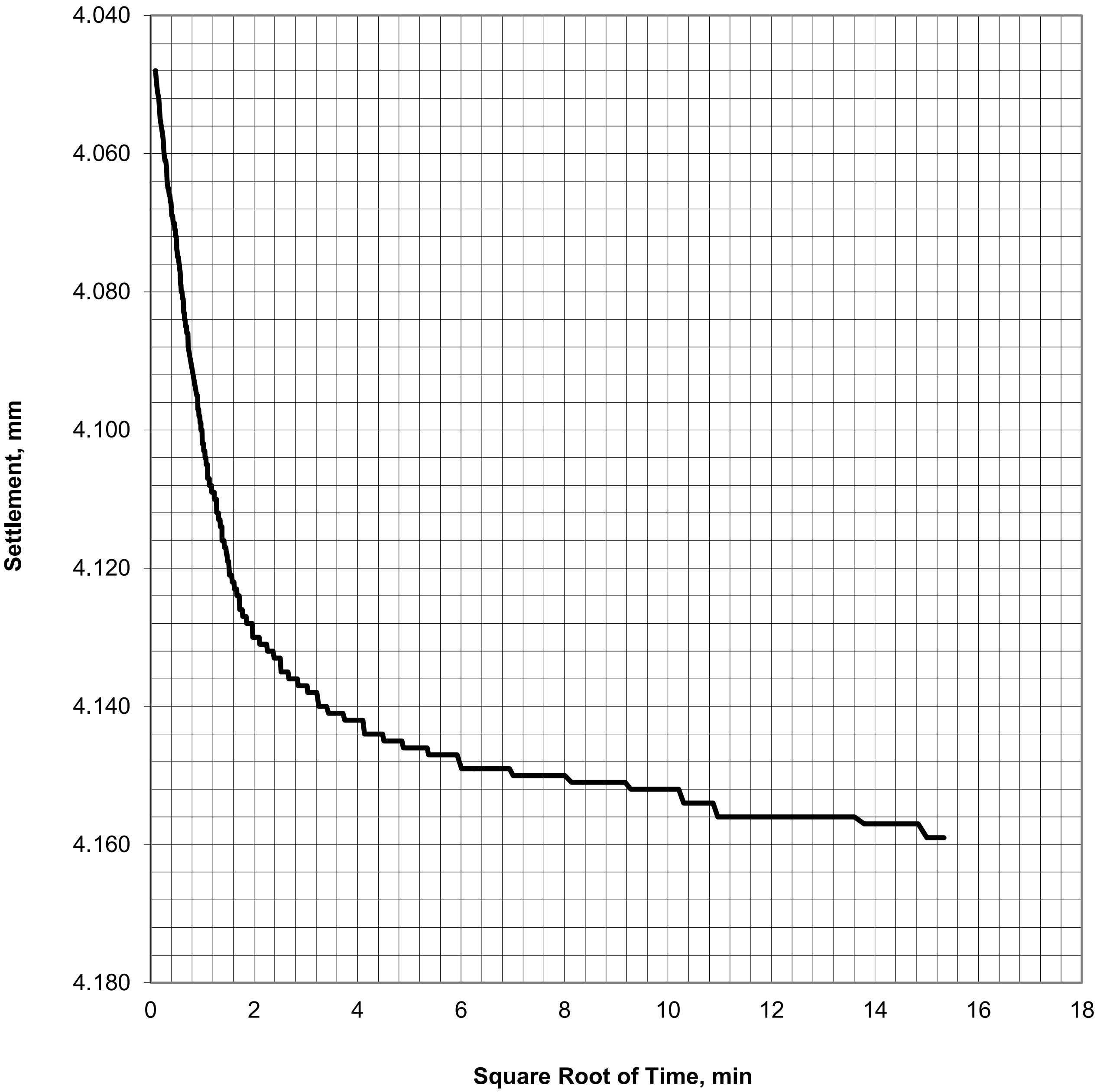
SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B-22

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-3-13	Tested By/Date	AKV 1/9/2013
Sample	S-2	Calculated By/Date	JFL 2/4/2013
Depth, ft	6.3	Checked By/Date	JFL 2/26/2013



Increment Number 12

Applied Stress, tsf 0.61

NOTES:
1. Abbreviations:
   ft = feet
   min = minutes
   mm = mimilimeters
   tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-3-13, SAMPLE S-2 @6.3ft

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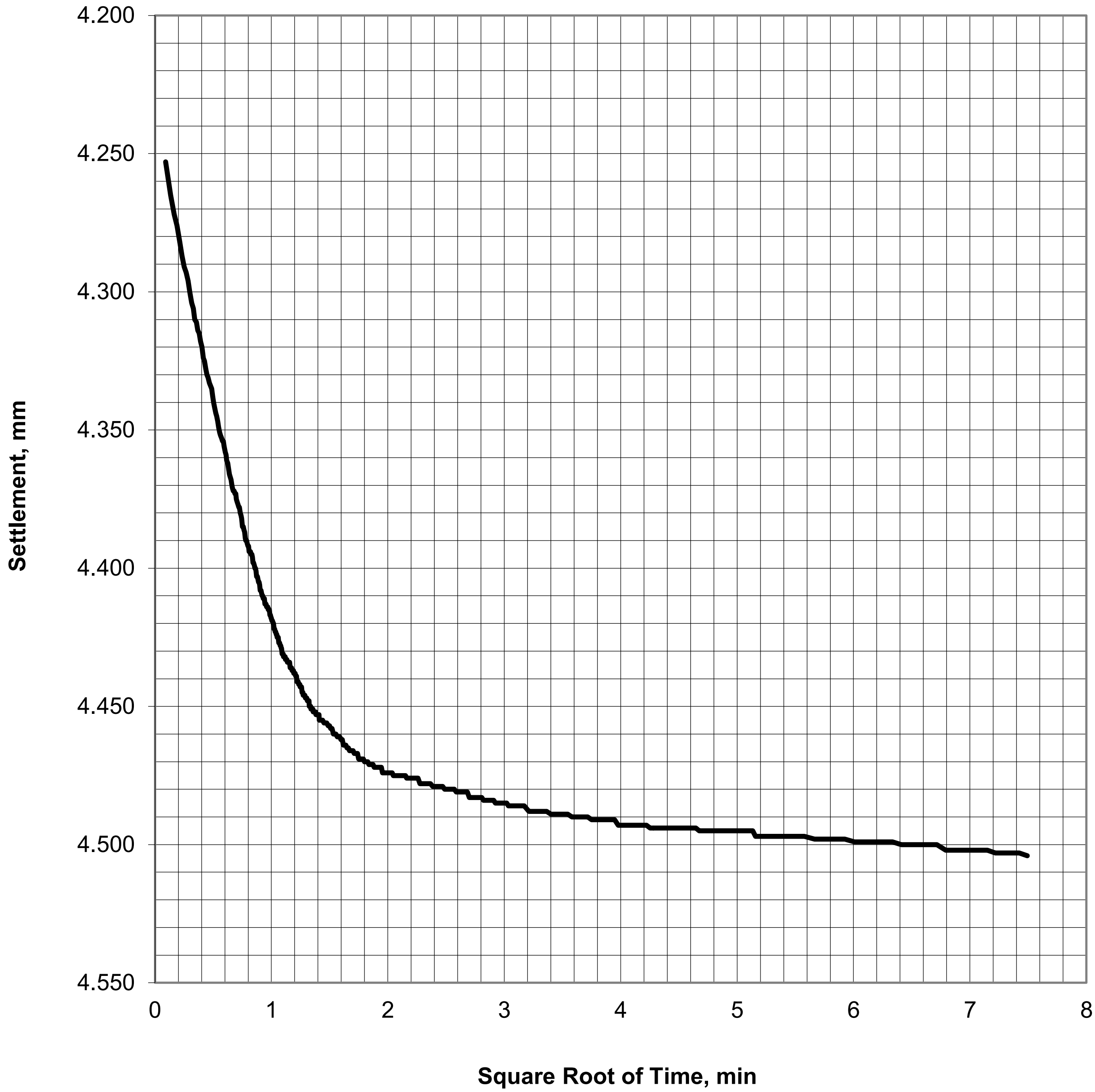
SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B-22

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-3-13	Tested By/Date	AKV 1/9/2013
Sample	S-2	Calculated By/Date	JFL 2/4/2013
Depth, ft	6.3	Checked By/Date	JFL 2/26/2013



Increment Number 13

Applied Stress, tsf 2.44

NOTES:
1. Abbreviations:
   ft = feet
   min = minutes
   mm = mimilimeters
   tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-3-13, SAMPLE S-2 @6.3ft

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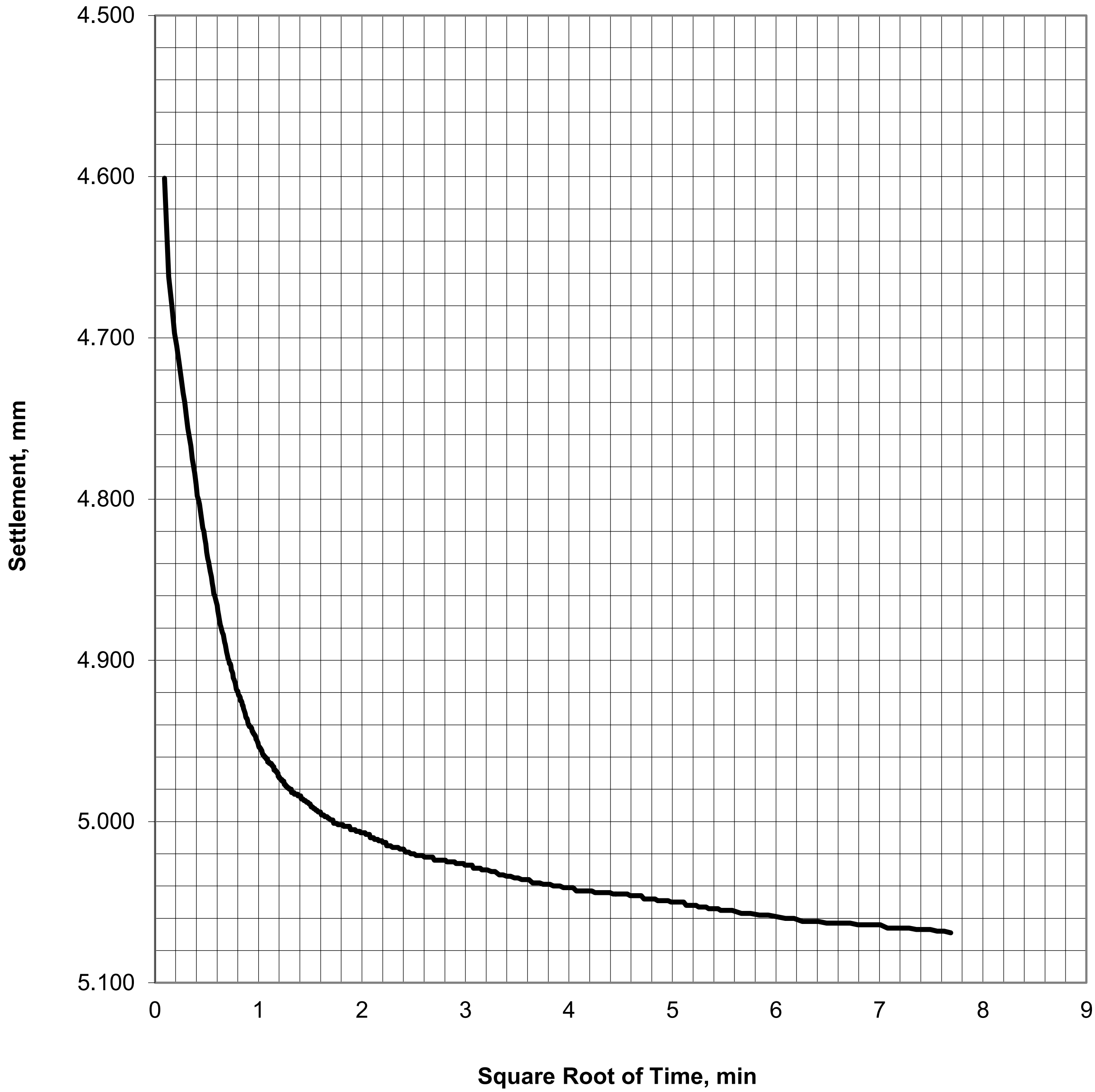
FIG. B-22
Sheet 13 of 21

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-3-13	Tested By/Date	AKV 1/9/2013
Sample	S-2	Calculated By/Date	JFL 2/4/2013
Depth, ft	6.3	Checked By/Date	JFL 2/26/2013



Increment Number 14

Applied Stress, tsf 9.77

NOTES:
1. Abbreviations:
ft = feet
min = minutes
mm = mimilimeters
tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-3-13, SAMPLE S-2 @6.3ft

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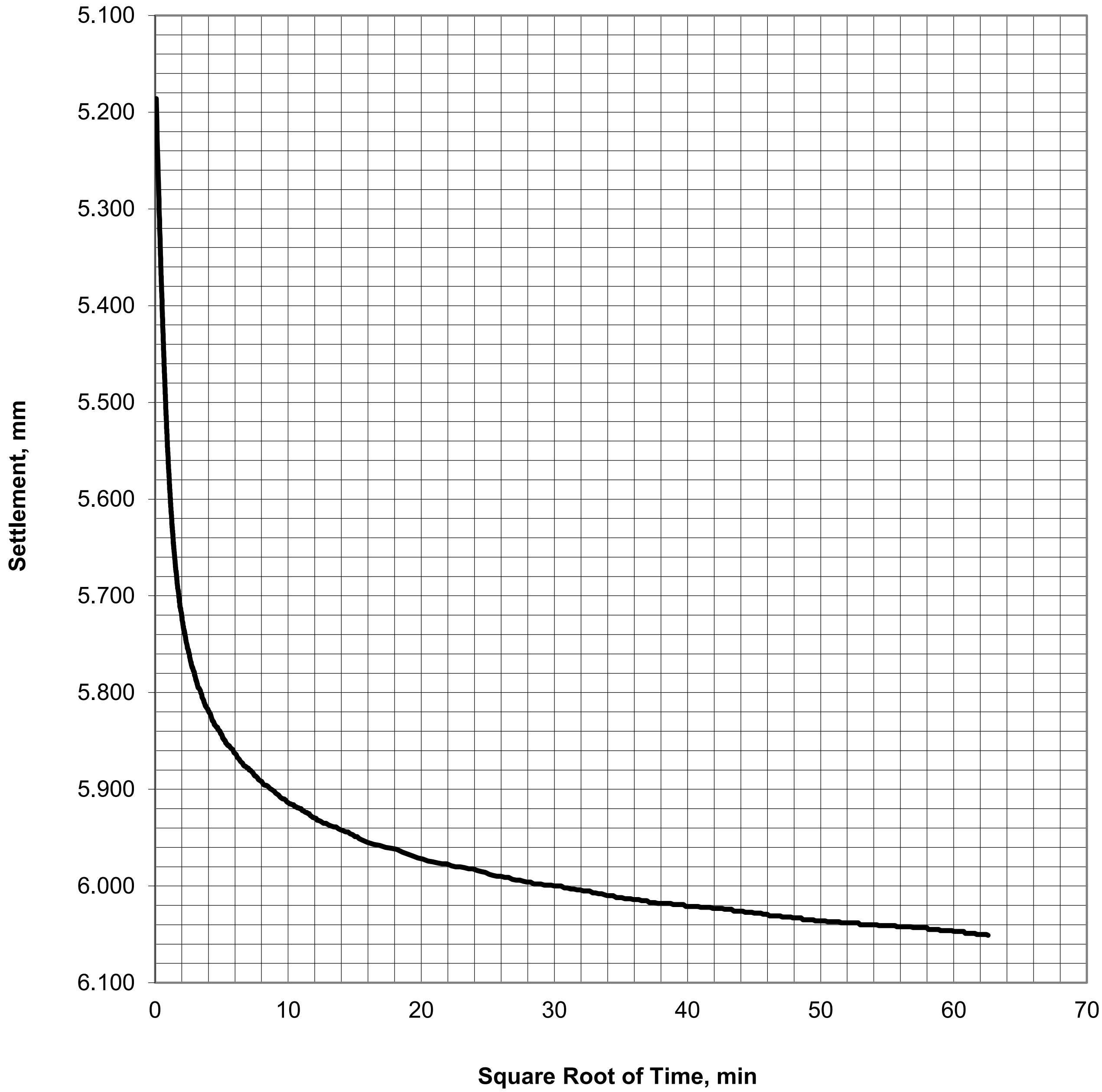
FIG. B-22

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-3-13	Tested By/Date	AKV 1/9/2013
Sample	S-2	Calculated By/Date	JFL 2/4/2013
Depth, ft	6.3	Checked By/Date	JFL 2/26/2013



Increment Number 15

Applied Stress, tsf 19.55

NOTES:

1. Abbreviations:
   ft = feet
   min = minutes
   mm = mimilimeters
   tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-3-13, SAMPLE S-2 @6.3ft

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SHANNON & WILSON, INC.
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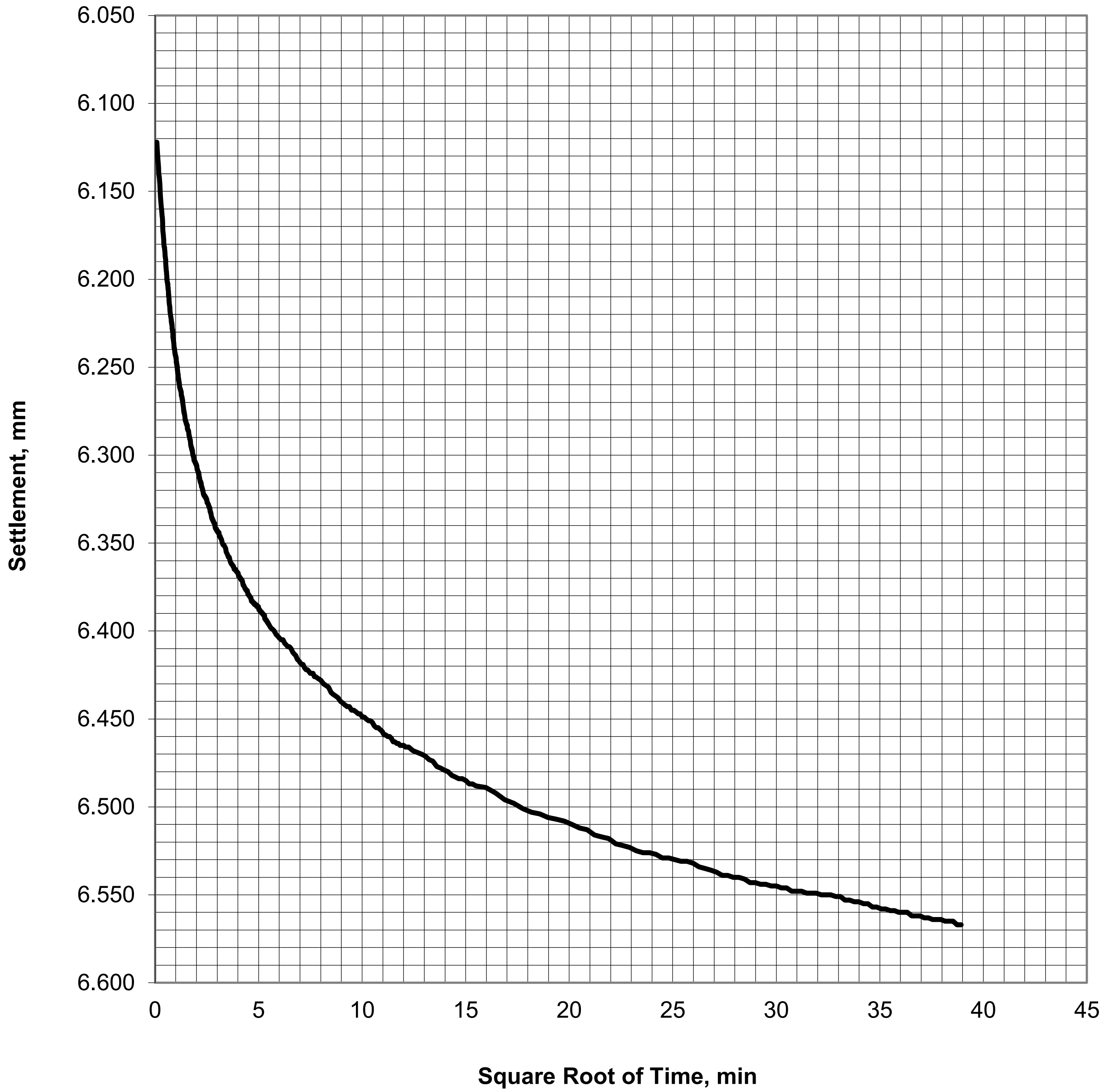
FIG. B-22

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-3-13	Tested By/Date	AKV 1/9/2013
Sample	S-2	Calculated By/Date	JFL 2/4/2013
Depth, ft	6.3	Checked By/Date	JFL 2/26/2013



Increment Number 16

Applied Stress, tsf 29.32

NOTES:
1. Abbreviations:
ft = feet
min = minutes
mm = mimilimeters
tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-3-13, SAMPLE S-2 @6.3ft

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SHANNON & WILSON, INC.
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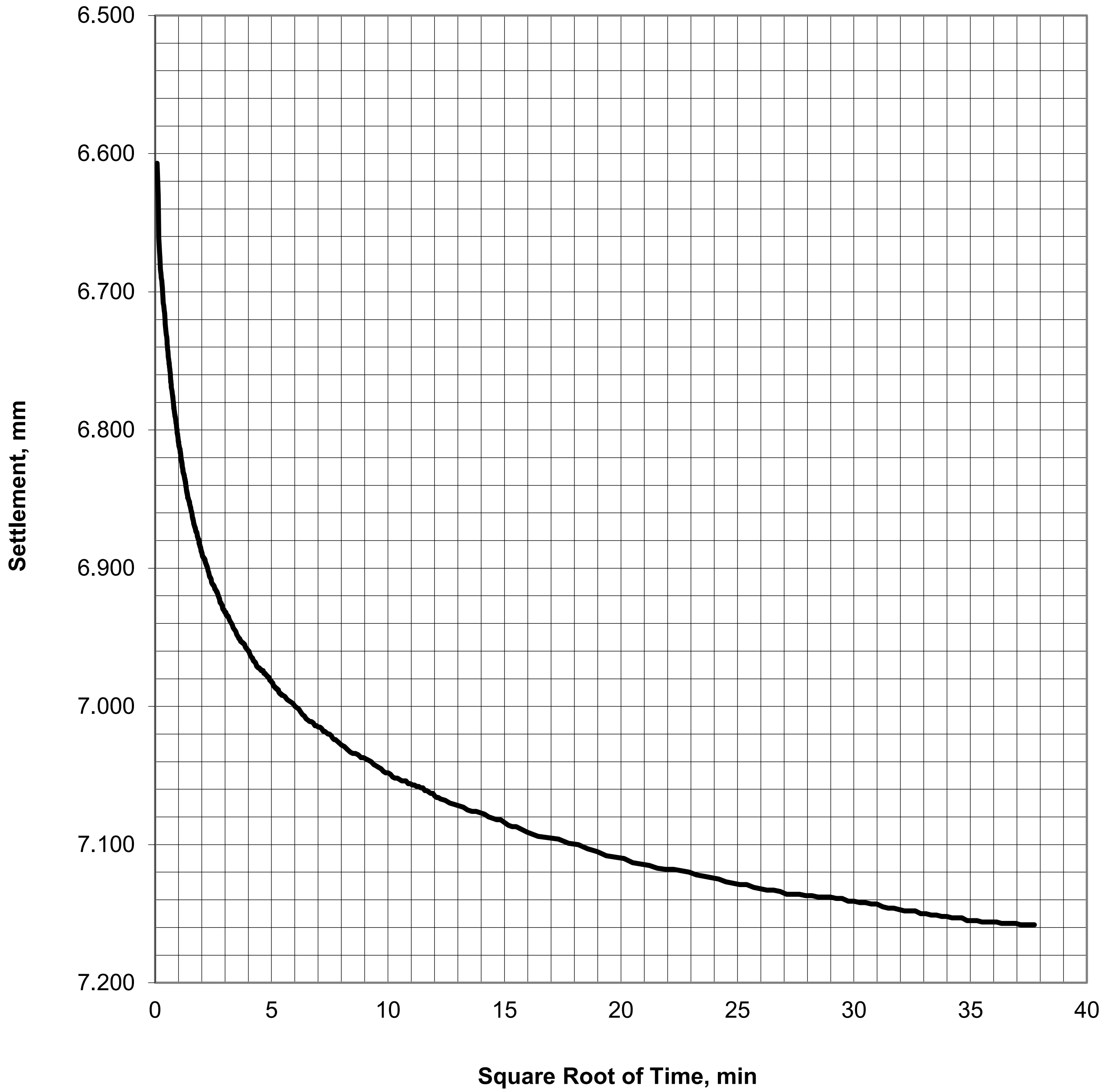
FIG. B-22

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-3-13	Tested By/Date	AKV 1/9/2013
Sample	S-2	Calculated By/Date	JFL 2/4/2013
Depth, ft	6.3	Checked By/Date	JFL 2/26/2013



Increment Number 17

Applied Stress, tsf 43.98

NOTES:
1. Abbreviations:
ft = feet
min = minutes
mm = mimilimeters
tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-3-13, SAMPLE S-2 @6.3ft

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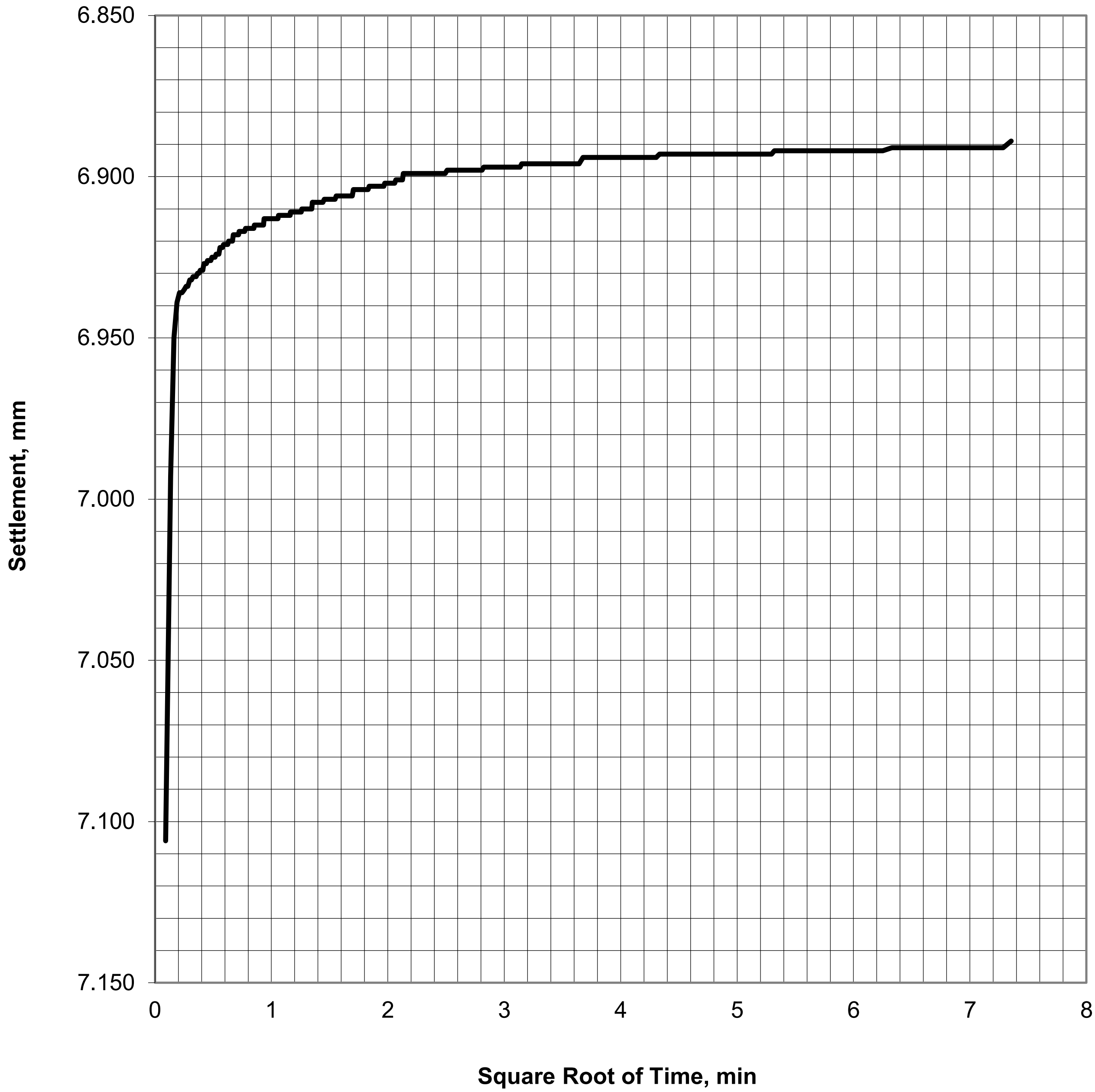
FIG. B-22

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-3-13	Tested By/Date	AKV 1/9/2013
Sample	S-2	Calculated By/Date	JFL 2/4/2013
Depth, ft	6.3	Checked By/Date	JFL 2/26/2013



Increment Number 18

Applied Stress, tsf 11.00

NOTES:
1. Abbreviations:
   ft = feet
   min = minutes
   mm = mimilimeters
   tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-3-13, SAMPLE S-2 @6.3ft

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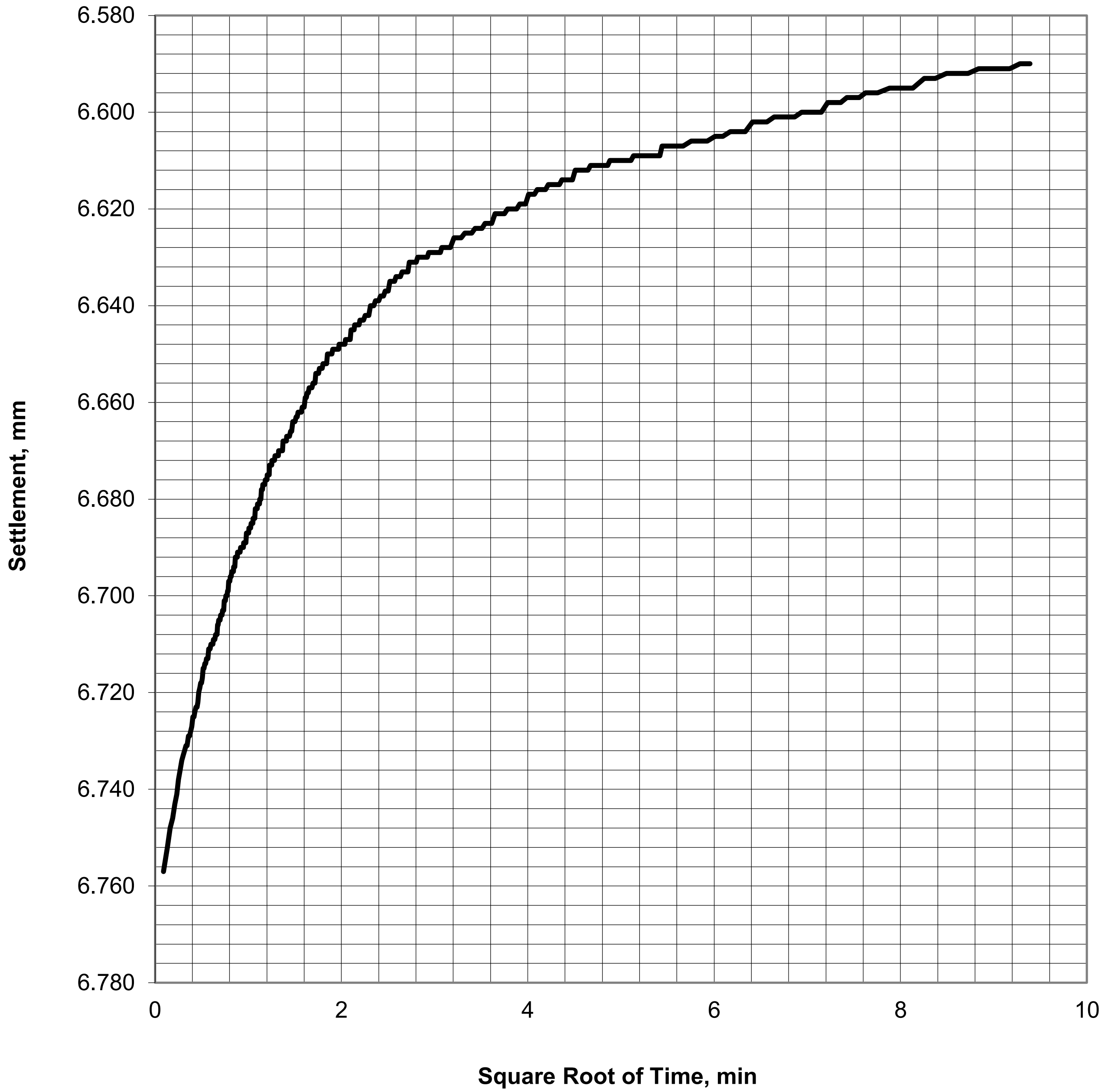
SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B-22

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-3-13	Tested By/Date	AKV 1/9/2013
Sample	S-2	Calculated By/Date	JFL 2/4/2013
Depth, ft	6.3	Checked By/Date	JFL 2/26/2013



Increment Number 19

Applied Stress, tsf 2.75

NOTES:
1. Abbreviations:
   - ft = feet
   - min = minutes
   - mm = mimilimeters
   - tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-3-13, SAMPLE S-2 @6.3ft

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SHANNON & WILSON, INC.
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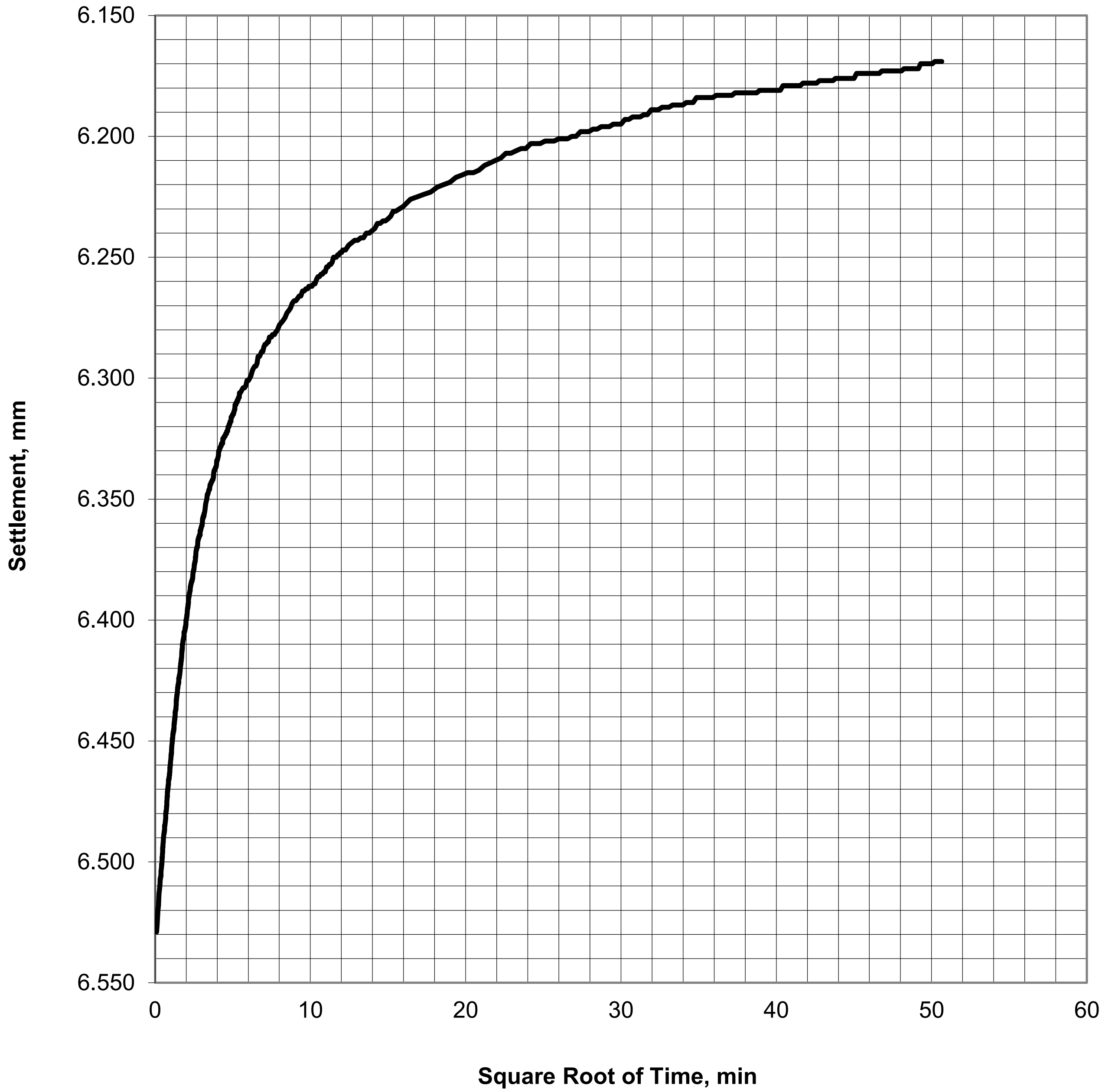
FIG. B-22

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-3-13	Tested By/Date	AKV 1/9/2013
Sample	S-2	Calculated By/Date	JFL 2/4/2013
Depth, ft	6.3	Checked By/Date	JFL 2/26/2013



Increment Number 20

Applied Stress, tsf 0.69

NOTES:
1. Abbreviations:
ft = feet
min = minutes
mm = mimilimeters
tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-3-13, SAMPLE S-2 @6.3ft

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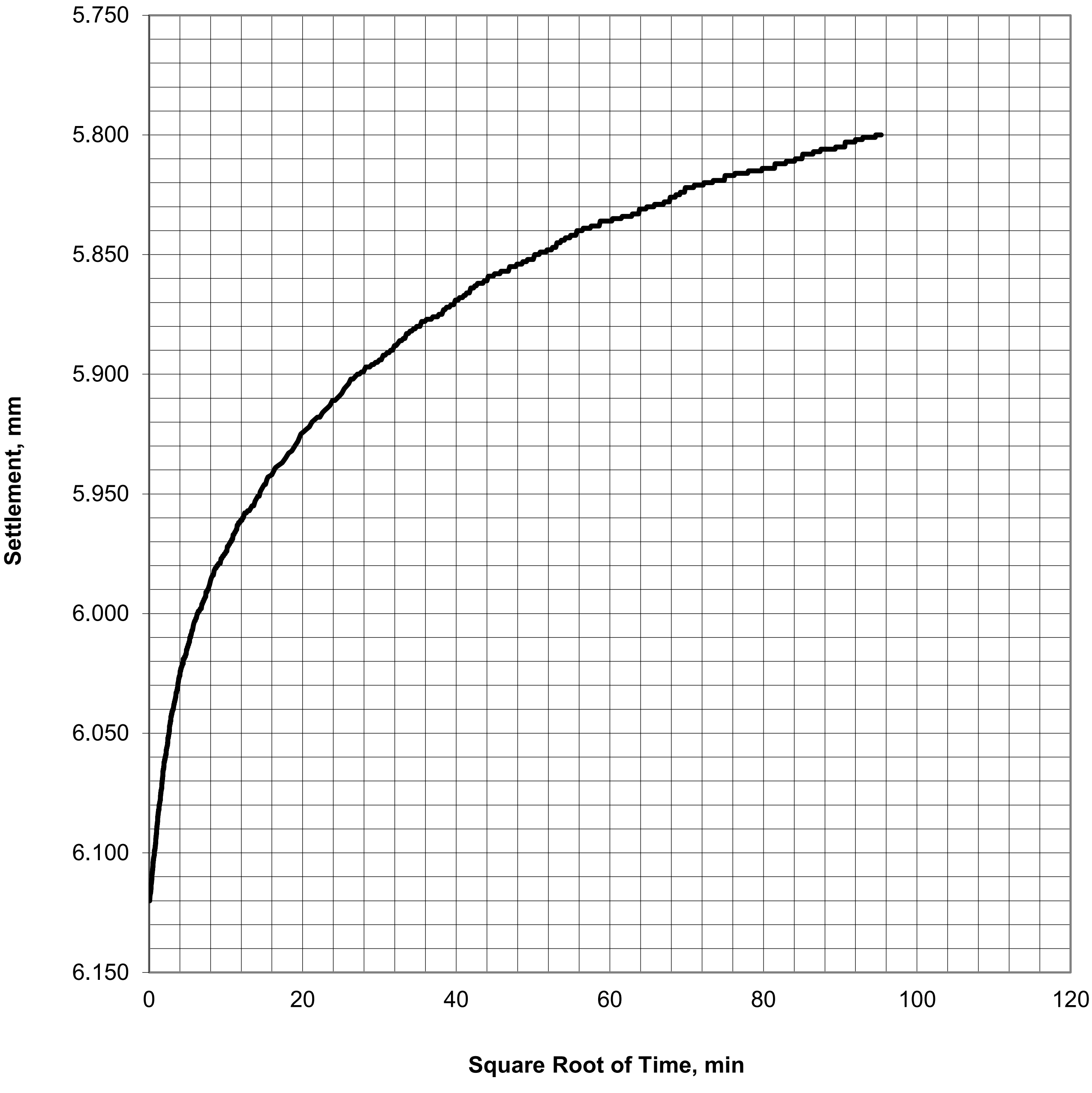
FIG. B-22
Sheet 20 of 21

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-3-13	Tested By/Date	AKV 1/9/2013
Sample	S-2	Calculated By/Date	JFL 2/4/2013
Depth, ft	6.3	Checked By/Date	JFL 2/26/2013



Increment Number 21

Applied Stress, tsf 0.17

NOTES:
1. Abbreviations:
ft = feet
min = minutes
mm = mimilimeters
tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-3-13, SAMPLE S-2 @6.3ft

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FIG. B-22
Sheet 21 of 21

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-4-12	Tested By/Date	AKV 1/25/2013
Sample	S-2	Calculated By/Date	JFL 2/27/2013
Depth, ft	5.4	Checked By/Date	JFL 2/27/2013

SAMPLE CLASSIFICATION:
Brown, clayey, organic SILT; OH

SAMPLE DATA:

Specific Gravity (estimated)	2.7
Liquid Limit	65
Plastic Limit	42
Plasticity Index	23

SPECIMEN DATA:	Before Inundation	First Load	Final Load
Height, inches	0.786	0.786	0.558
Diameter, inches	2.503	2.503	2.503
Sample Volume, cuin	3.866	3.866	2.744
Wet Density, pcf	101.7	101.7	124.5
Dry Density, pcf	67.5	67.5	95.1
Water Content, %	51%	51%	31%
Void Ratio	1.50	1.50	0.77
Saturation, %	92%	92%	100%

Increment	Applied Stress, tsf	ΔH at t_{100}, in	ΔH / H_o	Void Ratio	$t_{50,}$ min	Coeff. of Comp., MPa^{-1}	Coeff. of Consol., cm^2/sec	Coeff. of Perm., cm/sec
1	0.03	0.001	0.1%	1.495	1.8	0.65	2.0E-03	5.2E-08
2	0.06	0.003	0.3%	1.488	0.4	2.07	6.3E-03	5.2E-07
3	0.13	0.019	2.4%	1.436	0.4	8.44	6.6E-03	2.2E-06
4	0.26	0.030	3.8%	1.401	0.1	2.88	2.8E-02	3.2E-06
5	0.52	0.054	6.8%	1.326	0.3	3.04	9.3E-03	1.1E-06
6	1.03	0.072	9.2%	1.267	0.3	1.19	9.2E-03	4.6E-07
7	2.06	0.099	12.6%	1.182	0.6	0.86	4.2E-03	1.6E-07
8	4.12	0.126	16.0%	1.098	0.6	0.43	3.8E-03	7.2E-08
9	1.03	0.134	17.1%	1.071	0.3	-0.09	8.7E-03	3.7E-08
10	0.26	0.129	16.4%	1.086	0.8	0.21	2.6E-03	2.6E-08
11	0.06	0.121	15.4%	1.111	3.6	1.34	6.1E-04	3.8E-08
12	0.26	0.117	14.9%	1.126	0.5	-0.80	4.4E-03	1.6E-07
13	1.03	0.124	15.8%	1.102	0.4	0.32	5.6E-03	8.4E-08
14	4.12	0.137	17.4%	1.062	0.2	0.13	1.1E-02	7.1E-08
15	8.24	0.159	20.2%	0.993	0.5	0.18	3.8E-03	3.2E-08
16	16.49	0.187	23.8%	0.902	0.4	0.12	5.0E-03	2.8E-08
17	32.97	0.2224	28.29%	0.790	0.4	0.071	4.0E-03	1.4E-08
18	64.40	0.2554	32.49%	0.686	0.3	0.035	4.4E-03	8.4E-09
19	16.10	0.2630	33.47%	0.661	0.2	-0.005	7.2E-03	2.2E-09
20	4.03	0.2578	32.80%	0.678	0.5	0.014	3.0E-03	2.6E-09
21	1.00	0.2501	31.82%	0.702	1.5	0.084	9.89E-04	4.9E-09
22	0.13	0.2335	29.71%	0.755	18.0	0.631	7.36E-05	2.7E-09

NOTES:
1. Abbreviations:
cm = centimeter
cm^2 = square centimeter
Coeff. = Coefficient
Comp. = Compressibility
Consol. = Consolidation
cu in = cubic inch
ft = feet
H_o = initial height
ΔH = change in height
in = inch
min = minute
MPa = megapascal
pcf = pounds per cubic foot
Perm. = Permeability
sec = second
t_n = time at n% of primary consolidation
tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST SUMMARY
BORING B-4-12, SAMPLE S-2 @5.4ft

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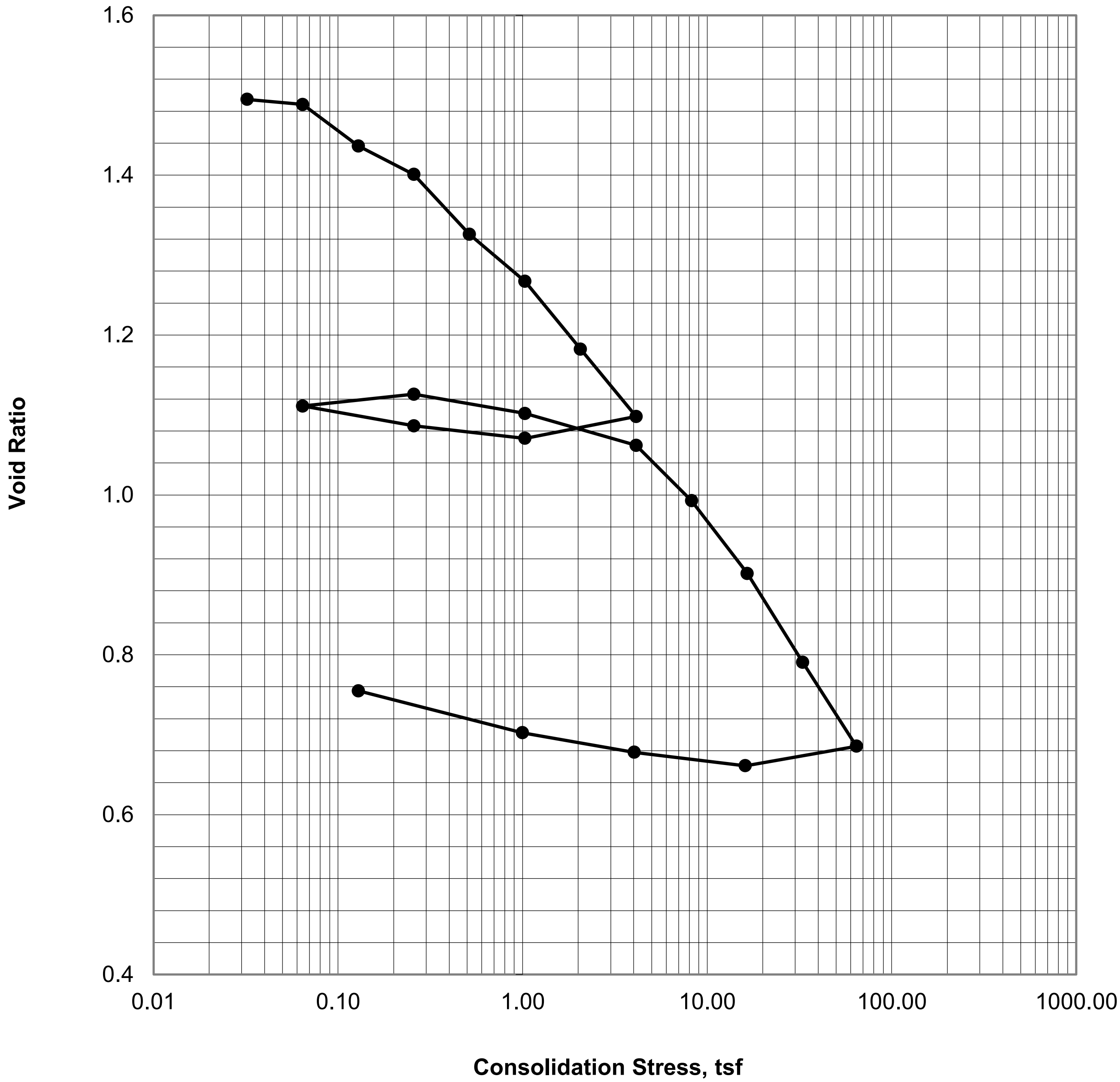
FIG. B-23

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-4-12	Tested By/Date	AKV 1/25/2013
Sample	S-2	Calculated By/Date	JFL 2/27/2013
Depth, ft	5.4	Checked By/Date	JFL 2/27/2013



Maximum Load, tsf 64.40

NOTES:
1. Abbreviations:
ft = feet
tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION
VOID RATIO vs STRESS PLOT
BORING B-4-12, SAMPLE S-2 @5.4ft

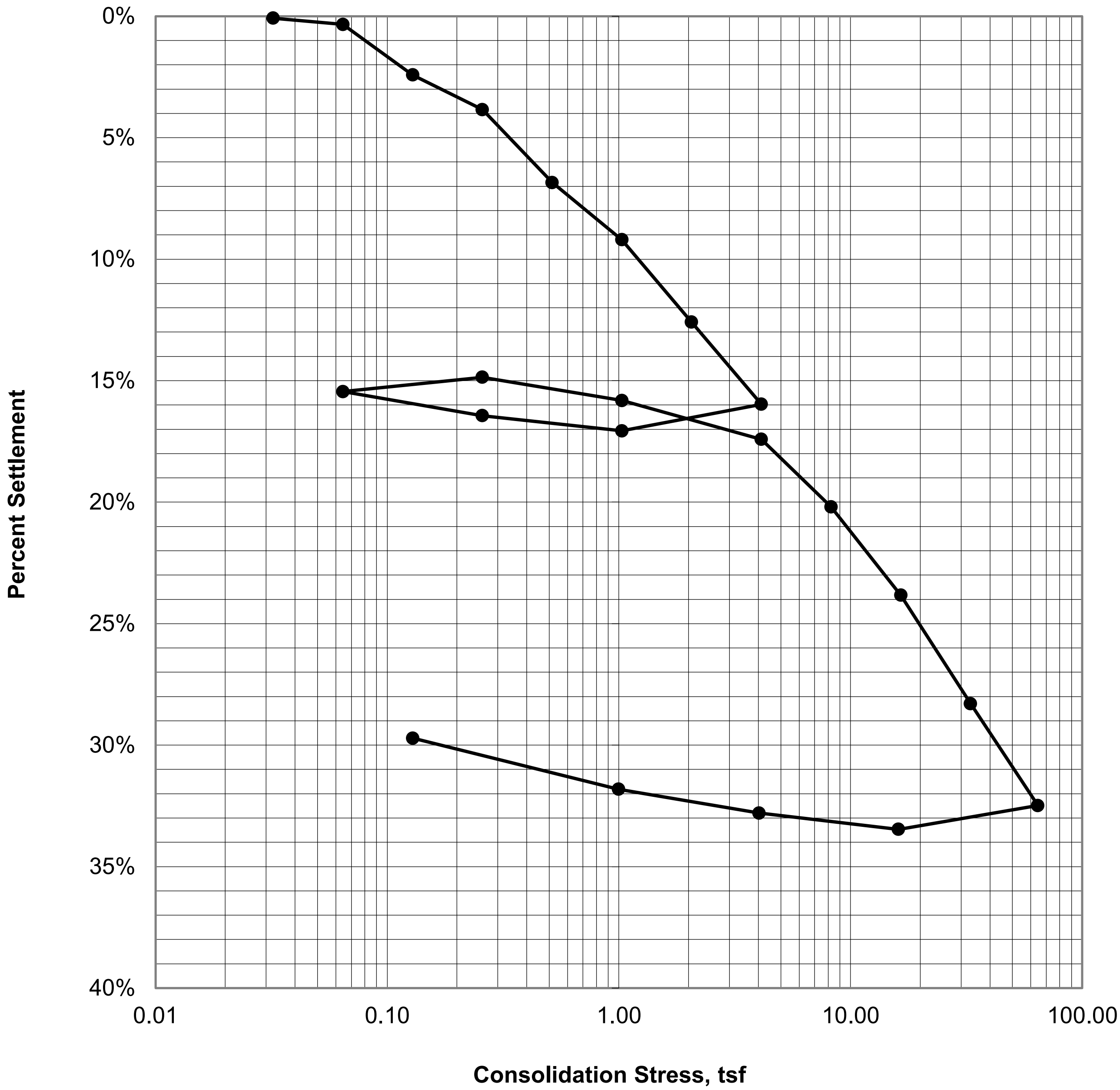
October 2013 21-1-12405-060

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B-24

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-4-12	Tested By/Date	AKV 1/25/2013
Sample	S-2	Calculated By/Date	JFL 2/27/2013
Depth, ft	5.4	Checked By/Date	JFL 2/27/2013



Maximum Load, tsf 64.40

NOTES:
1. Abbreviations:
ft = feet
tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION PERCENT SETTLEMENT vs STRESS PLOT BORING B-4-12, SAMPLE S-2 @5.4ft

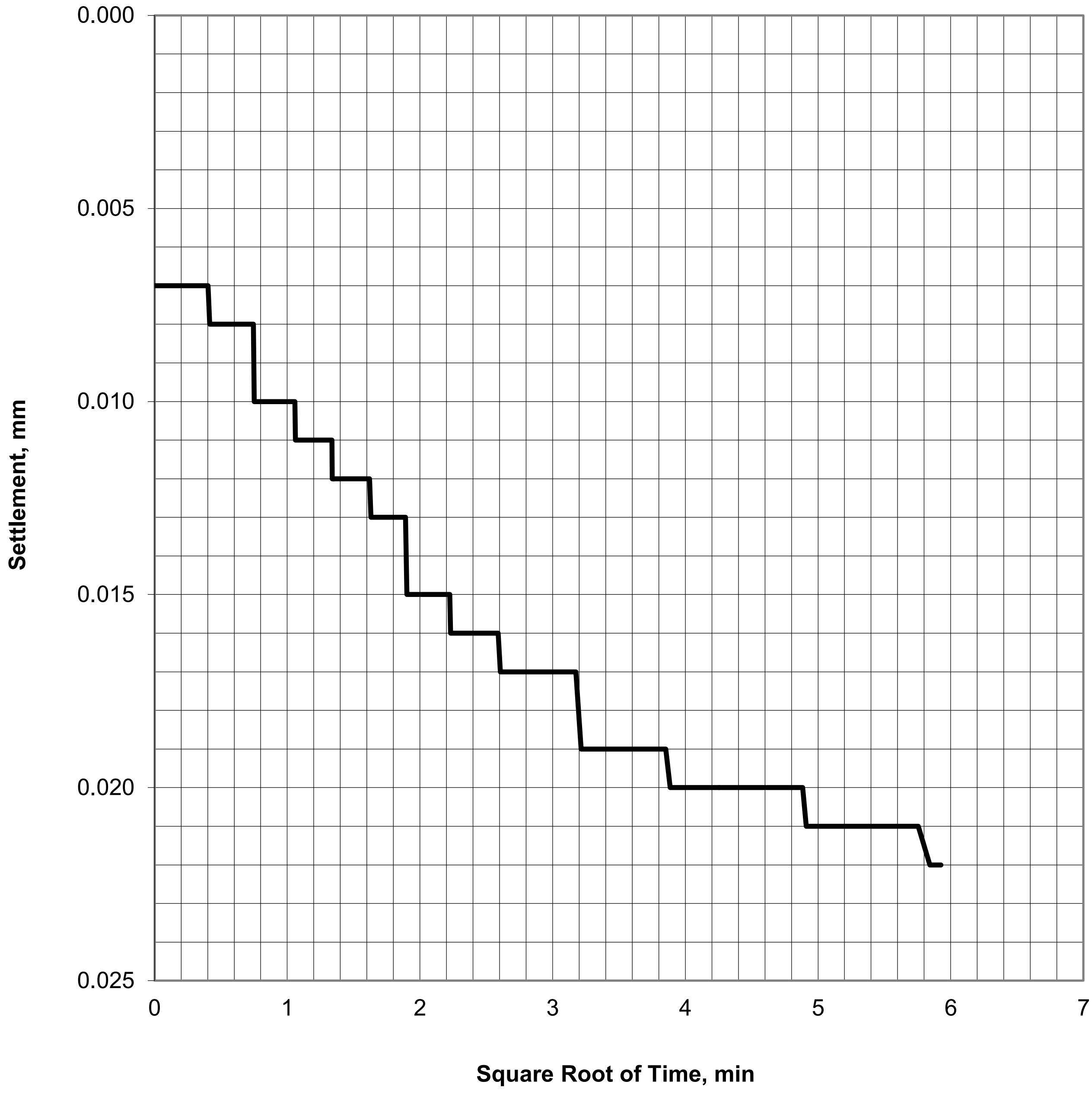
October 2013 21-1-12405-060

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B-25

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-4-12	Tested By/Date	AKV 1/25/2013
Sample	S-2	Calculated By/Date	JFL 2/27/2013
Depth, ft	5.4	Checked By/Date	JFL 2/27/2013



Increment Number 1

Applied Stress, tsf 0.03

NOTES:
1. Abbreviations:
   ft = feet
   min = minutes
   mm = mimilimeters
   tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-4-12, SAMPLE S-2 @5.4ft

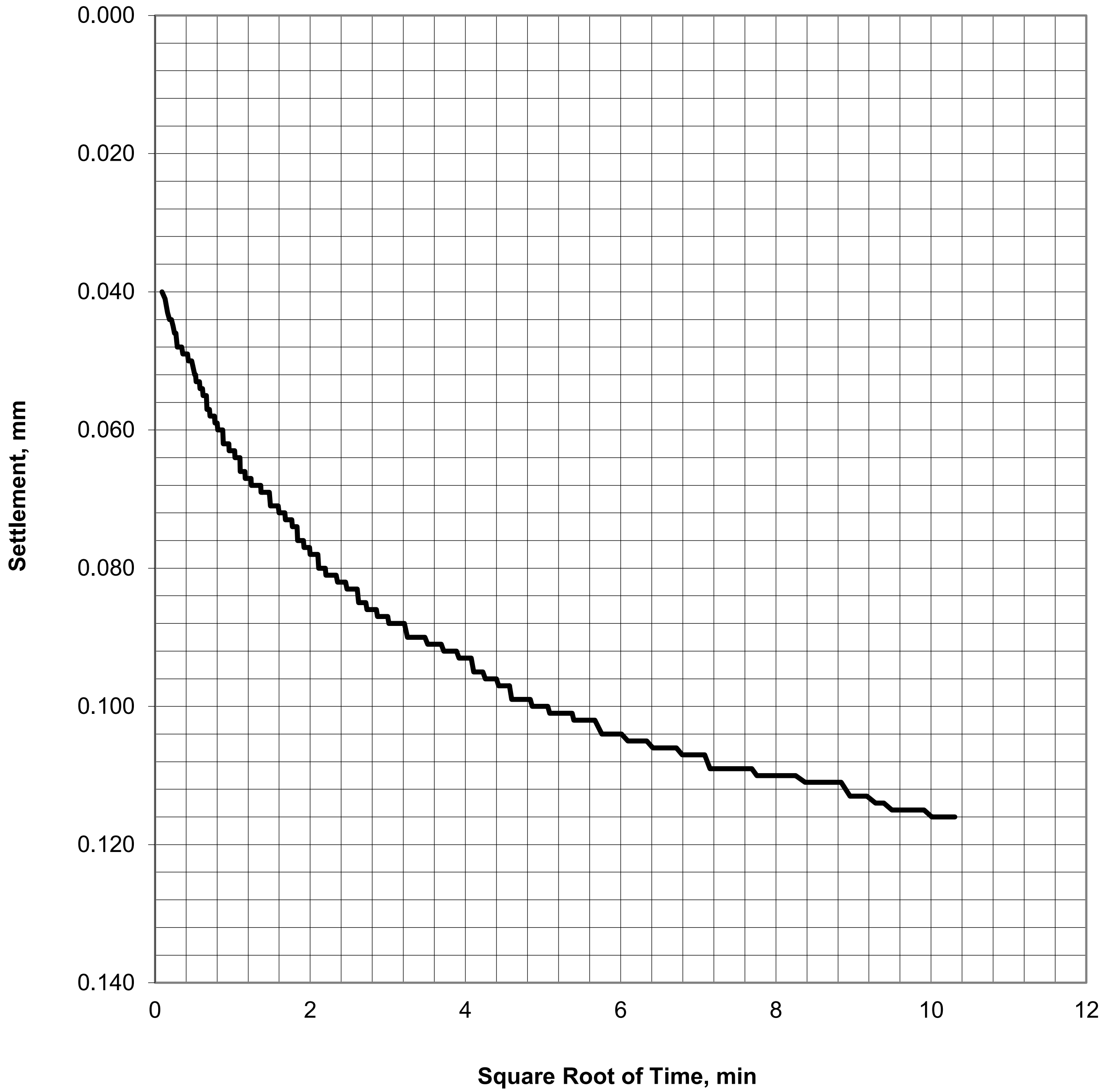
October 2013 21-1-12405-060

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B-26
Sheet 1 of 22

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-4-12	Tested By/Date	AKV 1/25/2013
Sample	S-2	Calculated By/Date	JFL 2/27/2013
Depth, ft	5.4	Checked By/Date	JFL 2/27/2013



Increment Number 2

Applied Stress, tsf 0.06

NOTES:
1. Abbreviations:
   ft = feet
   min = minutes
   mm = mimilimeters
   tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-4-12, SAMPLE S-2 @5.4ft

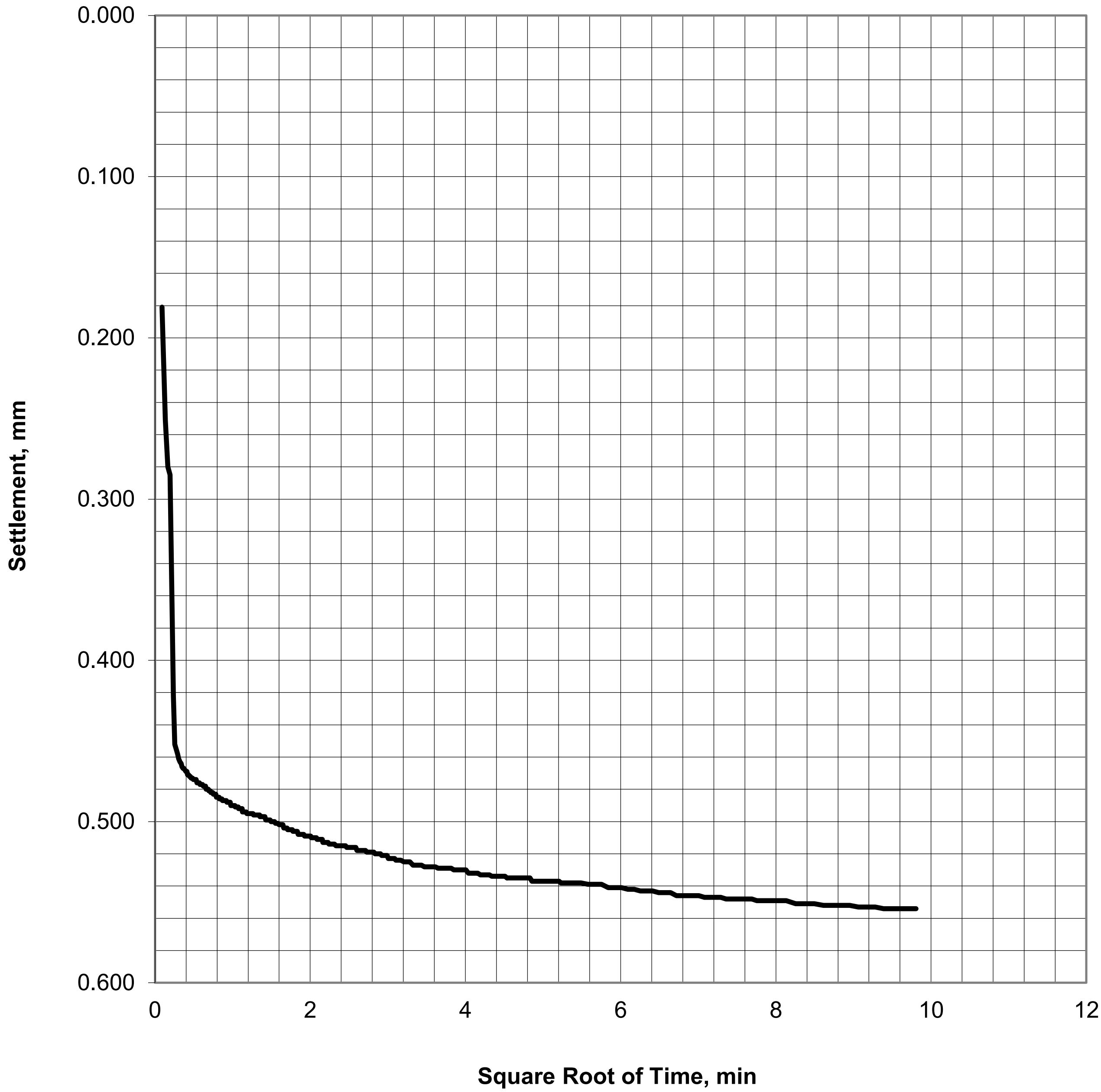
October 2013 21-1-12405-060

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B-26
Sheet 2 of 22

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-4-12	Tested By/Date	AKV 1/25/2013
Sample	S-2	Calculated By/Date	JFL 2/27/2013
Depth, ft	5.4	Checked By/Date	JFL 2/27/2013



Increment Number 3

Applied Stress, tsf 0.13

NOTES:
1. Abbreviations:
ft = feet
min = minutes
mm = mimilimeters
tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-4-12, SAMPLE S-2 @5.4ft

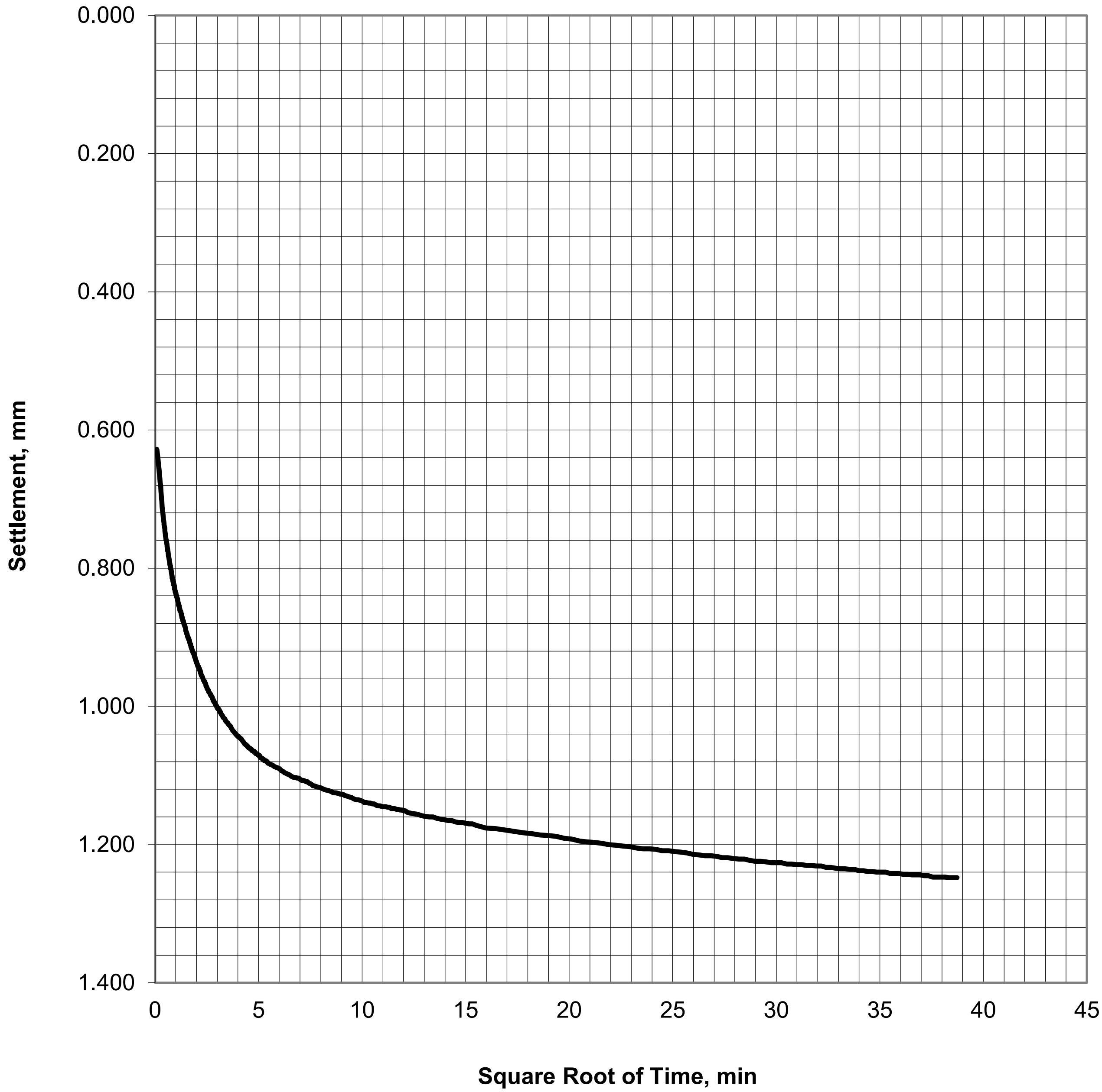
October 2013 21-1-12405-060

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B-26

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-4-12	Tested By/Date	AKV 1/25/2013
Sample	S-2	Calculated By/Date	JFL 2/27/2013
Depth, ft	5.4	Checked By/Date	JFL 2/27/2013



Increment Number 4

Applied Stress, tsf 0.26

NOTES:
1. Abbreviations:
ft = feet
min = minutes
mm = mimilimeters
tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-4-12, SAMPLE S-2 @5.4ft

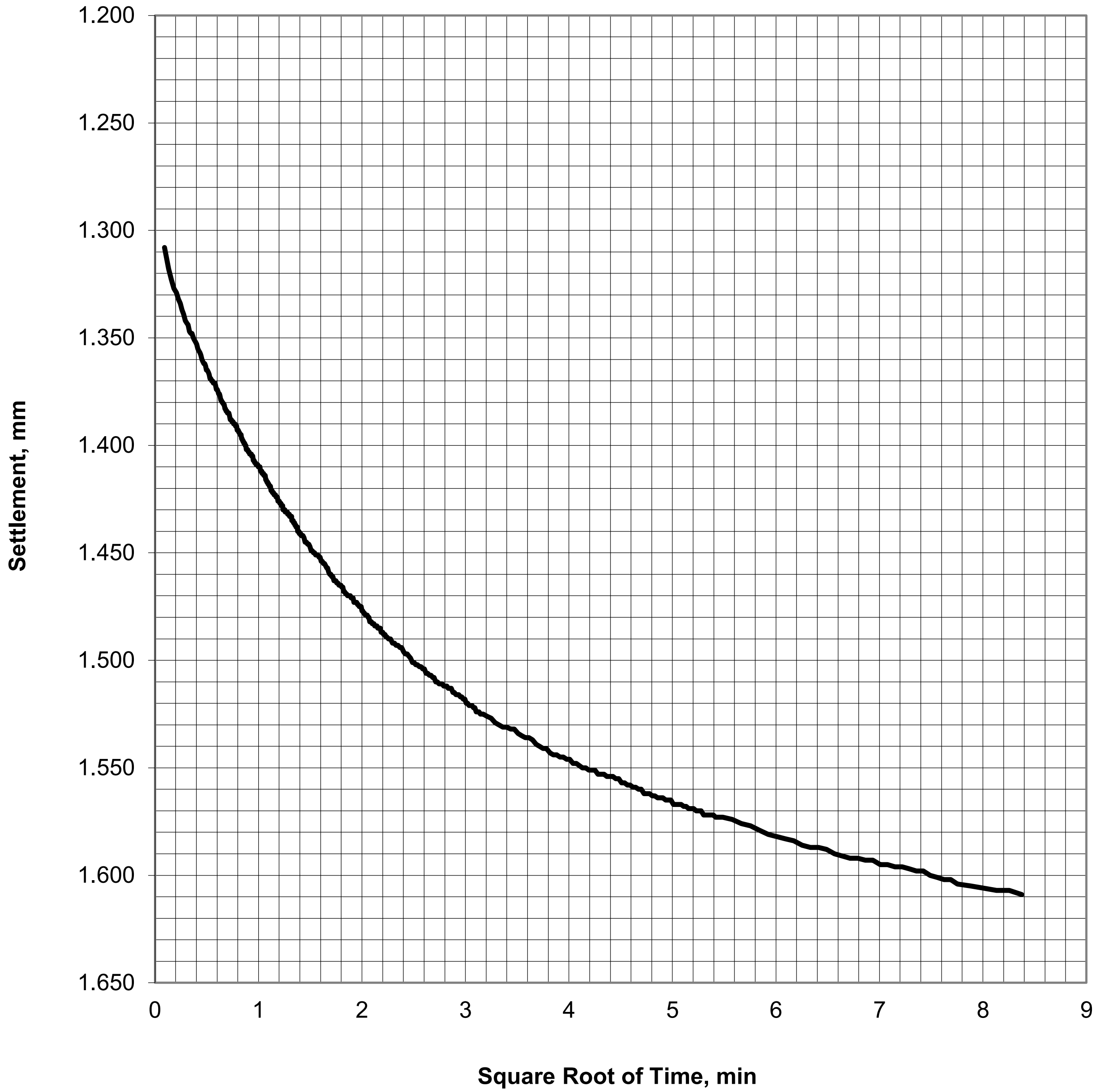
October 2013 21-1-12405-060

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B-26

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-4-12	Tested By/Date	AKV 1/25/2013
Sample	S-2	Calculated By/Date	JFL 2/27/2013
Depth, ft	5.4	Checked By/Date	JFL 2/27/2013



Increment Number 5

Applied Stress, tsf 0.52

NOTES:
1. Abbreviations:
   ft = feet
   min = minutes
   mm = mimilimeters
   tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-4-12, SAMPLE S-2 @5.4ft

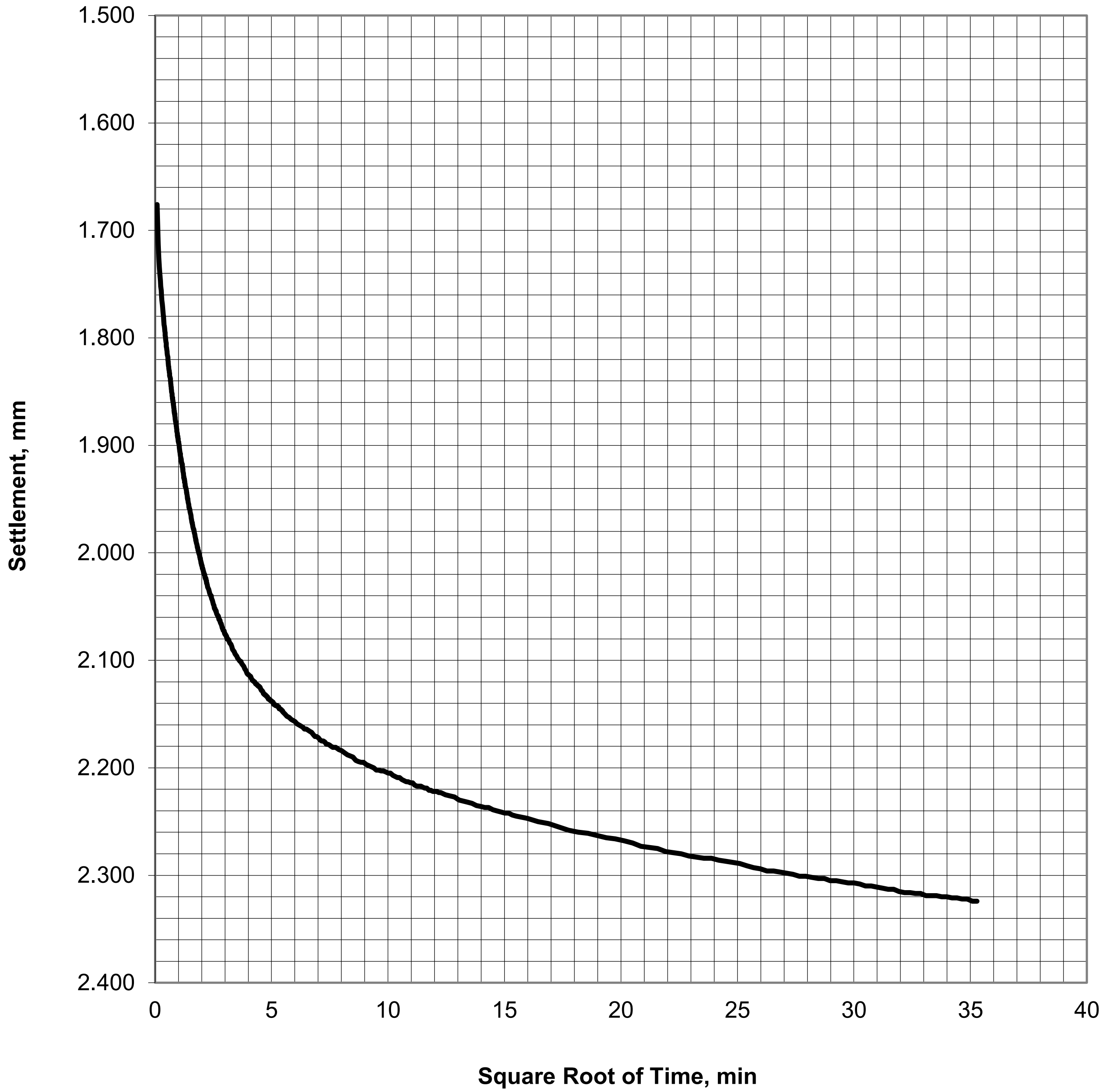
October 2013 21-1-12405-060

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B-26

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-4-12	Tested By/Date	AKV 1/25/2013
Sample	S-2	Calculated By/Date	JFL 2/27/2013
Depth, ft	5.4	Checked By/Date	JFL 2/27/2013



Increment Number 6

Applied Stress, tsf 1.03

NOTES:
1. Abbreviations:
   ft = feet
   min = minutes
   mm = mimilimeters
   tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-4-12, SAMPLE S-2 @5.4ft

October 2013 21-1-12405-060

SHANNON & WILSON, INC.
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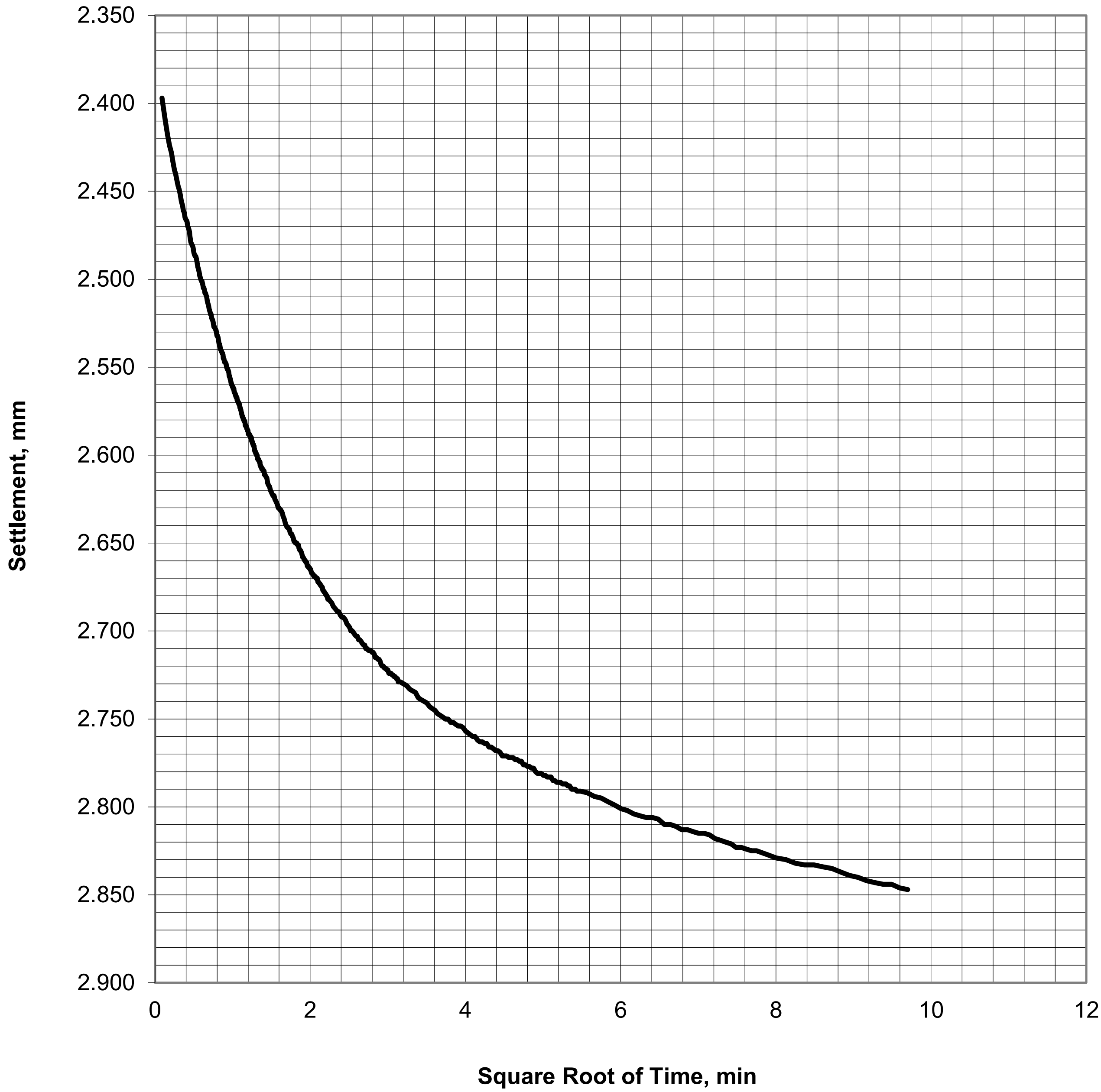
FIG. B-26

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-4-12	Tested By/Date	AKV 1/25/2013
Sample	S-2	Calculated By/Date	JFL 2/27/2013
Depth, ft	5.4	Checked By/Date	JFL 2/27/2013



Increment Number 7

Applied Stress, tsf 2.06

NOTES:
1. Abbreviations:
   ft = feet
   min = minutes
   mm = mimilimeters
   tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-4-12, SAMPLE S-2 @5.4ft

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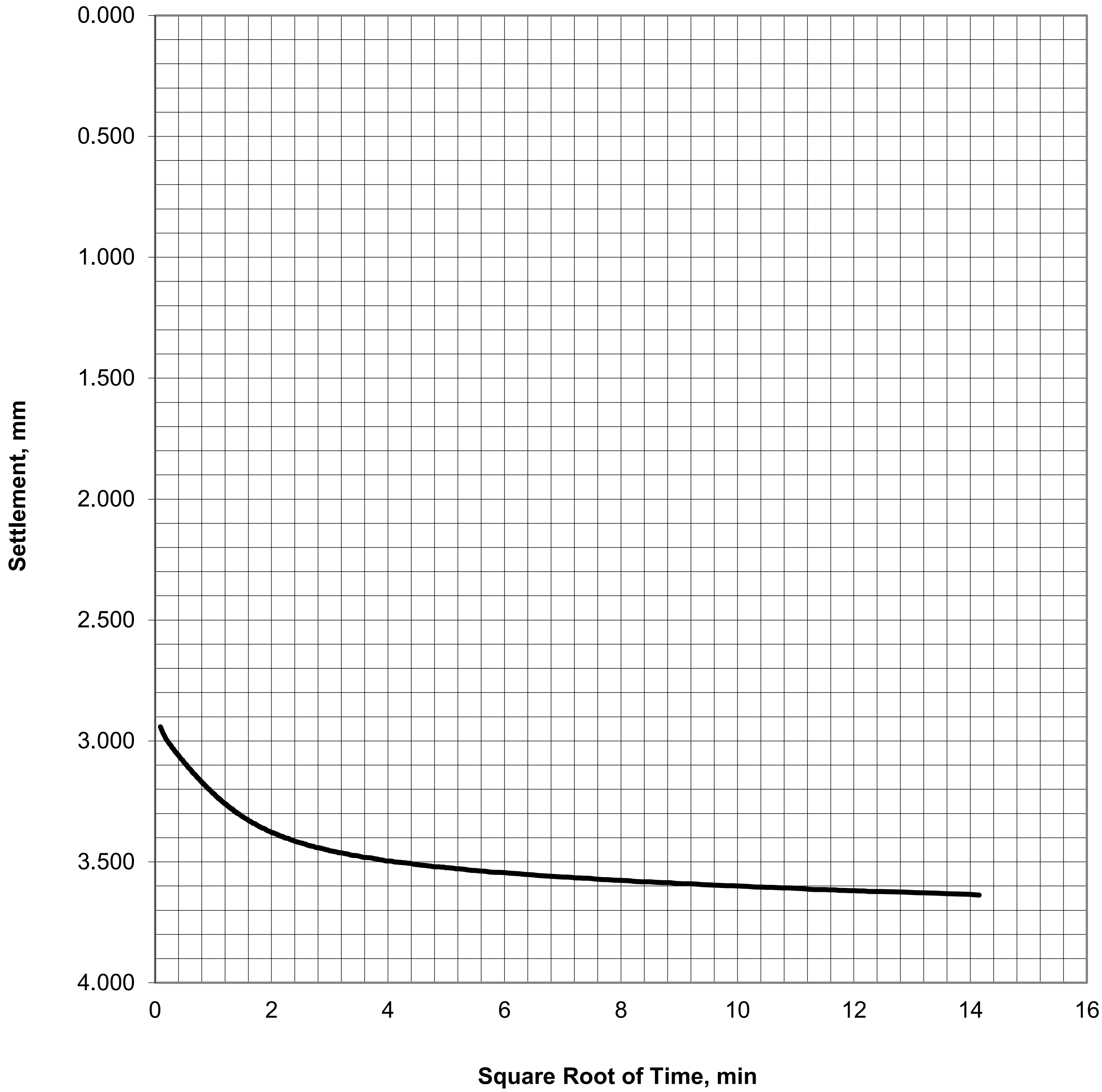
SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B-26
Sheet 7 of 22

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-4-12	Tested By/Date	AKV 1/25/2013
Sample	S-2	Calculated By/Date	JFL 2/27/2013
Depth, ft	5.4	Checked By/Date	JFL 2/27/2013



Increment Number 8
Applied Stress, tsf 4.12

NOTES:
1. Abbreviations:
ft = feet
min = minutes
mm = mimilimeters
tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-4-12, SAMPLE S-2 @5.4ft

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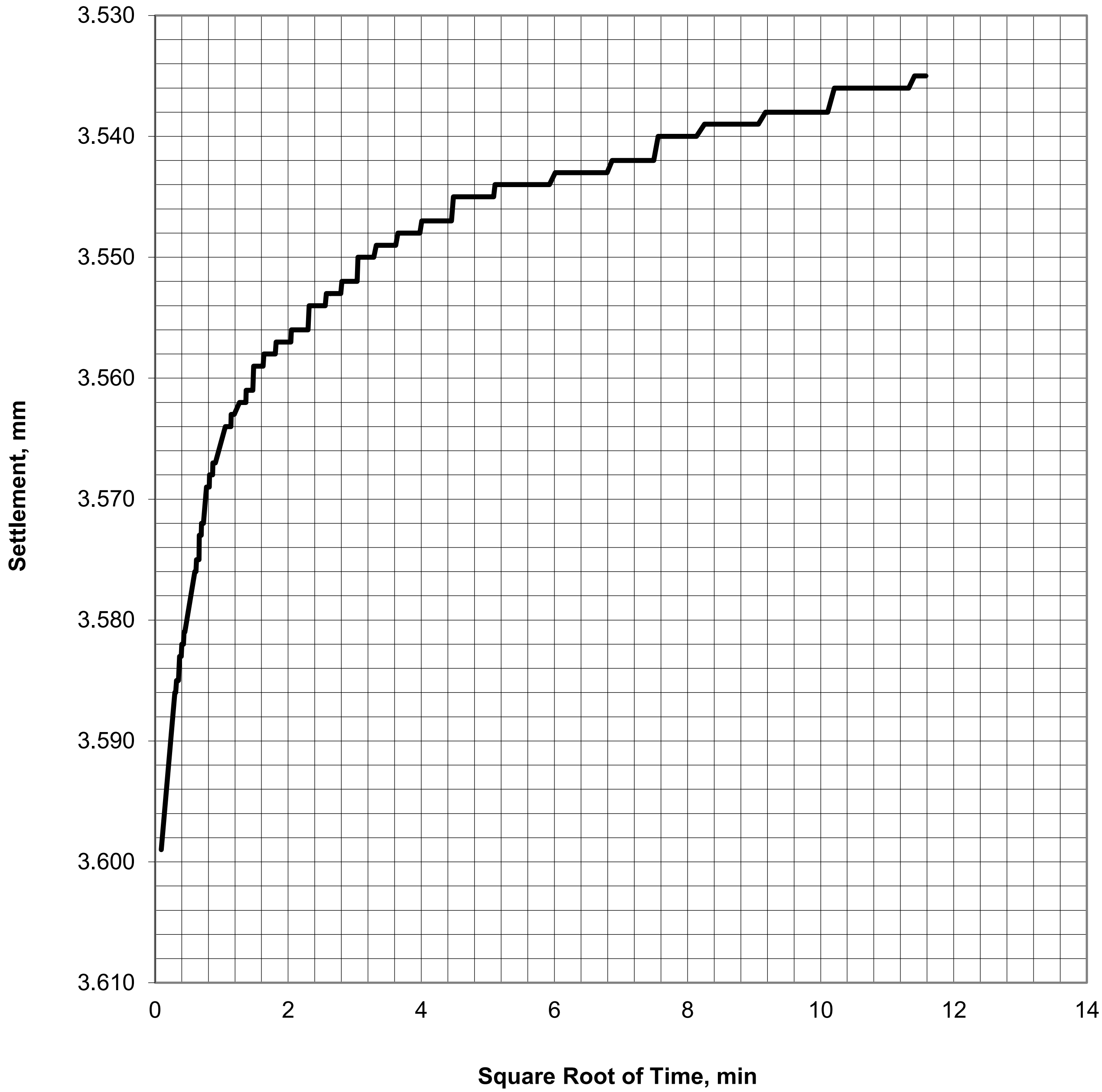
SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B-26

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-4-12	Tested By/Date	AKV 1/25/2013
Sample	S-2	Calculated By/Date	JFL 2/27/2013
Depth, ft	5.4	Checked By/Date	JFL 2/27/2013



Increment Number 9

Applied Stress, tsf 1.03

NOTES:
1. Abbreviations:
   ft = feet
   min = minutes
   mm = mimilimeters
   tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-4-12, SAMPLE S-2 @5.4ft

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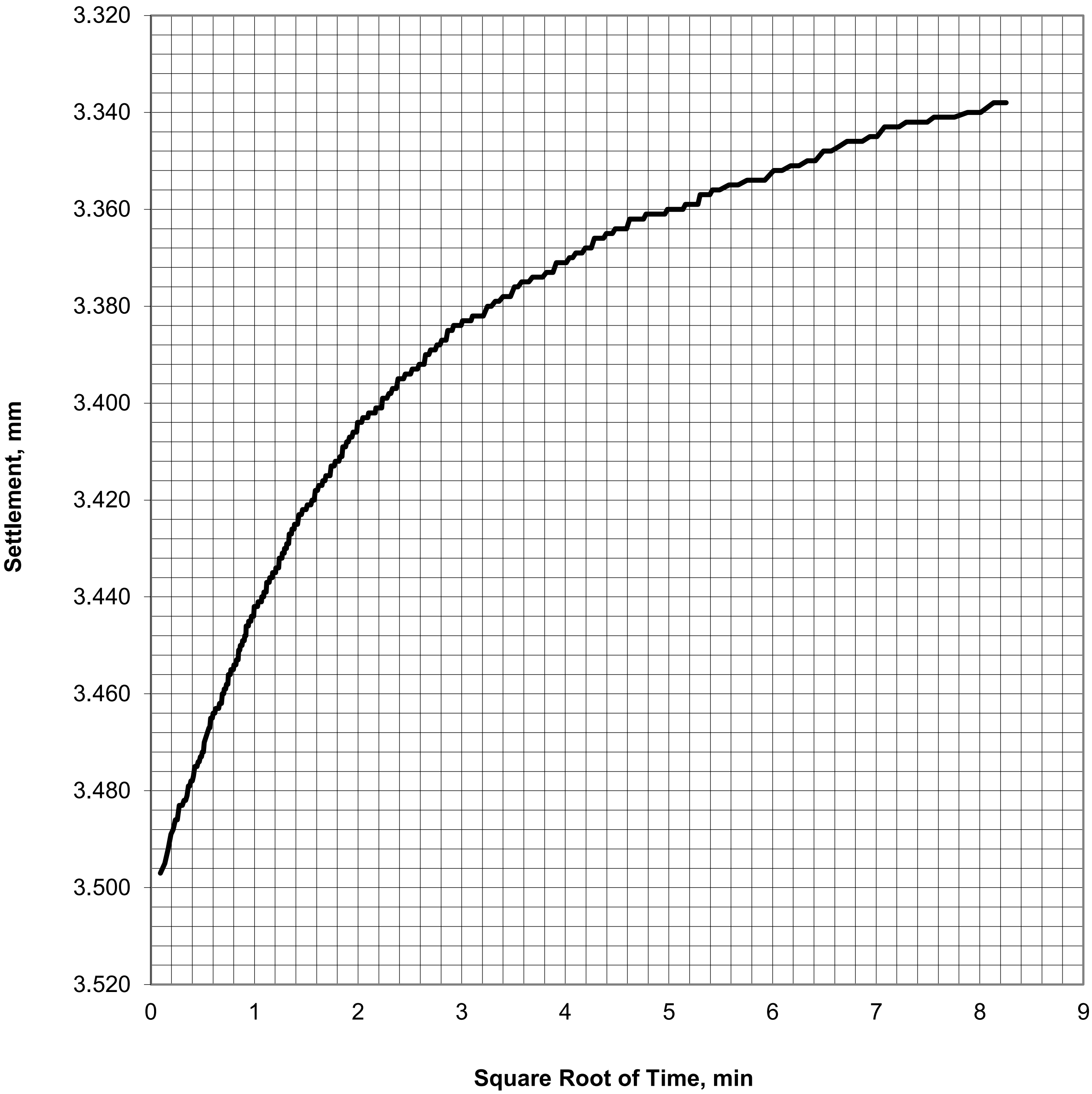
SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B-26

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-4-12	Tested By/Date	AKV 1/25/2013
Sample	S-2	Calculated By/Date	JFL 2/27/2013
Depth, ft	5.4	Checked By/Date	JFL 2/27/2013



Increment Number 10

Applied Stress, tsf 0.26

NOTES:
1. Abbreviations:
   ft = feet
   min = minutes
   mm = mimilimeters
   tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-4-12, SAMPLE S-2 @5.4ft

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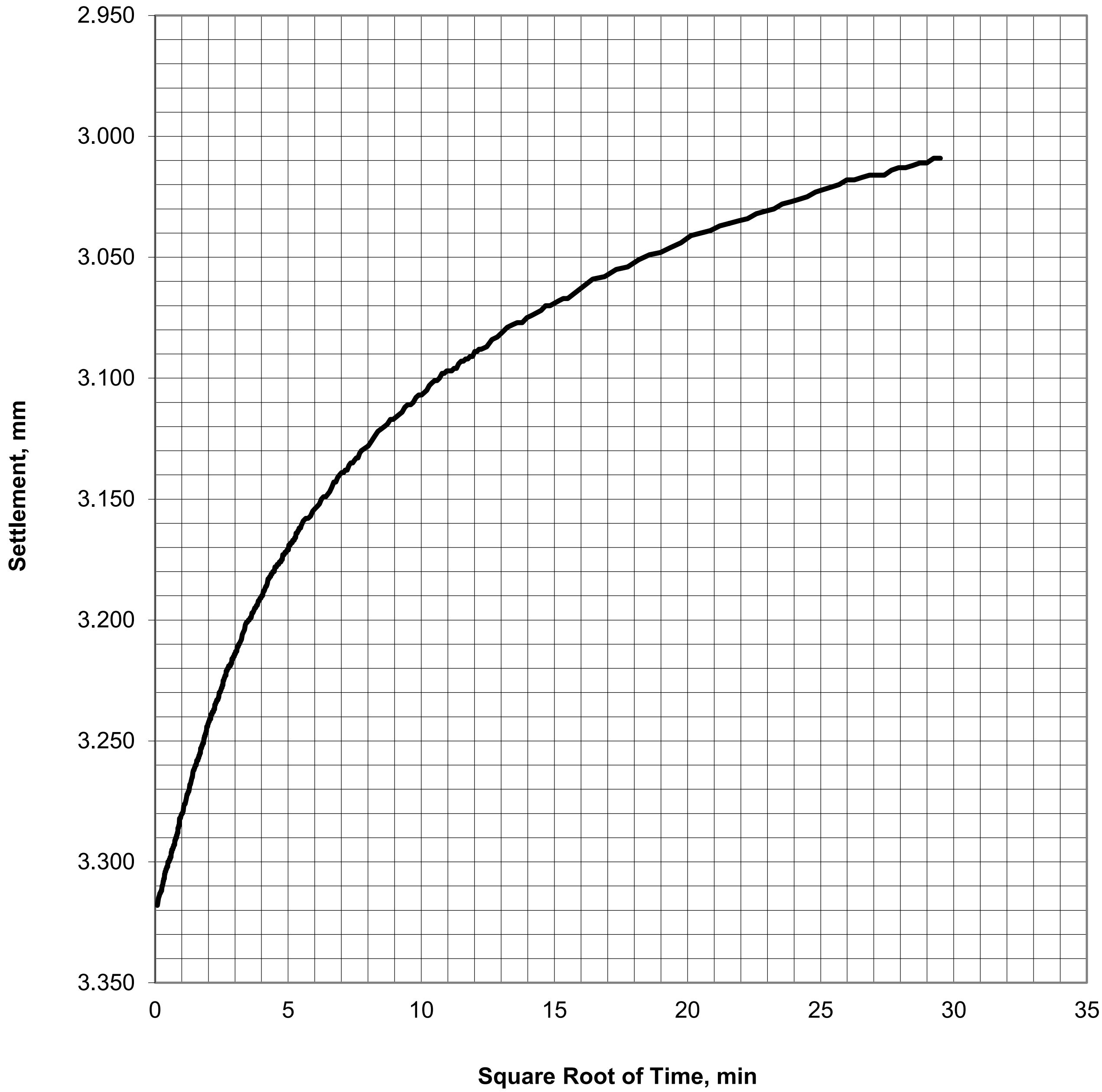
SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B-26

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-4-12	Tested By/Date	AKV 1/25/2013
Sample	S-2	Calculated By/Date	JFL 2/27/2013
Depth, ft	5.4	Checked By/Date	JFL 2/27/2013



Increment Number 11

Applied Stress, tsf 0.06

NOTES:
1. Abbreviations:
   ft = feet
   min = minutes
   mm = mimilimeters
   tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-4-12, SAMPLE S-2 @5.4ft

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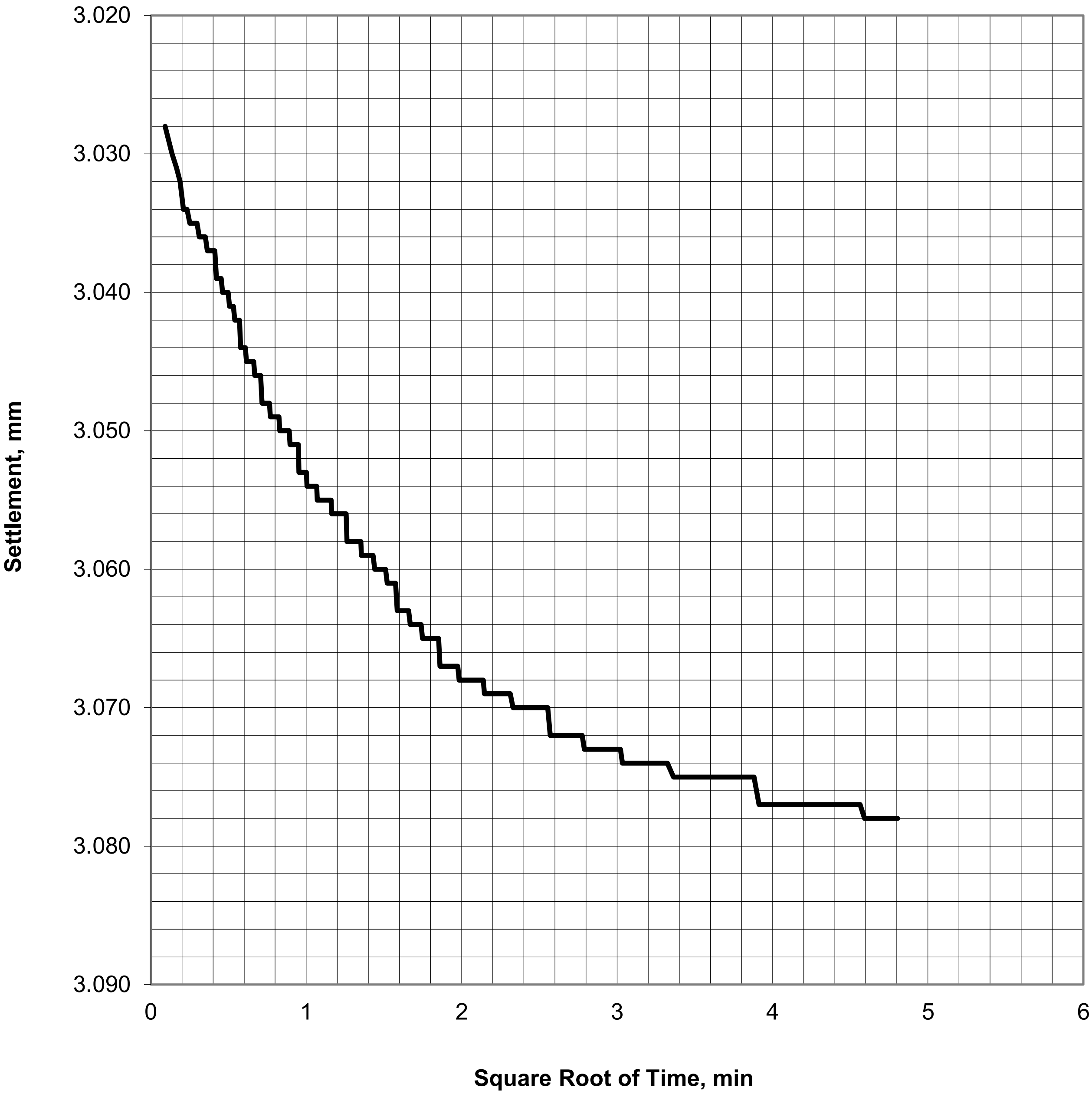
SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B-26

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-4-12	Tested By/Date	AKV 1/25/2013
Sample	S-2	Calculated By/Date	JFL 2/27/2013
Depth, ft	5.4	Checked By/Date	JFL 2/27/2013



Increment Number 12

Applied Stress, tsf 0.26

NOTES:
1. Abbreviations:
   ft = feet
   min = minutes
   mm = mimilimeters
   tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-4-12, SAMPLE S-2 @5.4ft

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SHANNON & WILSON, INC.
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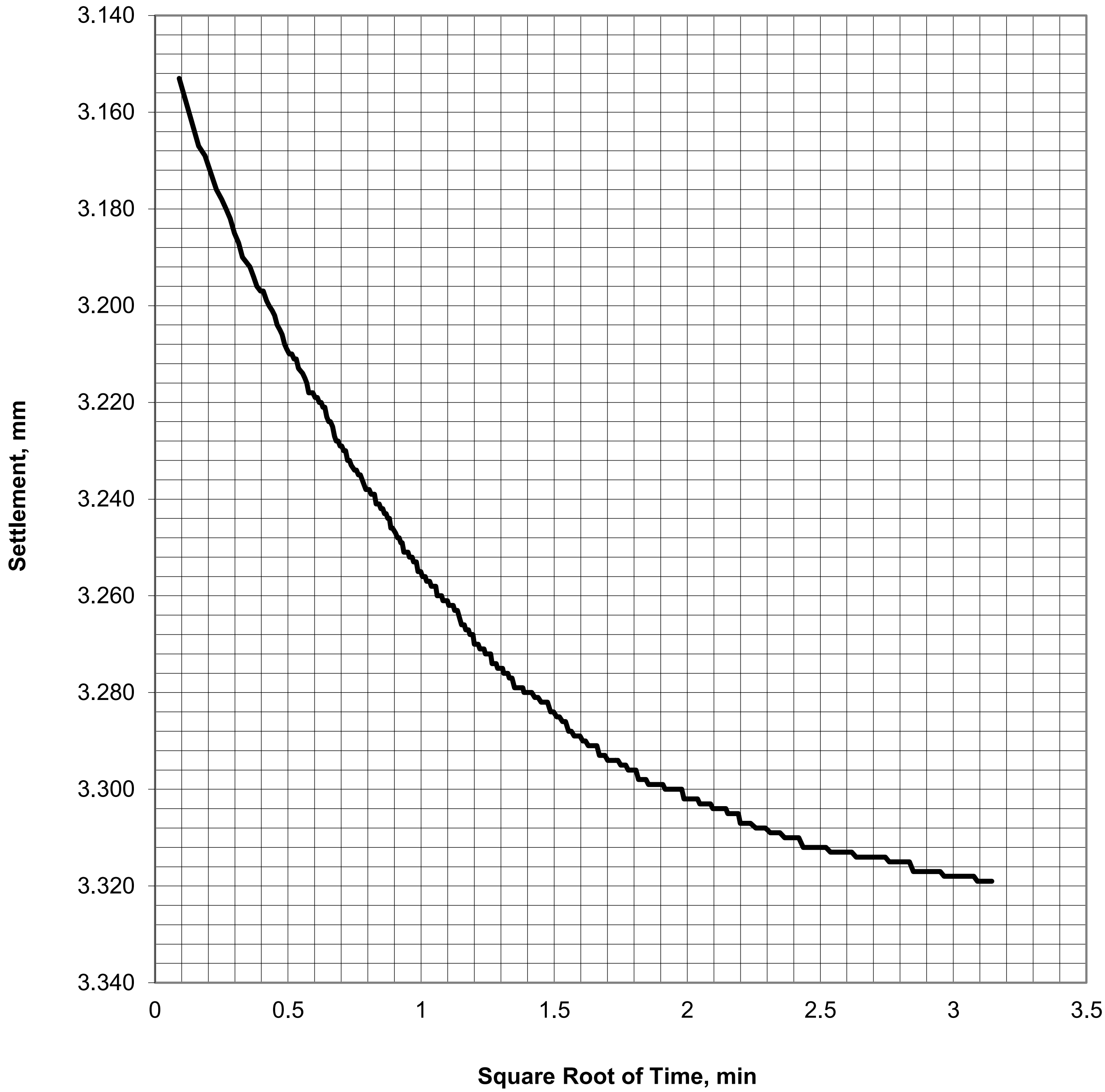
FIG. B-26
Sheet 12 of 22

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-4-12	Tested By/Date	AKV 1/25/2013
Sample	S-2	Calculated By/Date	JFL 2/27/2013
Depth, ft	5.4	Checked By/Date	JFL 2/27/2013



Increment Number 13

Applied Stress, tsf 1.03

NOTES:
1. Abbreviations:
   ft = feet
   min = minutes
   mm = mimilimeters
   tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-4-12, SAMPLE S-2 @5.4ft

October 2013 21-1-12405-060

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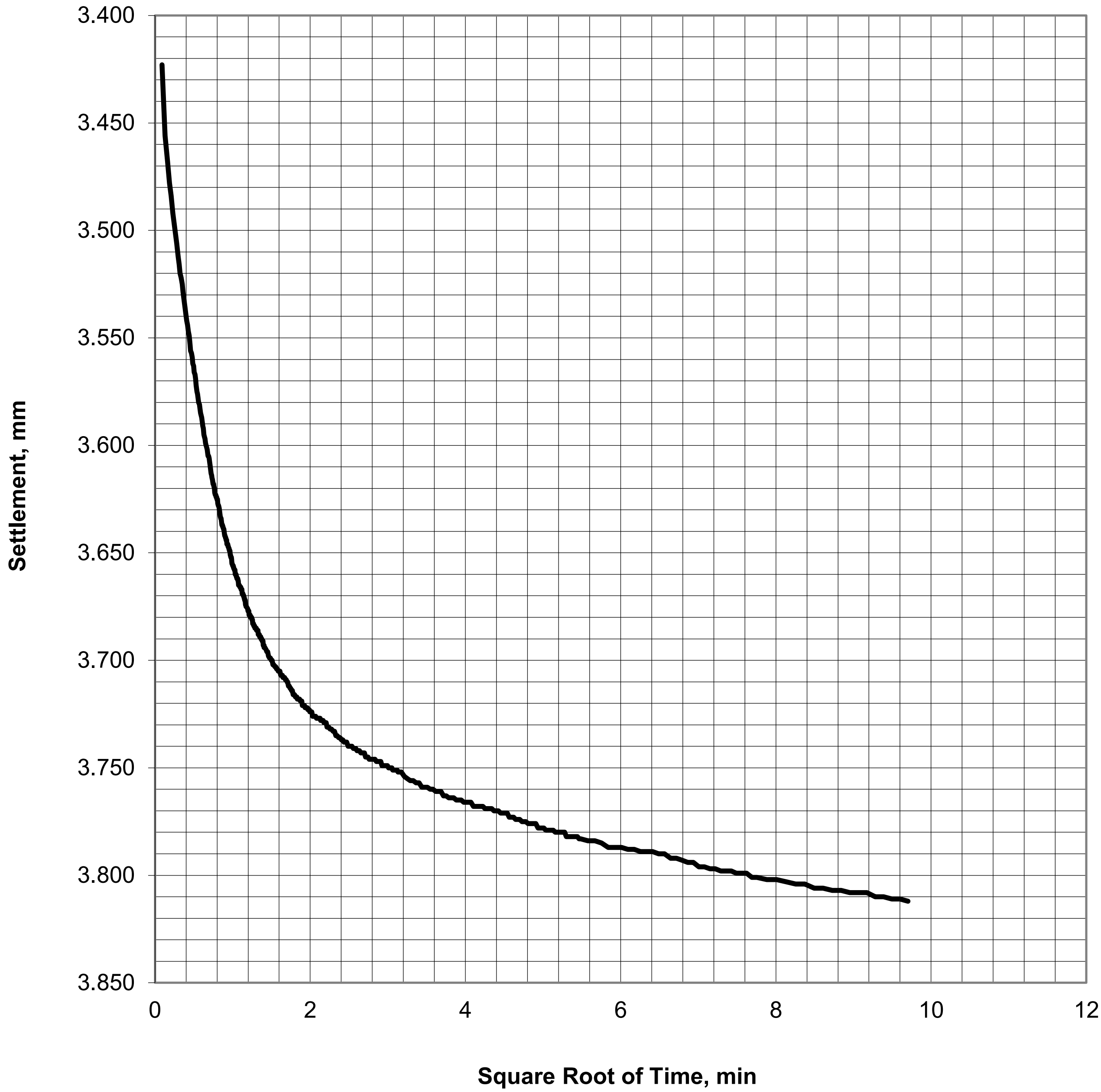
ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-4-12	Tested By/Date	AKV 1/25/2013
Sample	S-2	Calculated By/Date	JFL 2/27/2013
Depth, ft	5.4	Checked By/Date	JFL 2/27/2013



Increment Number 14

Applied Stress, tsf 4.12

NOTES:
1. Abbreviations:
   - ft = feet
   - min = minutes
   - mm = mimilimeters
   - tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-4-12, SAMPLE S-2 @5.4ft

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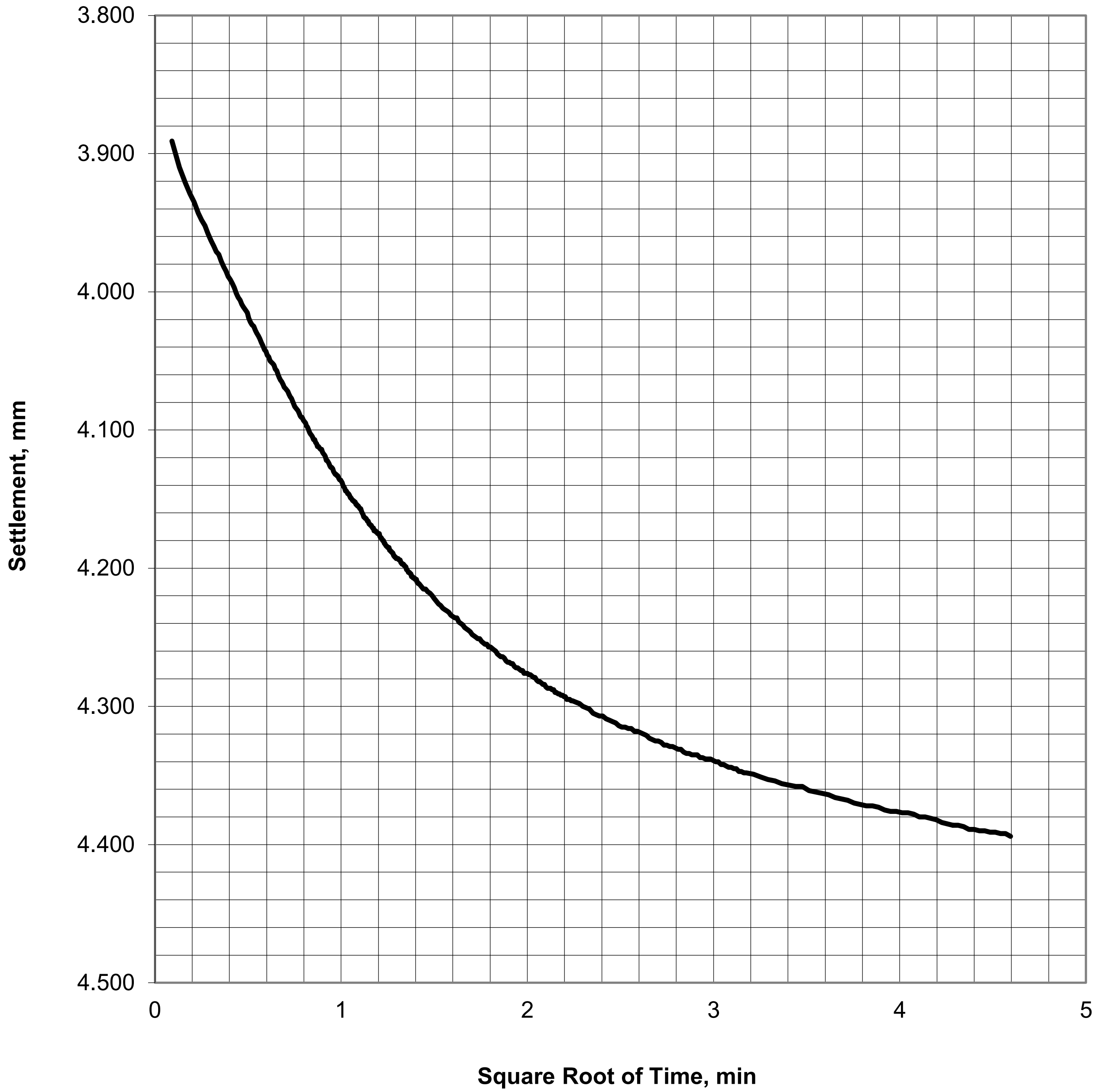
SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B-26

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-4-12	Tested By/Date	AKV 1/25/2013
Sample	S-2	Calculated By/Date	JFL 2/27/2013
Depth, ft	5.4	Checked By/Date	JFL 2/27/2013



Increment Number 15

Applied Stress, tsf 8.24

NOTES:
1. Abbreviations:
ft = feet
min = minutes
mm = mimilimeters
tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-4-12, SAMPLE S-2 @5.4ft

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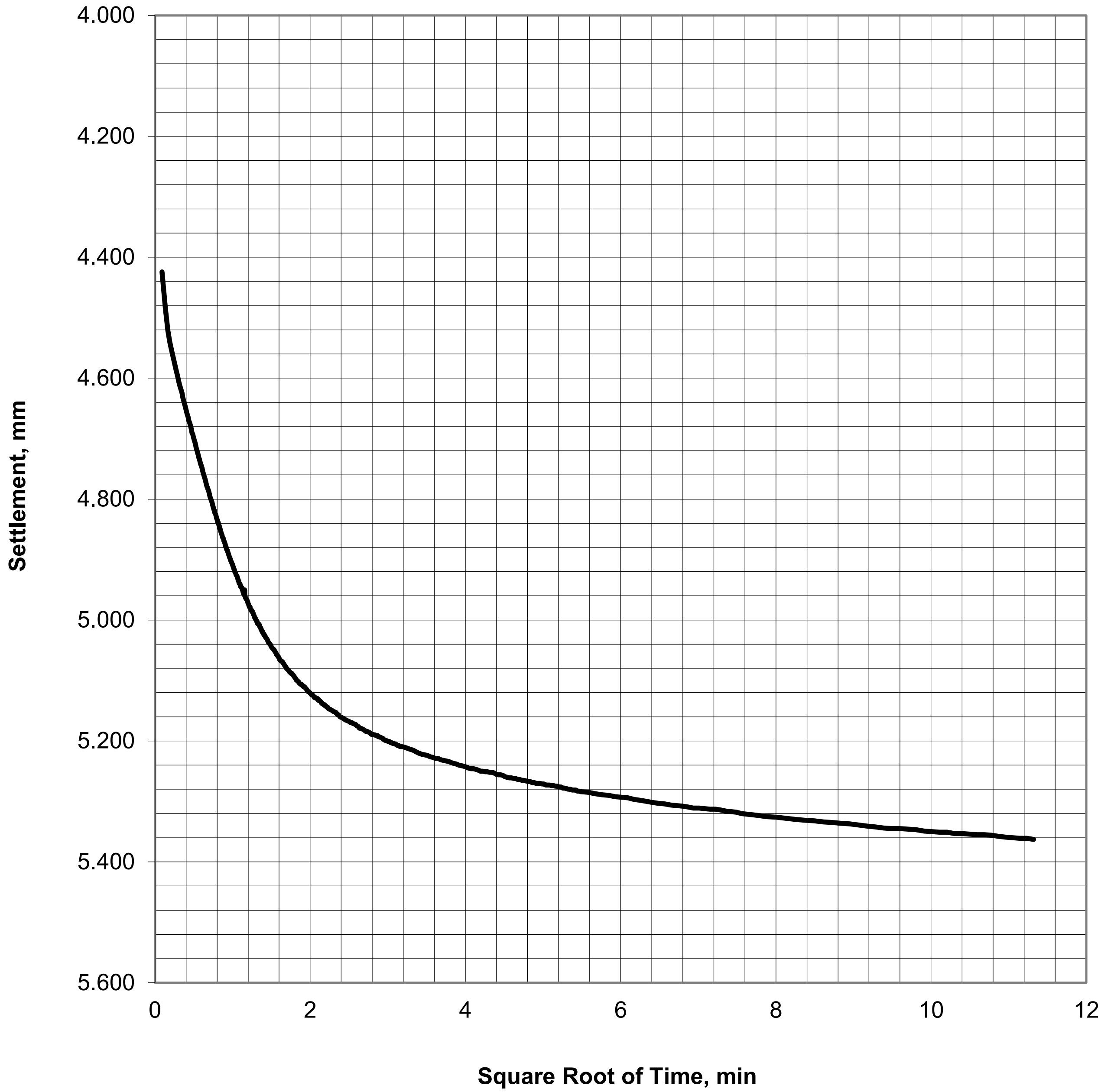
SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B-26

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-4-12	Tested By/Date	AKV 1/25/2013
Sample	S-2	Calculated By/Date	JFL 2/27/2013
Depth, ft	5.4	Checked By/Date	JFL 2/27/2013



Increment Number 16

Applied Stress, tsf 16.49

NOTES:
1. Abbreviations:
   ft = feet
   min = minutes
   mm = mimilimeters
   tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-4-12, SAMPLE S-2 @5.4ft

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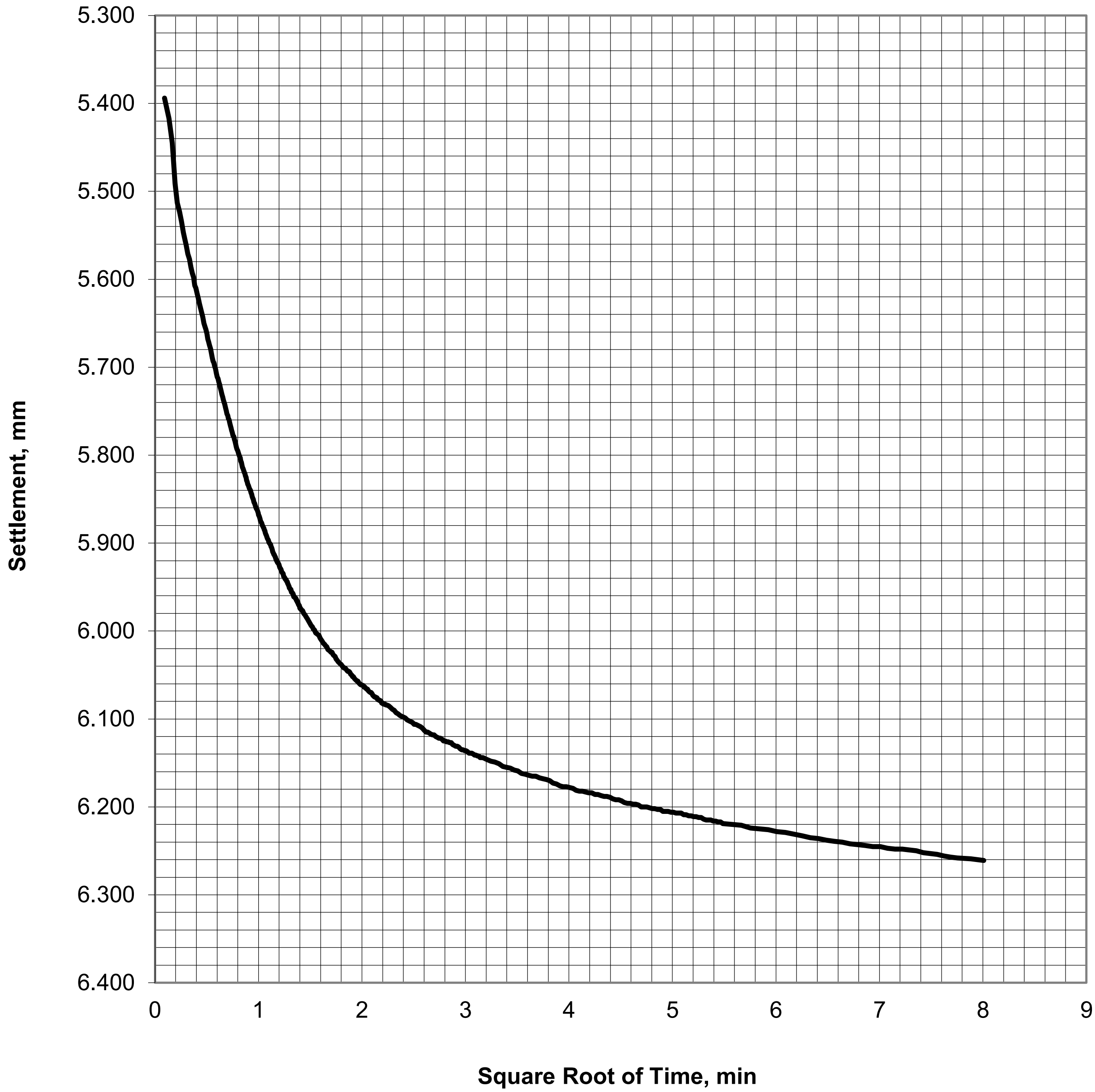
SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B-26

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-4-12	Tested By/Date	AKV 1/25/2013
Sample	S-2	Calculated By/Date	JFL 2/27/2013
Depth, ft	5.4	Checked By/Date	JFL 2/27/2013



Increment Number 17

Applied Stress, tsf 32.97

NOTES:
1. Abbreviations:
   ft = feet
   min = minutes
   mm = mimilimeters
   tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-4-12, SAMPLE S-2 @5.4ft

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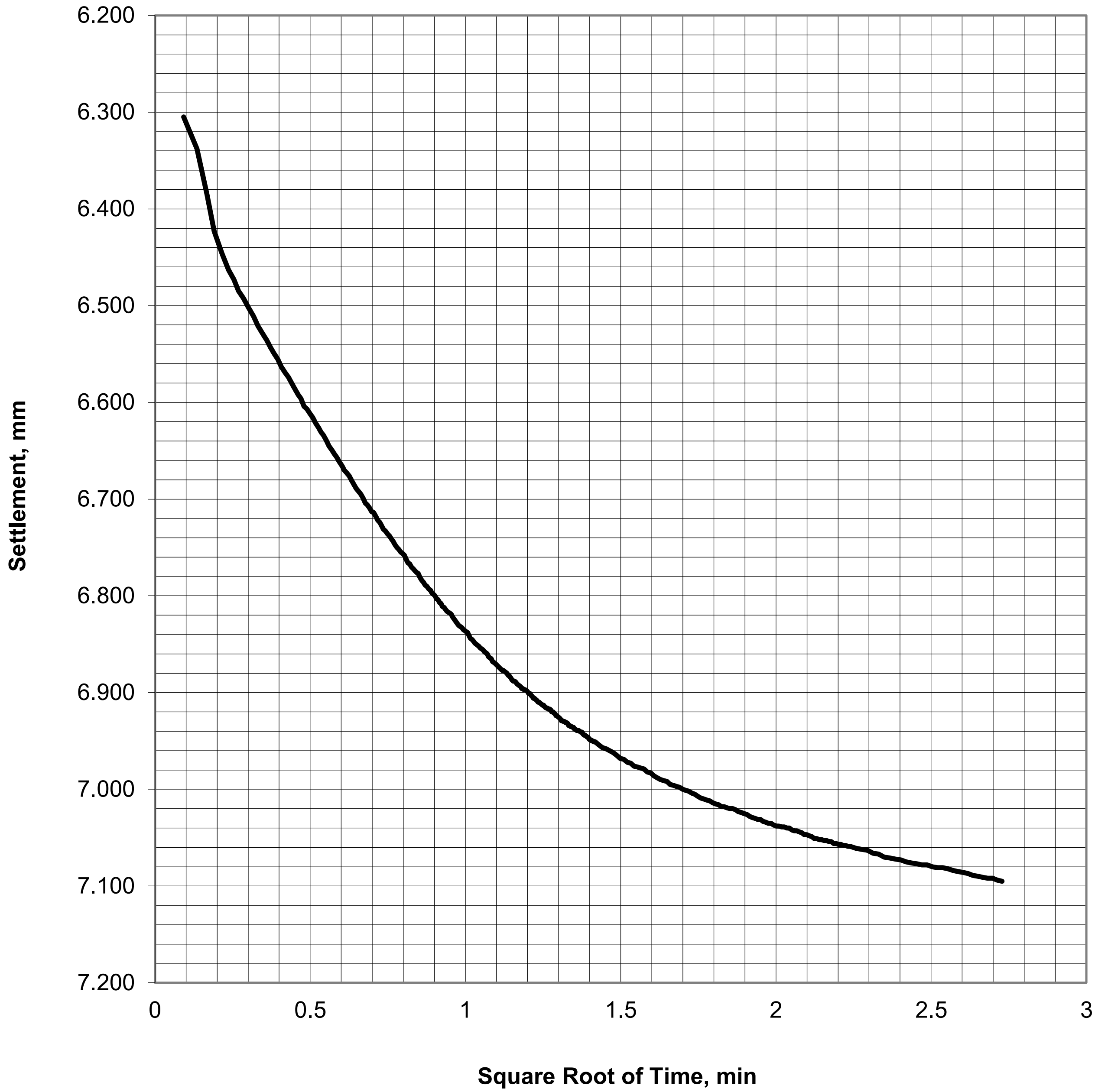
Geotechnical and Environmental Consultants

FIG. B-26

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-4-12	Tested By/Date	AKV 1/25/2013
Sample	S-2	Calculated By/Date	JFL 2/27/2013
Depth, ft	5.4	Checked By/Date	JFL 2/27/2013



Increment Number 18

Applied Stress, tsf 64.40

NOTES:
1. Abbreviations:
   ft = feet
   min = minutes
   mm = mimilimeters
   tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-4-12, SAMPLE S-2 @5.4ft

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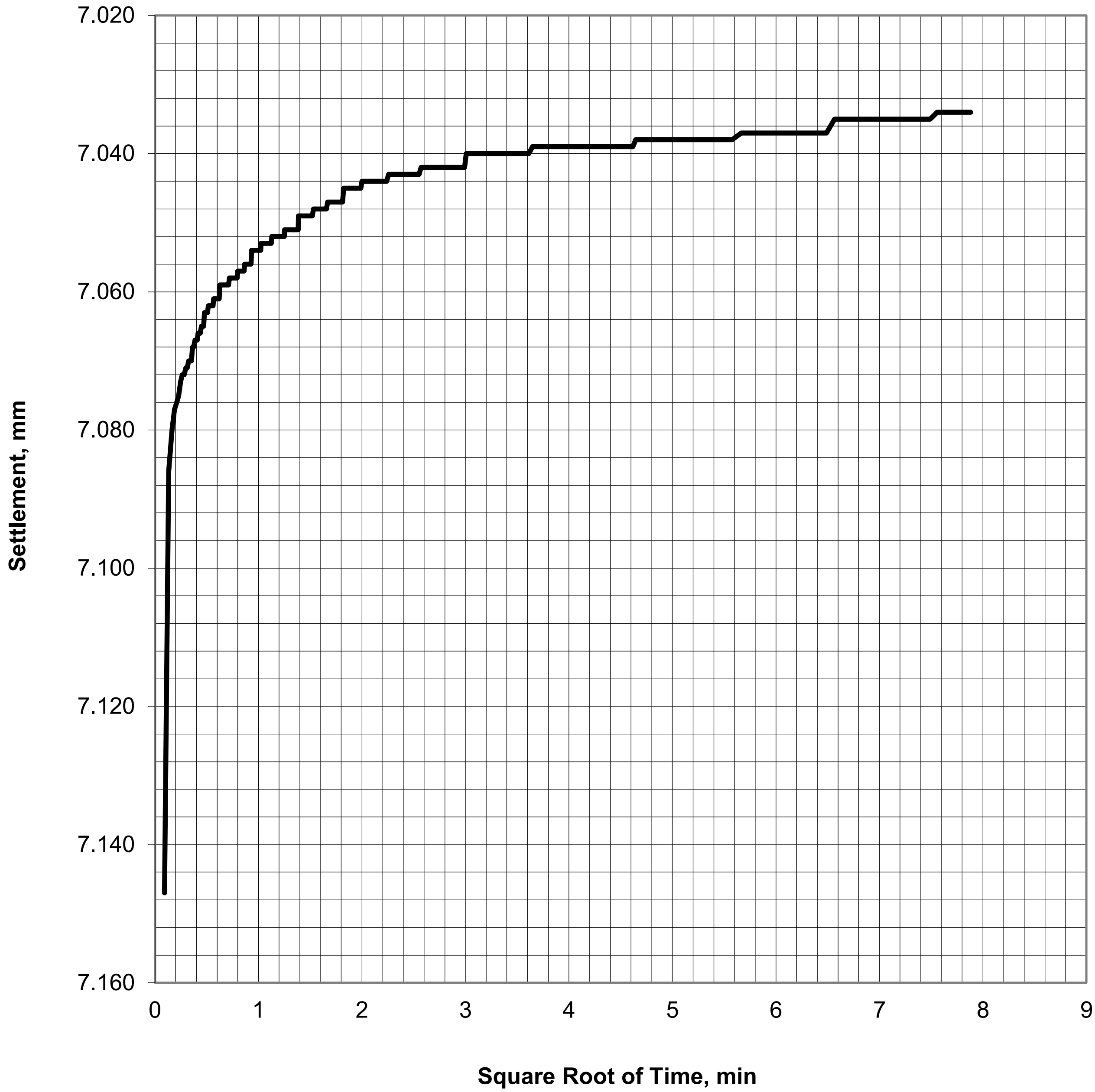
SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B-26

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-4-12	Tested By/Date	AKV 1/25/2013
Sample	S-2	Calculated By/Date	JFL 2/27/2013
Depth, ft	5.4	Checked By/Date	JFL 2/27/2013



Increment Number 19

Applied Stress, tsf 16.10

NOTES:
1. Abbreviations:
   - ft = feet
   - min = minutes
   - mm = mimilimeters
   - tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-4-12, SAMPLE S-2 @5.4ft

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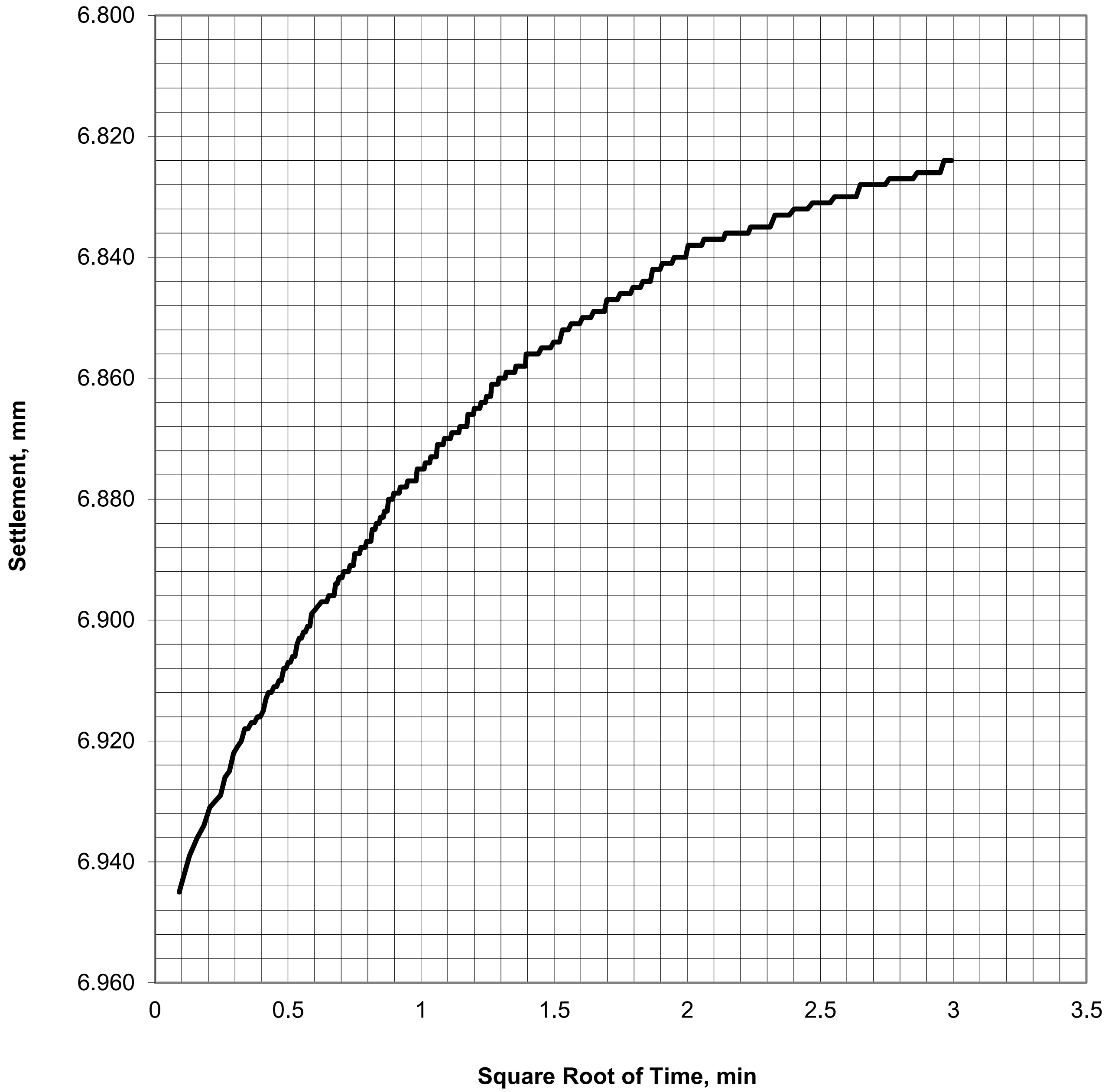
SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B-26
Sheet 19 of 22

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-4-12	Tested By/Date	AKV 1/25/2013
Sample	S-2	Calculated By/Date	JFL 2/27/2013
Depth, ft	5.4	Checked By/Date	JFL 2/27/2013



Increment Number 20

Applied Stress, tsf 4.03

NOTES:
1. Abbreviations:
ft = feet
min = minutes
mm = mimilimeters
tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-4-12, SAMPLE S-2 @5.4ft

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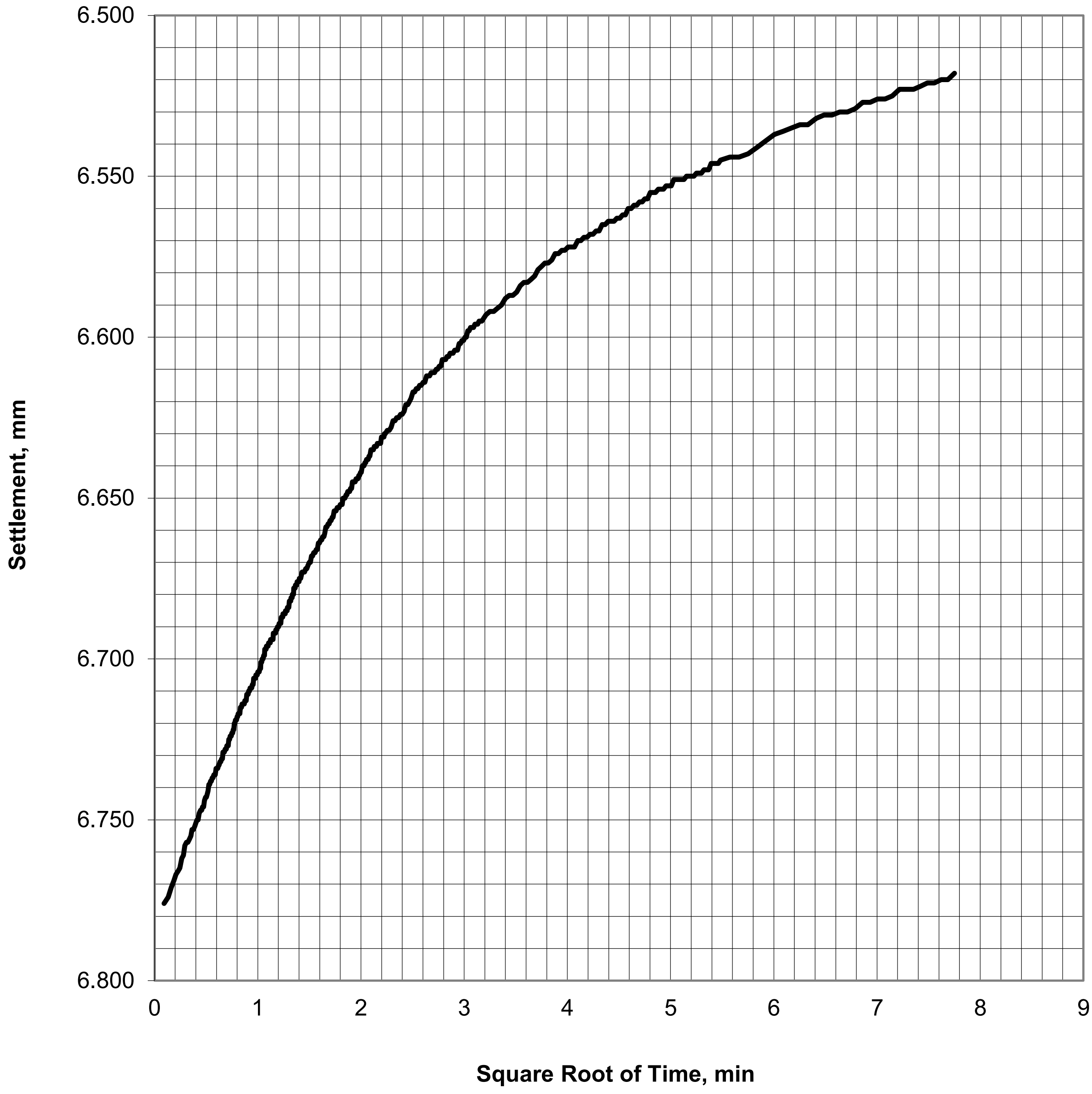
SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B-26
Sheet 20 of 22

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-4-12	Tested By/Date	AKV 1/25/2013
Sample	S-2	Calculated By/Date	JFL 2/27/2013
Depth, ft	5.4	Checked By/Date	JFL 2/27/2013



Increment Number 21

Applied Stress, tsf 1.00

NOTES:
1. Abbreviations:
   ft = feet
   min = minutes
   mm = mimilimeters
   tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-4-12, SAMPLE S-2 @5.4ft

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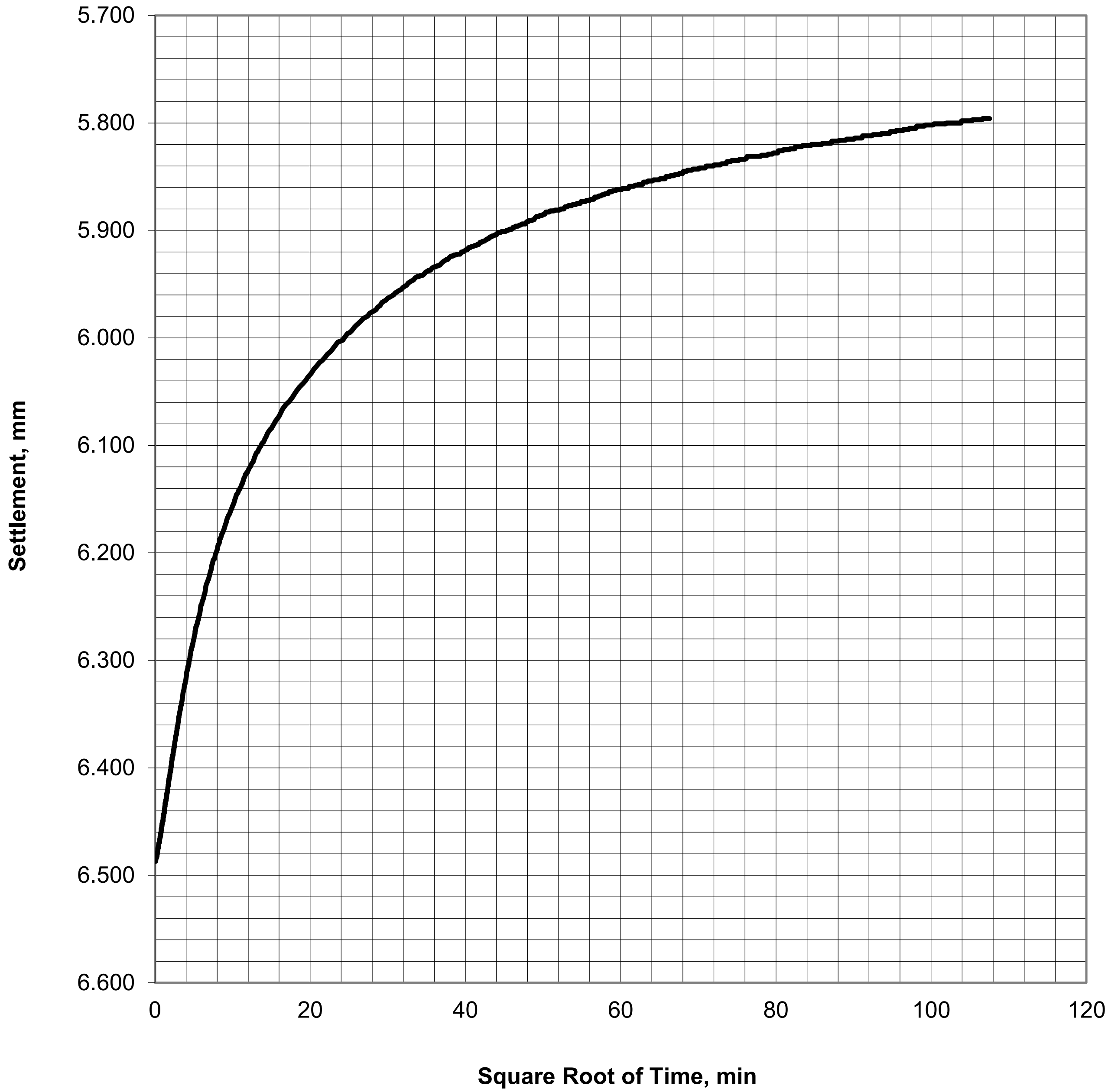
FIG. B-26

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-4-12	Tested By/Date	AKV 1/25/2013
Sample	S-2	Calculated By/Date	JFL 2/27/2013
Depth, ft	5.4	Checked By/Date	JFL 2/27/2013



Increment Number 22

Applied Stress, tsf 0.13

NOTES:
1. Abbreviations:
 ft = feet
 min = minutes
 mm = mimilimeters
 tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-4-12, SAMPLE S-2 @5.4ft

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FIG. B-26

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-4-12	Tested By/Date	JFL 1/9/2013
Sample	S-6	Calculated By/Date	JFL 1/22/2013
Depth, ft	15.6	Checked By/Date	JFL 2/26/2013

SAMPLE CLASSIFICATION:
Gray, slightly clayey SILT, trace of fine sand; trace of fine organics; ML

SAMPLE DATA:

Specific Gravity (estimated)	2.7
Liquid Limit	31
Plastic Limit	27
Plasticity Index	4

SPECIMEN DATA:

	Before Inundation	First Load	Final Load
Height, inches	0.789	0.789	0.652
Diameter, inches	2.816	2.816	2.816
Sample Volume, cuin	4.913	4.913	4.061
Wet Density, pcf	115.6	115.6	128.6
Dry Density, pcf	85.0	85.0	102.9
Water Content, %	36%	36%	25%
Void Ratio	0.98	0.98	0.64
Saturation, %	99%	99%	100%

Increment	Applied Stress, tsf	ΔH at t_{100}, in	ΔH / H_o	Void Ratio	t_{50}, min	Coeff. of Comp., MPa^{-1}	Coeff. of Consol., cm^2/sec	Coeff. of Perm., cm/sec
1	0.03	0.000	0.0%	0.982	395.5	0.20	2.72E-04	2.7E-09
2	0.05	0.001	0.1%	0.980	0.1	0.81	1.92E-02	7.7E-07
3	0.10	0.003	0.3%	0.976	0.3	0.91	1.66E-02	7.5E-07
4	0.20	0.006	0.7%	0.969	0.1	0.73	2.81E-02	1.0E-06
5	0.41	0.010	1.3%	0.956	0.1	0.62	3.54E-02	1.1E-06
6	0.81	0.018	2.3%	0.937	0.1	0.49	4.62E-02	1.1E-06
7	1.63	0.029	3.7%	0.910	0.1	0.35	2.40E-02	4.3E-07
8	3.26	0.046	5.9%	0.866	0.1	0.28	5.65E-02	8.1E-07
9	6.51	0.066	8.4%	0.817	0.1	0.16	8.51E-02	7.1E-07
10	13.03	0.089	11.3%	0.760	0.1	0.09	1.14E-01	5.6E-07
11	26.05	0.117	14.8%	0.689	0.1	0.06	7.15E-02	2.3E-07
12	39.08	0.132	16.8%	0.650	0.0	0.03	1.16E-01	2.1E-07
13	52.92	0.146	18.5%	0.615	0.0	0.03	9.74E-02	1.5E-07
14	13.03	0.149	18.9%	0.609	0.1	0.00	5.47E-02	5.7E-09
15	3.26	0.145	18.4%	0.618	0.0	0.01	3.68E-02	2.3E-08
16	0.81	0.140	17.8%	0.630	0.2	0.05	1.27E-02	3.9E-08
17	0.20	0.1347	17.07%	0.644	2.8	0.237	7.32E-03	1.0E-07

NOTES:
1. Abbreviations:
cm = centimeter
cm^2 = square centimeter
Coeff. = Coefficient
Comp. = Compressibility
Consol. = Consolidation
cu in = cubic inch
ft = feet
H_o = initial height
ΔH = change in height
in = inch
min = minute
MPa = megapascal
pcf = pounts per cubic foot
Perm. = Permeability
sec = second
t_n = time at n% of primary consolidation
tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST SUMMARY
BORING B-4-12, SAMPLE S-6 @15.6ft

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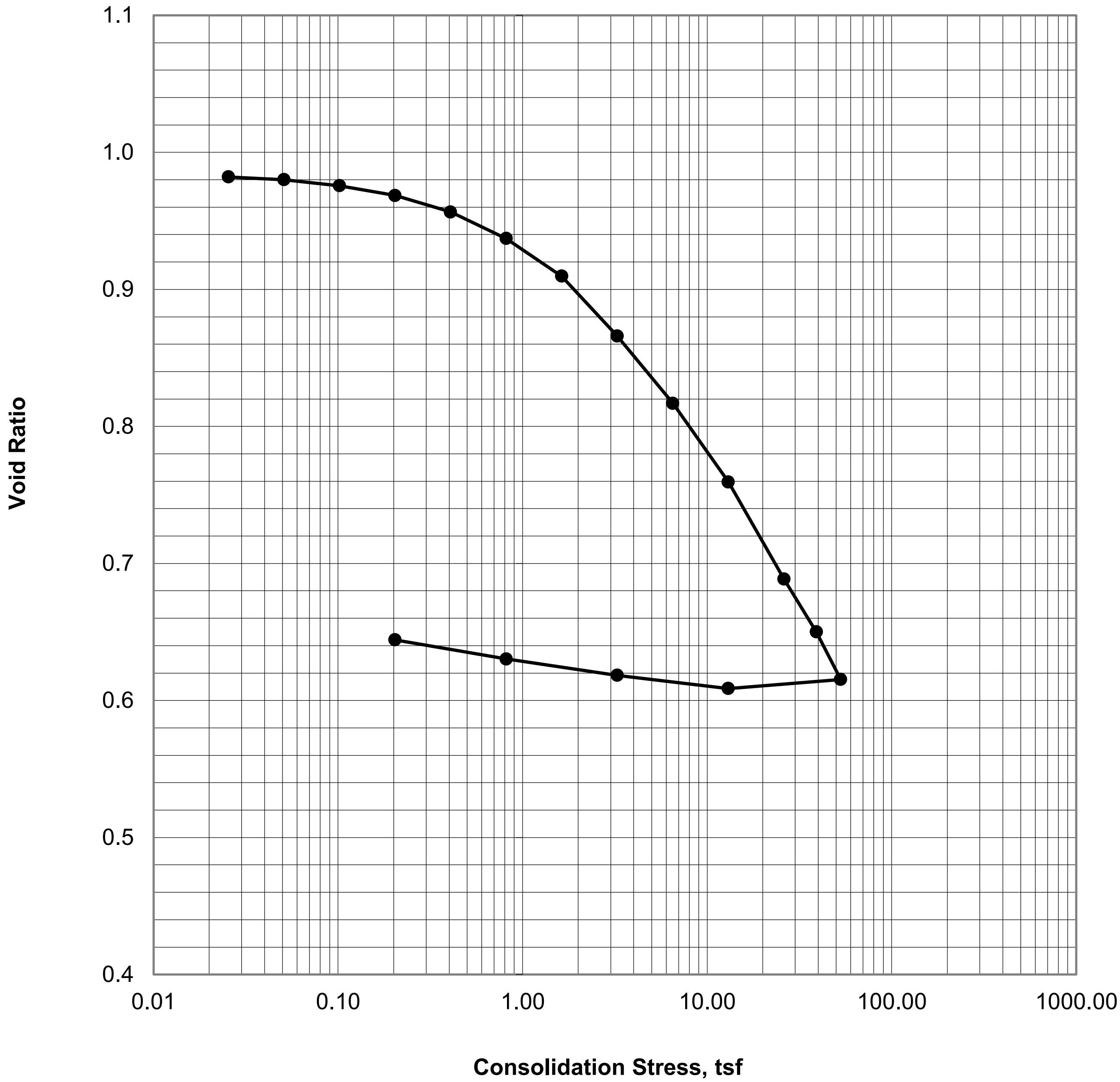
SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B-27

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-4-12	Tested By/Date	JFL 1/9/2013
Sample	S-6	Calculated By/Date	JFL 1/22/2013
Depth, ft	15.6	Checked By/Date	JFL 2/26/2013



Maximum Load, tsf 52.92

NOTES:
1. Abbreviations:
ft = feet
tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION VOID RATIO vs STRESS PLOT BORING B-4-12, SAMPLE S-6 @15.6ft

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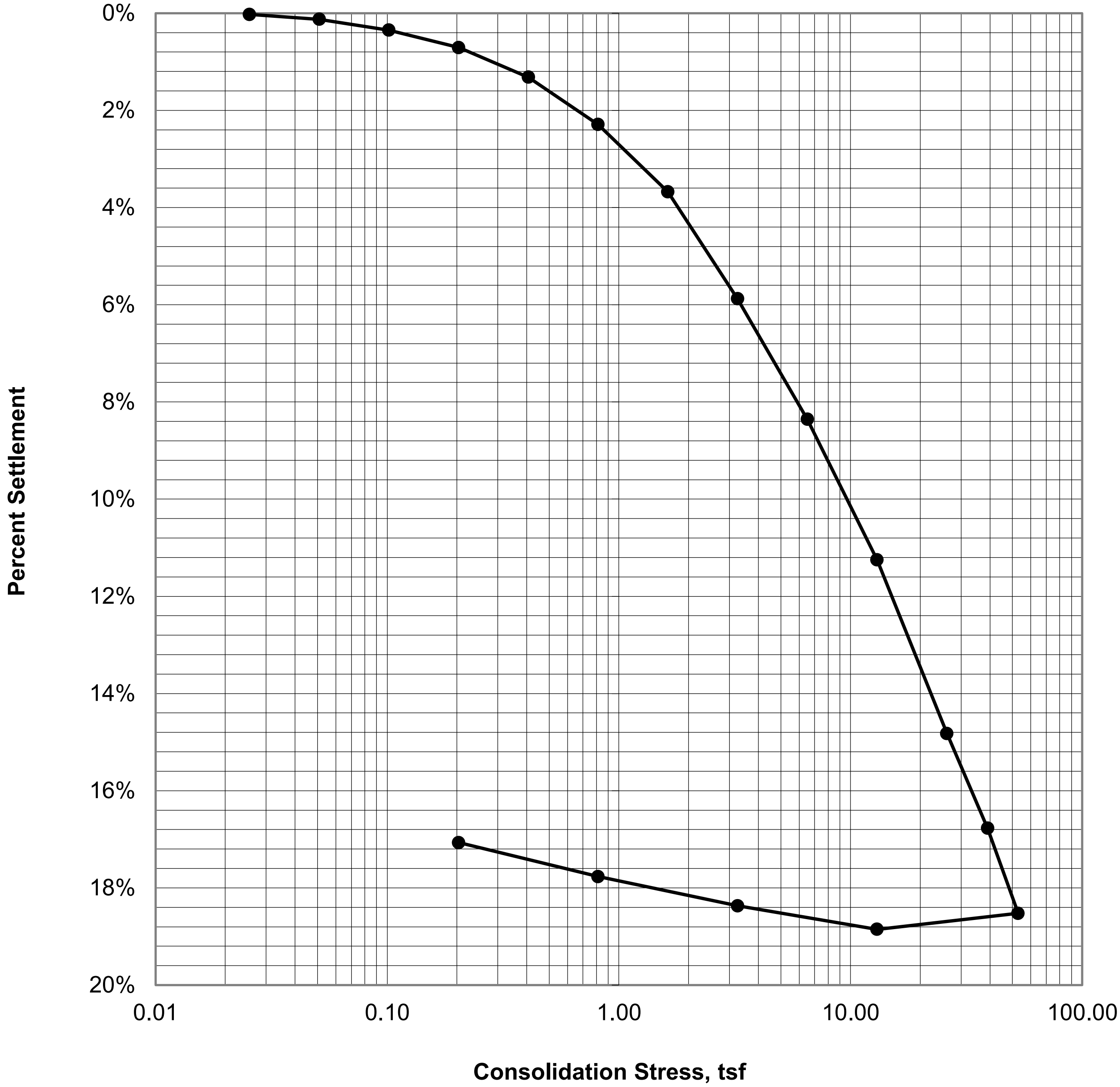
SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B-28

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-4-12	Tested By/Date	JFL 1/9/2013
Sample	S-6	Calculated By/Date	JFL 1/22/2013
Depth, ft	15.6	Checked By/Date	JFL 2/26/2013



Maximum Load, tsf 52.92

NOTES:
1. Abbreviations:
ft = feet
tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION PERCENT SETTLEMENT vs STRESS PLOT BORING B-4-12, SAMPLE S-6 @15.6ft

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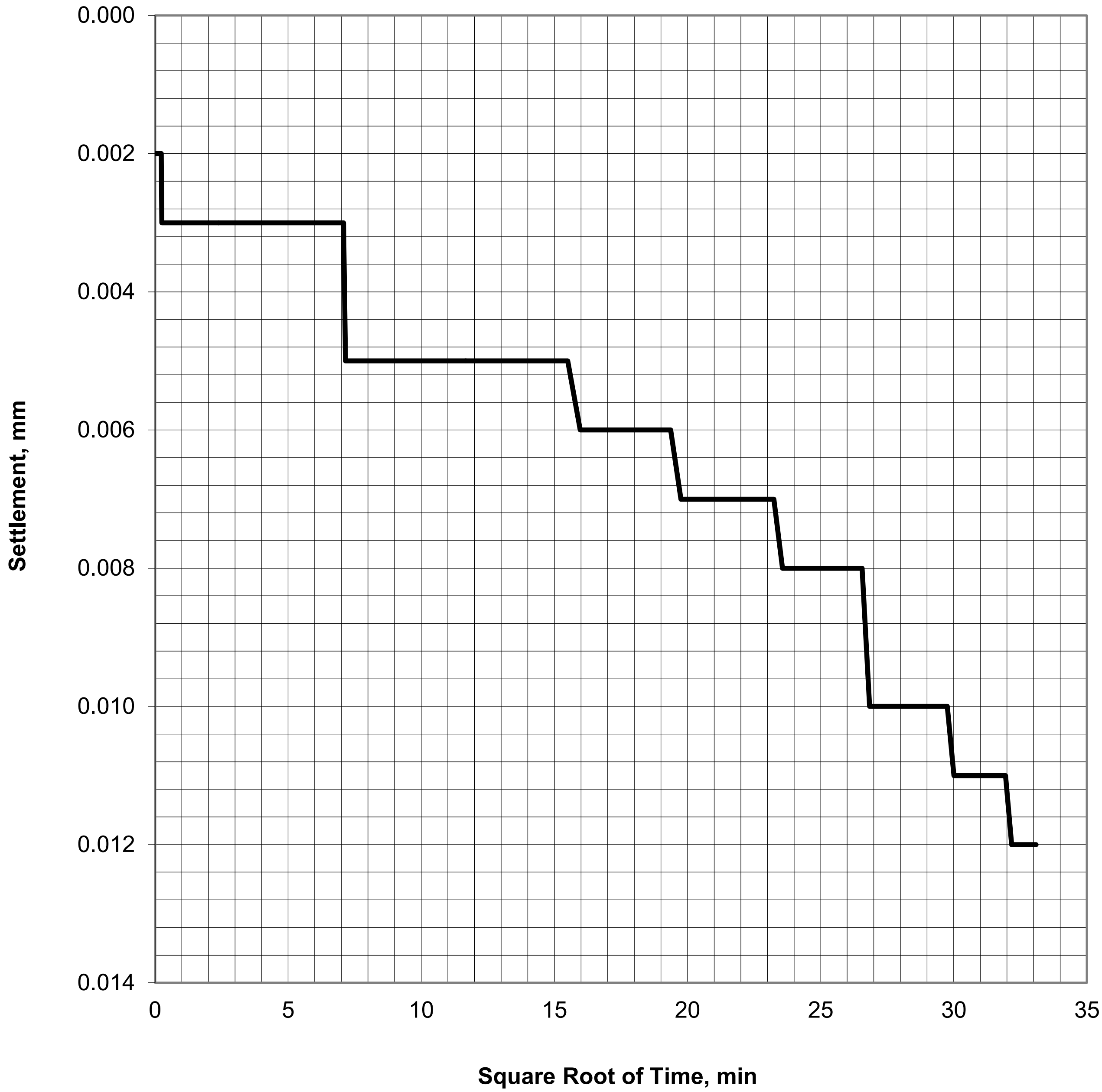
SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B-29

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-4-12	Tested By/Date	JFL 1/9/2013
Sample	S-6	Calculated By/Date	JFL 1/22/2013
Depth, ft	15.6	Checked By/Date	JFL 2/26/2013



Increment Number 1

Applied Stress, tsf 0.03

NOTES:
1. Abbreviations:
   ft = feet
   min = minutes
   mm = mimilimeters
   tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-4-12, SAMPLE S-6 @15.6ft

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SHANNON & WILSON, INC.
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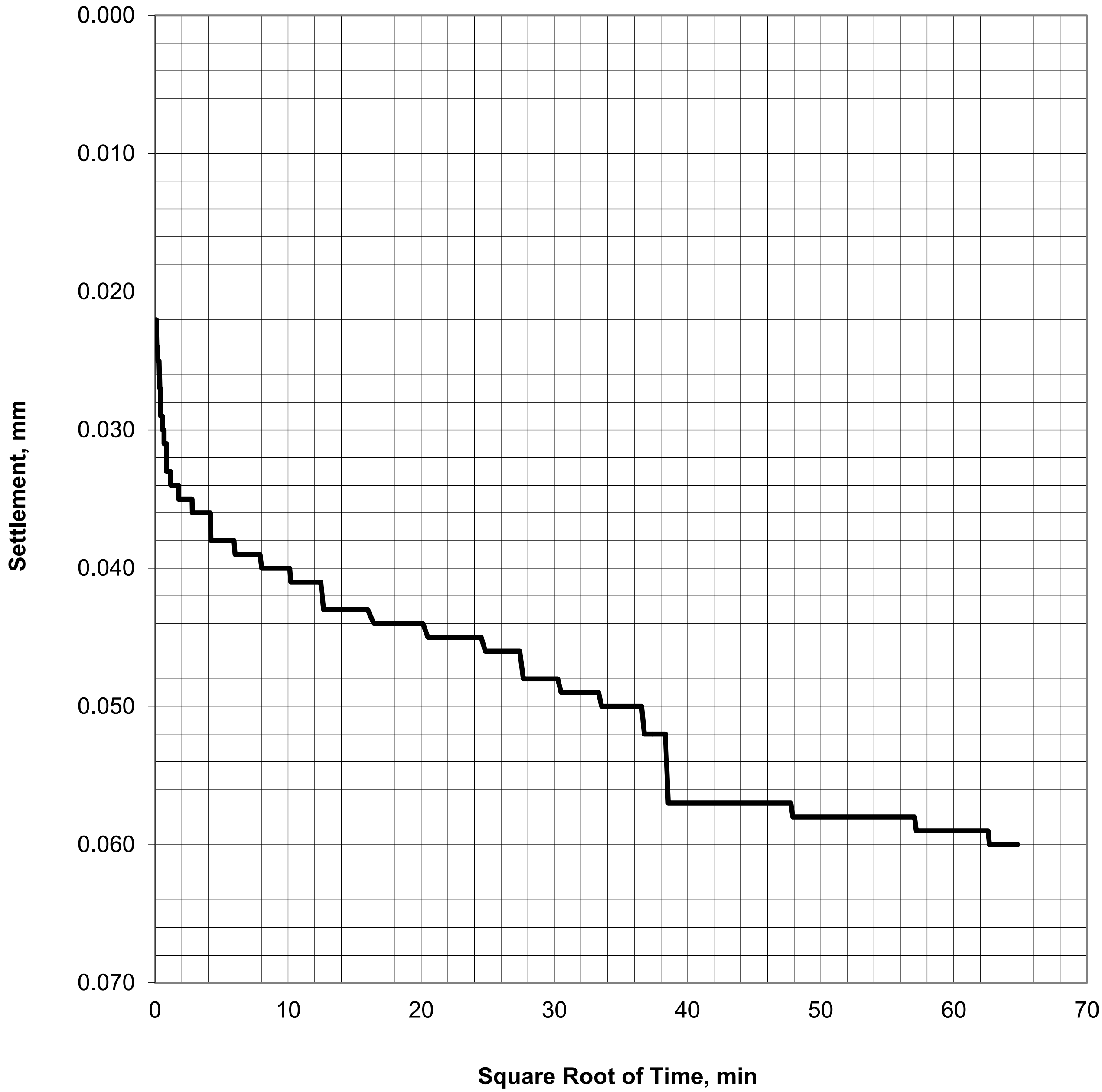
FIG. B-30
Sheet 1 of 17

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-4-12	Tested By/Date	JFL 1/9/2013
Sample	S-6	Calculated By/Date	JFL 1/22/2013
Depth, ft	15.6	Checked By/Date	JFL 2/26/2013



Increment Number 2

Applied Stress, tsf 0.05

NOTES:
1. Abbreviations:
ft = feet
min = minutes
mm = mimilimeters
tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT BORING B-4-12, SAMPLE S-6 @15.6ft

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SHANNON & WILSON, INC.
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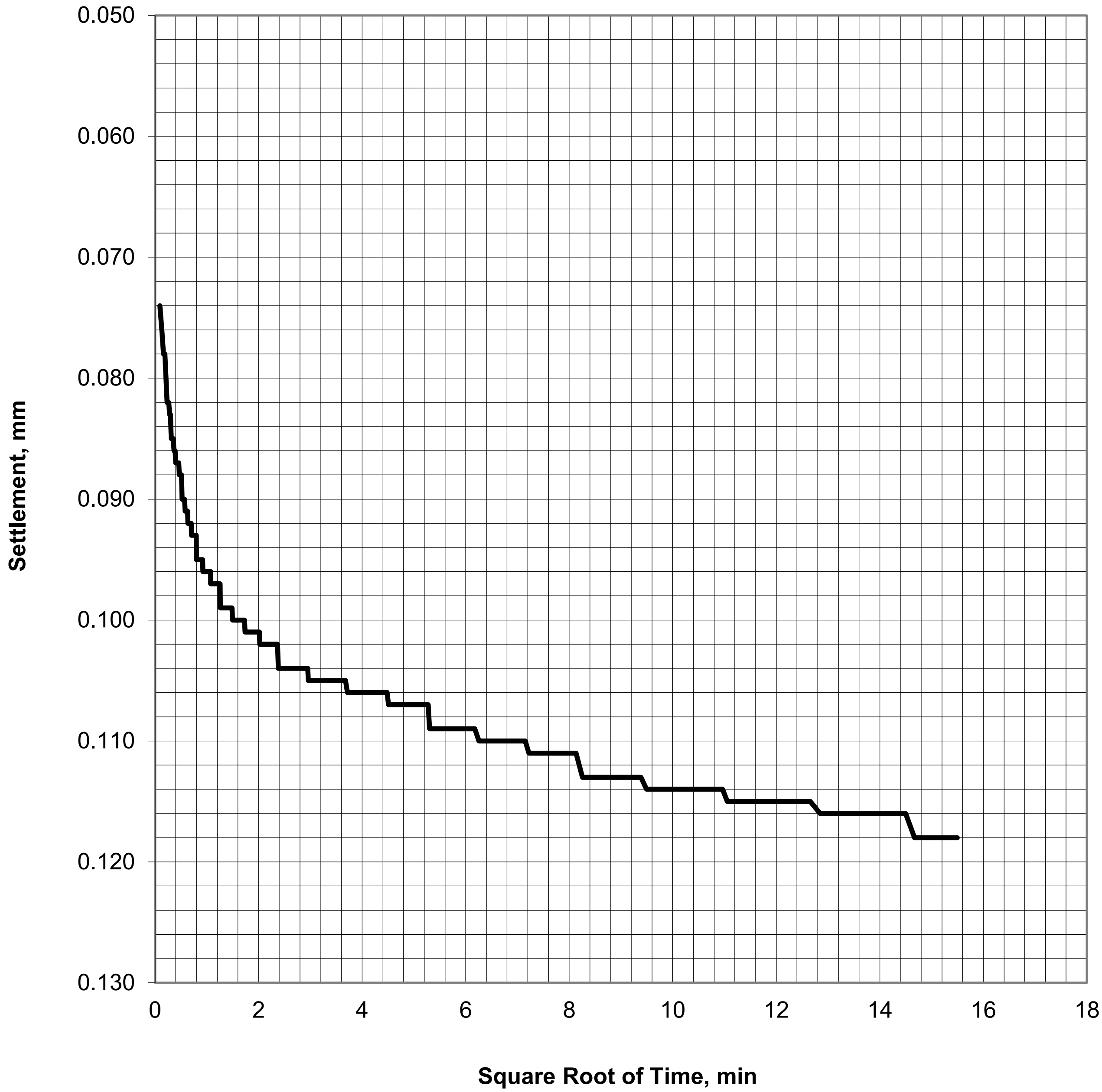
FIG. B-30
Sheet 2 of 17

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-4-12	Tested By/Date	JFL 1/9/2013
Sample	S-6	Calculated By/Date	JFL 1/22/2013
Depth, ft	15.6	Checked By/Date	JFL 2/26/2013



Increment Number 3

Applied Stress, tsf 0.10

NOTES:
1. Abbreviations:
   ft = feet
   min = minutes
   mm = mimilimeters
   tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-4-12, SAMPLE S-6 @15.6ft

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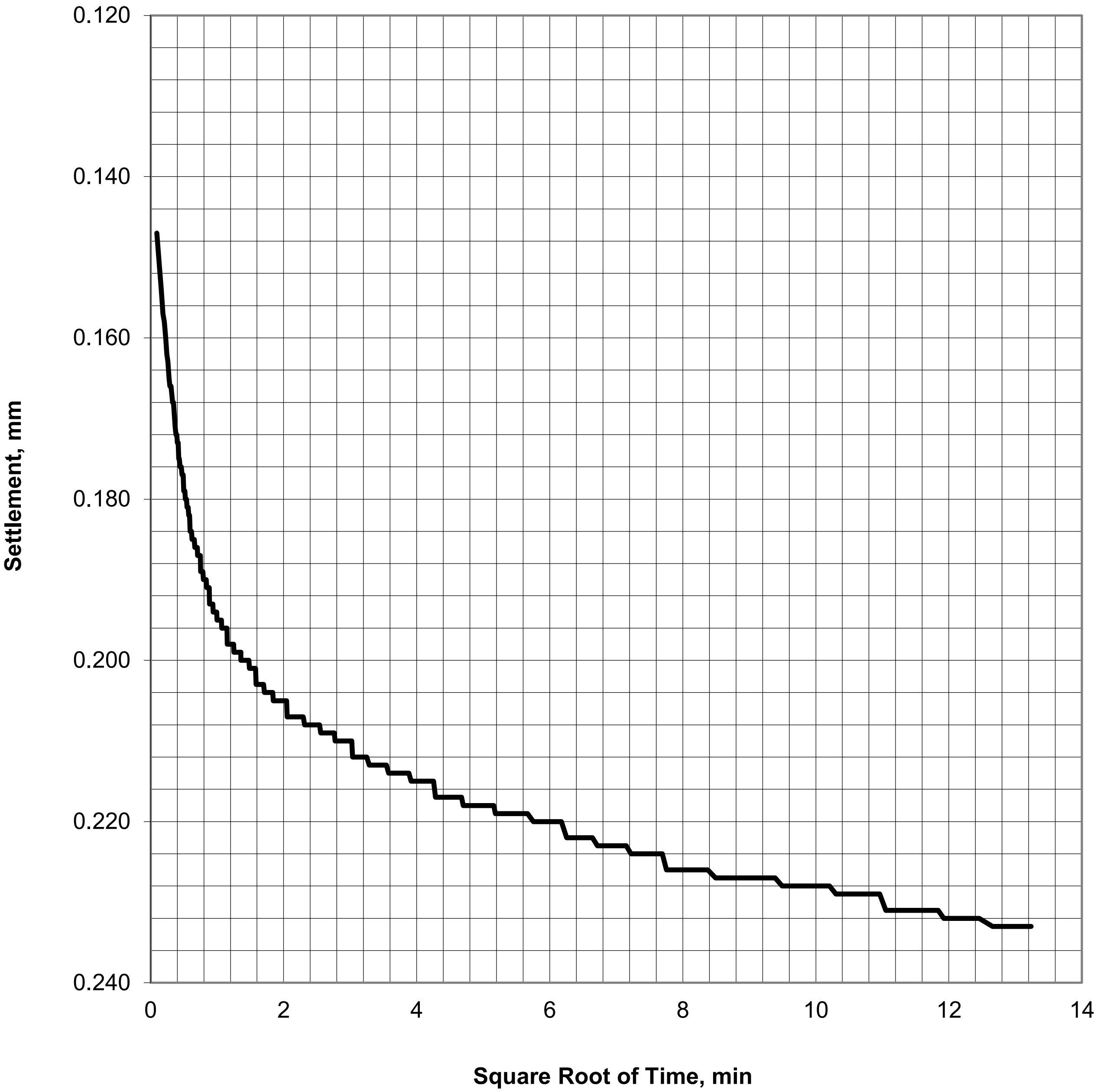
SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B-30
Sheet 3 of 17

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-4-12	Tested By/Date	JFL 1/9/2013
Sample	S-6	Calculated By/Date	JFL 1/22/2013
Depth, ft	15.6	Checked By/Date	JFL 2/26/2013



Increment Number 4

Applied Stress, tsf 0.20

NOTES:
1. Abbreviations:
ft = feet
min = minutes
mm = mimilimeters
tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-4-12, SAMPLE S-6 @15.6ft

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SHANNON & WILSON, INC.
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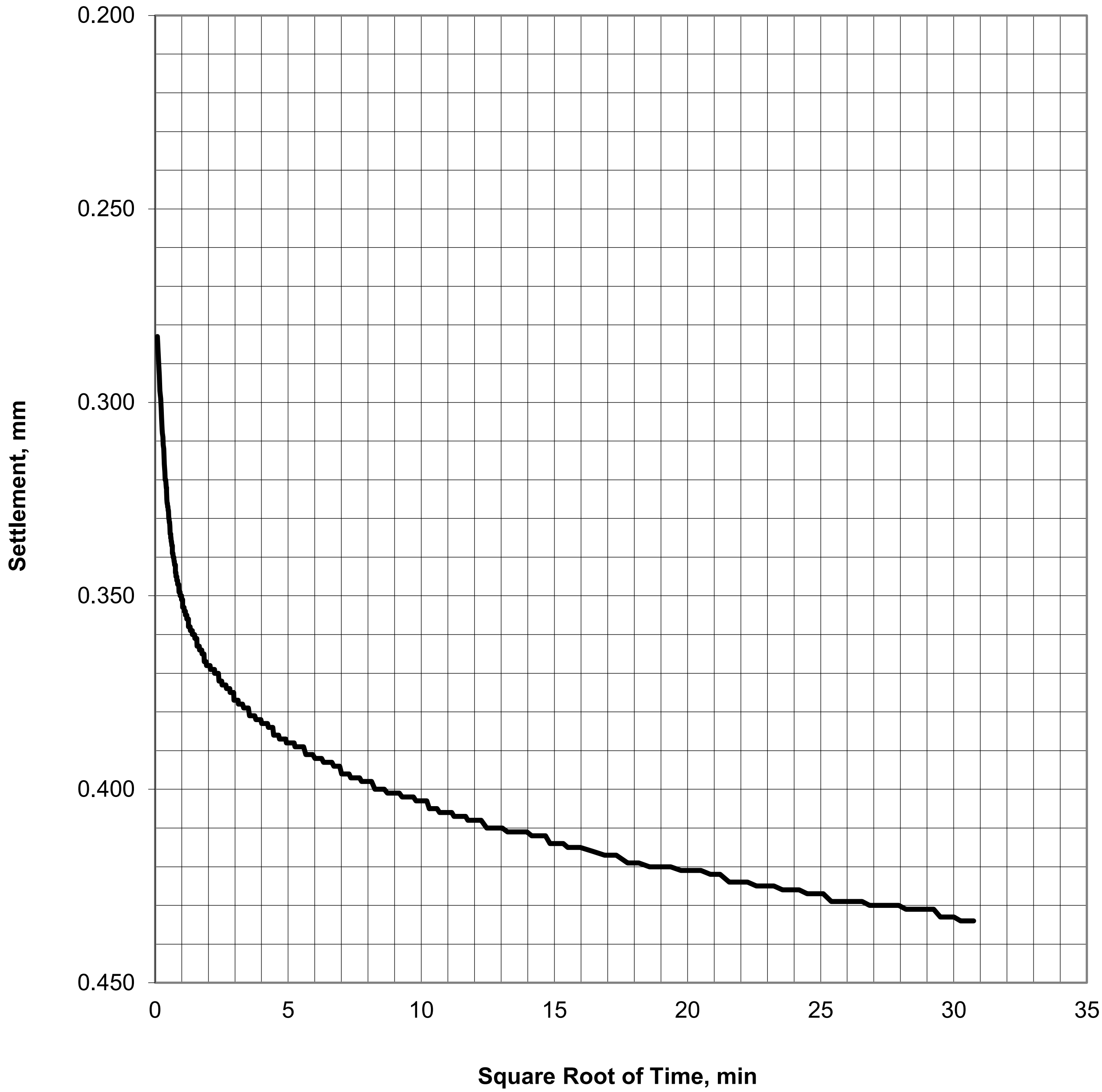
FIG. B-30

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-4-12	Tested By/Date	JFL 1/9/2013
Sample	S-6	Calculated By/Date	JFL 1/22/2013
Depth, ft	15.6	Checked By/Date	JFL 2/26/2013



Increment Number 5

Applied Stress, tsf 0.41

NOTES:
1. Abbreviations:
ft = feet
min = minutes
mm = mimilimeters
tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-4-12, SAMPLE S-6 @15.6ft

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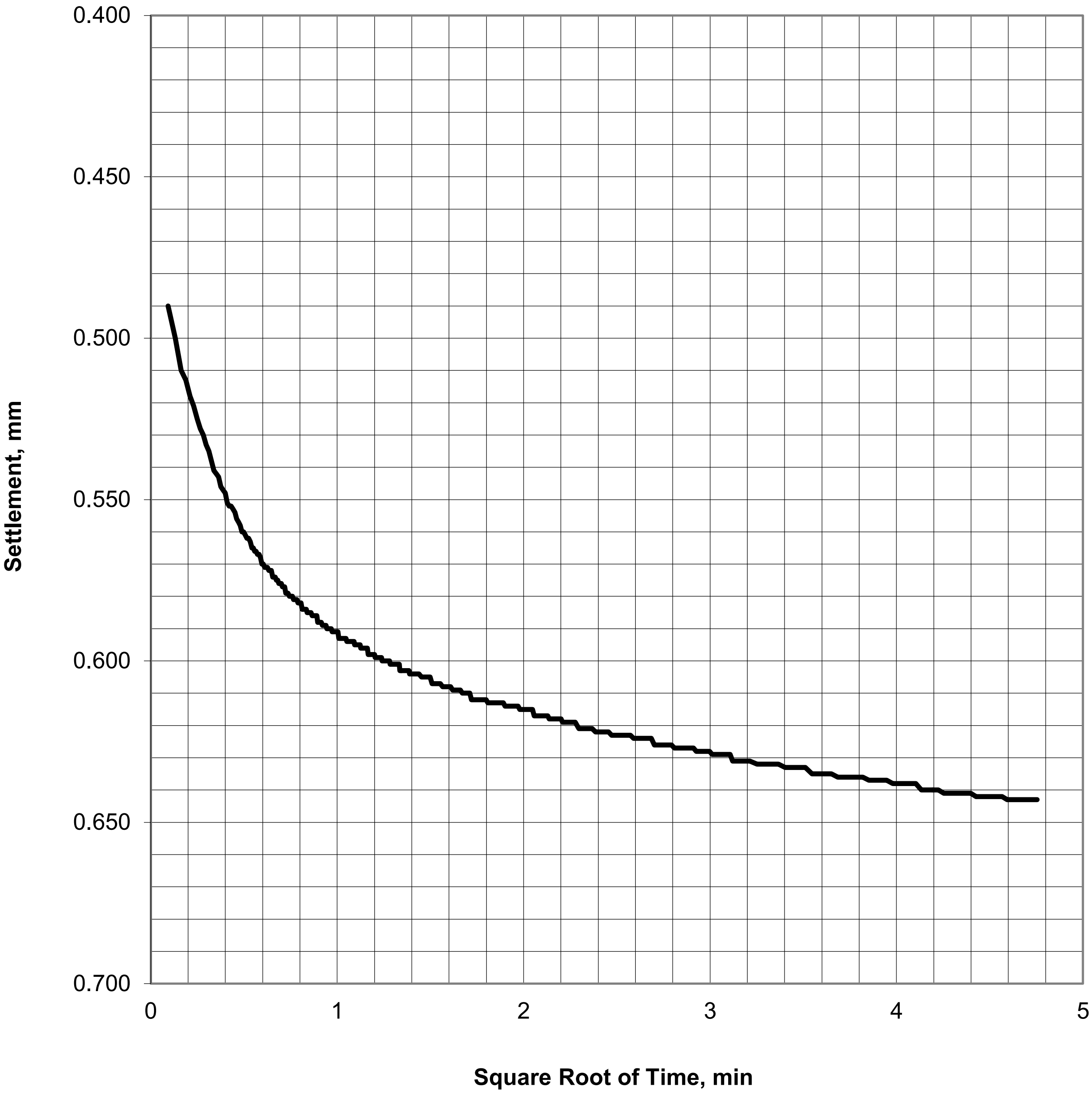
SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B-30

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-4-12	Tested By/Date	JFL 1/9/2013
Sample	S-6	Calculated By/Date	JFL 1/22/2013
Depth, ft	15.6	Checked By/Date	JFL 2/26/2013



Increment Number 6

Applied Stress, tsf 0.81

NOTES:
1. Abbreviations:
   ft = feet
   min = minutes
   mm = mimilimeters
   tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-4-12, SAMPLE S-6 @15.6ft

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SHANNON & WILSON, INC.
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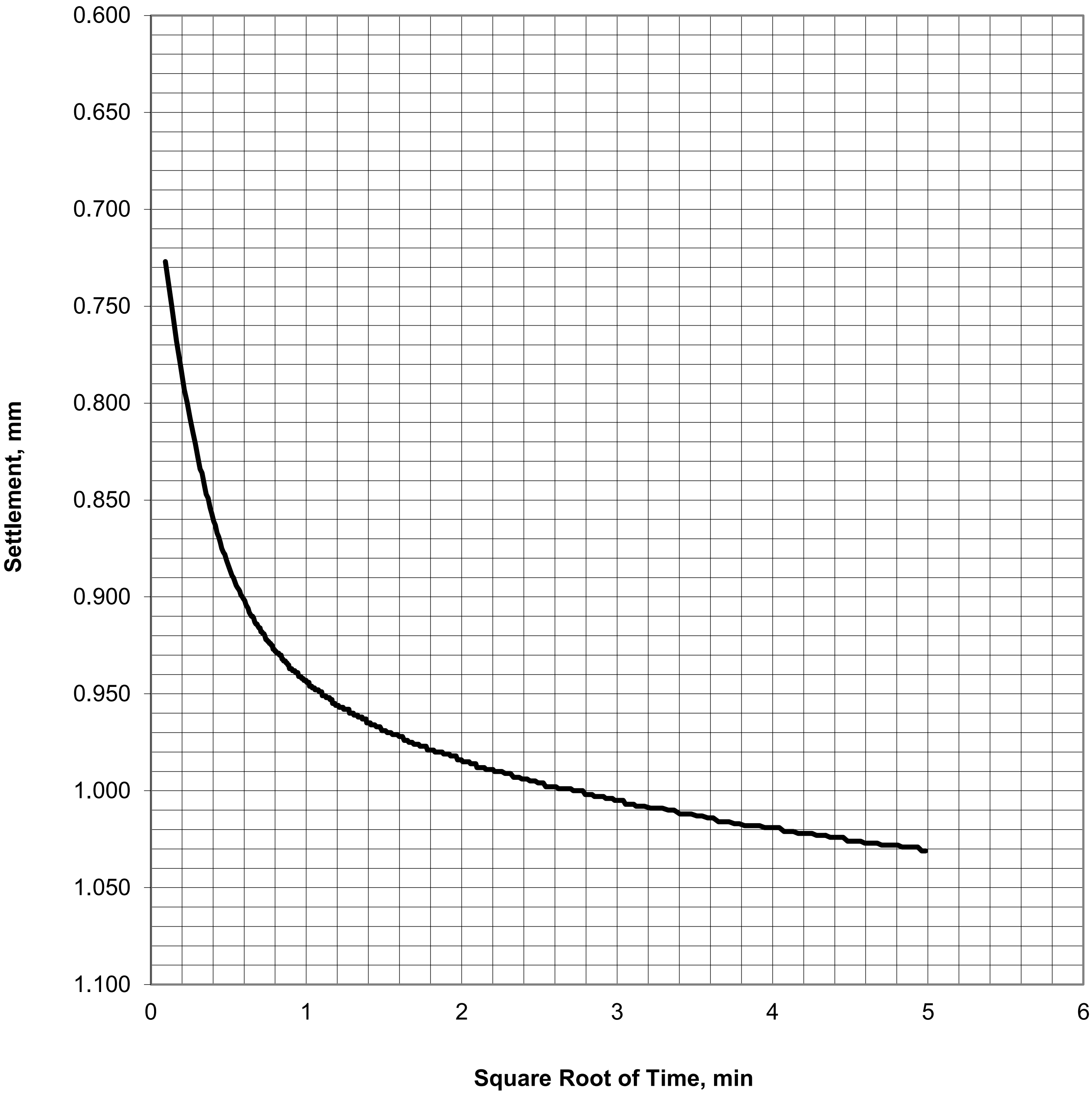
FIG. B-30

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-4-12	Tested By/Date	JFL 1/9/2013
Sample	S-6	Calculated By/Date	JFL 1/22/2013
Depth, ft	15.6	Checked By/Date	JFL 2/26/2013



Increment Number 7

Applied Stress, tsf 1.63

NOTES:
1. Abbreviations:
ft = feet
min = minutes
mm = mimilimeters
tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-4-12, SAMPLE S-6 @15.6ft

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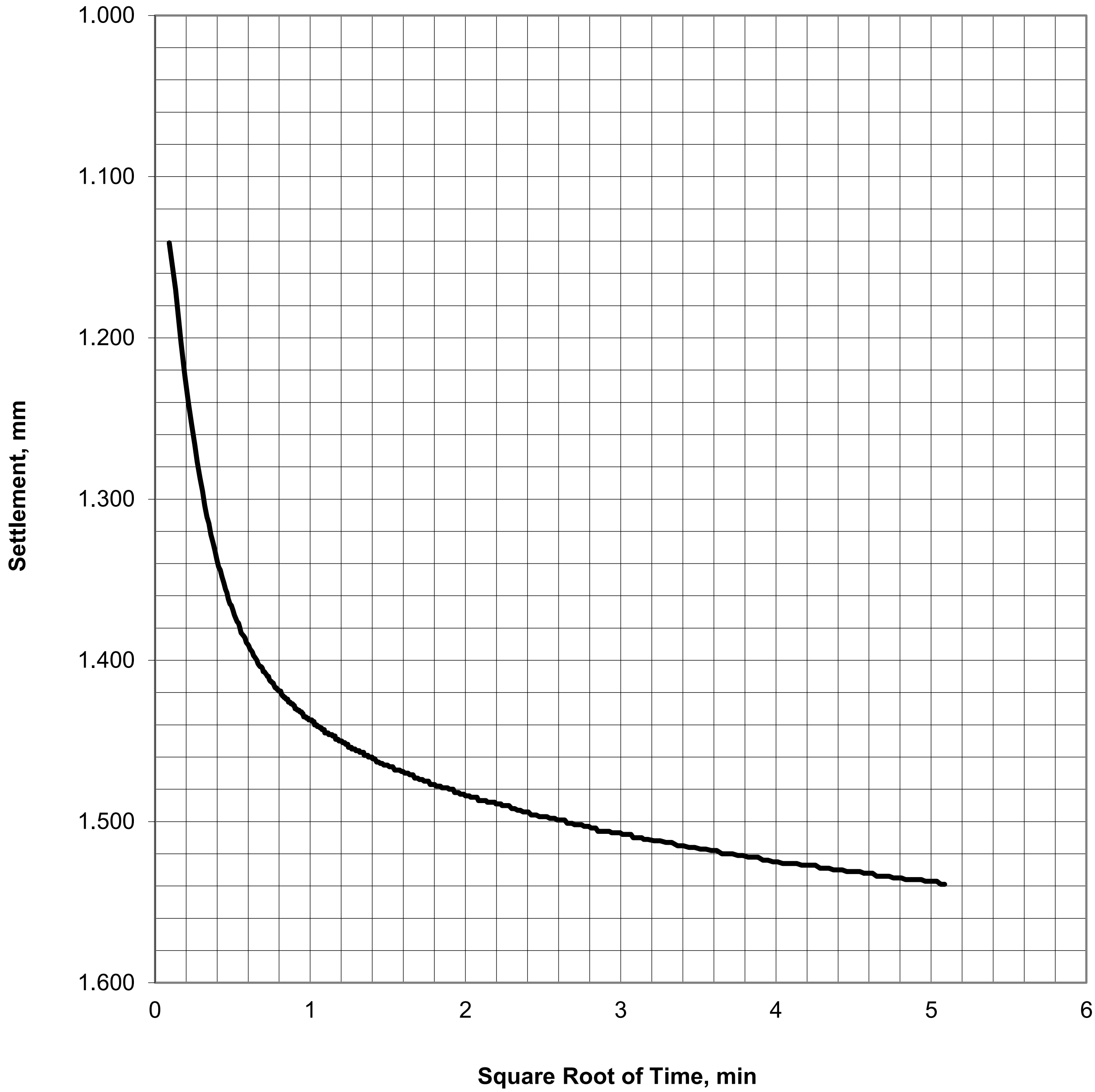
FIG. B-30
Sheet 7 of 17

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-4-12	Tested By/Date	JFL 1/9/2013
Sample	S-6	Calculated By/Date	JFL 1/22/2013
Depth, ft	15.6	Checked By/Date	JFL 2/26/2013



Increment Number 8

Applied Stress, tsf 3.26

NOTES:
1. Abbreviations:
- ft = feet
- min = minutes
- mm = mimilimeters
- tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-4-12, SAMPLE S-6 @15.6ft

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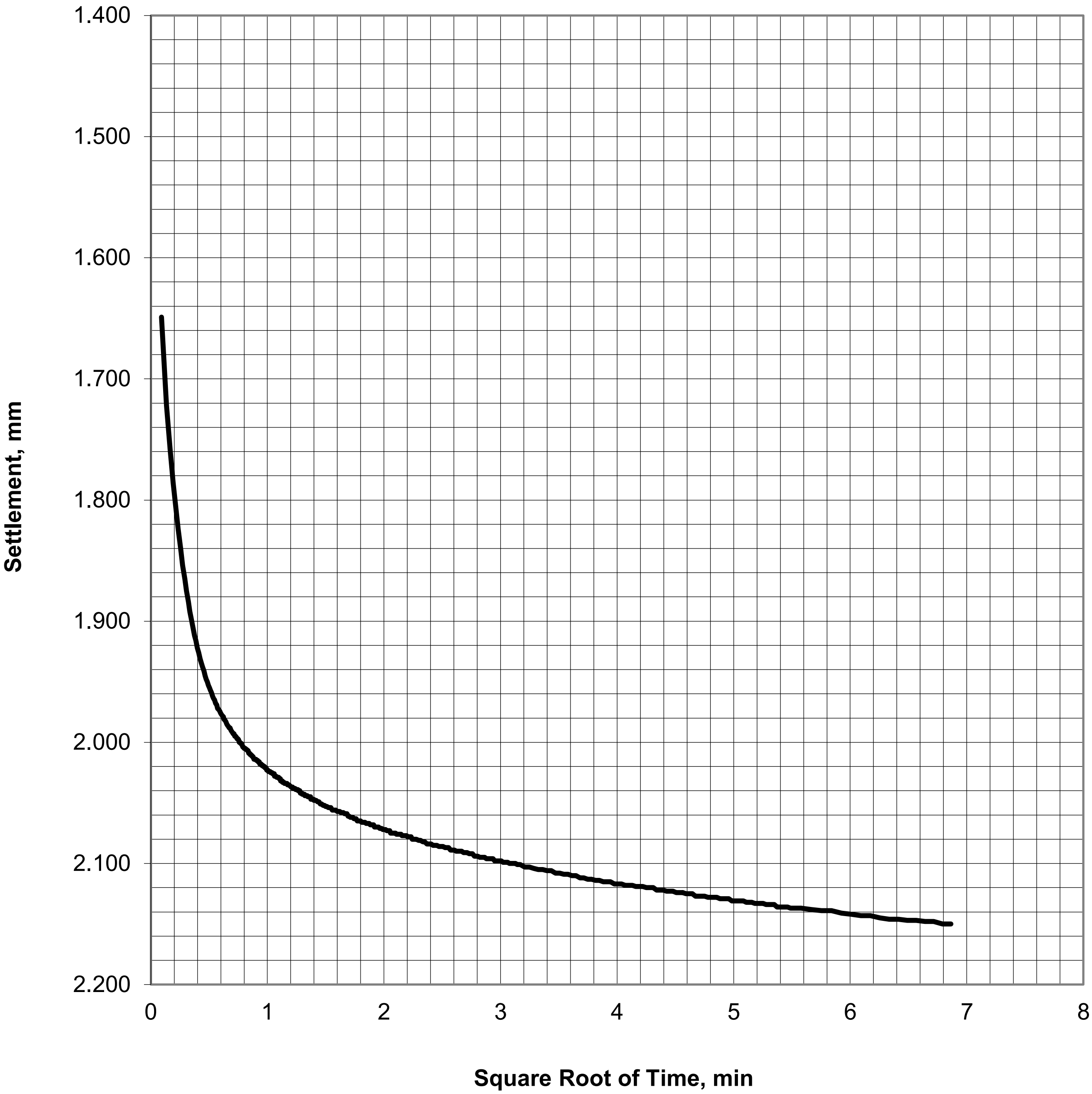
SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B-30

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-4-12	Tested By/Date	JFL 1/9/2013
Sample	S-6	Calculated By/Date	JFL 1/22/2013
Depth, ft	15.6	Checked By/Date	JFL 2/26/2013



Increment Number 9

Applied Stress, tsf 6.51

NOTES:
1. Abbreviations:
ft = feet
min = minutes
mm = mimilimeters
tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-4-12, SAMPLE S-6 @15.6ft

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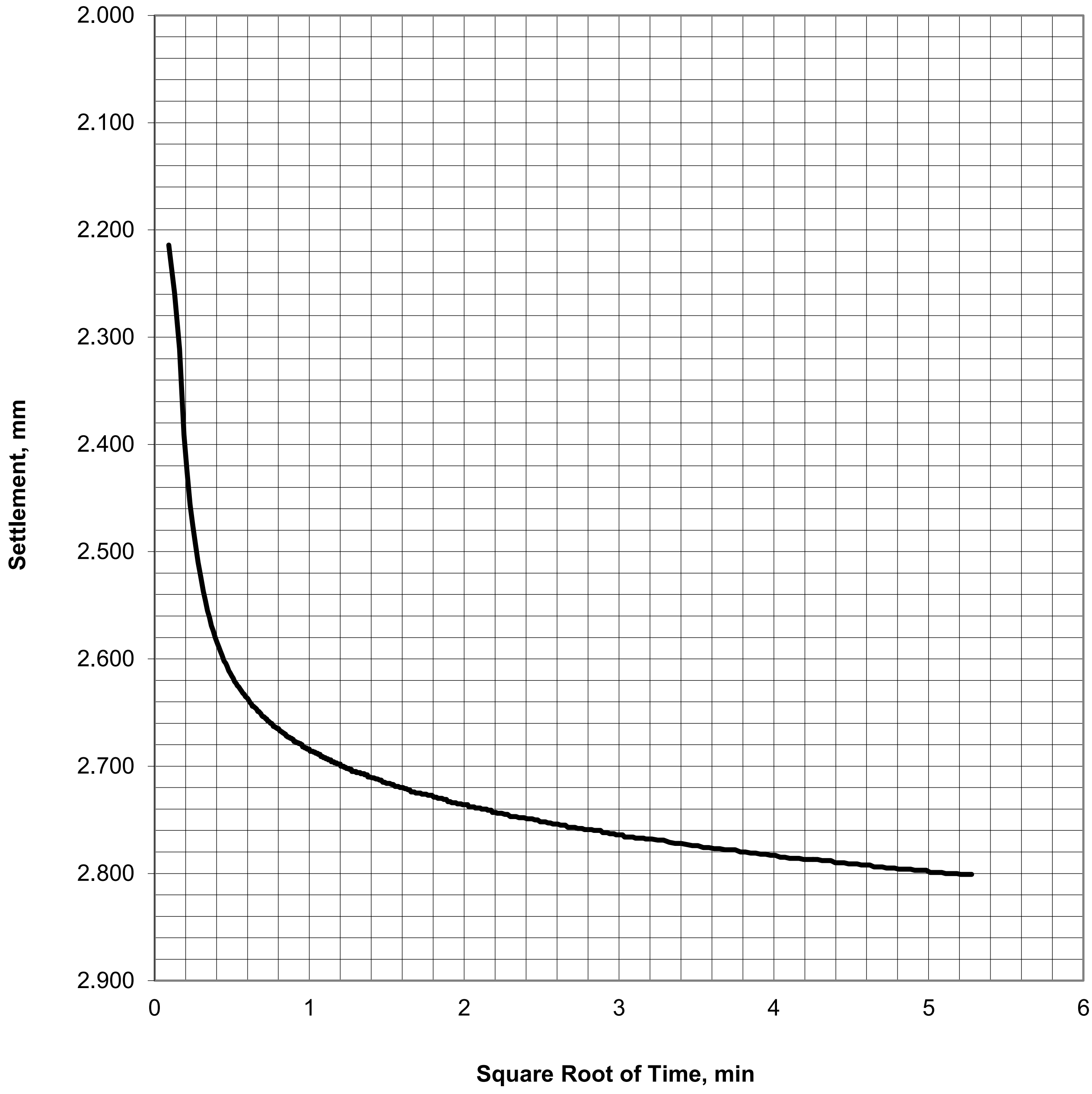
FIG. B-30

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-4-12	Tested By/Date	JFL 1/9/2013
Sample	S-6	Calculated By/Date	JFL 1/22/2013
Depth, ft	15.6	Checked By/Date	JFL 2/26/2013



Increment Number 10

Applied Stress, tsf 13.03

NOTES:
1. Abbreviations:
ft = feet
min = minutes
mm = mimilimeters
tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-4-12, SAMPLE S-6 @15.6ft

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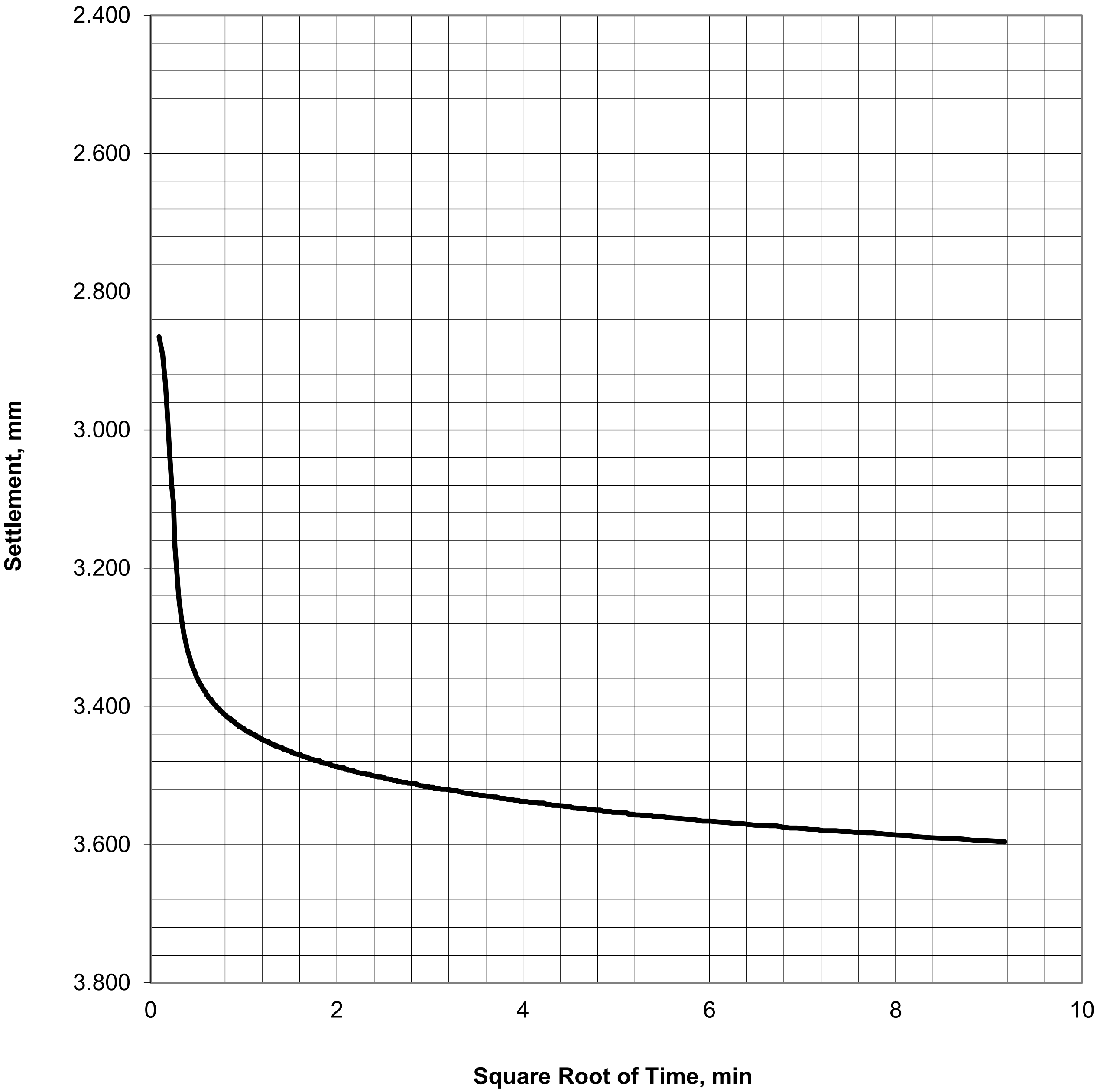
FIG. B-30
Sheet 10 of 17

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-4-12	Tested By/Date	JFL 1/9/2013
Sample	S-6	Calculated By/Date	JFL 1/22/2013
Depth, ft	15.6	Checked By/Date	JFL 2/26/2013



Increment Number 11

Applied Stress, tsf 26.05

NOTES:
1. Abbreviations:
   ft = feet
   min = minutes
   mm = mimilimeters
   tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-4-12, SAMPLE S-6 @15.6ft

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SHANNON & WILSON, INC.
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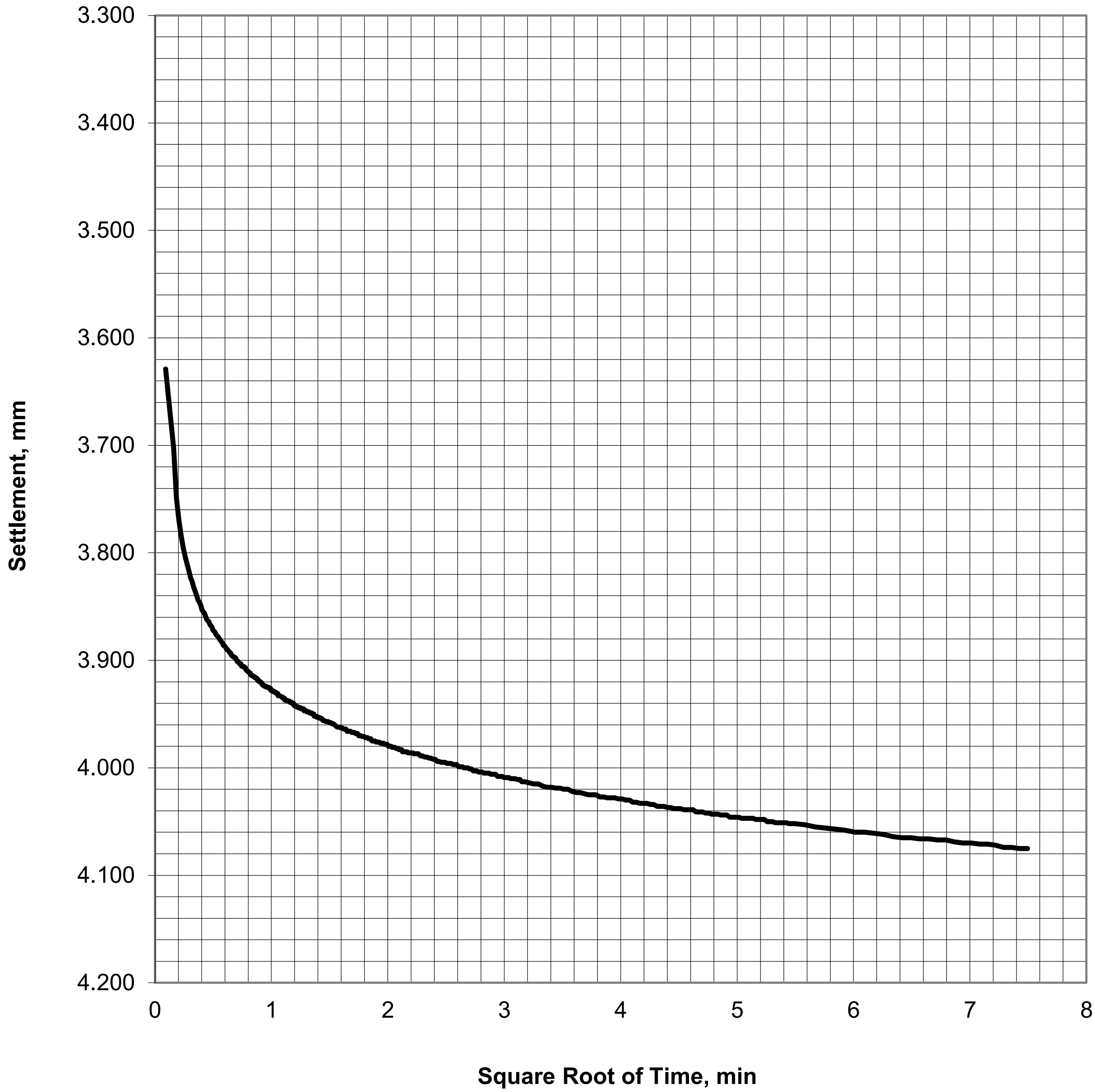
FIG. B-30
Sheet 11 of 17

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-4-12	Tested By/Date	JFL 1/9/2013
Sample	S-6	Calculated By/Date	JFL 1/22/2013
Depth, ft	15.6	Checked By/Date	JFL 2/26/2013



Increment Number 12

Applied Stress, tsf 39.08

NOTES:
1. Abbreviations:
   ft = feet
   min = minutes
   mm = mimilimeters
   tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-4-12, SAMPLE S-6 @15.6ft

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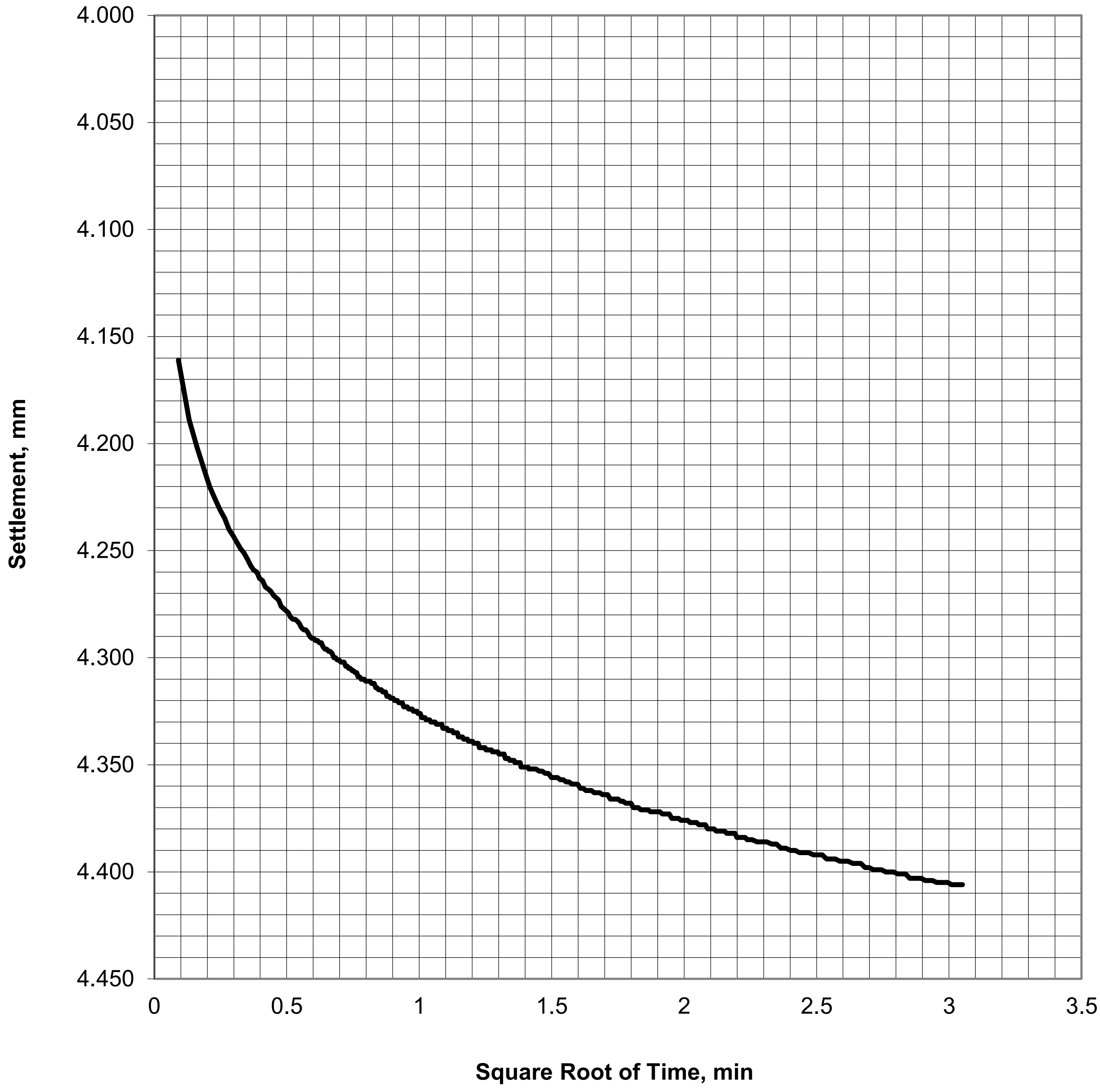
FIG. B-30
Sheet 12 of 17

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-4-12	Tested By/Date	JFL 1/9/2013
Sample	S-6	Calculated By/Date	JFL 1/22/2013
Depth, ft	15.6	Checked By/Date	JFL 2/26/2013



Increment Number 13
Applied Stress, tsf 52.92

NOTES:
1. Abbreviations:
ft = feet
min = minutes
mm = mimilimeters
tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT BORING B-4-12, SAMPLE S-6 @15.6ft

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SHANNON & WILSON, INC.
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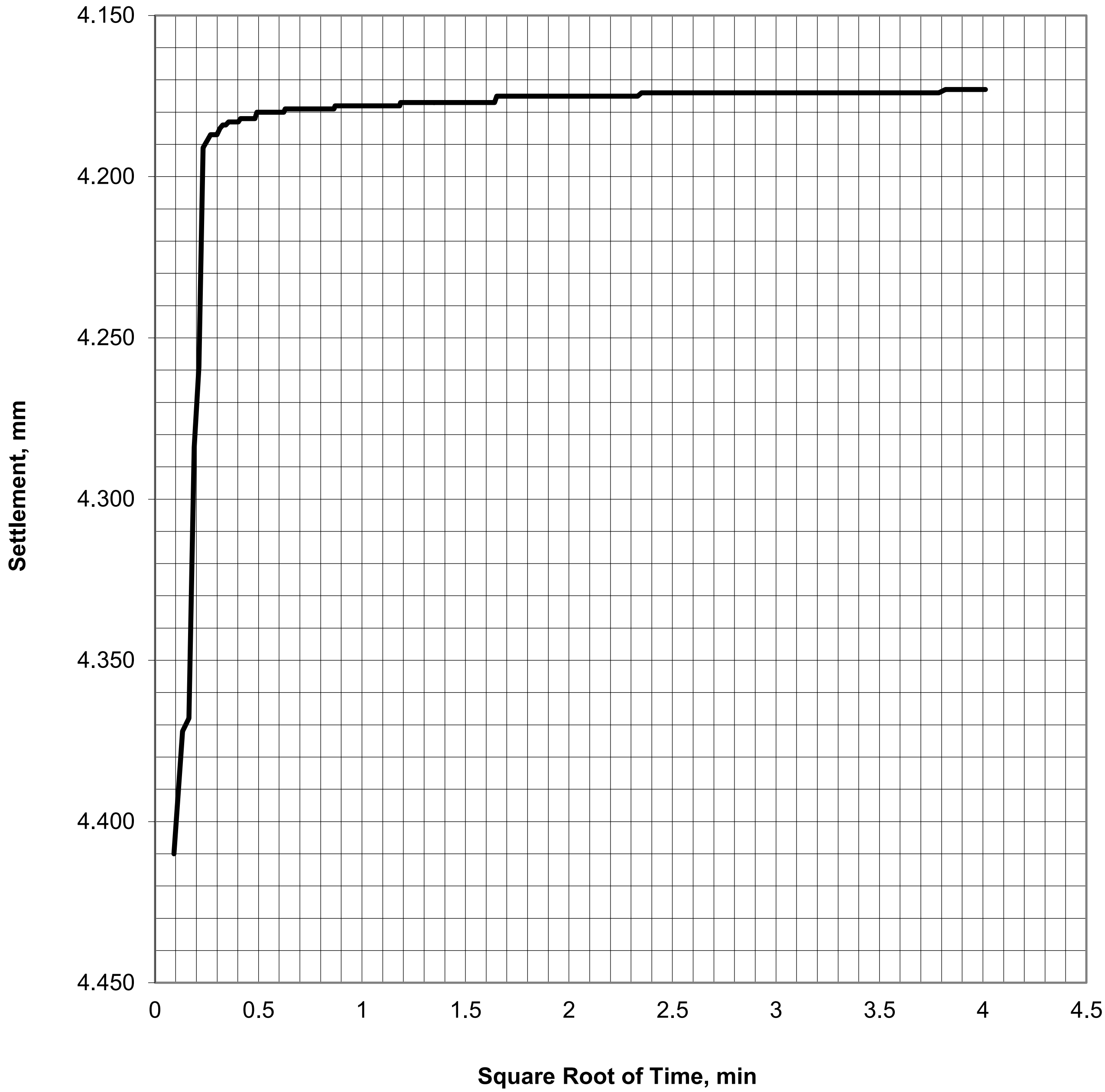
FIG. B-30
Sheet 13 of 17

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-4-12	Tested By/Date	JFL 1/9/2013
Sample	S-6	Calculated By/Date	JFL 1/22/2013
Depth, ft	15.6	Checked By/Date	JFL 2/26/2013



Increment Number 14

Applied Stress, tsf 13.03

NOTES:
1. Abbreviations:
   ft = feet
   min = minutes
   mm = mimilimeters
   tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-4-12, SAMPLE S-6 @15.6ft

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SHANNON & WILSON, INC.
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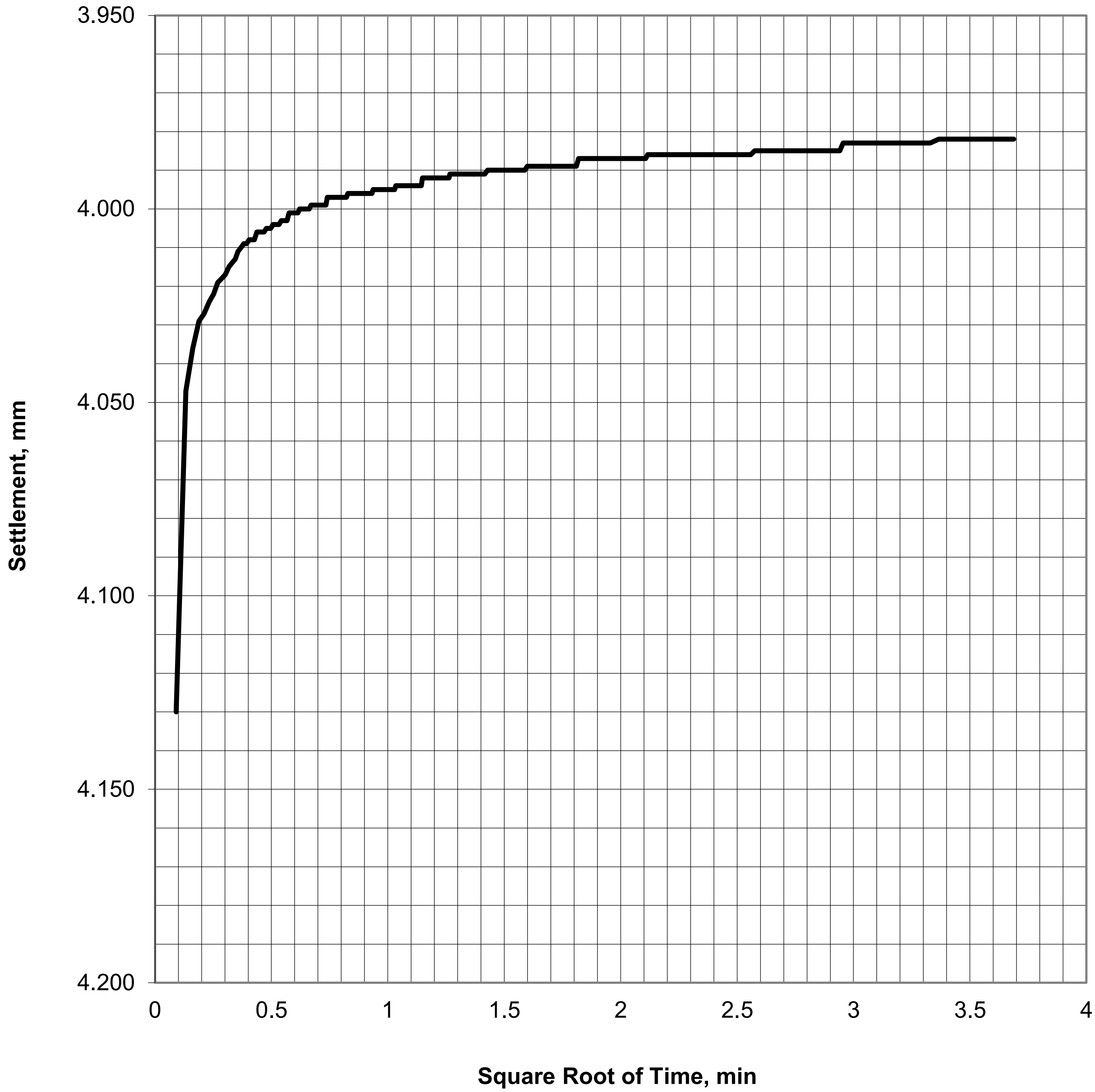
FIG. B-30

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-4-12	Tested By/Date	JFL 1/9/2013
Sample	S-6	Calculated By/Date	JFL 1/22/2013
Depth, ft	15.6	Checked By/Date	JFL 2/26/2013



Increment Number 15

Applied Stress, tsf 3.26

NOTES:
1. Abbreviations:
   - ft = feet
   - min = minutes
   - mm = mimilimeters
   - tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-4-12, SAMPLE S-6 @15.6ft

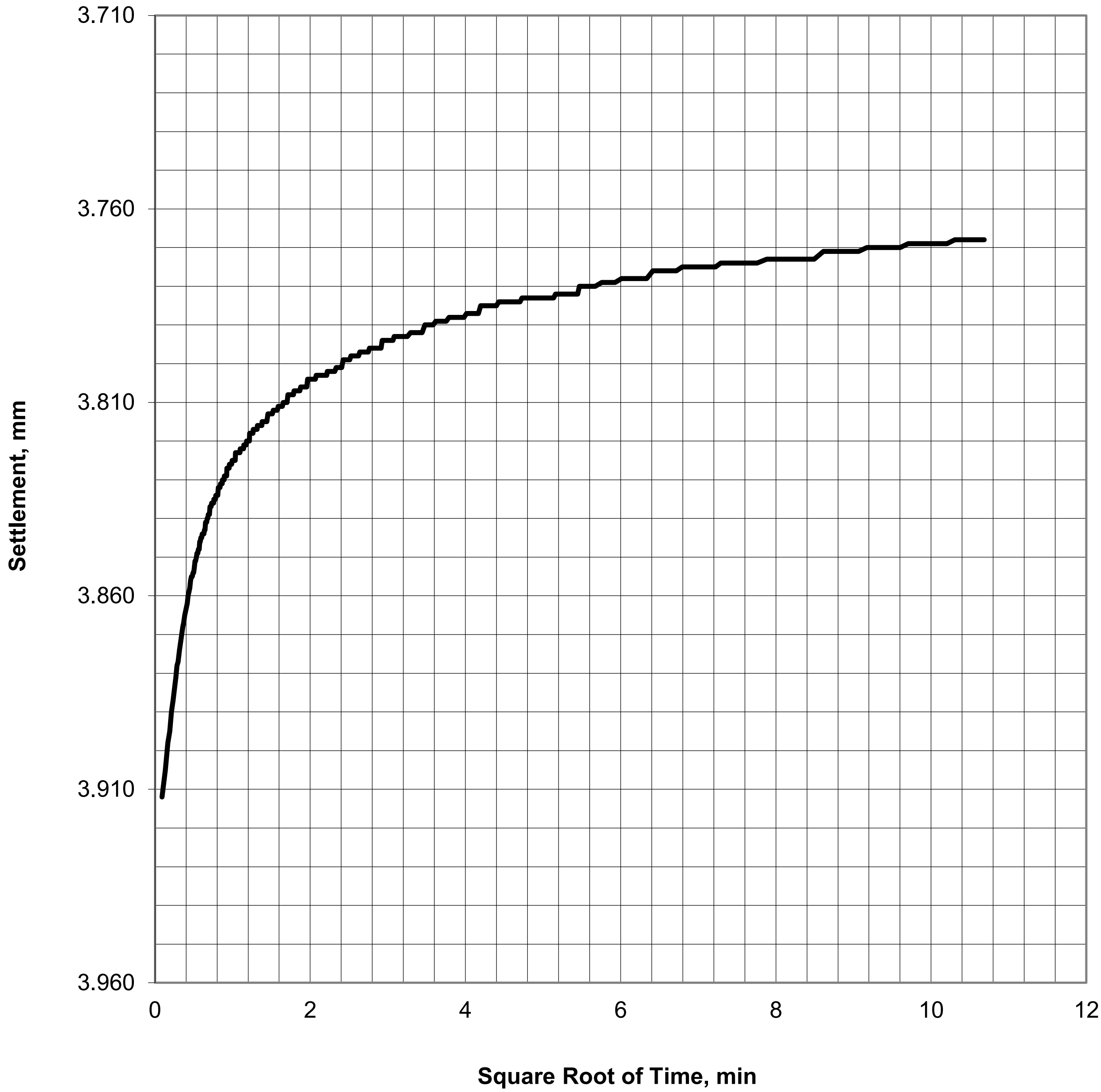
October 2013 21-1-12405-060

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B-30

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-4-12	Tested By/Date	JFL 1/9/2013
Sample	S-6	Calculated By/Date	JFL 1/22/2013
Depth, ft	15.6	Checked By/Date	JFL 2/26/2013



Increment Number 16

Applied Stress, tsf 0.81

NOTES:
1. Abbreviations:
   ft = feet
   min = minutes
   mm = mimilimeters
   tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-4-12, SAMPLE S-6 @15.6ft

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SHANNON & WILSON, INC.
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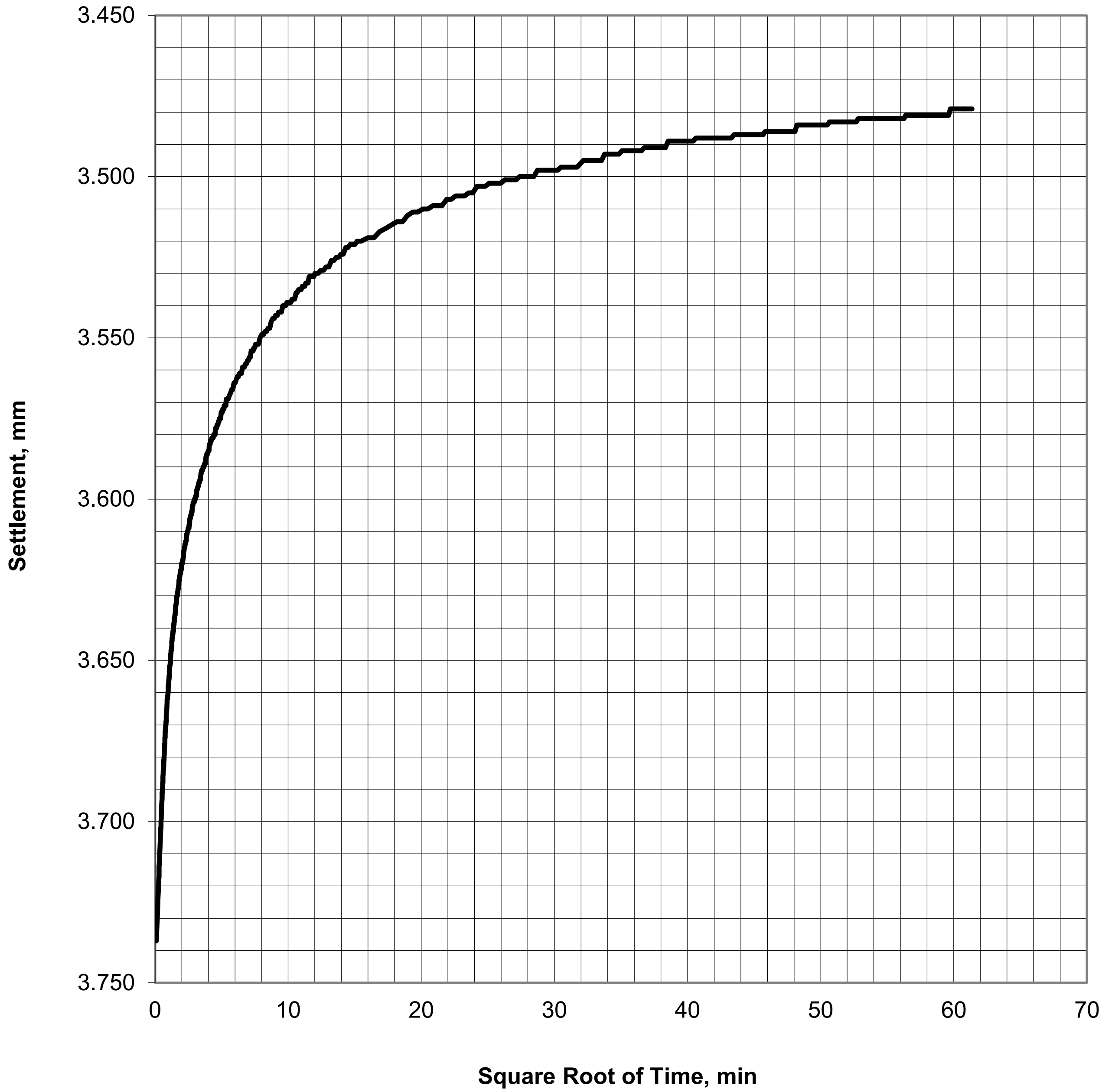
FIG. B-30
Sheet 16 of 17

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-4-12	Tested By/Date	JFL 1/9/2013
Sample	S-6	Calculated By/Date	JFL 1/22/2013
Depth, ft	15.6	Checked By/Date	JFL 2/26/2013



Increment Number 17

Applied Stress, tsf 0.20

NOTES:
1. Abbreviations:
ft = feet
min = minutes
mm = mimilimeters
tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-4-12, SAMPLE S-6 @15.6ft

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FIG. B-30

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-5-12	Tested By/Date	AKV 1/9/2013
Sample	S-2	Calculated By/Date	JFL 2/27/2013
Depth, ft	5.7	Checked By/Date	JFL 2/27/2013

SAMPLE CLASSIFICATION:
Gray-brown, organic SILT; OH

SAMPLE DATA:

Specific Gravity (estimated)	2.7
Liquid Limit	92
Plastic Limit	46
Plasticity Index	46

SPECIMEN DATA:	Before Inundation	First Load	Final Load
Height, inches	0.786	0.786	0.469
Diameter, inches	2.815	2.815	2.815
Sample Volume, cuin	4.894	4.894	2.921
Wet Density, pcf	84.5	84.5	109.8
Dry Density, pcf	45.3	45.3	76.0
Water Content, %	86%	86%	45%
Void Ratio	2.72	2.72	1.22
Saturation, %	86%	86%	99%

Increment	Applied Stress, tsf	ΔH at t_{100}, in	ΔH / H_o	Void Ratio	$t_{50,}$ min	Coeff. of Comp., MPa^{-1}	Coeff. of Consol., cm^2/sec	Coeff. of Perm., cm/sec
1	0.06	0.000	0.0%	2.718	1023.5	0.06	1.7E-05	2.8E-11
2	0.13	0.004	0.5%	2.700	0.4	2.87	8.7E-03	6.6E-07
3	0.25	0.014	1.8%	2.651	0.5	4.03	6.0E-03	6.4E-07
4	0.51	0.031	4.0%	2.569	0.6	3.36	3.7E-03	3.3E-07
5	1.02	0.060	7.7%	2.433	0.6	2.80	3.9E-03	3.0E-07
6	2.04	0.106	13.5%	2.216	0.5	2.22	4.2E-03	2.7E-07
7	4.07	0.175	22.2%	1.892	0.7	1.66	2.8E-03	1.4E-07
8	1.02	0.200	25.4%	1.772	0.6	-0.41	2.9E-03	4.0E-08
9	0.25	0.178	22.6%	1.878	5.7	1.46	3.3E-04	1.7E-08
10	0.06	0.151	19.2%	2.003	8.4	6.80	2.5E-04	5.7E-08
11	0.25	0.139	17.7%	2.062	0.9	-3.22	2.3E-03	2.4E-07
12	1.02	0.162	20.6%	1.951	0.9	1.51	2.2E-03	1.1E-07
13	4.07	0.204	26.0%	1.752	0.6	0.68	2.8E-03	6.2E-08
14	8.14	0.256	32.5%	1.509	2.0	0.63	6.2E-04	1.4E-08
15	16.29	0.311	39.5%	1.250	2.9	0.33	3.5E-04	4.6E-09
16	32.58	0.356	45.3%	1.036	2.9	0.14	3.0E-04	1.8E-09
17	8.14	0.3649	46.40%	0.993	3.8	-0.018	2.2E-04	2.0E-10
18	2.04	0.3619	46.03%	1.007	0.1	0.024	2.7E-02	3.2E-08
19	0.51	0.3373	42.89%	1.123	31.6	0.797	3.1E-05	1.2E-09
20	0.13	0.3198	40.66%	1.206	42.6	2.266	2.8E-05	3.0E-09

NOTES:
1. Abbreviations:
cm = centimeter
cm^2 = square centimeter
Coeff. = Coefficient
Comp. = Compressibility
Consol. = Consolidation
cu in = cubic inch
ft = feet
H_o = initial height
ΔH = change in height
in = inch
min = minute
MPa = megapascal
pcf = pounds per cubic foot
Perm. = Permeability
sec = second
t_n = time at n% of primary consolidation
tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST SUMMARY
BORING B-5-12, SAMPLE S-2 @5.7ft

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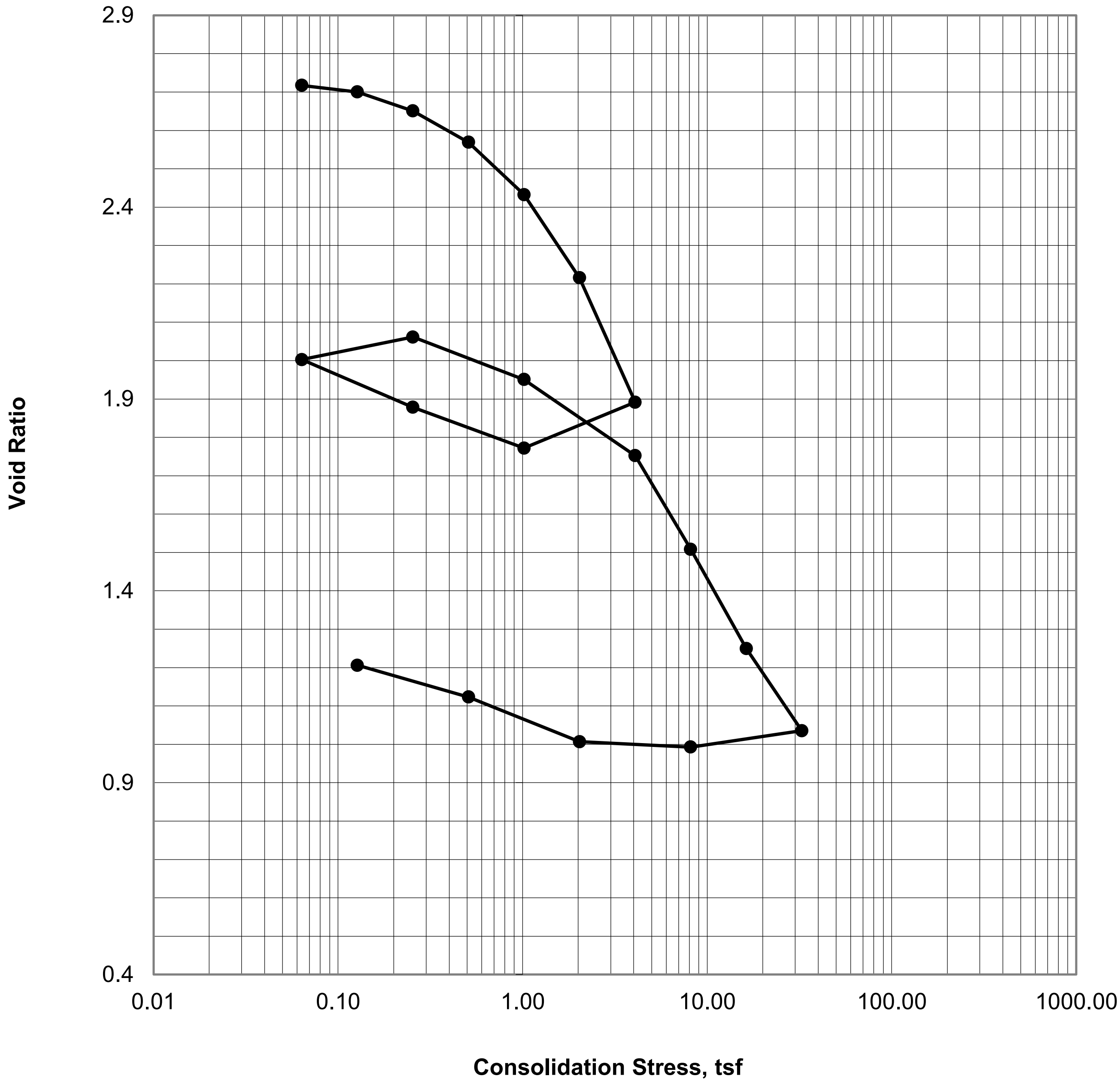
SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B-31

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-5-12	Tested By/Date	AKV 1/9/2013
Sample	S-2	Calculated By/Date	JFL 2/27/2013
Depth, ft	5.7	Checked By/Date	JFL 2/27/2013



Maximum Load, tsf 32.58

NOTES:
1. Abbreviations:
ft = feet
tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION VOID RATIO vs STRESS PLOT BORING B-5-12, SAMPLE S-2 @5.7ft

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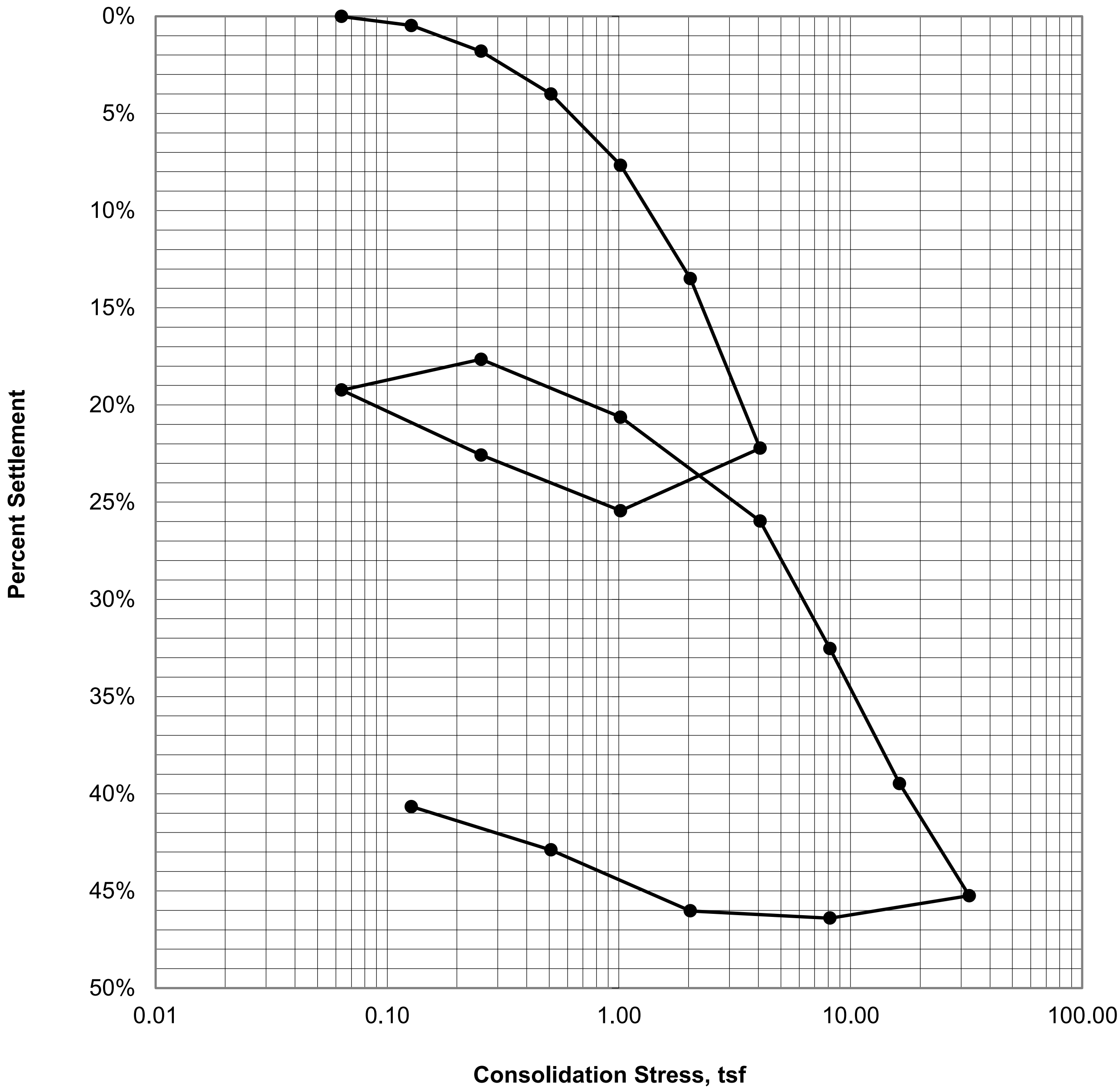
SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B-32

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-5-12	Tested By/Date	AKV 1/9/2013
Sample	S-2	Calculated By/Date	JFL 2/27/2013
Depth, ft	5.7	Checked By/Date	JFL 2/27/2013



Maximum Load, tsf 32.58

NOTES:
1. Abbreviations:
ft = feet
tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION PERCENT SETTLEMENT vs STRESS PLOT BORING B-5-12, SAMPLE S-2 @5.7ft

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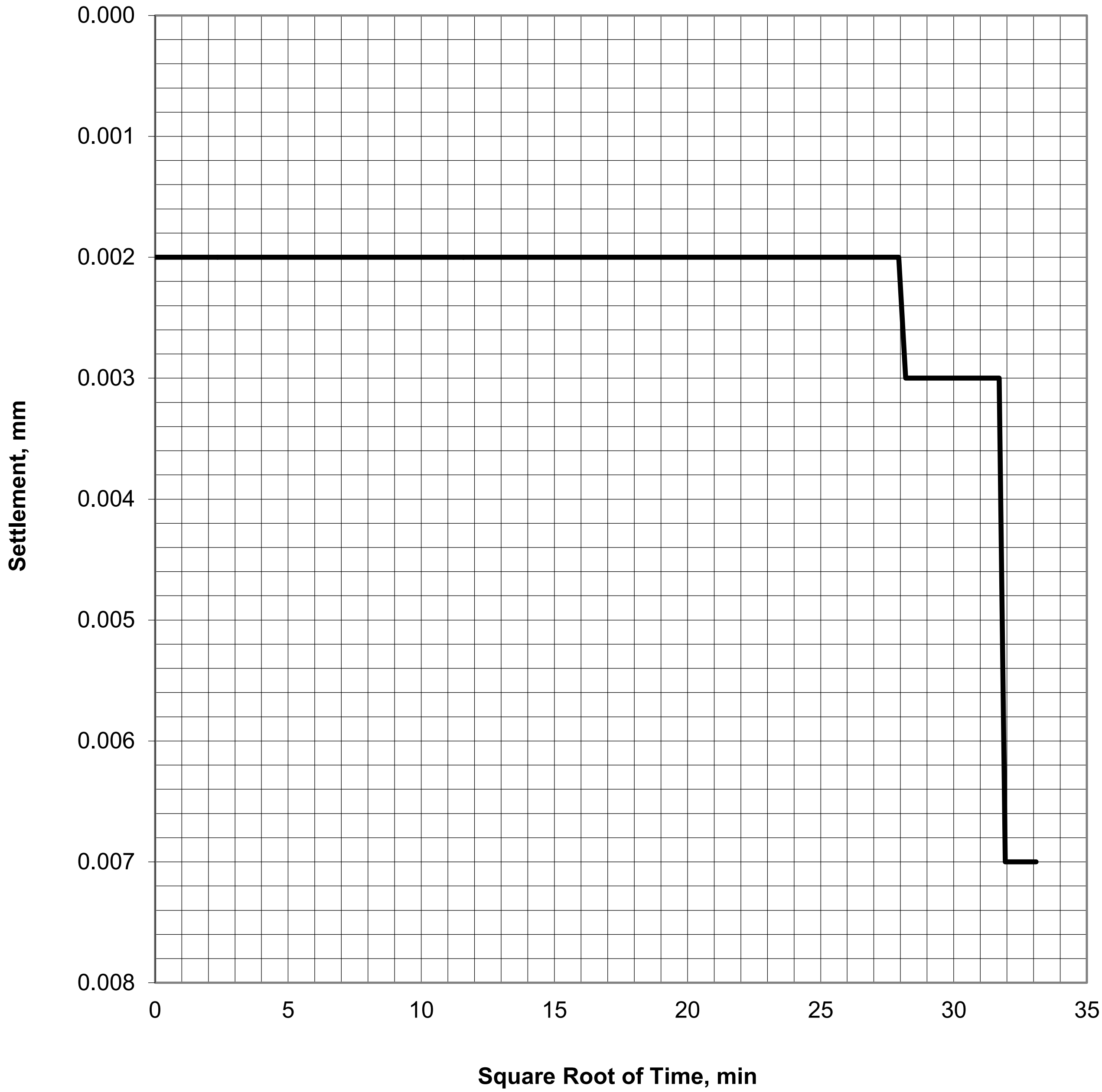
SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B-33

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-5-12	Tested By/Date	AKV 1/9/2013
Sample	S-2	Calculated By/Date	JFL 2/27/2013
Depth, ft	5.7	Checked By/Date	JFL 2/27/2013



Increment Number 1

Applied Stress, tsf 0.06

NOTES:
1. Abbreviations:
   ft = feet
   min = minutes
   mm = mimilimeters
   tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-5-12, SAMPLE S-2 @5.7ft

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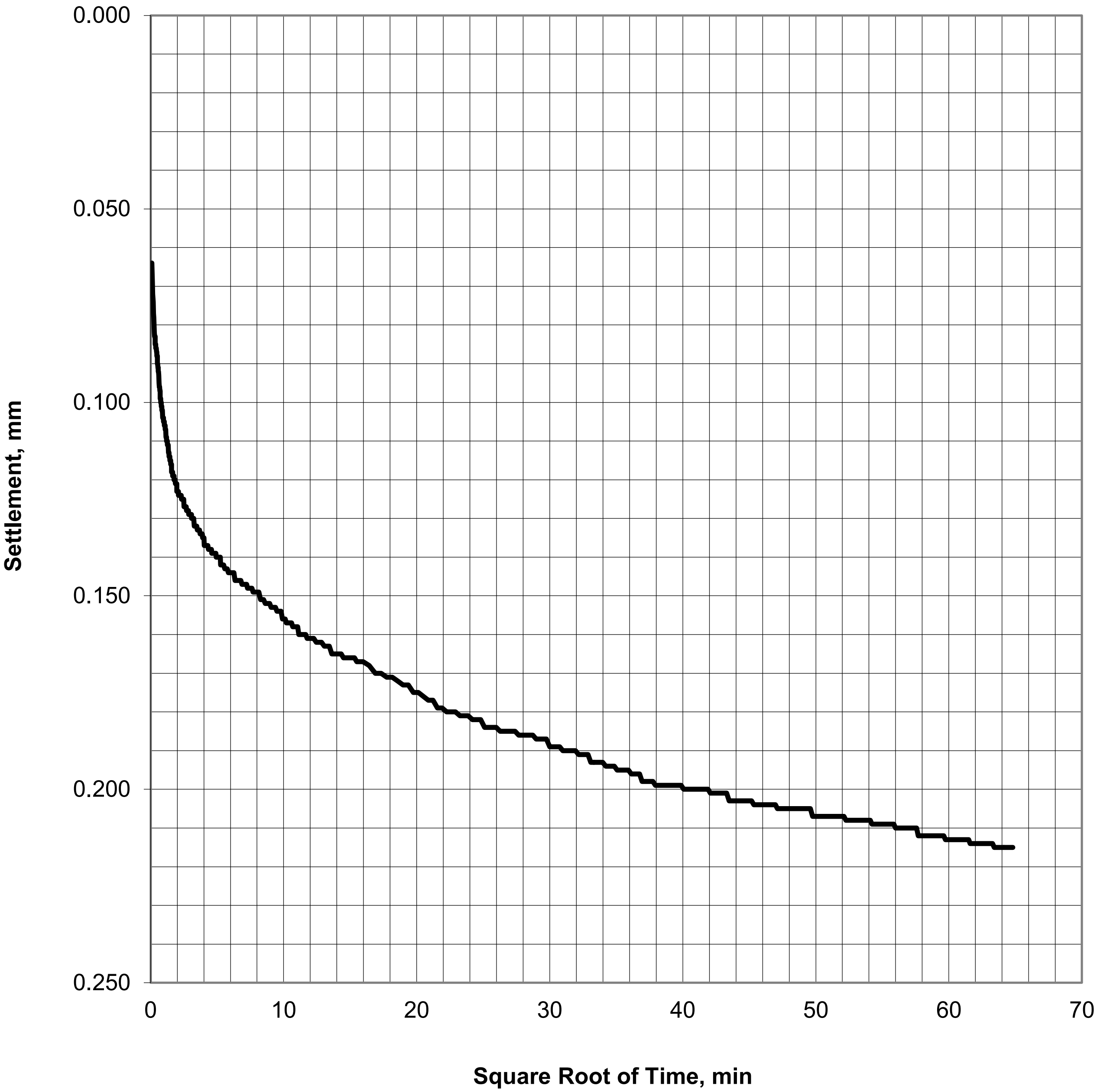
SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B-34

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-5-12	Tested By/Date	AKV 1/9/2013
Sample	S-2	Calculated By/Date	JFL 2/27/2013
Depth, ft	5.7	Checked By/Date	JFL 2/27/2013



Increment Number 2

Applied Stress, tsf 0.13

NOTES:
1. Abbreviations:
ft = feet
min = minutes
mm = mimilimeters
tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-5-12, SAMPLE S-2 @5.7ft

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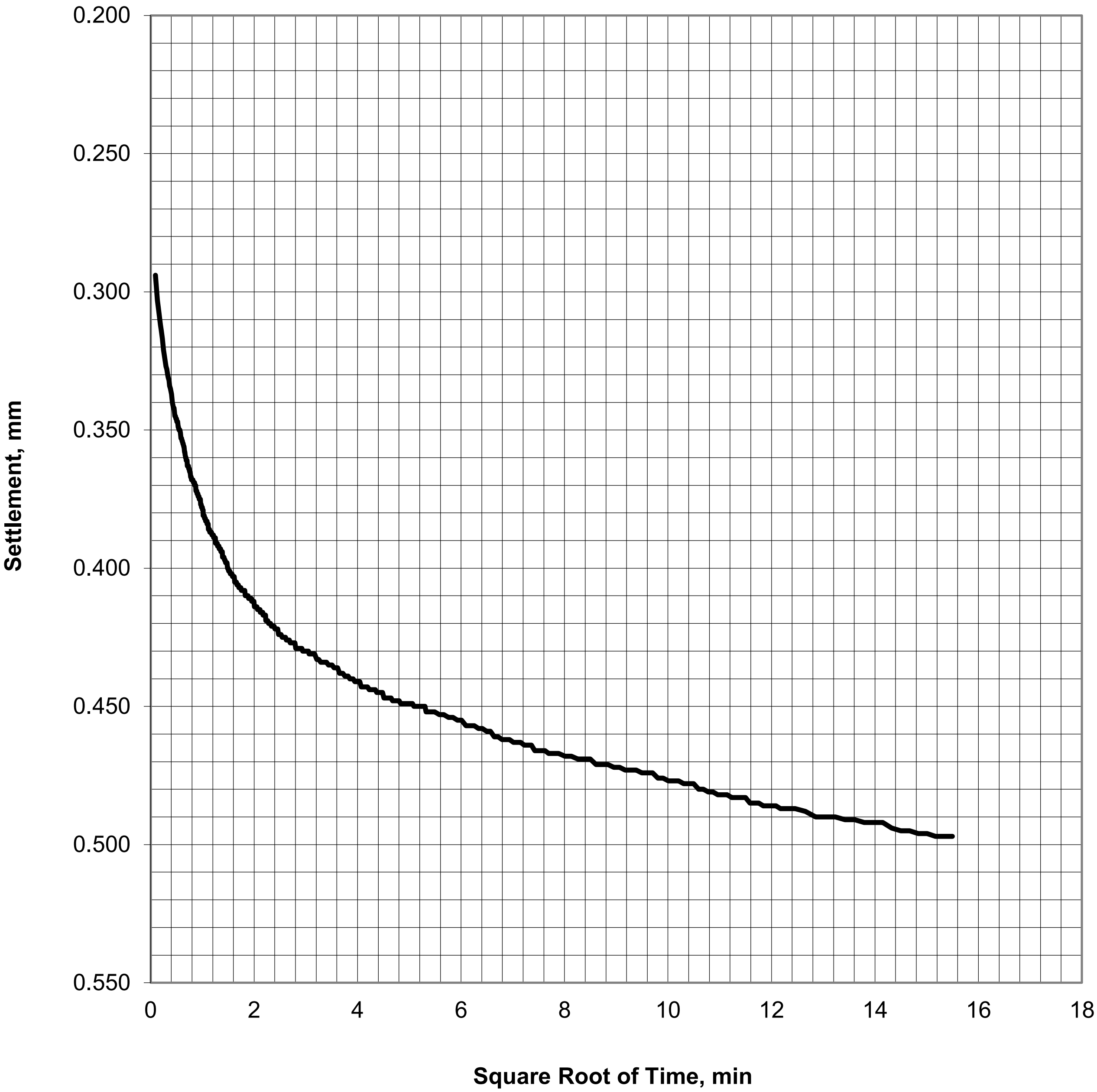
SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B-34
Sheet 2 of 20

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-5-12	Tested By/Date	AKV 1/9/2013
Sample	S-2	Calculated By/Date	JFL 2/27/2013
Depth, ft	5.7	Checked By/Date	JFL 2/27/2013



Increment Number 3

Applied Stress, tsf 0.25

NOTES:
1. Abbreviations:
   ft = feet
   min = minutes
   mm = mimilimeters
   tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-5-12, SAMPLE S-2 @5.7ft

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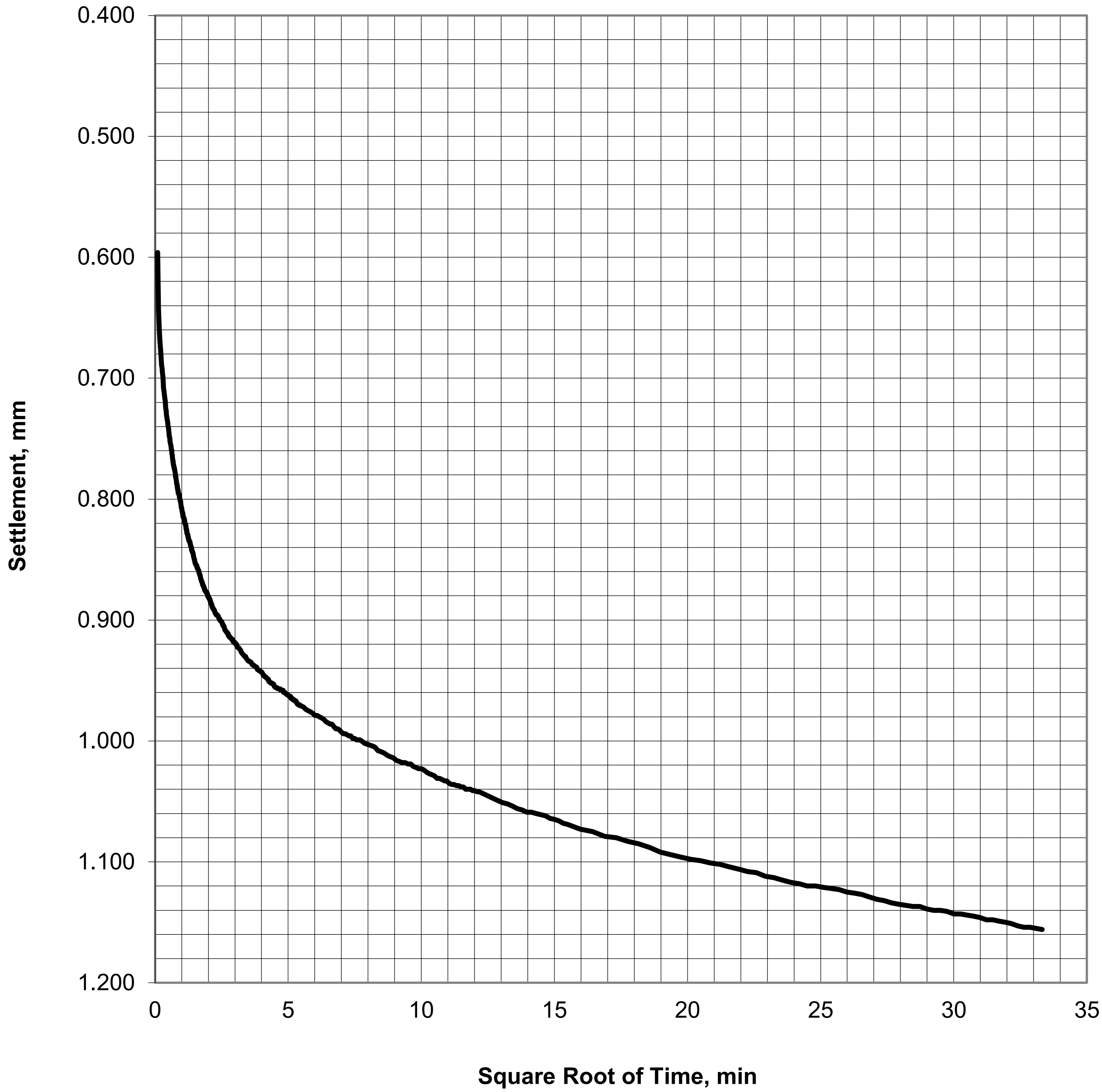
SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B-34
Sheet 3 of 20

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-5-12	Tested By/Date	AKV 1/9/2013
Sample	S-2	Calculated By/Date	JFL 2/27/2013
Depth, ft	5.7	Checked By/Date	JFL 2/27/2013



Increment Number 4

Applied Stress, tsf 0.51

NOTES:
1. Abbreviations:
- ft = feet
- min = minutes
- mm = mimilimeters
- tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-5-12, SAMPLE S-2 @5.7ft

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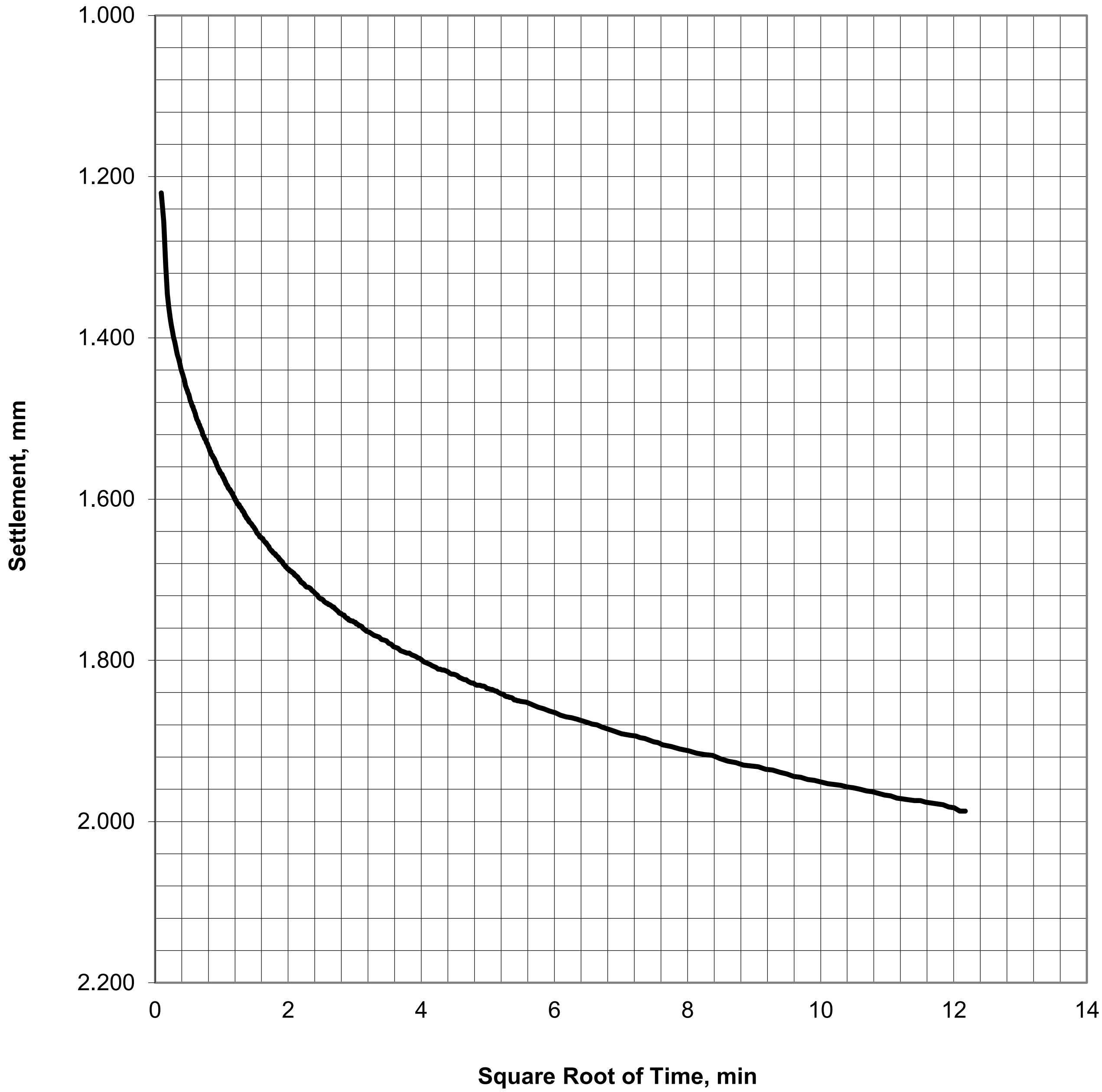
SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B-34

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-5-12	Tested By/Date	AKV 1/9/2013
Sample	S-2	Calculated By/Date	JFL 2/27/2013
Depth, ft	5.7	Checked By/Date	JFL 2/27/2013



Increment Number 5

Applied Stress, tsf 1.02

NOTES:
1. Abbreviations:
   ft = feet
   min = minutes
   mm = mimilimeters
   tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-5-12, SAMPLE S-2 @5.7ft

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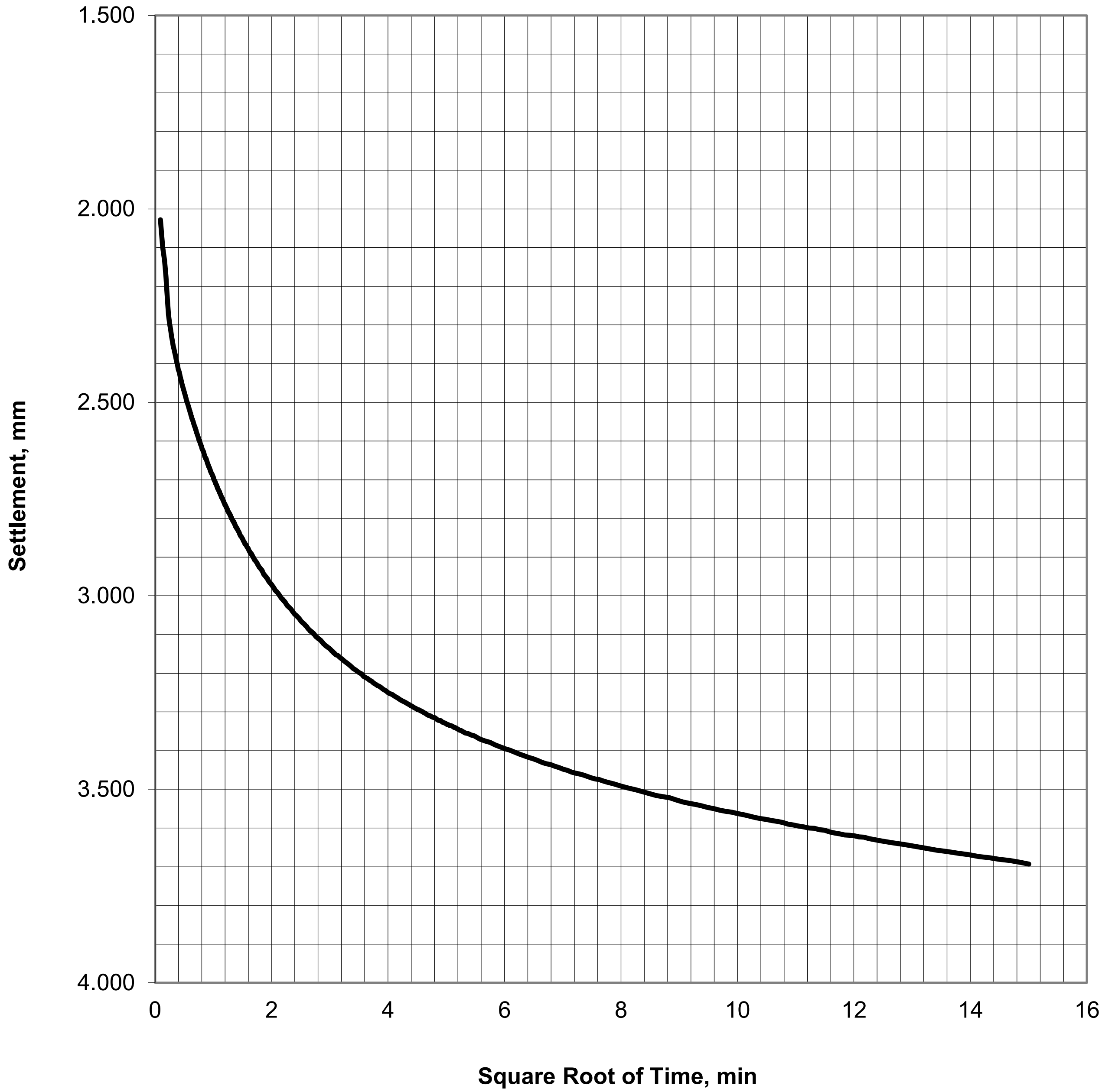
SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B-34
Sheet 5 of 20

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-5-12	Tested By/Date	AKV 1/9/2013
Sample	S-2	Calculated By/Date	JFL 2/27/2013
Depth, ft	5.7	Checked By/Date	JFL 2/27/2013



Increment Number 6

Applied Stress, tsf 2.04

NOTES:
1. Abbreviations:
   ft = feet
   min = minutes
   mm = mimilimeters
   tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-5-12, SAMPLE S-2 @5.7ft

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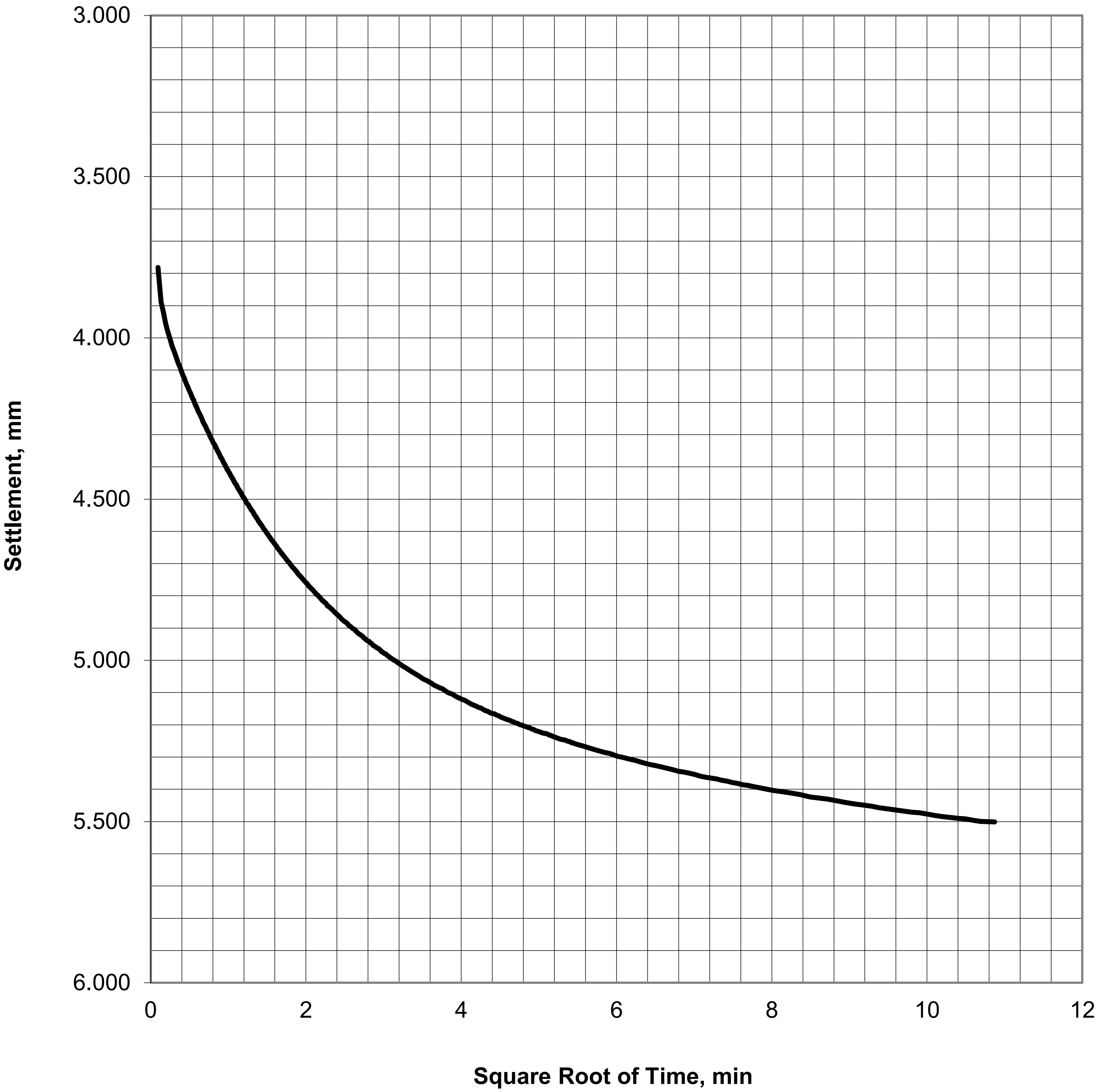
SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B-34
Sheet 6 of 20

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-5-12	Tested By/Date	AKV 1/9/2013
Sample	S-2	Calculated By/Date	JFL 2/27/2013
Depth, ft	5.7	Checked By/Date	JFL 2/27/2013



Increment Number 7

Applied Stress, tsf 4.07

NOTES:
1. Abbreviations:
   ft = feet
   min = minutes
   mm = mimilimeters
   tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-5-12, SAMPLE S-2 @5.7ft

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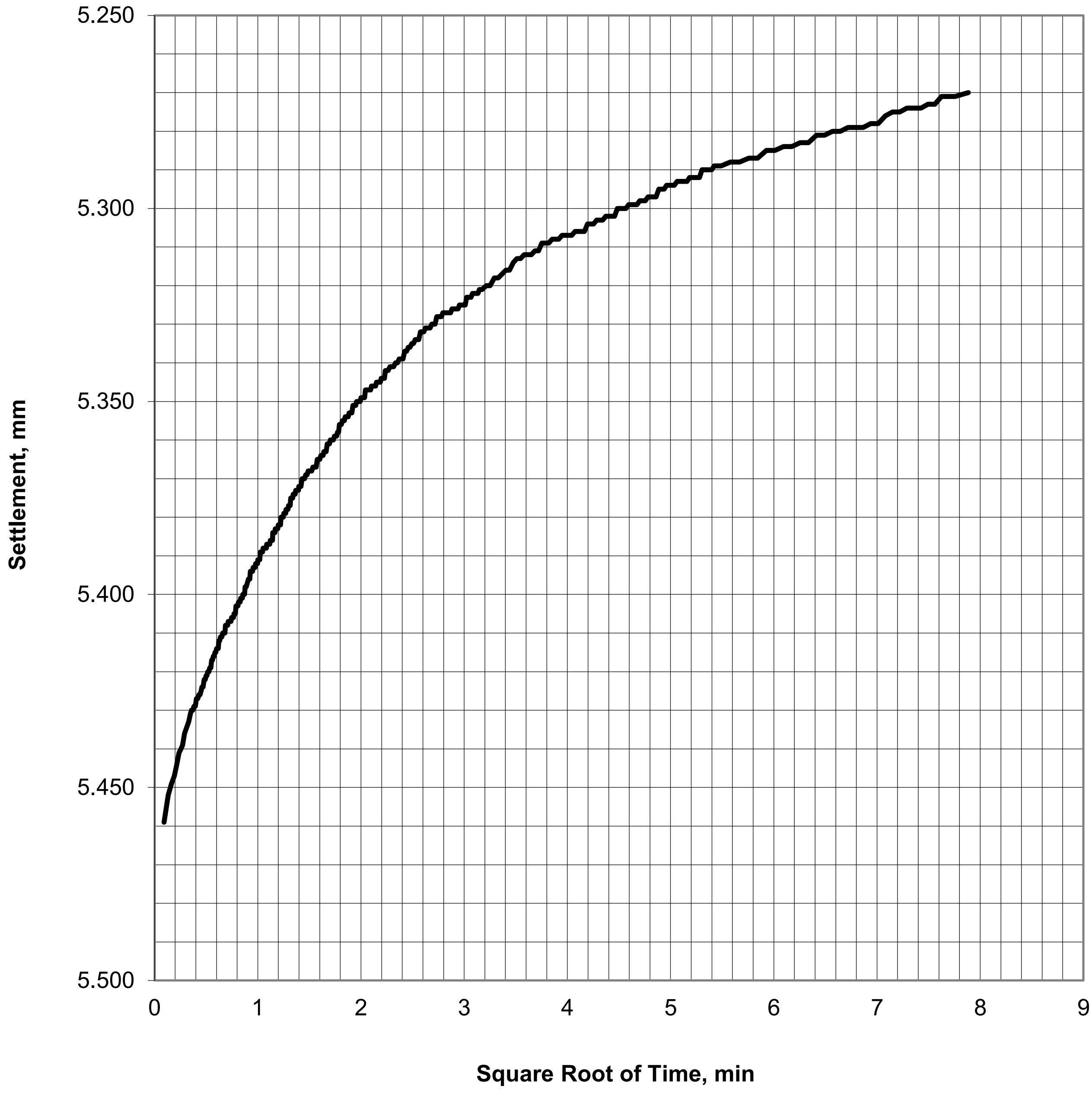
SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B-34
Sheet 7 of 20

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-5-12	Tested By/Date	AKV 1/9/2013
Sample	S-2	Calculated By/Date	JFL 2/27/2013
Depth, ft	5.7	Checked By/Date	JFL 2/27/2013



Increment Number 8

Applied Stress, tsf 1.02

NOTES:
1. Abbreviations:
ft = feet
min = minutes
mm = mimilimeters
tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-5-12, SAMPLE S-2 @5.7ft

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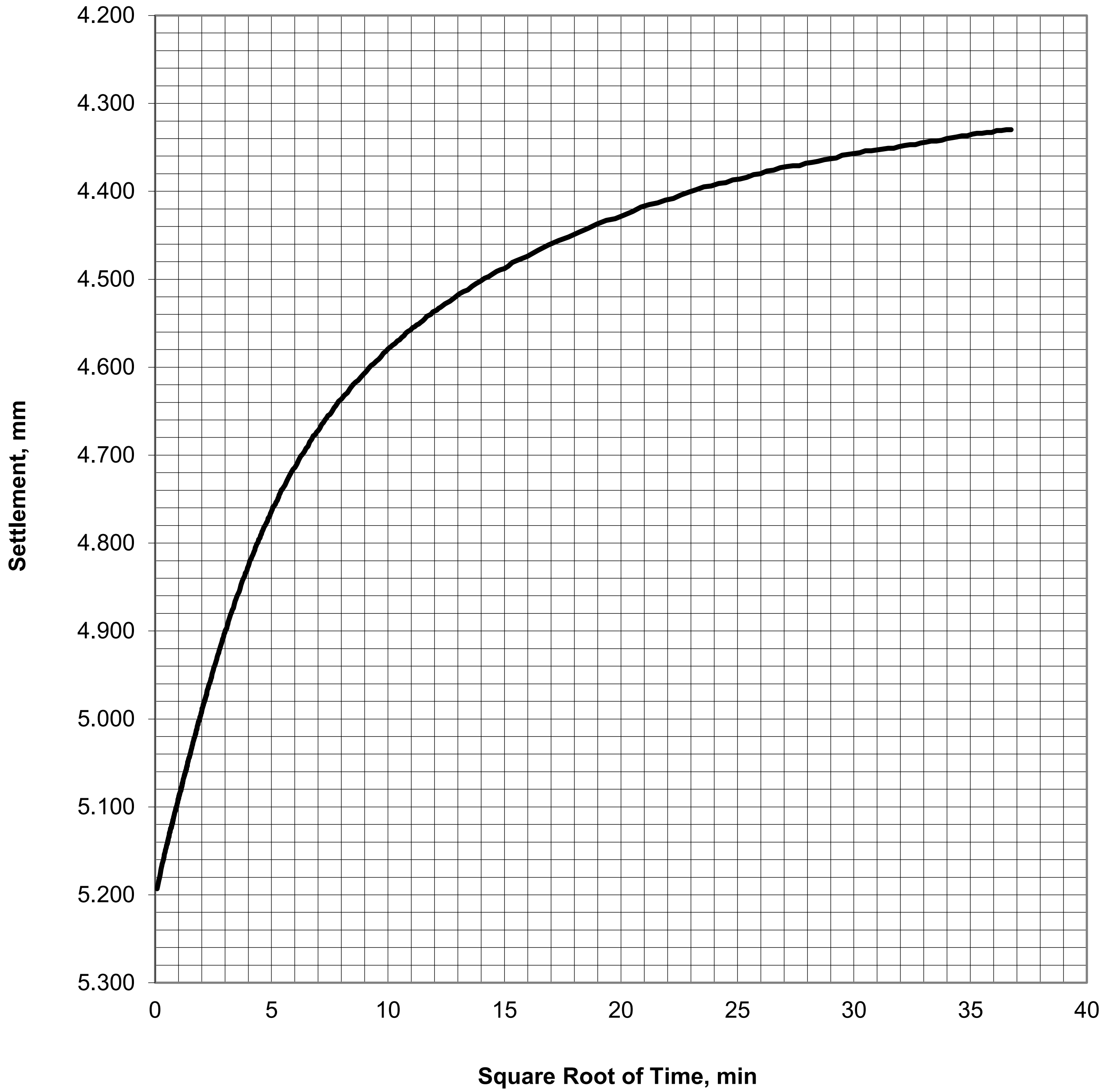
SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B-34

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-5-12	Tested By/Date	AKV 1/9/2013
Sample	S-2	Calculated By/Date	JFL 2/27/2013
Depth, ft	5.7	Checked By/Date	JFL 2/27/2013



Increment Number 9

Applied Stress, tsf 0.25

NOTES:
1. Abbreviations:
   ft = feet
   min = minutes
   mm = mimilimeters
   tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-5-12, SAMPLE S-2 @5.7ft

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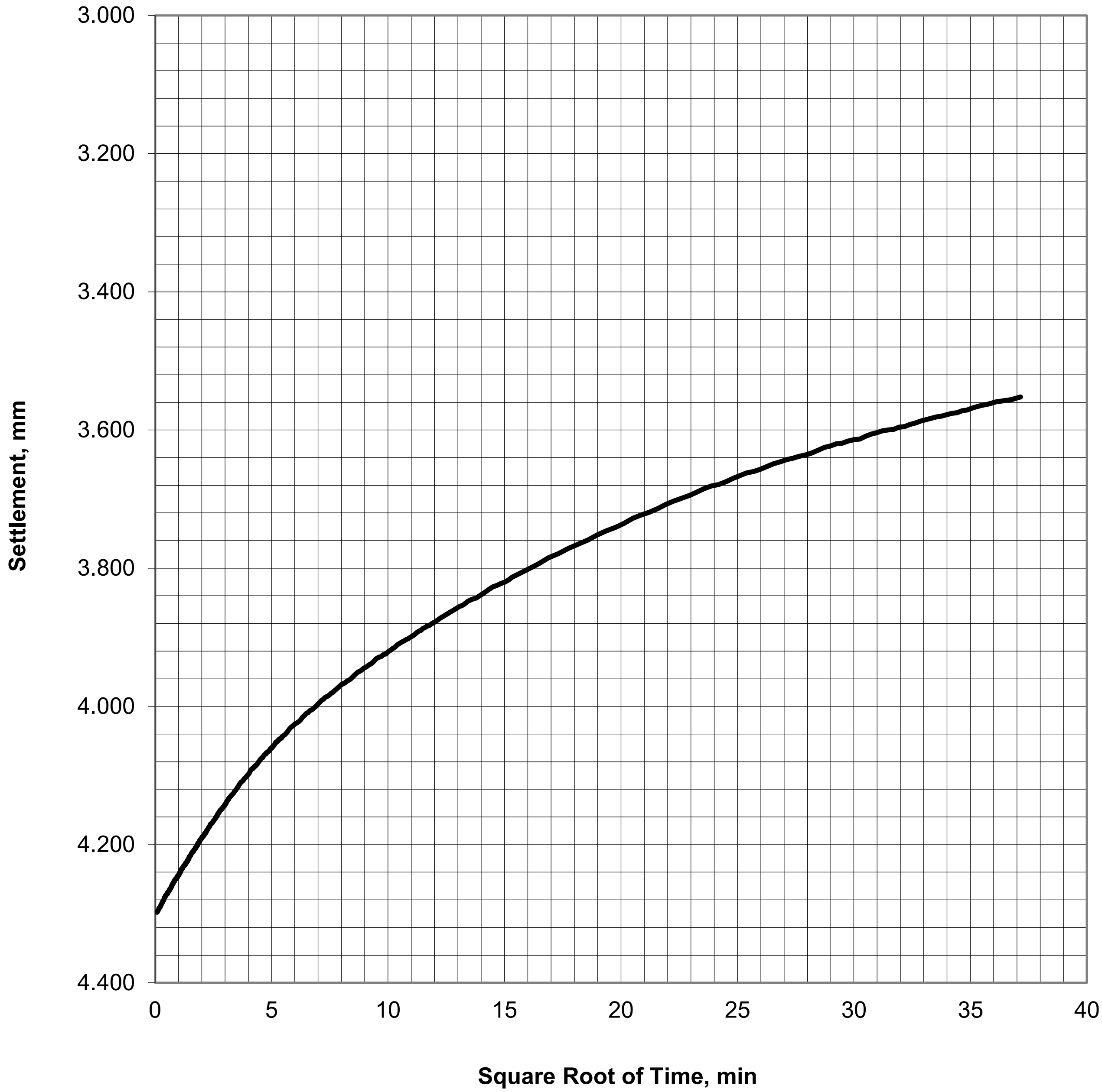
SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B-34

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-5-12	Tested By/Date	AKV 1/9/2013
Sample	S-2	Calculated By/Date	JFL 2/27/2013
Depth, ft	5.7	Checked By/Date	JFL 2/27/2013



Increment Number 10

Applied Stress, tsf 0.06

NOTES:
1. Abbreviations:
ft = feet
min = minutes
mm = mimilimeters
tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-5-12, SAMPLE S-2 @5.7ft

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SHANNON & WILSON, INC.
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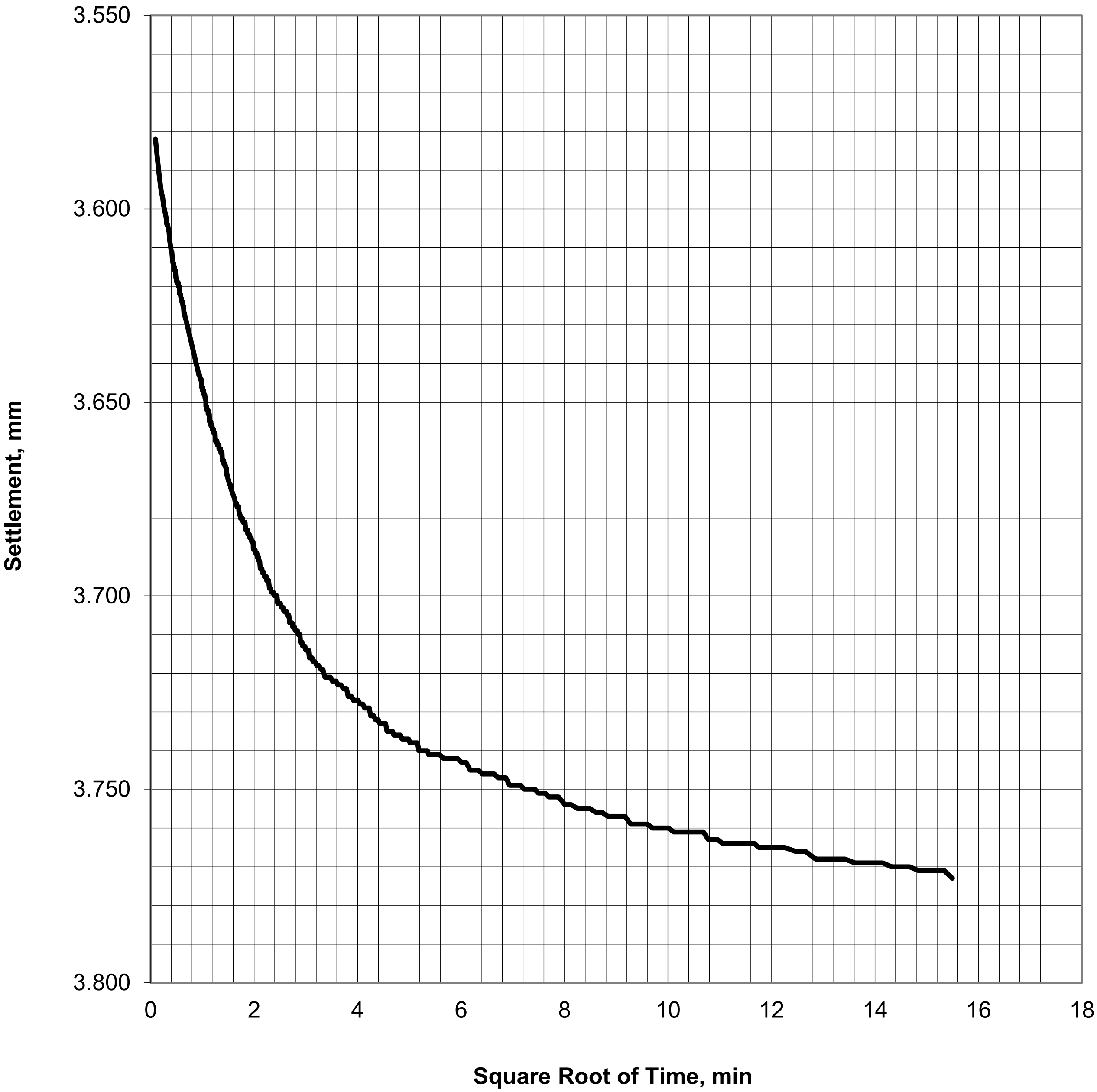
FIG. B-34

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-5-12	Tested By/Date	AKV 1/9/2013
Sample	S-2	Calculated By/Date	JFL 2/27/2013
Depth, ft	5.7	Checked By/Date	JFL 2/27/2013



Increment Number 11

Applied Stress, tsf 0.25

NOTES:
1. Abbreviations:
   ft = feet
   min = minutes
   mm = mimilimeters
   tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-5-12, SAMPLE S-2 @5.7ft

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SHANNON & WILSON, INC.
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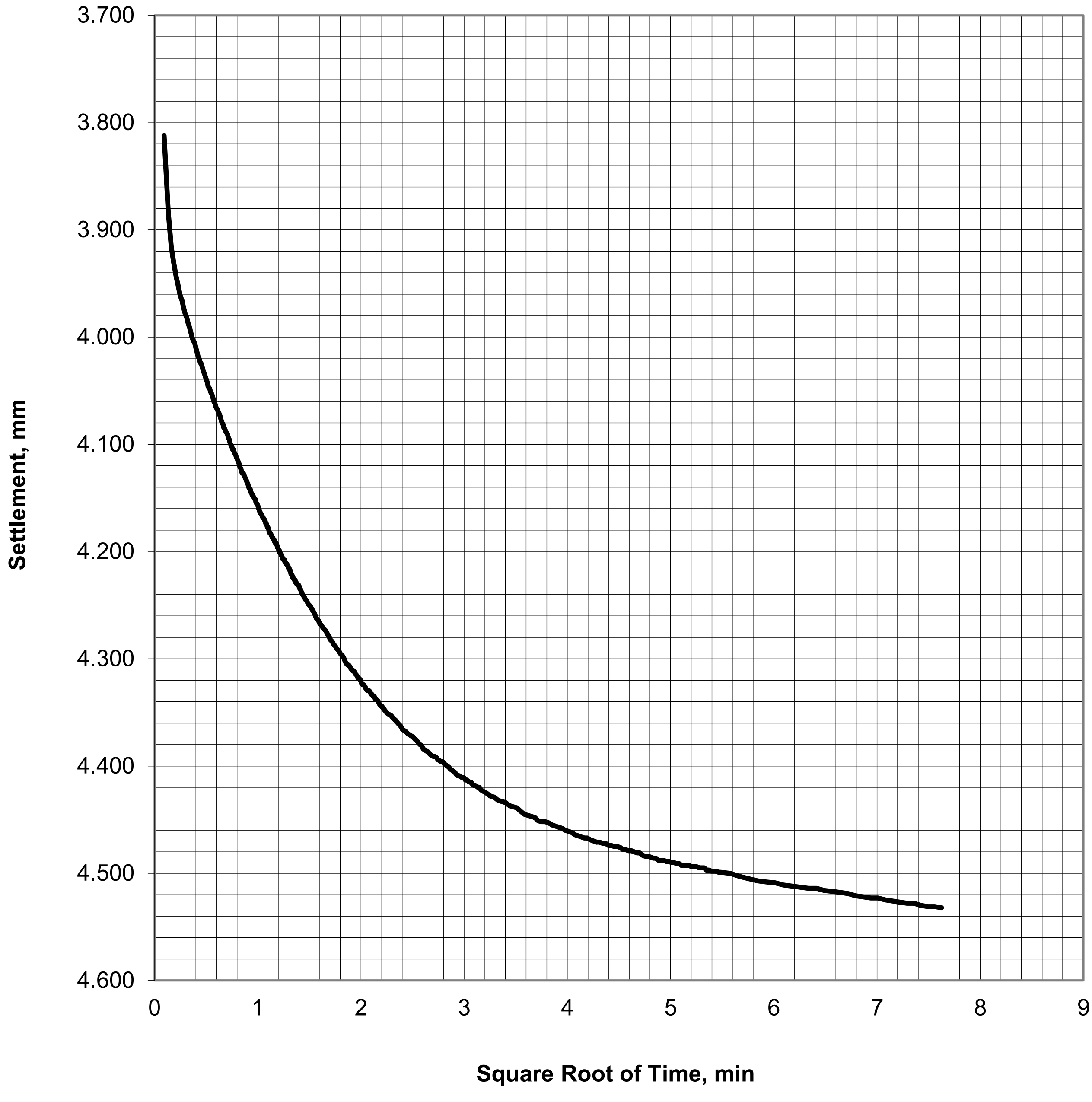
FIG. B-34

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-5-12	Tested By/Date	AKV 1/9/2013
Sample	S-2	Calculated By/Date	JFL 2/27/2013
Depth, ft	5.7	Checked By/Date	JFL 2/27/2013



Increment Number 12

Applied Stress, tsf 1.02

NOTES:
1. Abbreviations:
ft = feet
min = minutes
mm = mimilimeters
tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-5-12, SAMPLE S-2 @5.7ft

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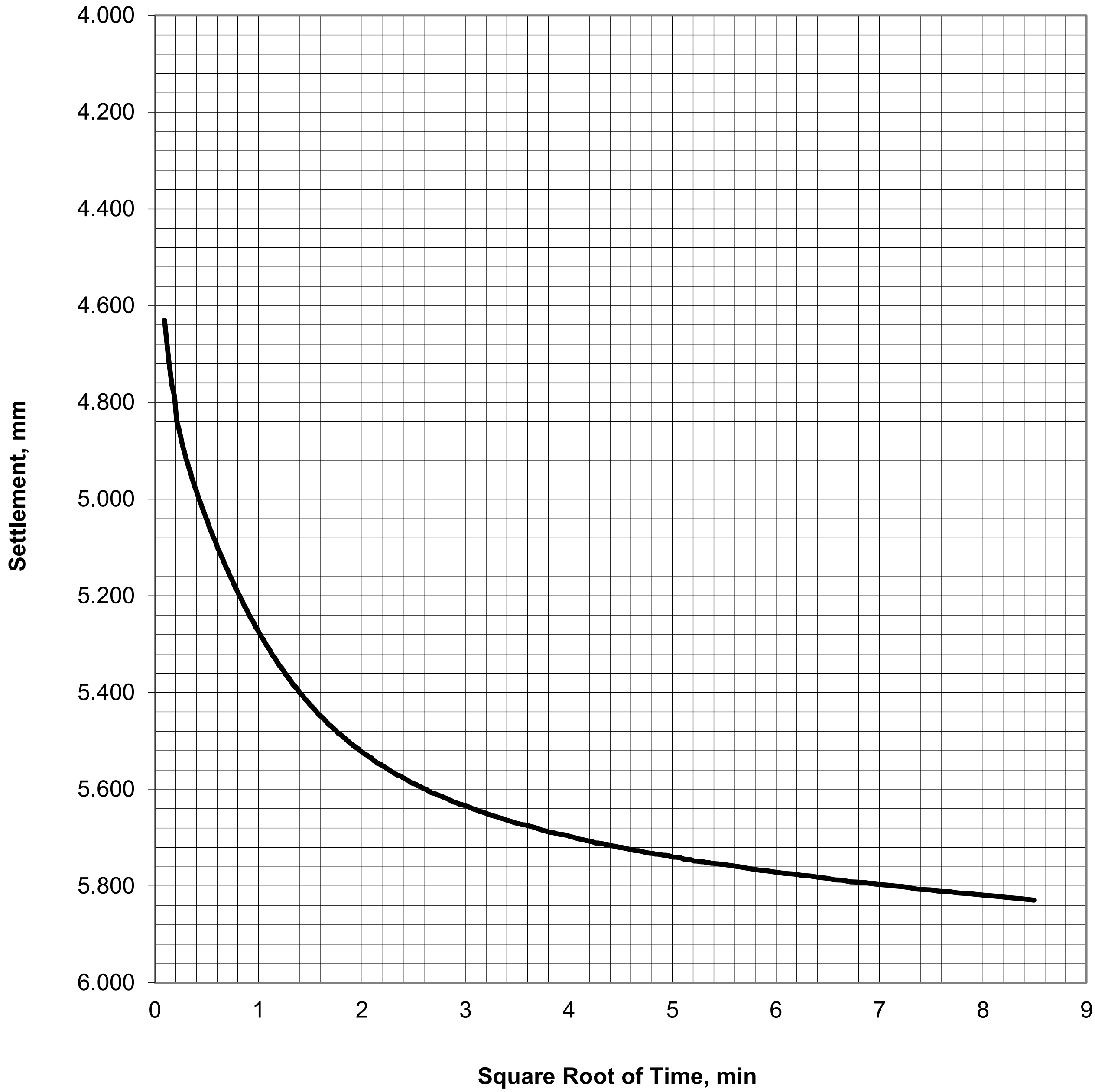
FIG. B-34

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-5-12	Tested By/Date	AKV 1/9/2013
Sample	S-2	Calculated By/Date	JFL 2/27/2013
Depth, ft	5.7	Checked By/Date	JFL 2/27/2013



Increment Number 13

Applied Stress, tsf 4.07

NOTES:
1. Abbreviations:
ft = feet
min = minutes
mm = mimilimeters
tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-5-12, SAMPLE S-2 @5.7ft

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SHANNON & WILSON, INC.
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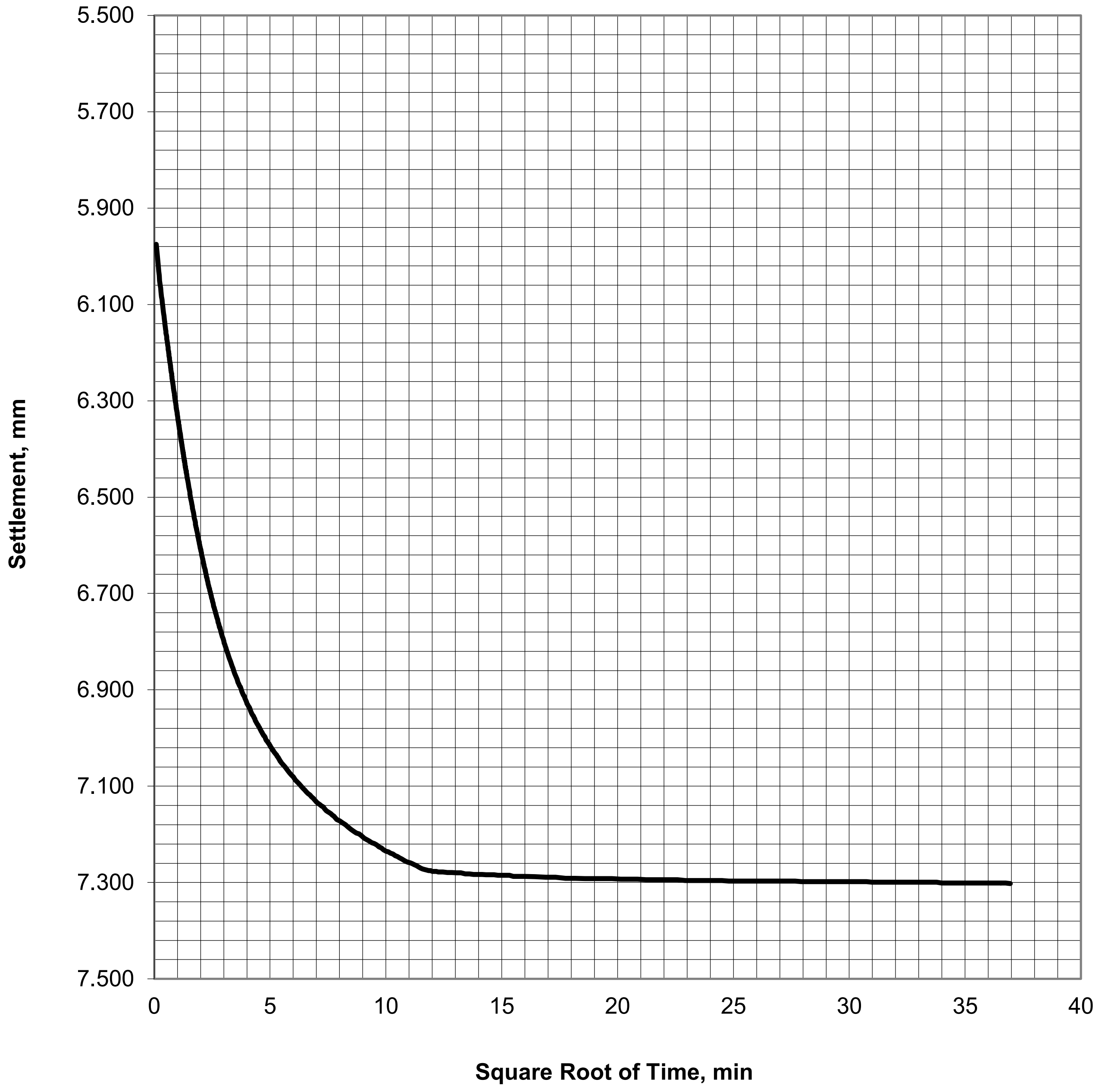
FIG. B-34

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-5-12	Tested By/Date	AKV 1/9/2013
Sample	S-2	Calculated By/Date	JFL 2/27/2013
Depth, ft	5.7	Checked By/Date	JFL 2/27/2013



Increment Number 14

Applied Stress, tsf 8.14

NOTES:
1. Abbreviations:
   ft = feet
   min = minutes
   mm = mimilimeters
   tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-5-12, SAMPLE S-2 @5.7ft

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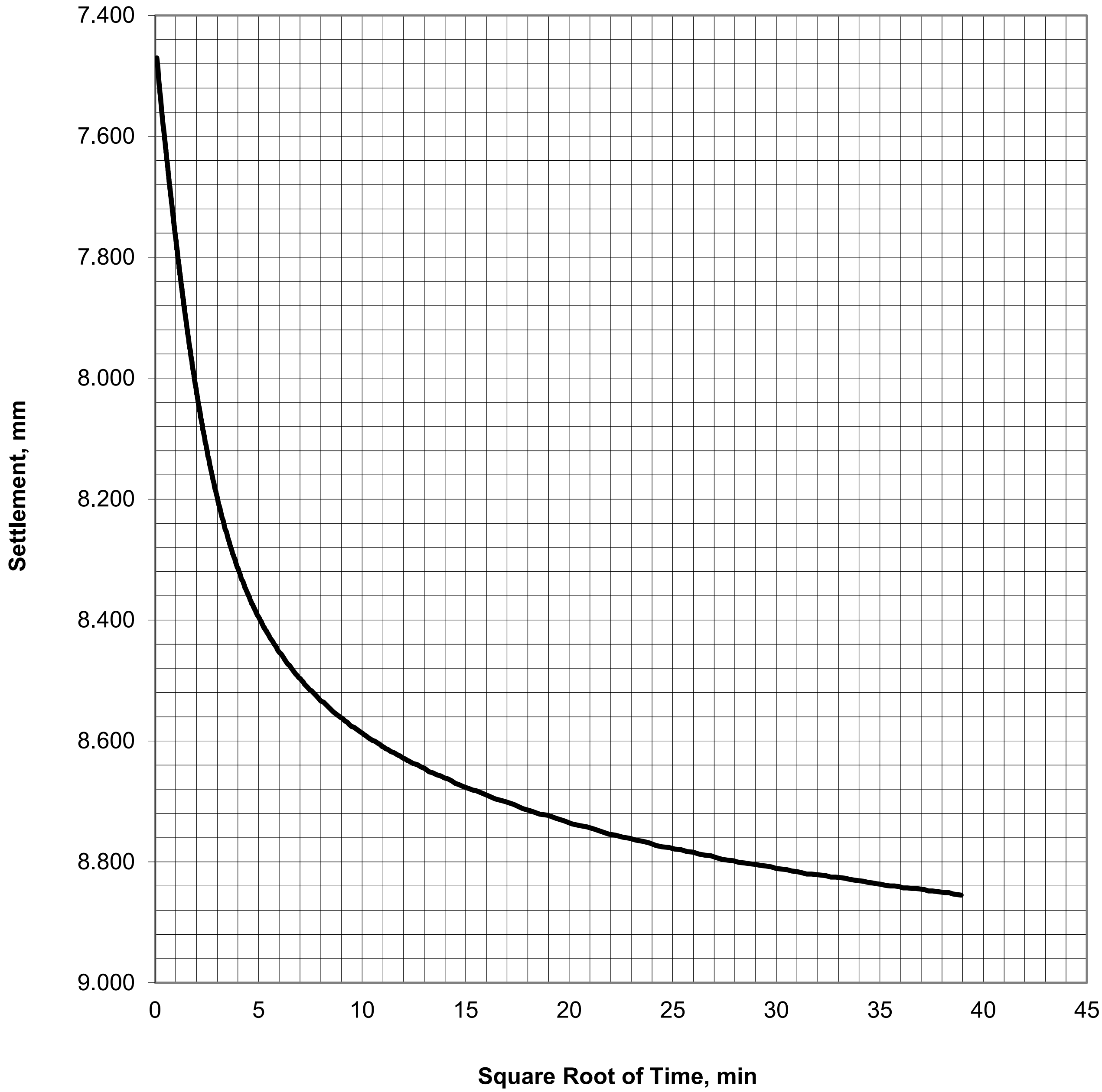
SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B-34

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-5-12	Tested By/Date	AKV 1/9/2013
Sample	S-2	Calculated By/Date	JFL 2/27/2013
Depth, ft	5.7	Checked By/Date	JFL 2/27/2013



Increment Number 15

Applied Stress, tsf 16.29

NOTES:
1. Abbreviations:
ft = feet
min = minutes
mm = mimilimeters
tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-5-12, SAMPLE S-2 @5.7ft

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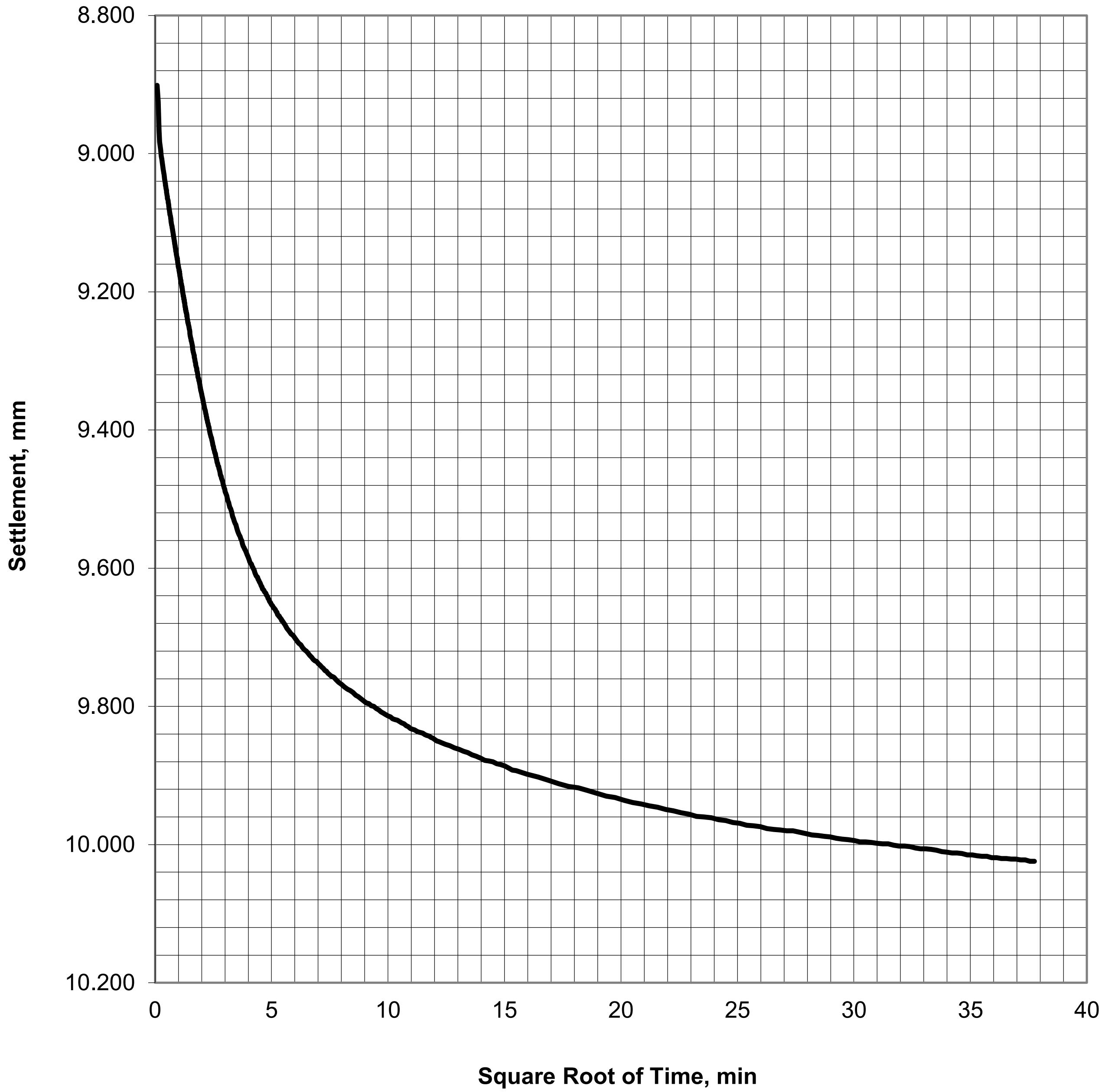
SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B-34

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-5-12	Tested By/Date	AKV 1/9/2013
Sample	S-2	Calculated By/Date	JFL 2/27/2013
Depth, ft	5.7	Checked By/Date	JFL 2/27/2013



Increment Number 16

Applied Stress, tsf 32.58

NOTES:
1. Abbreviations:
ft = feet
min = minutes
mm = mimilimeters
tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-5-12, SAMPLE S-2 @5.7ft

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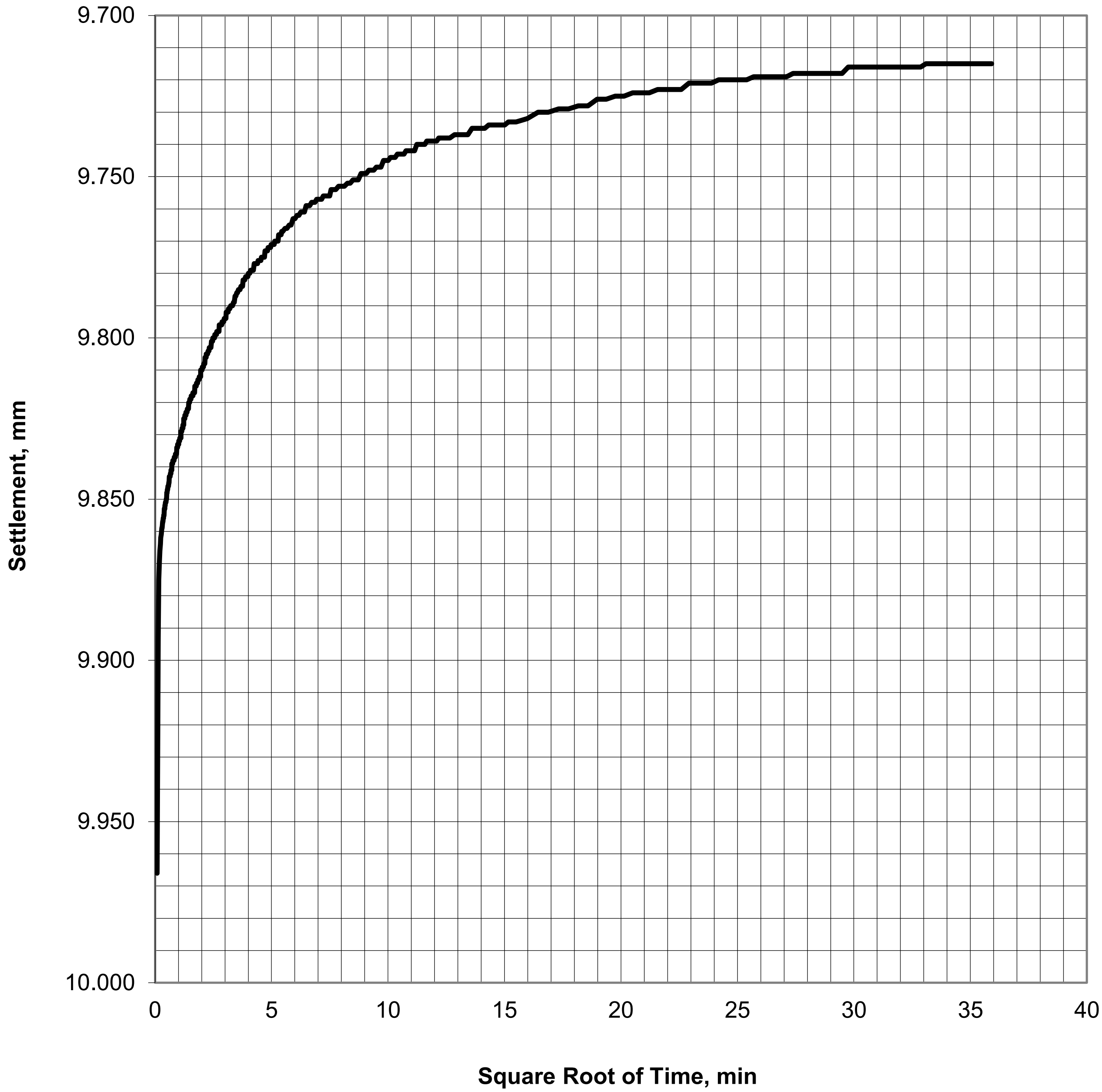
SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B-34

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-5-12	Tested By/Date	AKV 1/9/2013
Sample	S-2	Calculated By/Date	JFL 2/27/2013
Depth, ft	5.7	Checked By/Date	JFL 2/27/2013



Increment Number 17

Applied Stress, tsf 8.14

NOTES:
1. Abbreviations:
ft = feet
min = minutes
mm = mimilimeters
tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-5-12, SAMPLE S-2 @5.7ft

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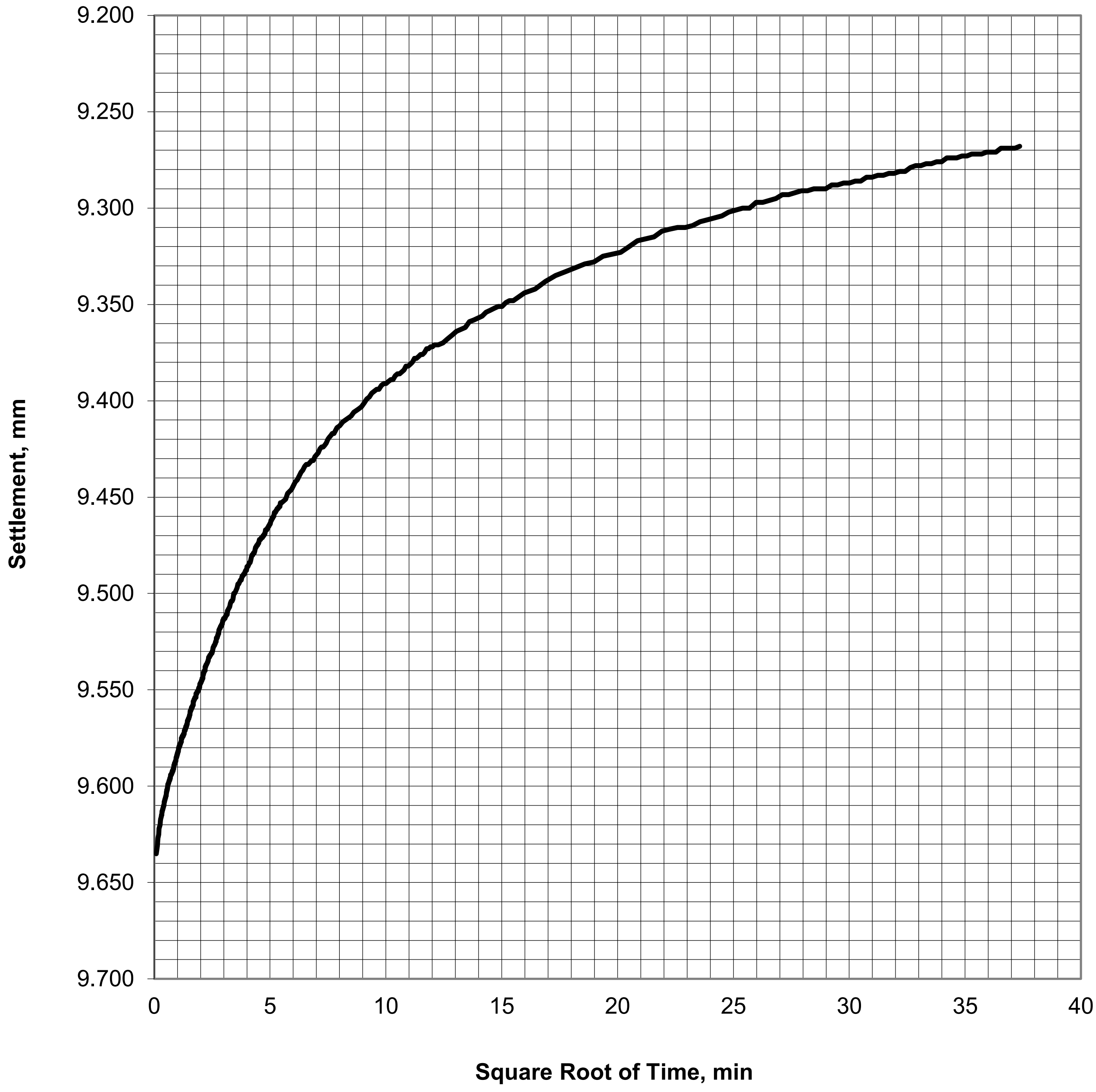
SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B-34

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-5-12	Tested By/Date	AKV 1/9/2013
Sample	S-2	Calculated By/Date	JFL 2/27/2013
Depth, ft	5.7	Checked By/Date	JFL 2/27/2013



Increment Number 18

Applied Stress, tsf 2.04

NOTES:
1. Abbreviations:
   ft = feet
   min = minutes
   mm = mimilimeters
   tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-5-12, SAMPLE S-2 @5.7ft

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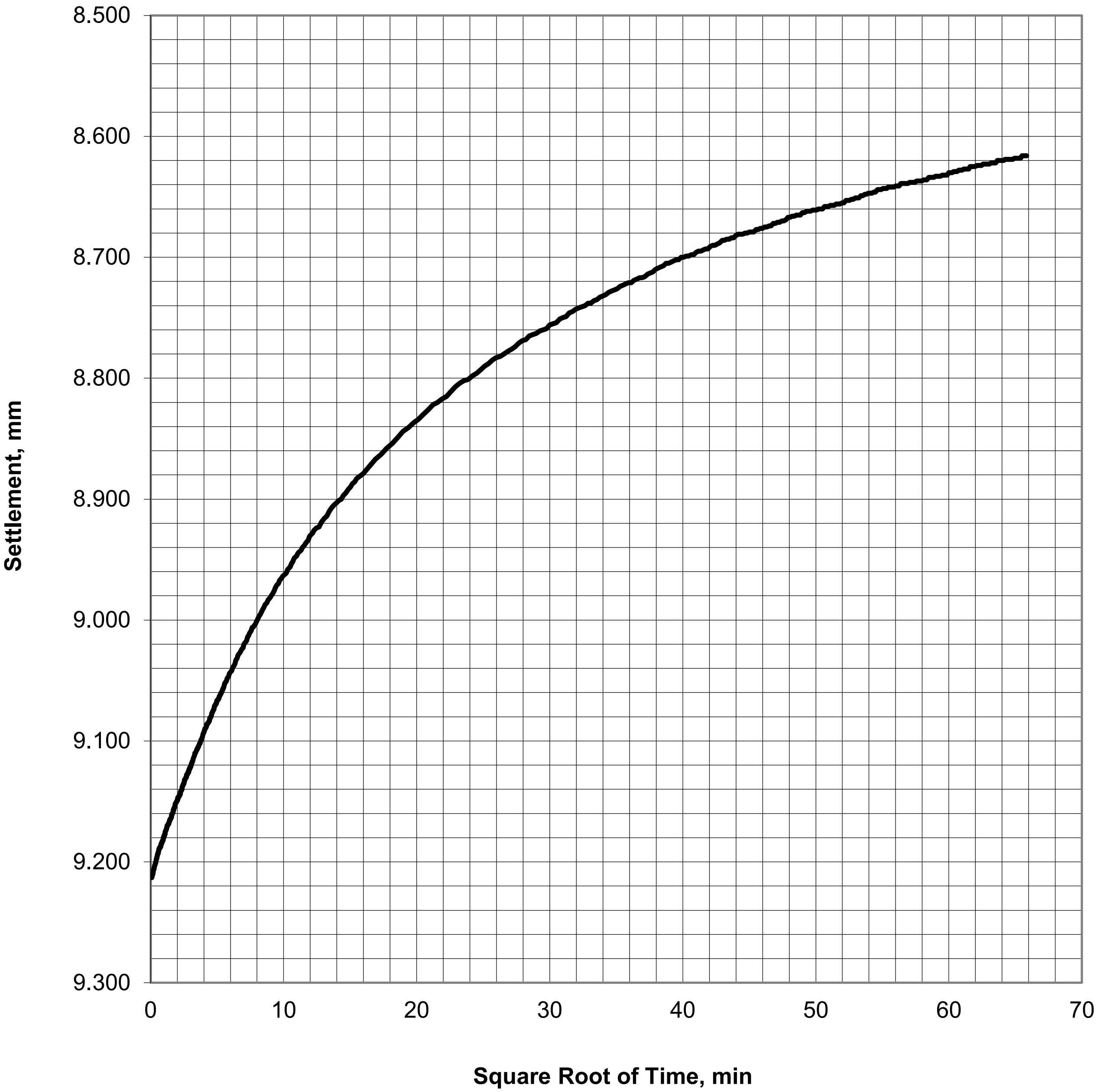
SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B-34

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-5-12	Tested By/Date	AKV 1/9/2013
Sample	S-2	Calculated By/Date	JFL 2/27/2013
Depth, ft	5.7	Checked By/Date	JFL 2/27/2013



Increment Number 19

Applied Stress, tsf 0.51

NOTES:
1. Abbreviations:
ft = feet
min = minutes
mm = mimilimeters
tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-5-12, SAMPLE S-2 @5.7ft

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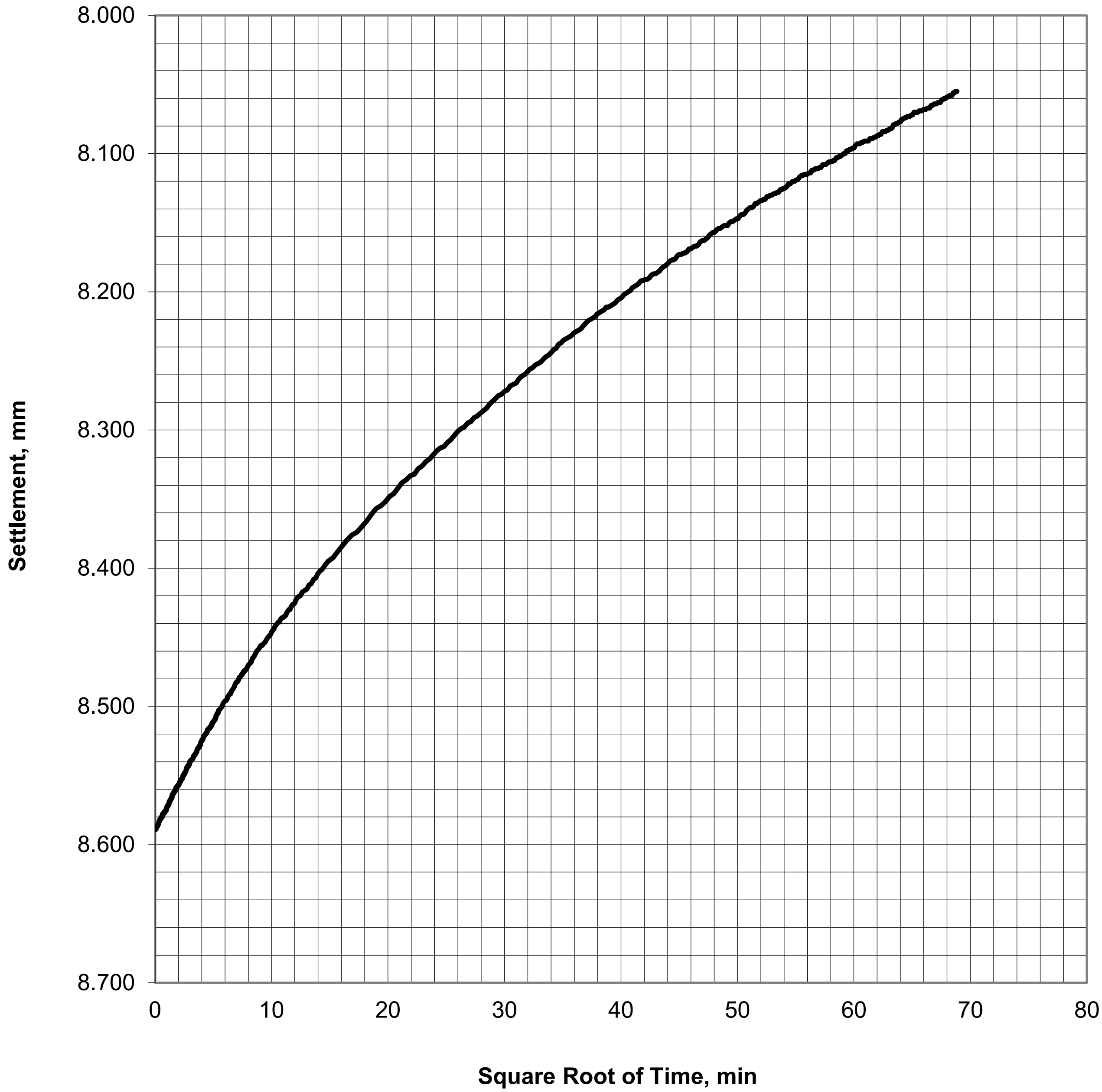
SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B-34

ONE DIMENSIONAL CONSOLIDATION TEST

Boring	B-5-12	Tested By/Date	AKV 1/9/2013
Sample	S-2	Calculated By/Date	JFL 2/27/2013
Depth, ft	5.7	Checked By/Date	JFL 2/27/2013



Increment Number 20

Applied Stress, tsf 0.13

NOTES:
1. Abbreviations:
   ft = feet
   min = minutes
   mm = mimilimeters
   tsf = tons per square foot

Smith Island Site Restoration
Snohomish County, Washington

ONE DIMENSIONAL CONSOLIDATION TEST INCREMENT
BORING B-5-12, SAMPLE S-2 @5.7ft

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FIG. B-34

CONSOLIDATED UNDRAINED TRIAXIAL COMPRESSION TEST
SUMMARY OF TEST DATA

Boring B-4-12
Sample S-6
Depth, ft 16.0

Tested By/Date AKV 1/8/2013
Calculated By/Date JFL 2/13/13
Checked By/Date JFL 3/20/13

SAMPLE CLASSIFICATION:

Gray, slightly clayey SILT, trace of fine sand; trace of fine organics; ML.

SAMPLE DATA:

B-Value at End of Saturation	1.00
Consolidation Stress, psf	288
Cell Pressure during Shear, psf	4421
Initial Pore Pressure, psf	4133
Shear Rate, in/min	0.0110

SPECIMEN DATA:

	Initial	Post-Consol	Post-Shear
Height, inches	5.857	5.852	4.680
Diameter, inches	2.502	2.502	
Aspect Ratio	2.34	2.34	
Wet Weight, grams	886.53	879.67	879.67
Water Content	35.8%	34.7%	34.7%
Wet Density, pcf	117.3	116.5	116.5
Dry Density, pcf	86.4	86.4	86.4

Axial Strain, in/in	Deviator Stress, psf	Excess Pore Pres., psf	Major Eff. Prin. Stress, psf	Minor Eff. Prin. Stress, psf	Prin. Eff. Stress Ratio	Stress Path Parameters, psf p	p'	q
0.0067	479	72	695	216	3.22	528	456	240
0.0133	709	43	954	245	3.90	643	599	355
0.0200	916	0	1204	288	4.18	746	746	458
0.0266	1083	-58	1429	346	4.13	830	887	542
0.0333	1219	-86	1594	374	4.26	898	984	610
0.0400	1325	-130	1743	418	4.17	951	1080	663
0.0467	1407	-158	1854	446	4.15	992	1150	704
0.0533	1480	-187	1955	475	4.11	1028	1215	740
0.0599	1543	-216	2047	504	4.06	1059	1275	771
0.0665	1594	-245	2127	533	3.99	1085	1330	797
0.0734	1649	-259	2196	547	4.01	1113	1372	825
0.0799	1690	-288	2266	576	3.93	1133	1421	845
0.0865	1728	-302	2319	590	3.93	1152	1454	864
0.0935	1762	-317	2366	605	3.91	1169	1486	881
0.1000	1787	-331	2407	619	3.89	1182	1513	894
0.1066	1813	-346	2446	634	3.86	1194	1540	906
0.1135	1834	-360	2482	648	3.83	1205	1565	917
0.1201	1853	-374	2515	662	3.80	1214	1589	926
0.1261	1862	-374	2525	662	3.81	1219	1594	931
0.1326	1870	-389	2547	677	3.76	1223	1612	935
0.1402	1880	-389	2557	677	3.78	1228	1617	940
0.1467	1882	-403	2573	691	3.72	1229	1632	941
0.1533	1881	-403	2572	691	3.72	1229	1632	941
0.1599	1880	-403	2571	691	3.72	1228	1631	940
0.1665	1879	-418	2584	706	3.66	1227	1645	939
0.1731	1860	-418	2566	706	3.64	1218	1636	930
0.1796	1844	-418	2550	706	3.61	1210	1628	922
0.1862	1838	-418	2543	706	3.60	1207	1624	919
0.1928	1822	-418	2527	706	3.58	1199	1616	911
0.2003	1808	-418	2513	706	3.56	1192	1609	904

NOTES:
1. Abbreviations:
   ft = feet
   in = inch
   min = minute
   pcf = pounds per cubic foot
   psf = pounds per square foot
   Pres. = Pressure
   Eff. = Effective
   Prin. = Principal
   CU = Consolidated Undrained

Smith Island Site Restoration
Snohomish County, Washington

CU TRIAXIAL TEST SUMMARY
BORING B-4-12, SAMPLE S-6 @16ft

October 2013 21-1-12405-060

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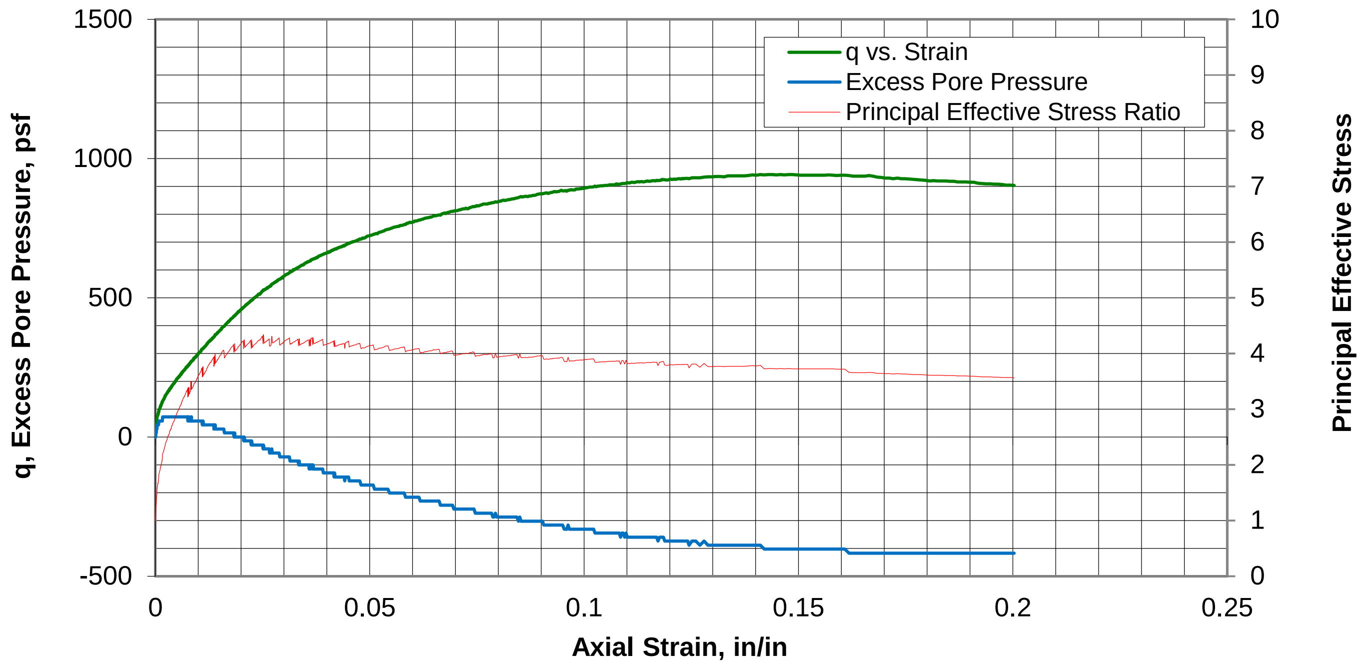
Geotechnical and Environmental Consultants

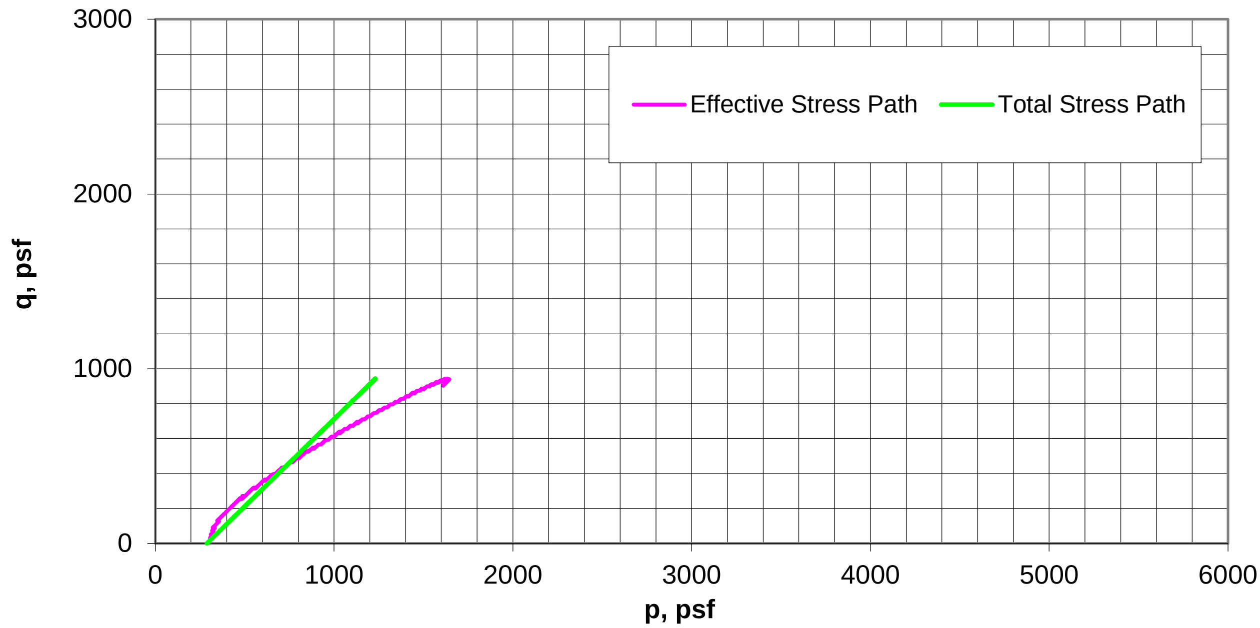
FIG. B-35
Sheet 1 of 2

CONSOLIDATED UNDRAINED TRIAXIAL COMPRESSION TEST

Boring B-4-12
Sample S-6
Depth, ft 16

Tested By/Date AKV 1/8/2013
Calculated By/Date JFL 2/13/13
Checked By/Date JFL 3/20/13





Effective Stress at End-of-Consolidation, psf 288
Cell Pressure during Shear, psf 4421

NOTES:
1. Abbreviations:
ft = feet
in = inch
psf = pounds per square foot
CU = Consolidated Undrained

Smith Island Site Restoration
Snohomish County, Washington

CU TRIAXIAL TEST SUMMARY
BORING B-4-12, SAMPLE S-6 @16.5ft

October 2013
21-1-12405-060

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FIG. B-35
Sheet 2 of 2

CONSOLIDATED UNDRAINED TRIAXIAL COMPRESSION TEST
SUMMARY OF TEST DATA

Boring B-4-12
Sample S-6
Depth, ft 16.5

Tested By/Date AKV 1/8/2013
Calculated By/Date JFL 2/13/13
Checked By/Date JFL 3/20/13

SAMPLE CLASSIFICATION:
Gray, slightly clayey SILT, trace of fine sand; trace of fine organics; ML.

SAMPLE DATA:

B-Value at End of Saturation	1.00
Consolidation Stress, psf	1152
Cell Pressure during Shear, psf	5314
Initial Pore Pressure, psf	4162
Shear Rate, in/min	0.0110

SPECIMEN DATA:

	Initial	Post-Consol	Post-Shear
Height, inches	5.569	5.552	4.439
Diameter, inches	2.503	2.503	
Aspect Ratio	2.22	2.22	
Wet Weight, grams	823.83	802.80	802.80
Water Content	38.6%	35.0%	35.0%
Wet Density, pcf	114.5	111.9	111.9
Dry Density, pcf	82.6	82.9	82.9

Axial Strain, in/in	Deviator Stress, psf	Excess Pore Pres., psf	Major Eff. Prin. Stress, psf	Minor Eff. Prin. Stress, psf	Prin. Eff. Stress Ratio	Stress Path Parameters, psf p	p'	q
0.0066	1258	446	1964	706	2.78	1781	1335	629
0.0133	1457	490	2119	662	3.20	1880	1391	728
0.0200	1635	504	2283	648	3.52	1970	1466	818
0.0267	1783	504	2431	648	3.75	2043	1539	891
0.0333	1877	475	2554	677	3.77	2091	1616	939
0.0400	1967	461	2659	691	3.85	2136	1675	984
0.0468	2039	446	2745	706	3.89	2172	1725	1020
0.0534	2096	432	2816	720	3.91	2200	1768	1048
0.0600	2166	418	2900	734	3.95	2235	1817	1083
0.0666	2221	403	2970	749	3.97	2262	1859	1110
0.0732	2275	389	3038	763	3.98	2289	1901	1137
0.0801	2291	374	3069	778	3.95	2298	1923	1146
0.0868	2336	360	3128	792	3.95	2320	1960	1168
0.0934	2365	346	3172	806	3.93	2335	1989	1183
0.1000	2392	331	3213	821	3.91	2348	2017	1196
0.1066	2420	317	3256	835	3.90	2362	2045	1210
0.1135	2437	317	3272	835	3.92	2370	2054	1218
0.1201	2448	302	3298	850	3.88	2376	2074	1224
0.1267	2460	288	3324	864	3.85	2382	2094	1230
0.1330	2482	274	3360	878	3.83	2393	2119	1241
0.1400	2495	274	3374	878	3.84	2400	2126	1248
0.1469	2491	259	3384	893	3.79	2398	2139	1246
0.1529	2491	259	3383	893	3.79	2397	2138	1245
0.1598	2494	245	3401	907	3.75	2399	2154	1247
0.1667	2501	245	3408	907	3.76	2402	2158	1250
0.1737	2491	230	3412	922	3.70	2397	2167	1245
0.1796	2479	230	3401	922	3.69	2392	2161	1240
0.1866	2461	216	3397	936	3.63	2383	2167	1231
0.1935	2455	216	3391	936	3.62	2380	2164	1228
0.2004	2459	216	3395	936	3.63	2381	2165	1229

NOTES:
1. Abbreviations:
ft = feet
in = inch
min = minute
pcf = pounds per cubic foot
psf = pounds per square foot
Pres. = Pressure
Eff. = Effective
Prin. = Principal
CU = Consolidated Undrained

Smith Island Site Restoration
Snohomish County, Washington

CU TRIAXIAL TEST SUMMARY
BORING B-4-12, SAMPLE S-6 @16.5ft

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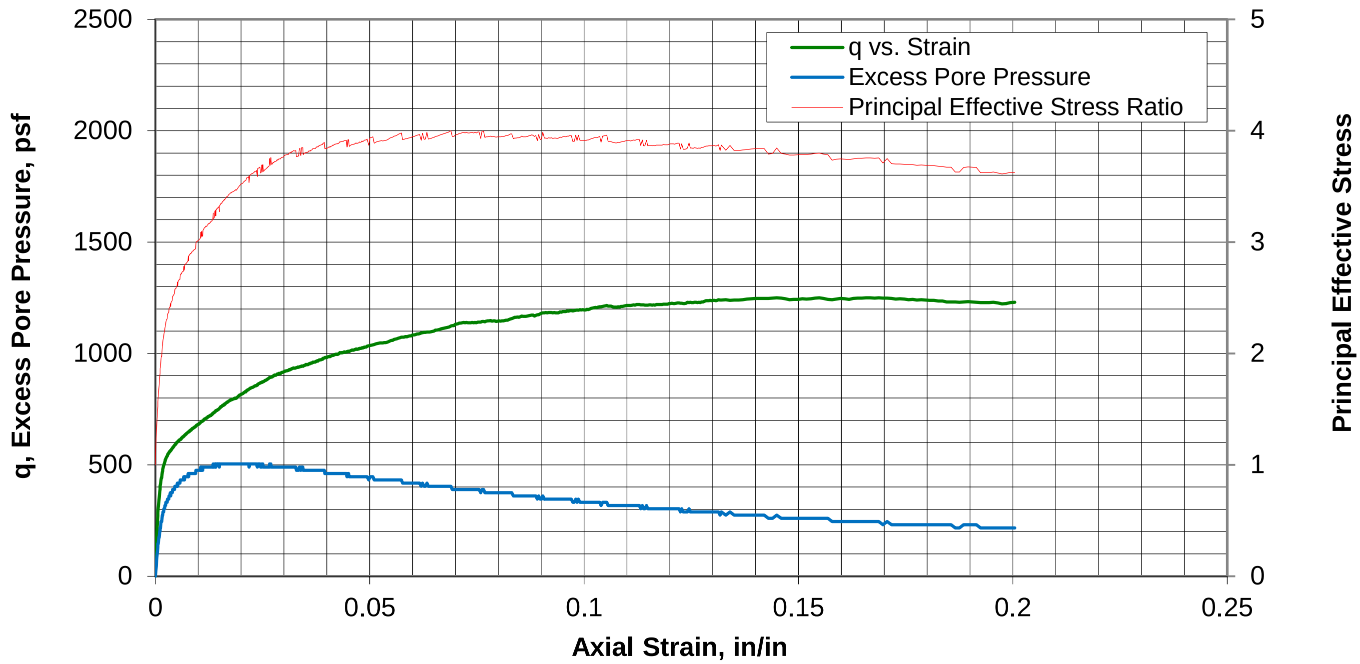
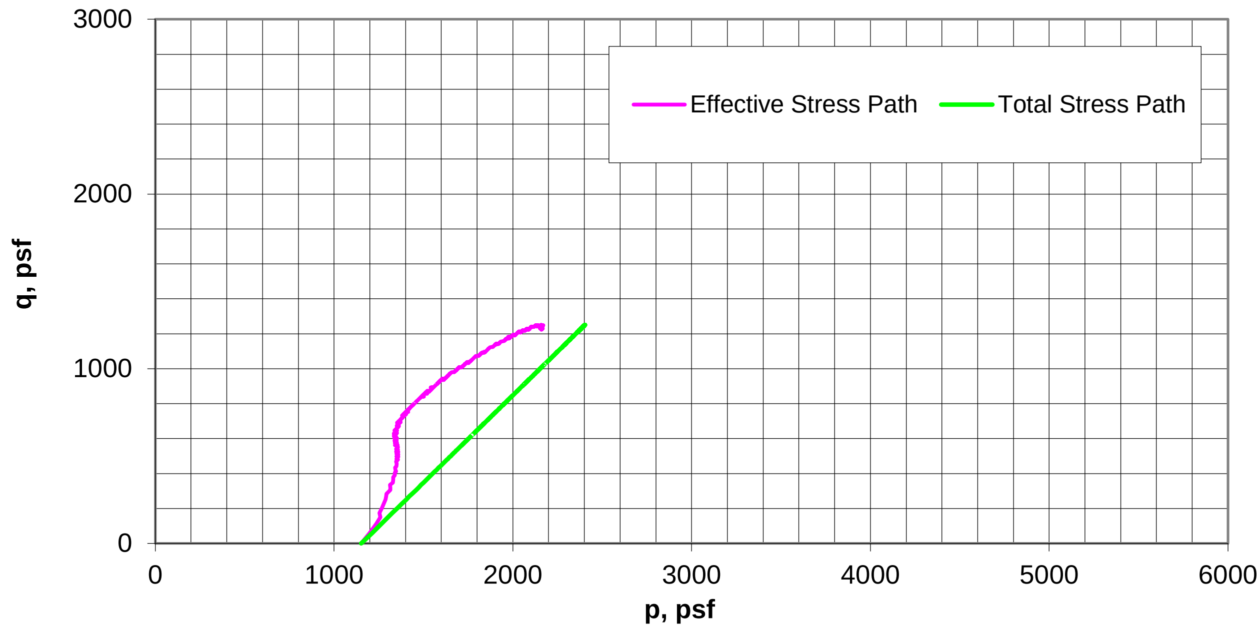
FIG. B-36
Sheet 1 of 2

CONSOLIDATED UNDRAINED TRIAXIAL COMPRESSION TEST

Boring	B-4-12	Tested By/Date	AKV 1/8/2013
Sample	S-6	Calculated By/Date	JFL 2/13/13
Depth, ft	16.5	Checked By/Date	JFL 3/20/13





Effective Stress at End-of-Consolidation, psf 1152

Cell Pressure during Shear, psf 5314

NOTES:
1. Abbreviations:
   - ft = feet
   - in = inch
   - psf = pounds per square foot
   - CU = Consolidated Undrained

Smith Island Site Restoration
Snohomish County, Washington

CU TRIAXIAL TEST SUMMARY
BORING B-4-12, SAMPLE S-6 @16.5ft

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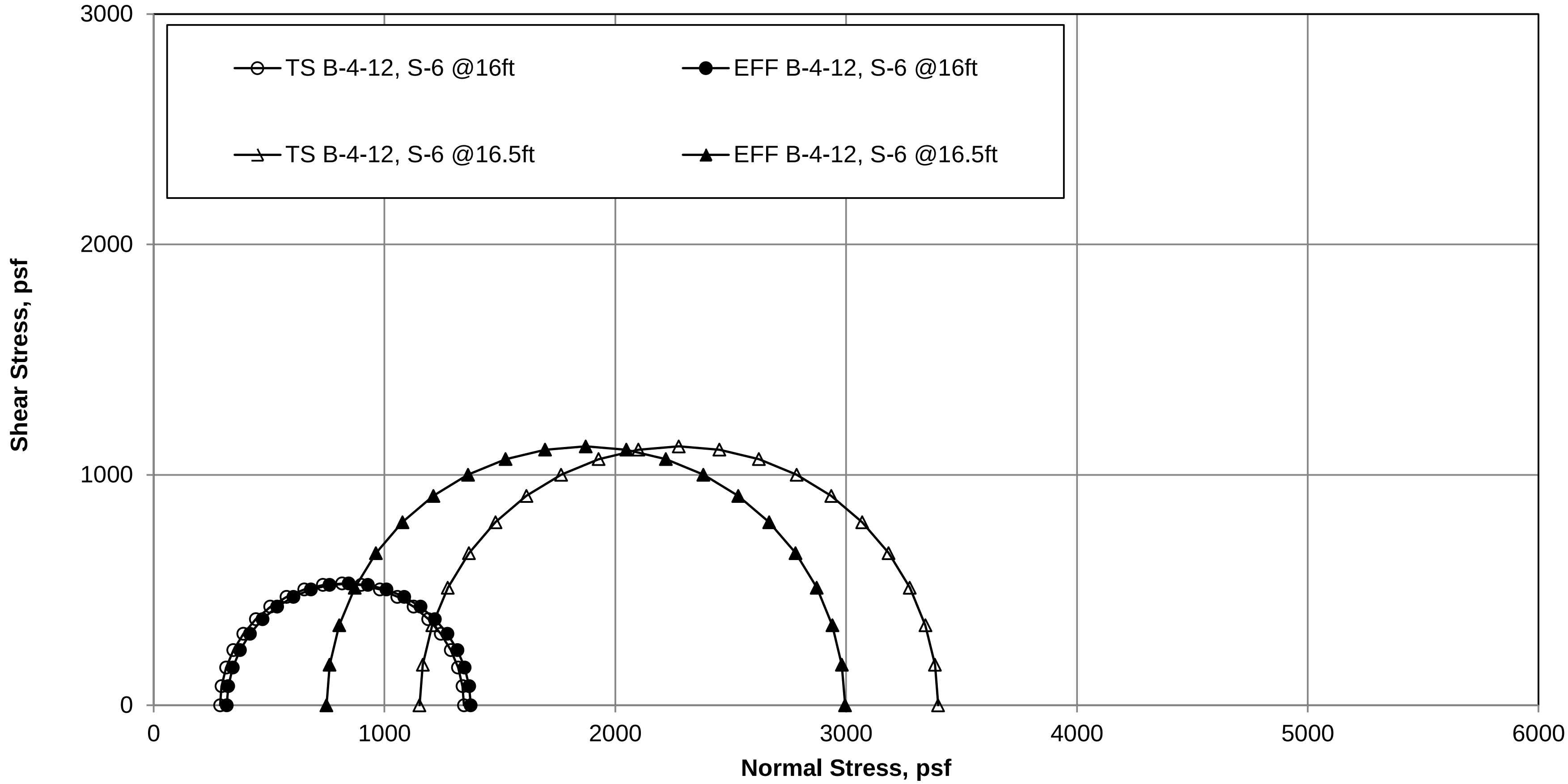
FIG. B-36
Sheet 2 of 2



NOTES

1. The Mohr's circles in this plot are based on total or effective stresses computed from results of triaxial testing.

2. The Mohr's circles in this plot are based on the **maximum principal effective stress ratio** observed during loading.

3. Abbreviations:
   ft = feet
   psf = pounds per square foot
   TS = total stress
   EFF = effective stress
   CU = Consolidated Undrained

Smith Island Site Restoration
Snohomish County, Washington

CU TRIAXIAL TEST
MOHR'S CIRCLE PLOT
BORING B-4-12, SAMPLE S-6

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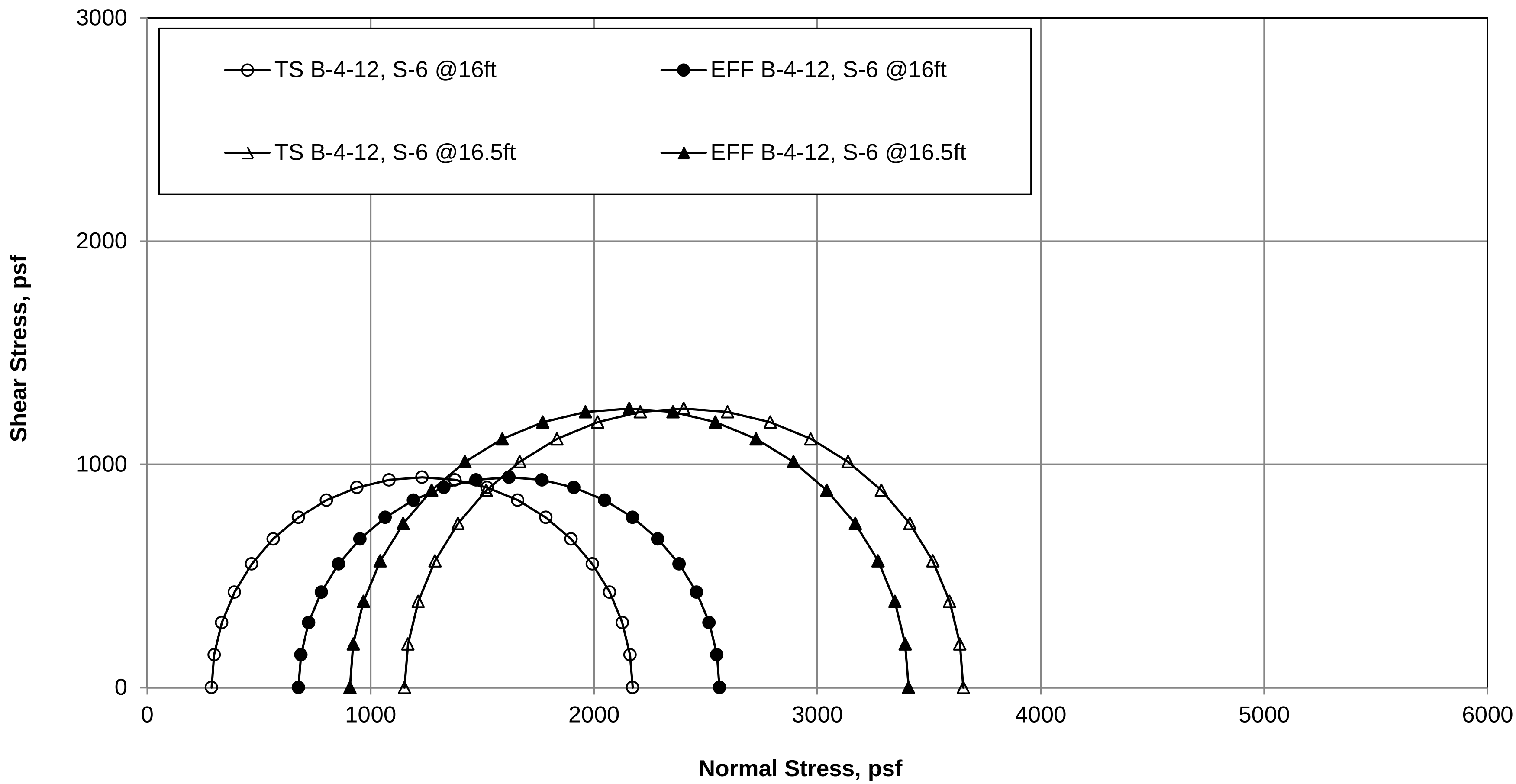
FIG. B-37
Sheet 1 of 2

FIG. B-37
Sheet 1 of 2



NOTES

1. The Mohr's circles in this plot are based on total or effective stresses computed from results of triaxial testing.

2. The Mohr's circles in this plot are based on the **maximum principal stress difference** observed during loading.

3. Abbreviations:
   ft = feet
   psf = pounds per square foot
   TS = total stress
   EFF = effective stress
   CU = Consolidated Undrained

Smith Island Site Restoration
Snohomish County, Washington

CU TRIAXIAL TEST
MOHR'S CIRCLE PLOT
BORING B-4-12, SAMPLE S-6

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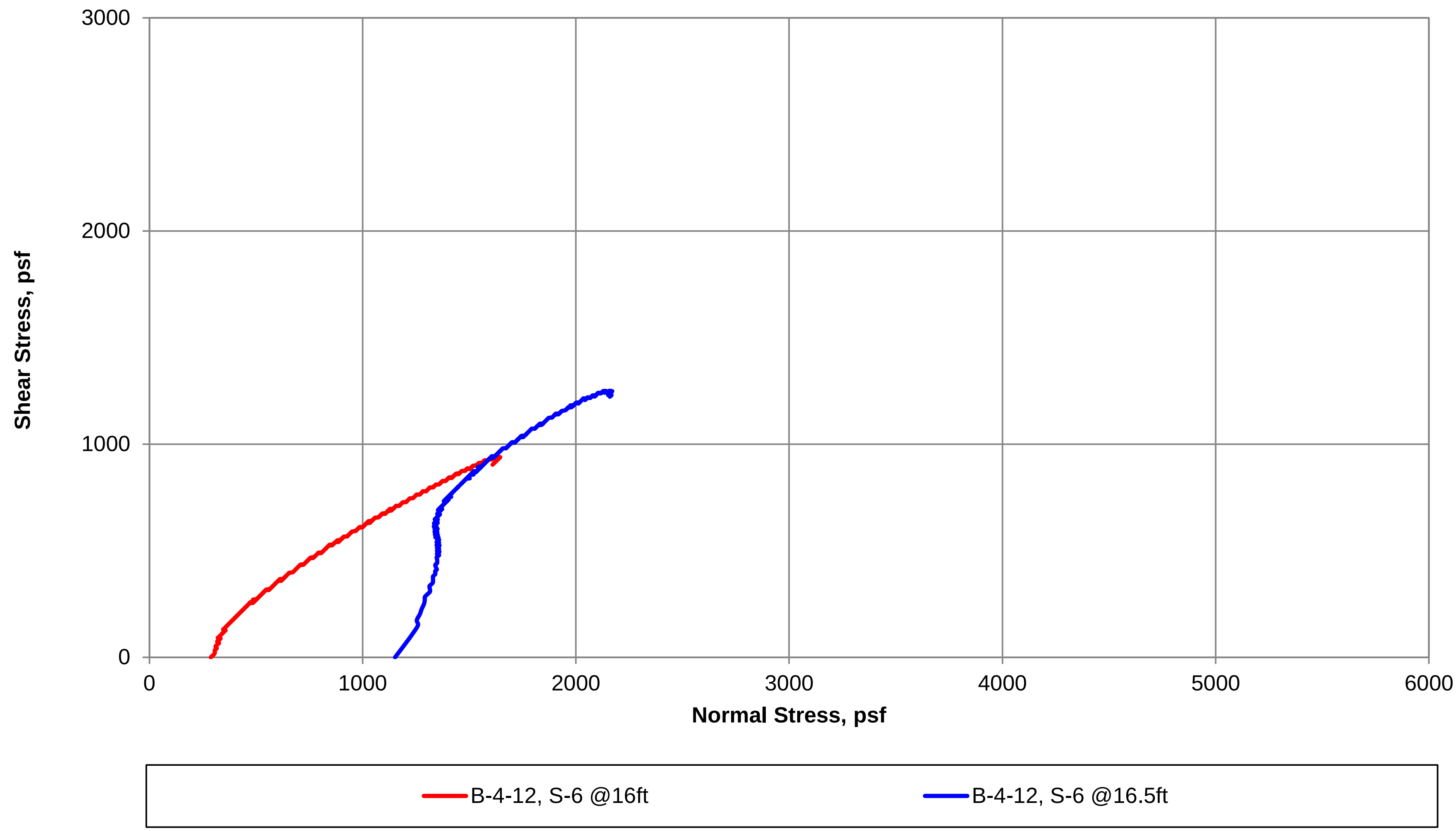
FIG. B-37
Sheet 2 of 2

FIG. B-37
Sheet 2 of 2



NOTES

1. Effective stress paths are computed from results of triaxial testing.

2. Abbreviation:
ft = feet
psf = pounds per square foot
CU = Consolidated Undrained

FIG. B-38

Smith Island Site Restoration
Snohomish County, Washington

CU TRIAXIAL TEST
EFFECTIVE STRESS PATH PLOT
BORING B-4-12, SAMPLE S-6

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FIG. B-38

Report B-1

Report from HWA GeoSciences, Inc.

Dated February 4, 2013

"Materials Laboratory Report, Triaxial Shear Strength Testing, Smith Island Project"

HWA GEOSCIENCES INC.
Geotechnical & Pavement Engineering • Hydrogeology • Geoenvironmental • Inspection & Testing

February 4, 2013
HWA Project No. 2011-048-23, Task 004

Shannon & Wilson, Inc.
400 N 34th Street, Suite 100
Seattle, Washington 98103

Attention: Mr. Joe Laprade, CET

Subject: **Materials Laboratory Report**
Triaxial Shear Strength Testing
Smith Island Project

Dear Mr. Laprade;

As requested, HWA GeoSciences Inc. (HWA) performed laboratory testing for the subject project. Herein we present the results of our laboratory analyses, which are summarized on the attached Figures. The laboratory testing program was performed in general accordance with your instructions and appropriate ASTM Standards as outlined below.

SAMPLE INFORMATION: The subject samples were delivered to our laboratory on January 25, 2013 by Shannon & Wilson personnel. The samples were in split, 3-inch diameter by 12 inch long Shelby tubes and were designated with boring, sample and depth information. Based on manual-visual methods, the soil description for the samples are as follows:

B-1, S-6 @ 15ft	Dark gray SILT (ML)
B-3, S-2 @ 5 ft	Dark gray clayey SILT with organic material (ML)
B-3, S-6 @ 15 ft	Dark gray clayey SILT with organic material (ML)

MOISTURE CONTENT OF SOIL: The moisture content of selected soil samples (percent by dry mass) was determined in general accordance with ASTM D 2216. The results are shown on Figures 1-10.

CONSOLIDATED UNDRAINED TRIAXIAL COMPRESSION OF SOILS (MULTI-STAGE TRIAXIAL SHEAR): The samples were tested in general accordance with method ASTM D 4767 to determine the shear strength characteristics of the soil. On samples B-1, S-6 and B-3, S-6, one test point was run. On sample B-3, S-2, two test points were run. For all sample specimens, the sample was trimmed down to approximately 2.5 inch diameter and the length was trimmed to provide at least a 2:1 length to diameter ratio. On the single point tests, the sample was saturated, then consolidated to the client specified pressure, then loaded until approximately 18% strain was achieved. On the two point test, a specific

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testing protocol was specified by the client. The sample was saturated and consolidated to the initial effective pressure of 4 psi, and loaded to 4% strain. It was then re-consolidated to the second effective pressure, 8 psi, and then loaded to an additional 16% strain. In Figures 1, 2, 3, and 4, the results of these tests are shown, along with photographs of the after test specimen. For the specimen B-3, S-6 at 15ft, an anomaly was observed following the trimming step. As shown in Figure 5, the sample consisted of a top portion of dark silty material and a bottom portion of lighter colored clayey material, with a clear demarcation between the two materials. As can be seen in Figure 6, the after test photograph of this specimen, two distinct shear planes formed during testing, but neither shear plane formed along the interface between the two different materials. All test specimens were cut in half length-wise and examined following testing. Nothing significant was noted during this examination.

CLOSURE: Experience has shown that laboratory test values for soil and other natural materials vary with each representative sample. As such, HWA has no knowledge as to the extent and quantity of material the tested sample may represent. HWA also makes no warranty as to how representative either the sample tested or the test results obtained are to actual field conditions. It is a well established fact that sampling methods present varying degrees of disturbance or variance that affect sample representativeness.

No copy should be made of this report except in its entirety.

We appreciate the opportunity to provide laboratory testing services on this project. Should you have any questions or comments, or if we may be of further service, please call.

Sincerely,

HWA GEOSCIENCES INC.

Harold Benny
Materials Laboratory Manager

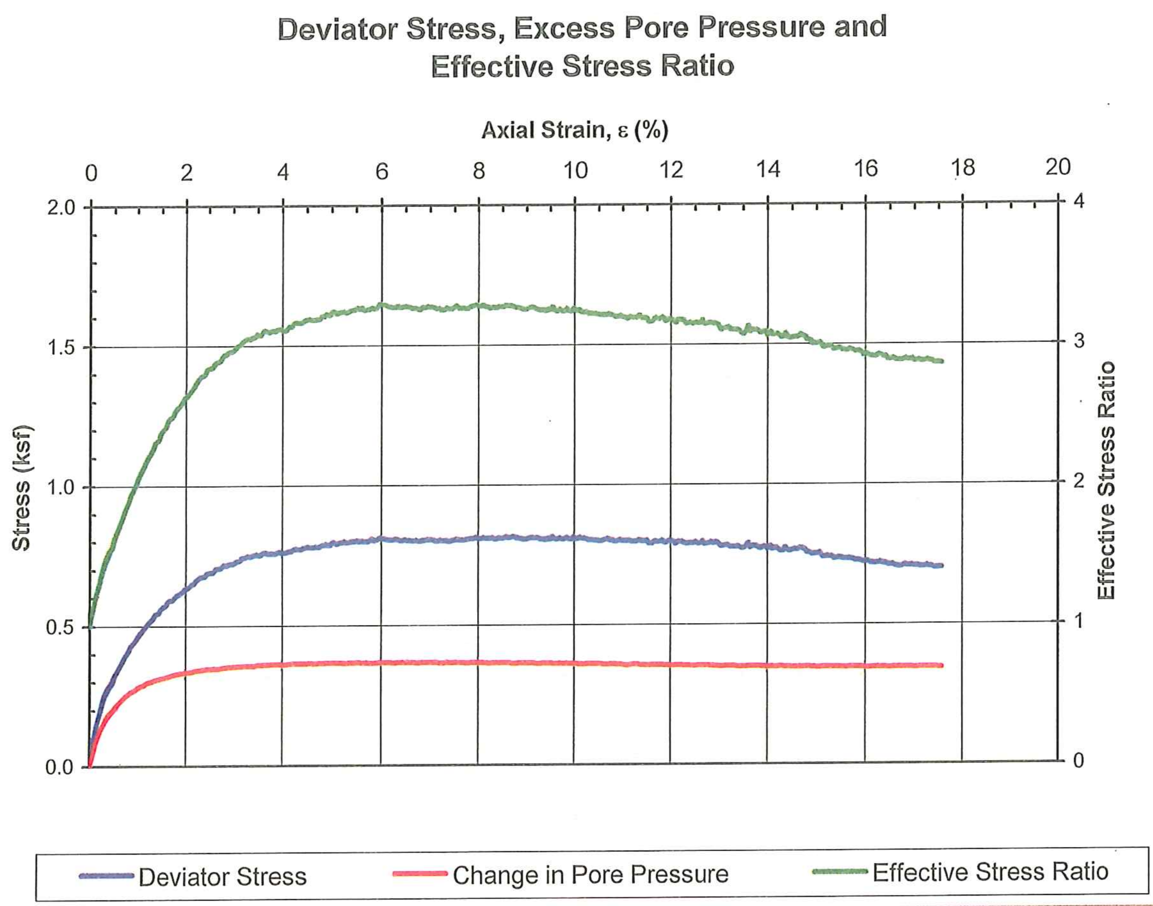
George Minassian, Ph.D., P.E.
Geotechnical Engineer

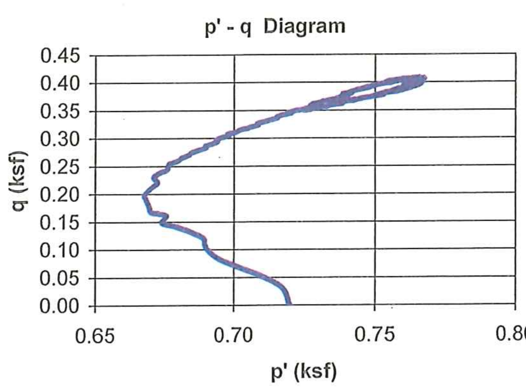
Attachments:

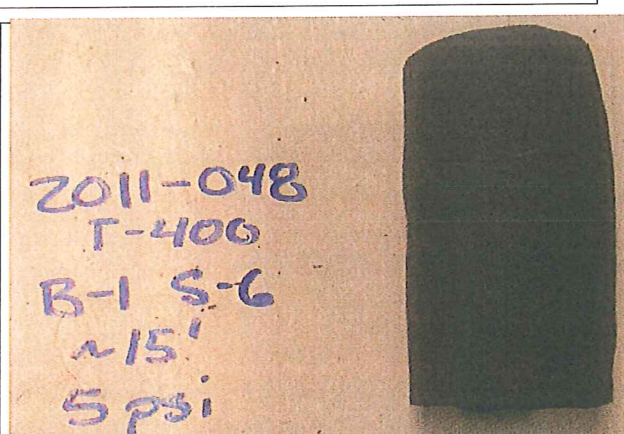
Figures 1-4	Consolidated-Undrained Triaxial Compression Test for Cohesive Soils
Figures 5-6	Before and After Testing Specimen Photographs

HWA GeoSciences Inc - Materials Testing Laboratory					
Consolidated-Undrained Triaxial Compression Test for Cohesive Soils (ASTM D 4767)					
Project Name:	Smith Island		Date:	1/25/2013	
Project No.:	2011-048		Exploration ID:	B-1	
Technician:	HBenny		Sample No:	S-6	
Sample Description:	Dark gray SILT		Sample Depth, ft:	15.0	
Strain Rate, %/min:	0.025		Confining Pressure, ksf:	0.72	
Initial Moisture, %	53.1	Initial Wet Density, pcf: 106.5	Initial Dry Density, pcf:	69.5	

Shear Plots:



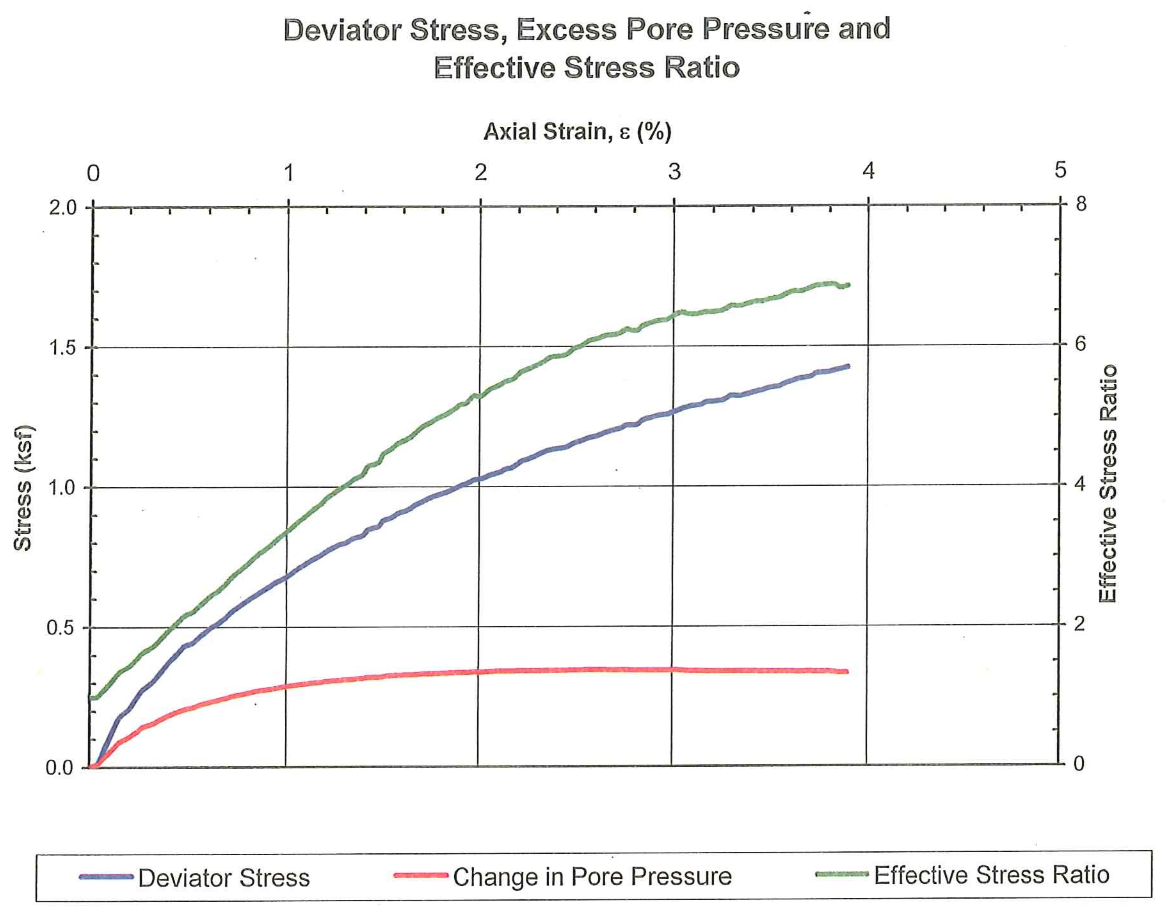


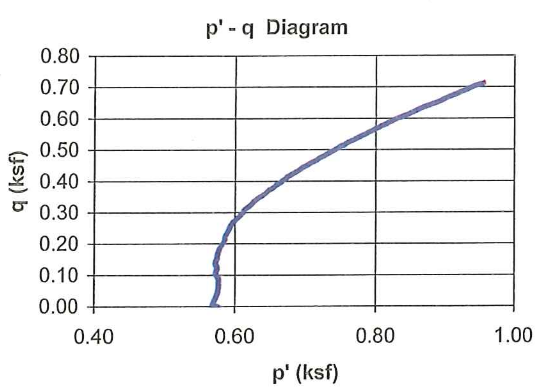


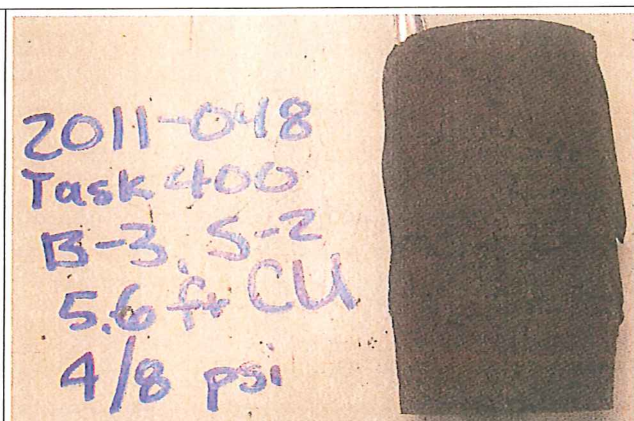
Reviewed by: George Minassian

Figure 1

HWA GeoSciences Inc - Materials Testing Laboratory						
Consolidated-Undrained Triaxial Compression Test for Cohesive Soils (ASTM D 4767)						
Project Name:	Smith Island			Date:	1/28/2013	
Project No.:	2011-048		Exploration ID:		B-3	
Technician:	HBenny		Sample No:		S-2	
Sample Description:	Dark gray clayey SILT with organic material			Sample Depth, ft:		5.6
Strain Rate, %/min:	0.025		Confining Pressure, ksf:		0.576	
Initial Moisture, %	58.8	Initial Wet Density, pcf:	102.4	Initial Dry Density, pcf:		64.5
Shear Plots:						





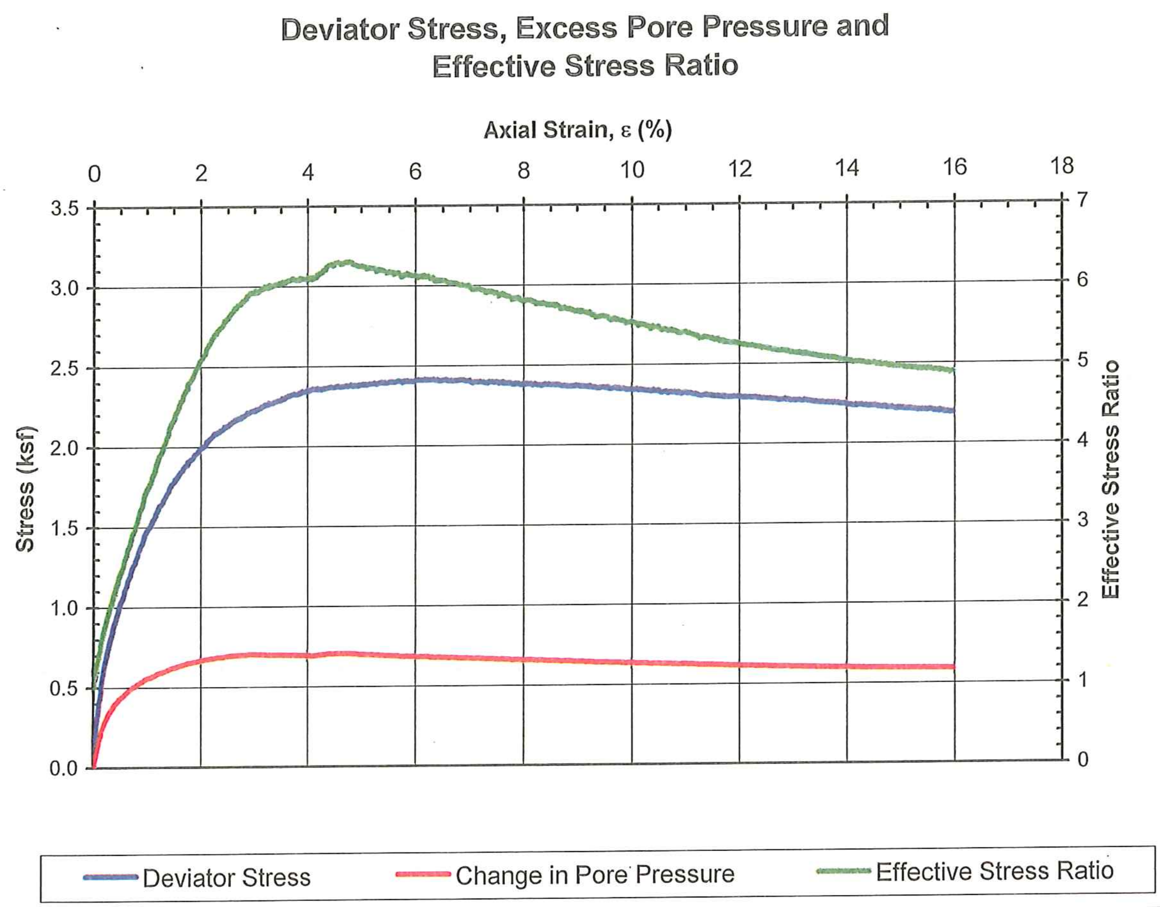


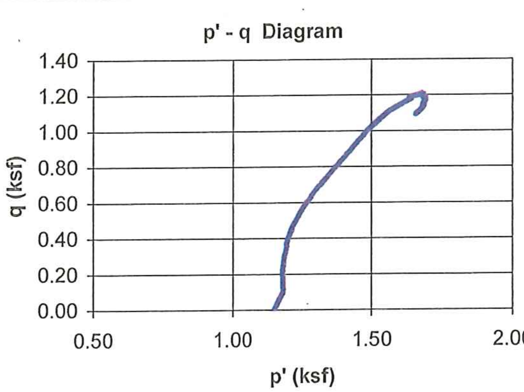
Reviewed by: George Minassian

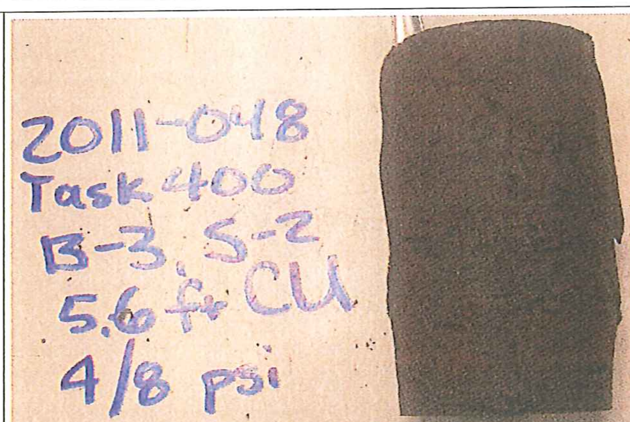
Figure 2

HWA GeoSciences Inc - Materials Testing Laboratory					
Consolidated-Undrained Triaxial Compression Test for Cohesive Soils (ASTM D 4767)					
Project Name:	Smith Island		Date:	1/28/2013	
Project No.:	2011-048	Exploration ID:		B-3	
Technician:	HBenny	Sample No:		S-2	
Sample Description:	Dark gray clayey SILT with organic material		Sample Depth, ft:		5.6
Strain Rate, %/min:	0.025	Confining Pressure, ksf:		1.152	
Initial Moisture, %	58.8	Initial Wet Density, pcf:	102.4	Initial Dry Density, pcf:	64.5

Shear Plots:



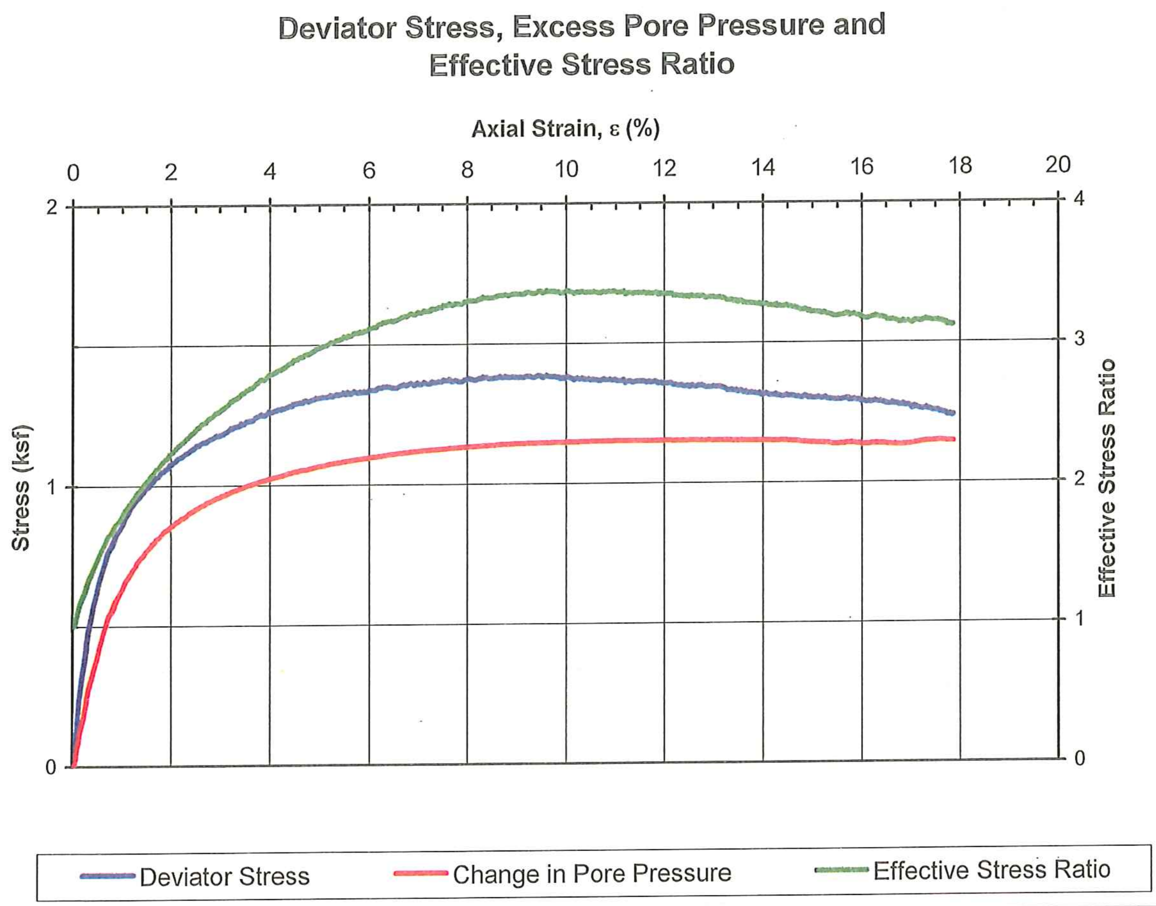


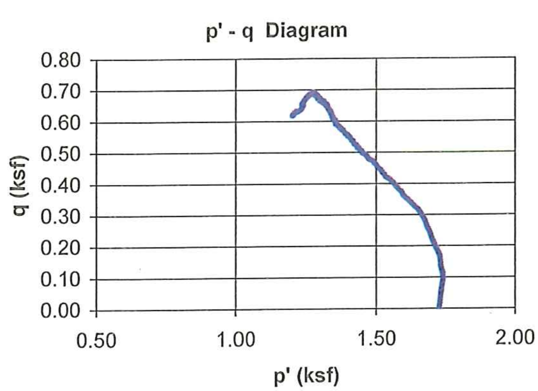


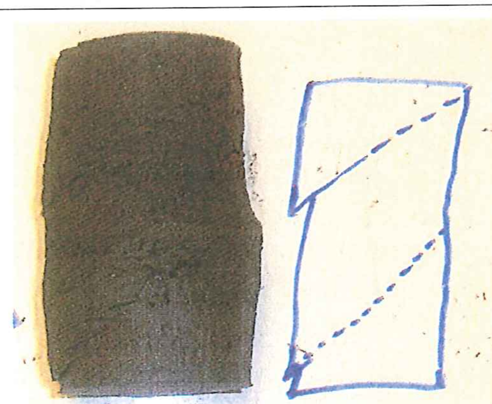
Reviewed by: George Minassian

Figure 3

HWA GeoSciences Inc - Materials Testing Laboratory					
Consolidated-Undrained Triaxial Compression Test for Cohesive Soils (ASTM D 4767)					
Project Name:	Smith Island		Date:	2/1/2013	
Project No.:	2011-048	Exploration ID:		B-3	
Technician:	HBenny	Sample No:		S-6	
Sample Description:	Dark gray clayey SILT with organics		Sample Depth, ft:		5.6
Strain Rate, %/min:	0.025	Confining Pressure, ksf:		1.728	
Initial Moisture, %	59.5	Initial Wet Density, pcf: 102.6		Initial Dry Density, pcf:	64.4
Shear Plots:					







Reviewed by: George Minassian

Figure 4

B–3, S–6 @ 15ft

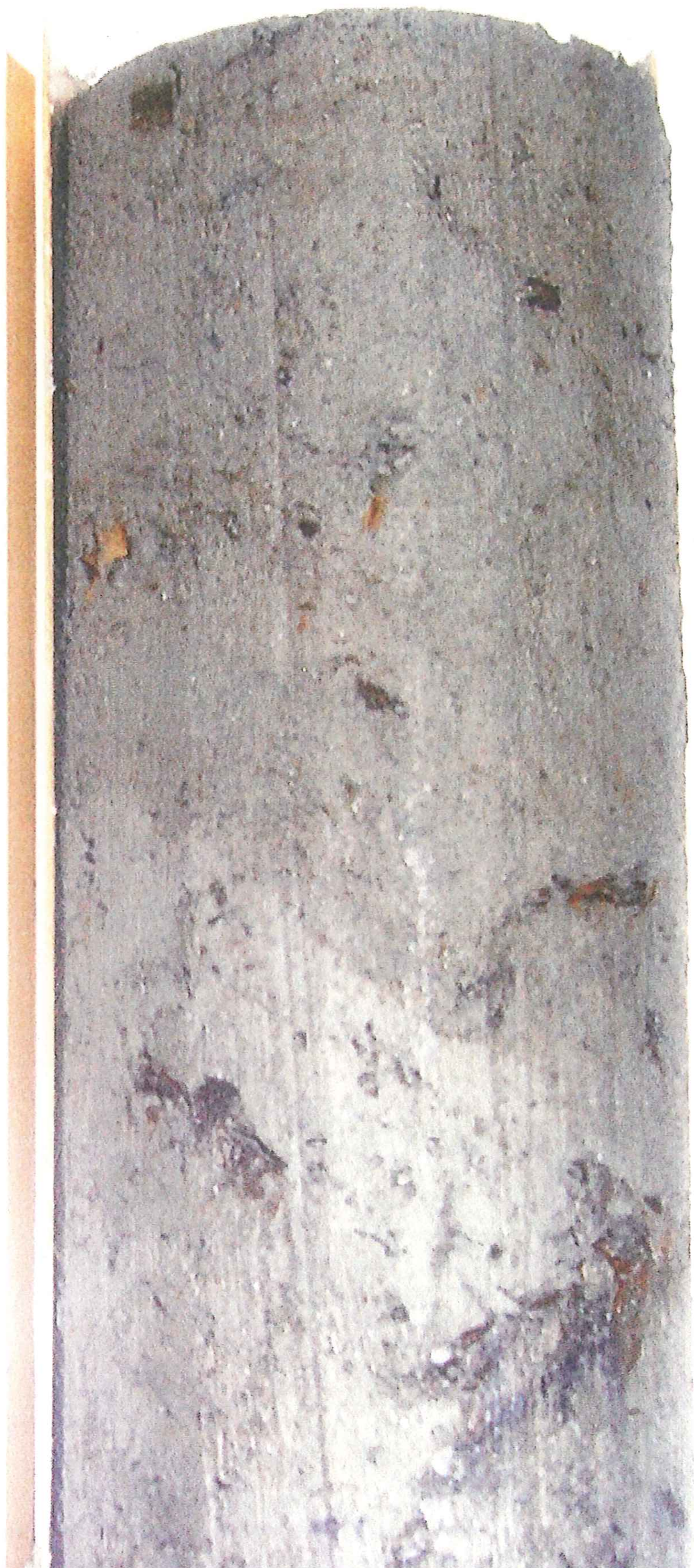
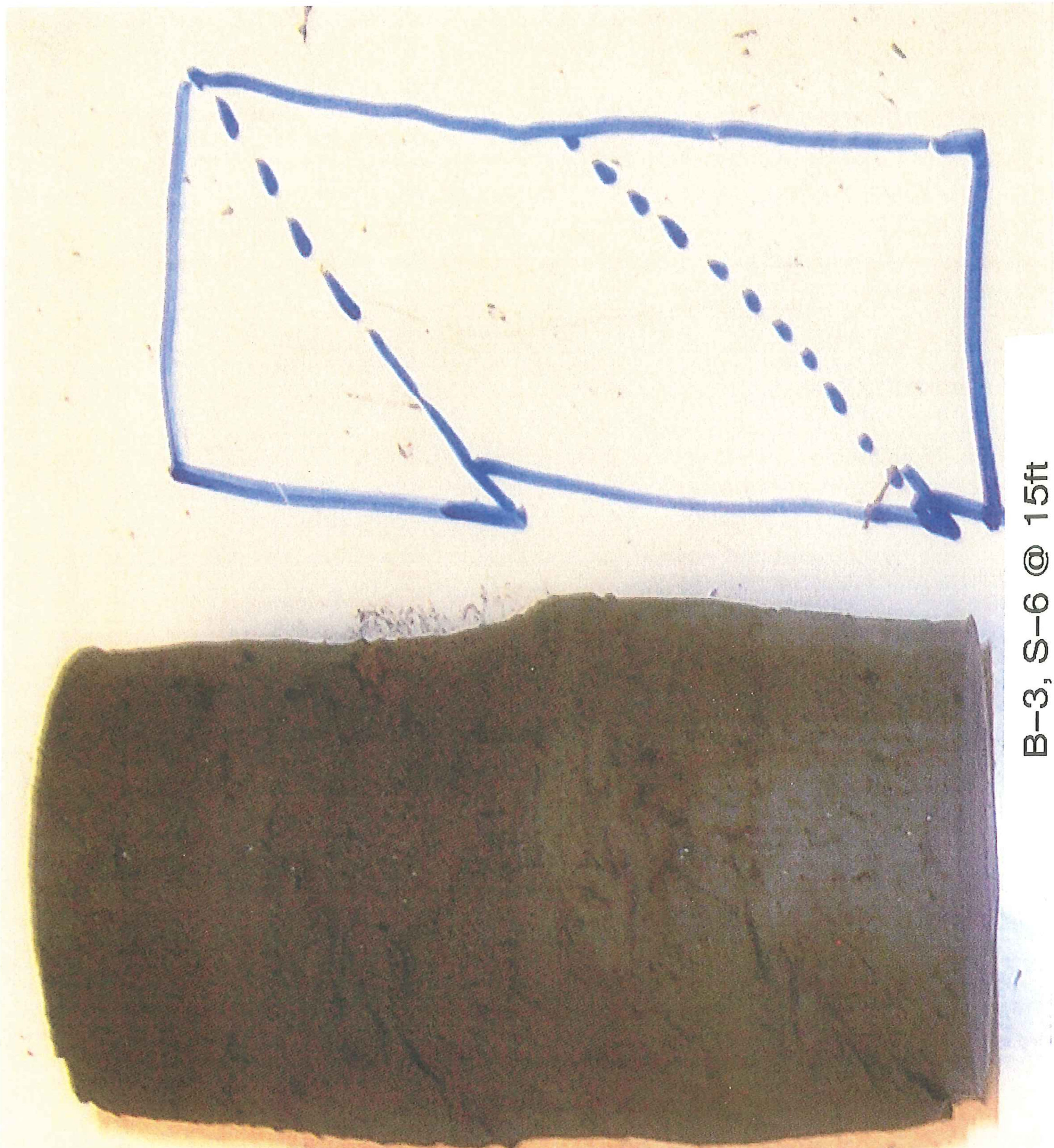


FIGURE 5



B–3, S–6 @ 15ft

FIGURE 6

APPENDIX C

ANALYTICAL LABORATORY RESULTS

APPENDIX C

ANALYTICAL LABORATORY RESULTS

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Shannon & Wilson
Cody Johnson
400 N. 34th Street, Suite 100
Seattle, Washington 98103

RE: Smith Island
Lab ID: 1212170

March 05, 2013

Attention Cody Johnson:

Fremont Analytical, Inc. received 4 sample(s) on 12/28/2012 for the analyses presented in the following report.

Sample Moisture (Percent Moisture)
Total Metals by EPA Method 6020

This report consists of the following:

- Case Narrative
- Analytical Results
- Applicable Quality Control Summary Reports
- Chain of Custody

All analyses were performed consistent with the Quality Assurance program of Fremont Analytical, Inc. Please contact the laboratory if you should have any questions about the results.

Thank you for using Fremont Analytical.

Sincerely,

M Clements

Michelle Clements
Sr. Chemist / Lab Manager

CLIENT:	Shannon & Wilson
Project:	Smith Island
Lab Order:	1212170

Work Order Sample Summary

Lab Sample ID	Client Sample ID	Date/Time Collected	Date/Time Received
1212170-001	B-4-12:2.5	12/27/2012 3:04 PM	12/28/2012 5:00 PM
1212170-002	B-4-12:10	12/27/2012 3:38 PM	12/28/2012 5:00 PM
1212170-003	B-5-12:2.5	12/27/2012 9:07 AM	12/28/2012 5:00 PM
1212170-004	B-5-12:12	12/27/2012 10:30 AM	12/28/2012 5:00 PM

Note: If no "Time Collected" is supplied, a default of 12:00AM is assigned

Case Narrative

WO#: **1212170**

Date: **3/5/2013**

CLIENT: Shannon & Wilson
Project: Smith Island

I. SAMPLE RECEIPT:
All samples were received intact. The internal ice chest temperatures were measured on receipt and are recorded on the attached Sample Receipt Checklist.

II. GENERAL REPORTING COMMENTS:
Results are reported on a wet weight basis unless dry-weight correction is denoted in the units field on the analytical report ("mg/kg-dry" or "ug/kg-dry").

Matrix Spike (MS) and MS Duplicate (MSD) samples are tested from an analytical batch of "like" matrix to check for possible matrix effect. The MS and MSD will provide site specific matrix data only for those samples which are spiked by the laboratory. The sample chosen for spike purposes may or may not have been a sample submitted in this sample delivery group. The validity of the analytical procedures for which data is reported in this analytical report is determined by the Laboratory Control Sample (LCS) and the Method Blank (MB). The LCS and the MB are processed with the samples and the MS/MSD to ensure method criteria are achieved throughout the entire analytical process.

III. ANALYSES AND EXCEPTIONS:
Exceptions associated with this report will be footnoted in the analytical results page(s) or the quality control summary page(s) and/or noted below.

Analytical Report

WO#: **1212170**
Date Reported: **3/5/2013**

CLIENT: Shannon & Wilson
Project: Smith Island

Lab ID: 1212170-001 **Collection Date:** 12/27/2012 3:04:00 PM
Client Sample ID: **B-4-12:2.5** **Matrix:** Soil

Analyses	Result	RL	Qual	Units	DF	Date Analyzed
Total Metals by EPA Method 6020				Batch ID: 3891		Analyst: MC
Arsenic	29.9	0.113		mg/Kg-dry	1	1/2/2013 1:23:32 PM
Sample Moisture (Percent Moisture)				Batch ID: R7055		Analyst: JY
Percent Moisture	35.2			wt%	1	12/31/2012 12:31:11 PM

Lab ID: 1212170-002 **Collection Date:** 12/27/2012 3:38:00 PM
Client Sample ID: **B-4-12:10** **Matrix:** Soil

Analyses	Result	RL	Qual	Units	DF	Date Analyzed
Total Metals by EPA Method 6020				Batch ID: 3891		Analyst: MC
Arsenic	7.87	0.0863		mg/Kg-dry	1	1/2/2013 2:15:09 PM
Sample Moisture (Percent Moisture)				Batch ID: R7055		Analyst: JY
Percent Moisture	26.2			wt%	1	12/31/2012 12:31:11 PM

Qualifiers:

B	Analyte detected in the associated Method Blank	D	Dilution was required
E	Value above quantitation range	H	Holding times for preparation or analysis exceeded
J	Analyte detected below quantitation limits	ND	Not detected at the Reporting Limit
RL	Reporting Limit	S	Spike recovery outside accepted recovery limits

Analytical Report

WO#: **1212170**
Date Reported: **3/5/2013**

CLIENT: Shannon & Wilson
Project: Smith Island

Lab ID: 1212170-003 **Collection Date:** 12/27/2012 9:07:00 AM
Client Sample ID: **B-5-12:2.5** **Matrix:** Soil

Analyses	Result	RL	Qual	Units	DF	Date Analyzed
Total Metals by EPA Method 6020				Batch ID: 3891		Analyst: MC
Arsenic	20.3	0.128		mg/Kg-dry	1	1/2/2013 2:25:42 PM
Lead	36.3	0.257		mg/Kg-dry	1	1/2/2013 2:25:42 PM
Sample Moisture (Percent Moisture)				Batch ID: R7055		Analyst: JY
Percent Moisture	39.6			wt%	1	12/31/2012 12:31:11 PM

Lab ID: 1212170-004 **Collection Date:** 12/27/2012 10:30:00 AM
Client Sample ID: **B-5-12:12** **Matrix:** Soil

Analyses	Result	RL	Qual	Units	DF	Date Analyzed
Total Metals by EPA Method 6020				Batch ID: 3891		Analyst: MC
Arsenic	9.35	0.111		mg/Kg-dry	1	1/2/2013 2:33:16 PM
Sample Moisture (Percent Moisture)				Batch ID: R7055		Analyst: JY
Percent Moisture	32.5			wt%	1	12/31/2012 12:31:11 PM

Qualifiers:

B	Analyte detected in the associated Method Blank	D	Dilution was required
E	Value above quantitation range	H	Holding times for preparation or analysis exceeded
J	Analyte detected below quantitation limits	ND	Not detected at the Reporting Limit
RL	Reporting Limit	S	Spike recovery outside accepted recovery limits

Fremont Analytical

Date: *3/5/2013*

Work Order: 1212170
CLIENT: Shannon & Wilson
Project: Smith Island

QC SUMMARY REPORT

Total Metals by EPA Method 6020

Sample ID: **MB-3891** SampType: **MBLK** Units: **mg/Kg** Prep Date: **12/31/2012** RunNo: **7071**
Client ID: **MBLKS** Batch ID: **3891** Analysis Date: **1/2/2013** SeqNo: **139978**

Analyte	Result	RL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Arsenic	ND	0.100									
Lead	ND	0.200									

Sample ID: **LCS-3891** SampType: **LCS** Units: **mg/Kg** Prep Date: **12/31/2012** RunNo: **7071**
Client ID: **LCSS** Batch ID: **3891** Analysis Date: **1/2/2013** SeqNo: **139979**

Analyte	Result	RL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Arsenic	102	0.200	102.0	0	99.6	83.43	115.7				
Lead	65.8	0.400	71.80	0	91.6	84.26	115.7				

Sample ID: **1212170-001ADUP** SampType: **DUP** Units: **mg/Kg-dry** Prep Date: **12/31/2012** RunNo: **7071**
Client ID: **B-4-12:2.5** Batch ID: **3891** Analysis Date: **1/2/2013** SeqNo: **139981**

Analyte	Result	RL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Arsenic	32.8	0.121						29.85	9.38	30	
Lead	21.9	0.241						20.14	8.20	30	

Sample ID: **1212170-001AMS** SampType: **MS** Units: **mg/Kg-dry** Prep Date: **12/31/2012** RunNo: **7071**
Client ID: **B-4-12:2.5** Batch ID: **3891** Analysis Date: **1/2/2013** SeqNo: **139983**

Analyte	Result	RL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Arsenic	94.0	0.125	62.71	29.85	102	75	125	86.13	8.73	0	
Lead	46.8	0.251	31.36	20.14	85.0	75	125	42.05	10.7	0	

Qualifiers:

B	Analyte detected in the associated Method Blank	D	Dilution was required	E	Value above quantitation range
H	Holding times for preparation or analysis exceeded	J	Analyte detected below quantitation limits	ND	Not detected at the Reporting Limit
R	RPD outside accepted recovery limits	RL	Reporting Limit	S	Spike recovery outside accepted recovery limits

Fremont Analytical

Date: *3/5/2013*

Work Order: 1212170
CLIENT: Shannon & Wilson
Project: Smith Island

QC SUMMARY REPORT
Total Metals by EPA Method 6020

Sample ID: **1212170-001AMSD** SampType: **MSD** Units: **mg/Kg-dry** Prep Date: **12/31/2012** RunNo: **7071**
Client ID: **B-4-12:2.5** Batch ID: **3891** Analysis Date: **1/2/2013** SeqNo: **139984**

Analyte	Result	RL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Arsenic	86.1	0.113	56.72	29.85	99.2	75	125	93.99	8.73	30	
Lead	42.0	0.227	28.36	20.14	77.3	75	125	46.81	10.7	30	

Qualifiers:

B	Analyte detected in the associated Method Blank	D	Dilution was required	E	Value above quantitation range
H	Holding times for preparation or analysis exceeded	J	Analyte detected below quantitation limits	ND	Not detected at the Reporting Limit
R	RPD outside accepted recovery limits	RL	Reporting Limit	S	Spike recovery outside accepted recovery limits

Fremont Analytical

Sample Log-In Check List

Client Name: **SW**

Logged by: **Troy Zehr**

Work Order Number: **1212170**

Date Received: **12/28/2012 5:00:00 PM**

Chain of Custody

		Yes	No	
1.	Were custodial seals present?	☐	☐	Not Required ☑
2.	Is Chain of Custody complete?	☑	☐	Not Present ☐
3.	How was the sample delivered?	Client		

Log In

		Yes	No	NA
4.	Coolers are present?	☑	☐	☐
5.	Was an attempt made to cool the samples?	☑	☐	☐
6.	Were all coolers received at a temperature of >0° C to 10.0°C	☑	☐	☐
7.	Sample(s) in proper container(s)?	☑	☐	
8.	Sufficient sample volume for indicated test(s)?	☑	☐	
9.	Are samples properly preserved?	☑	☐	
10.	Was preservative added to bottles?	☐	☑	☐
11.	Is there headspace present in VOA vials?	☐	☐	☑
12.	Did all sample containers arrive in good condition?(unbroken)	☑	☐	
13.	Does paperwork match bottle labels?	☑	☐	
14.	Are matrices correctly identified on Chain of Custody?	☑	☐	
15.	Is it clear what analyses were requested?	☑	☐	
16.	Were all holding times able to be met?	☑	☐	

Special Handling (if applicable)

		Yes	No	NA
17.	Was client notified of all discrepancies with this order?	☐	☐	☑

Person Notified: 　　Date:

By Whom: 　　Via: ☐ eMail ☐ Phone ☐ Fax ☐ In Person

Regarding:

Client Instructions:

18. Additional remarks/Disrepancies

Item Information

Item #	Temp °C	Condition
Cooler	4.9	Good

1212170

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS
CORPORATE HEADQUARTERS
400 N. 34th Street, Suite 100
Seattle, WA 98103
(206) 632-8020

CHAIN-OF-CUSTODY RECORD

Page 1 of 1

Laboratory: FA

Attn:

(include preservative if used)
Analysis Parameters/Sample Container Description

Sample Identity	Lab No.	Time	Date Sampled	Comp.	Grab	Av.						Total Number of Containers	Remarks/Matrix
B-4-12:2.5		1504	12/27/12		x	X						1	
B-4-12:10		1535	|		|	X						1	
B-5-12:2.5		507	|		|	X						1	
B-5-12:12		1330	12/27/12		|	X						1	

Project Information

Project No.: 21-1-24050-030
Project Name: Smith Island
Contact: Cody Johnson
Ongoing Project? Yes ☐ No ☒
Sampler:

Sample Receipt

Total No. of Containers:
COC Seals/Intact? Y/N/NA
Received Good Cond./Cold
Delivery Method:
(attach shipping bill, if any)

Instructions

Requested Turnaround Time: By Weds 1/2/13
Special Instructions:

Relinquished By: 1.	Relinquished By: 2.	Relinquished By: 3.
Signature: [signature] Time: 1700	Signature: Time:	Signature: Time:
Printed Name: Cody Johnson Date: 12/28/12	Printed Name: Date:	Printed Name: Date:
Company: S+W	Company:	Company:

Received By: 1.	Received By: 2.	Received By: 3.
Signature: [signature] Time: 17:08	Signature: Time:	Signature: Time:
Printed Name: Troy Zehr Date: 12/28	Printed Name: Date:	Printed Name: Date:
Company: FAI	Company:	Company:

Distribution: White - w/shipment - returned to Shannon & Wilson w/ laboratory report
Yellow - w/shipment - for consignee files
Pink - Shannon & Wilson - job file

No. 663

1311 N. 35th St.
Seattle, WA 98103
T: (206) 352-3790
F: (206) 352-7178
info@fremontanalytical.com

Shannon & Wilson
Cody Johnson
400 N. 34th Street, Suite 100
Seattle, Washington 98103

RE: Smith Island
Lab ID: 1301008

January 07, 2013

Attention Cody Johnson:

Fremont Analytical, Inc. received 2 sample(s) on 1/3/2013 for the analyses presented in the following report.

Sample Moisture (Percent Moisture)

Total Metals by EPA Method 6020

This report consists of the following:

- Case Narrative
- Analytical Results
- Applicable Quality Control Summary Reports
- Chain of Custody

All analyses were performed consistent with the Quality Assurance program of Fremont Analytical, Inc. Please contact the laboratory if you should have any questions about the results.

Thank you for using Fremont Analytical.

Sincerely,

M Clements

Michelle Clements
Sr. Chemist / Lab Manager

Fremont Analytical

Date: *01/07/2013*

CLIENT: Shannon & Wilson
Project: Smith Island
Lab Order: 1301008

Work Order Sample Summary

Lab Sample ID	Client Sample ID	Date/Time Collected	Date/Time Received
1301008-001	B-3-13:2.5	01/02/2013 1:28 PM	01/03/2013 3:43 PM
1301008-002	B-3-13:10	01/02/2013 2:01 PM	01/03/2013 3:43 PM

Note: If no "Time Collected" is supplied, a default of 12:00AM is assigned

Case Narrative

WO#: **1301008**

Date: **1/7/2013**

CLIENT: Shannon & Wilson
Project: Smith Island

I. SAMPLE RECEIPT:
All samples were received intact. The internal ice chest temperatures were measured on receipt and are recorded on the attached Sample Receipt Checklist.

II. GENERAL REPORTING COMMENTS:
Results are reported on a wet weight basis unless dry-weight correction is denoted in the units field on the analytical report ("mg/kg-dry" or "ug/kg-dry").

Matrix Spike (MS) and MS Duplicate (MSD) samples are tested from an analytical batch of "like" matrix to check for possible matrix effect. The MS and MSD will provide site specific matrix data only for those samples which are spiked by the laboratory. The sample chosen for spike purposes may or may not have been a sample submitted in this sample delivery group. The validity of the analytical procedures for which data is reported in this analytical report is determined by the Laboratory Control Sample (LCS) and the Method Blank (MB). The LCS and the MB are processed with the samples and the MS/MSD to ensure method criteria are achieved throughout the entire analytical process.

III. ANALYSES AND EXCEPTIONS:
Exceptions associated with this report will be footnoted in the analytical results page(s) or the quality control summary page(s) and/or noted below.

Analytical Report

WO#: **1301008**
Date Reported: **1/7/2013**

CLIENT: Shannon & Wilson
Project: Smith Island

Lab ID: 1301008-001 **Collection Date:** 1/2/2013 1:28:00 PM
Client Sample ID: **B-3-13:2.5** **Matrix:** Soil

Analyses	Result	RL	Qual	Units	DF	Date Analyzed
Total Metals by EPA Method 6020				Batch ID: 3899		Analyst: MC
Arsenic	14.8	0.113		mg/Kg-dry	1	1/7/2013 1:54:21 PM
Sample Moisture (Percent Moisture)				Batch ID: R7081		Analyst: MC
Percent Moisture	31.9			wt%	1	1/4/2013 11:25:08 AM

Lab ID: 1301008-002 **Collection Date:** 1/2/2013 2:01:00 PM
Client Sample ID: **B-3-13:10** **Matrix:** Soil

Analyses	Result	RL	Qual	Units	DF	Date Analyzed
Total Metals by EPA Method 6020				Batch ID: 3899		Analyst: MC
Arsenic	22.7	0.121		mg/Kg-dry	1	1/7/2013 2:46:06 PM
Sample Moisture (Percent Moisture)				Batch ID: R7081		Analyst: MC
Percent Moisture	39.5			wt%	1	1/4/2013 11:25:08 AM

Qualifiers:

B	Analyte detected in the associated Method Blank	D	Dilution was required
E	Value above quantitation range	H	Holding times for preparation or analysis exceeded
J	Analyte detected below quantitation limits	ND	Not detected at the Reporting Limit
RL	Reporting Limit	S	Spike recovery outside accepted recovery limits

Fremont Analytical

Date: *1/7/2013*

Work Order: 1301008
CLIENT: Shannon & Wilson
Project: Smith Island

QC SUMMARY REPORT
Total Metals by EPA Method 6020

Sample ID: **MB-3899** SampType: **MBLK** Units: **mg/Kg** Prep Date: **1/4/2013** RunNo: **7094**
Client ID: **MBLKS** Batch ID: **3899** Analysis Date: **1/7/2013** SeqNo: **140503**

Analyte	Result	RL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Arsenic	ND	0.100									

Sample ID: **LCS-3899** SampType: **LCS** Units: **mg/Kg** Prep Date: **1/4/2013** RunNo: **7094**
Client ID: **LCSS** Batch ID: **3899** Analysis Date: **1/7/2013** SeqNo: **140504**

Analyte	Result	RL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Arsenic	108	0.100	102.0	0	106	83.43	115.7				

Sample ID: **1301008-001ADUP** SampType: **DUP** Units: **mg/Kg-dry** Prep Date: **1/4/2013** RunNo: **7094**
Client ID: **B-3-13:2.5** Batch ID: **3899** Analysis Date: **1/7/2013** SeqNo: **140506**

Analyte	Result	RL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Arsenic	14.9	0.112						14.76	0.890	30	

Sample ID: **1301008-001AMS** SampType: **MS** Units: **mg/Kg-dry** Prep Date: **1/4/2013** RunNo: **7094**
Client ID: **B-3-13:2.5** Batch ID: **3899** Analysis Date: **1/7/2013** SeqNo: **140508**

Analyte	Result	RL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Arsenic	66.4	0.110	55.22	14.76	93.5	75	125				

Sample ID: **1301008-001AMSD** SampType: **MSD** Units: **mg/Kg-dry** Prep Date: **1/4/2013** RunNo: **7094**
Client ID: **B-3-13:2.5** Batch ID: **3899** Analysis Date: **1/7/2013** SeqNo: **140509**

Analyte	Result	RL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Arsenic	67.7	0.110	54.81	14.76	96.5	75	125	66.36	1.93	30	

Qualifiers:

B	Analyte detected in the associated Method Blank	D	Dilution was required	E	Value above quantitation range
H	Holding times for preparation or analysis exceeded	J	Analyte detected below quantitation limits	ND	Not detected at the Reporting Limit
R	RPD outside accepted recovery limits	RL	Reporting Limit	S	Spike recovery outside accepted recovery limits

Sample Log-In Check List

Client Name:	SW	Work Order Number:	1301008
Logged by:	Troy Zehr	Date Received:	1/3/2013 3:43:00 PM

Chain of Custody

1. Were custodial seals present? Yes ☐ No ☑ Not Required ☐
2. Is Chain of Custody complete? Yes ☑ No ☐ Not Present ☐
3. How was the sample delivered? Client

Log In

4. Coolers are present? Yes ☑ No ☐ NA ☐
5. Was an attempt made to cool the samples? Yes ☑ No ☐ NA ☐
6. Were all coolers received at a temperature of >0° C to 10.0°C Yes ☑ No ☐ NA ☐
7. Sample(s) in proper container(s)? Yes ☑ No ☐
8. Sufficient sample volume for indicated test(s)? Yes ☑ No ☐
9. Are samples properly preserved? Yes ☑ No ☐
10. Was preservative added to bottles? Yes ☐ No ☑ NA ☐
11. Is there headspace present in VOA vials? Yes ☐ No ☐ NA ☑
12. Did all sample containers arrive in good condition?(unbroken) Yes ☑ No ☐
13. Does paperwork match bottle labels? Yes ☑ No ☐
14. Are matrices correctly identified on Chain of Custody? Yes ☑ No ☐
15. Is it clear what analyses were requested? Yes ☑ No ☐
16. Were all holding times able to be met? Yes ☑ No ☐

Special Handling (if applicable)

17. Was client notified of all discrepancies with this order? Yes ☐ No ☐ NA ☑

Person Notified: ______ Date: ______
By Whom: ______ Via: ☐ eMail ☐ Phone ☐ Fax ☐ In Person
Regarding: ______
Client Instructions: ______

18. Additional remarks/Disrepancies

Item Information

Item #	Temp ºC	Condition
Cooler	4.1	Good

1301008

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS
CORPORATE HEADQUARTERS
400 N. 34th Street, Suite 100
Seattle, WA 98103
(206) 632-8020

CHAIN-OF-CUSTODY RECORD

Page 1 of 1

Laboratory FA

Attn:

(include preservative if used)
Analysis Parameters/Sample Container Description

Sample Identity	Lab No.	Time	Date Sampled	Comp.	Grab	Ar						Total Number of Containers	Remarks/Matrix
B-3-13:2.5		1325	1/2/13			X						1	
B-3-13:10		1401	↓			X						1	

Project Information	
Project No.:	
Project Name:	Smith Island
Contact:	Cody Johnson
Ongoing Project?	Yes ☑ No ☐
Sampler:	

Sample Receipt	
Total No. of Containers:	
COC Seals/Intact? Y/N/NA	
Received Good Cond./Cold	
Delivery Method: (attach shipping bill, if any)	

Instructions
Requested Turnaround Time: By Monday 1/7
Special Instructions:

Distribution: White - w/shipment - returned to Shannon & Wilson w/ laboratory report
Yellow - w/shipment - for consignee files
Pink - Shannon & Wilson - job file

Reliquished By: 1.	Reliquished By: 2.	Reliquished By: 3.
Signature: [signature] Time: 1543	Signature: Time:	Signature: Time:
Printed Name: Cody Johnson Date: 1/4/12	Printed Name: Date:	Printed Name: Date:
Company: SHW	Company:	Company:

Received By: 1.	Received By: 2.	Received By: 3.
Signature: [signature] Time: 15:43	Signature: Time:	Signature: Time:
Printed Name: Troy Zehr Date: 1/3/13	Printed Name: Date:	Printed Name: Date:
Company: FAI	Company:	Company:

No. 664

1311 N. 35th St.
Seattle, WA 98103
T: (206) 352-3790
F: (206) 352-7178
info@fremontanalytical.com

Shannon & Wilson
Cody Johnson
400 N. 34th Street, Suite 100
Seattle, Washington 98103

RE: Smith Island
Lab ID: 1301017

January 07, 2013

Attention Cody Johnson:

Fremont Analytical, Inc. received 2 sample(s) on 1/4/2013 for the analyses presented in the following report.

Sample Moisture (Percent Moisture)
Total Metals by EPA Method 6020

This report consists of the following:

- Case Narrative
- Analytical Results
- Applicable Quality Control Summary Reports
- Chain of Custody

All analyses were performed consistent with the Quality Assurance program of Fremont Analytical, Inc. Please contact the laboratory if you should have any questions about the results.

Thank you for using Fremont Analytical.

Sincerely,

Michelle Clements
Sr. Chemist / Lab Manager

Date: *01/07/2013*

CLIENT: Shannon & Wilson
Project: Smith Island
Lab Order: 1301017

Work Order Sample Summary

Lab Sample ID	Client Sample ID	Date/Time Collected	Date/Time Received
1301017-001	B-2-13:2.5	01/03/2013 3:10 PM	01/04/2013 3:10 PM
1301017-002	B-2-13:10	01/03/2013 3:30 PM	01/04/2013 3:10 PM

Note: If no "Time Collected" is supplied, a default of 12:00AM is assigned

Fremont Analytical

Case Narrative

WO#: **1301017**

Date: **1/7/2013**

CLIENT: Shannon & Wilson

Project: Smith Island

I. SAMPLE RECEIPT:

All samples were received intact. The internal ice chest temperatures were measured on receipt and are recorded on the attached Sample Receipt Checklist.

II. GENERAL REPORTING COMMENTS:

Results are reported on a wet weight basis unless dry-weight correction is denoted in the units field on the analytical report ("mg/kg-dry" or "ug/kg-dry").

Matrix Spike (MS) and MS Duplicate (MSD) samples are tested from an analytical batch of "like" matrix to check for possible matrix effect. The MS and MSD will provide site specific matrix data only for those samples which are spiked by the laboratory. The sample chosen for spike purposes may or may not have been a sample submitted in this sample delivery group. The validity of the analytical procedures for which data is reported in this analytical report is determined by the Laboratory Control Sample (LCS) and the Method Blank (MB). The LCS and the MB are processed with the samples and the MS/MSD to ensure method criteria are achieved throughout the entire analytical process.

III. ANALYSES AND EXCEPTIONS:

Exceptions associated with this report will be footnoted in the analytical results page(s) or the quality control summary page(s) and/or noted below.

Analytical Report

WO#: **1301017**
Date Reported: **1/7/2013**

CLIENT: Shannon & Wilson
Project: Smith Island

Lab ID: 1301017-001 **Collection Date:** 1/3/2013 3:10:00 PM
Client Sample ID: **B-2-13:2.5** **Matrix:** Soil

Analyses	Result	RL	Qual	Units	DF	Date Analyzed
Total Metals by EPA Method 6020				Batch ID: 3899		Analyst: MC
Arsenic	15.6	0.231		mg/Kg-dry	1	1/7/2013 3:18:23 PM
Sample Moisture (Percent Moisture)				Batch ID: R7084		Analyst: JY
Percent Moisture	67.3			wt%	1	1/4/2013 3:10:46 PM

Lab ID: 1301017-002 **Collection Date:** 1/3/2013 3:30:00 PM
Client Sample ID: **B-2-13:10** **Matrix:** Soil

Analyses	Result	RL	Qual	Units	DF	Date Analyzed
Total Metals by EPA Method 6020				Batch ID: 3899		Analyst: MC
Arsenic	13.6	0.127		mg/Kg-dry	1	1/7/2013 3:30:51 PM
Sample Moisture (Percent Moisture)				Batch ID: R7084		Analyst: JY
Percent Moisture	38.1			wt%	1	1/4/2013 3:10:46 PM

Qualifiers:

B	Analyte detected in the associated Method Blank	D	Dilution was required
E	Value above quantitation range	H	Holding times for preparation or analysis exceeded
J	Analyte detected below quantitation limits	ND	Not detected at the Reporting Limit
RL	Reporting Limit	S	Spike recovery outside accepted recovery limits

Fremont Analytical

Date: *1/7/2013*

Work Order: 1301017
CLIENT: Shannon & Wilson
Project: Smith Island

QC SUMMARY REPORT

Total Metals by EPA Method 6020

Sample ID: **MB-3899** SampType: **MBLK** Units: **mg/Kg** Prep Date: **1/4/2013** RunNo: **7094**
Client ID: **MBLKS** Batch ID: **3899** Analysis Date: **1/7/2013** SeqNo: **140503**

Analyte	Result	RL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Arsenic	ND	0.100									

Sample ID: **LCS-3899** SampType: **LCS** Units: **mg/Kg** Prep Date: **1/4/2013** RunNo: **7094**
Client ID: **LCSS** Batch ID: **3899** Analysis Date: **1/7/2013** SeqNo: **140504**

Analyte	Result	RL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Arsenic	108	0.100	102.0	0	106	83.43	115.7				

Sample ID: **1301008-001ADUP** SampType: **DUP** Units: **mg/Kg-dry** Prep Date: **1/4/2013** RunNo: **7094**
Client ID: **BATCH** Batch ID: **3899** Analysis Date: **1/7/2013** SeqNo: **140506**

Analyte	Result	RL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Arsenic	14.9	0.112						14.76	0.890	30	

Sample ID: **1301008-001AMS** SampType: **MS** Units: **mg/Kg-dry** Prep Date: **1/4/2013** RunNo: **7094**
Client ID: **BATCH** Batch ID: **3899** Analysis Date: **1/7/2013** SeqNo: **140508**

Analyte	Result	RL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Arsenic	66.4	0.110	55.22	14.76	93.5	75	125				

Sample ID: **1301008-001AMSD** SampType: **MSD** Units: **mg/Kg-dry** Prep Date: **1/4/2013** RunNo: **7094**
Client ID: **BATCH** Batch ID: **3899** Analysis Date: **1/7/2013** SeqNo: **140509**

Analyte	Result	RL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Arsenic	67.7	0.110	54.81	14.76	96.5	75	125	66.36	1.93	30	

Qualifiers:

B	Analyte detected in the associated Method Blank	D	Dilution was required	E	Value above quantitation range
H	Holding times for preparation or analysis exceeded	J	Analyte detected below quantitation limits	ND	Not detected at the Reporting Limit
R	RPD outside accepted recovery limits	RL	Reporting Limit	S	Spike recovery outside accepted recovery limits

Sample Log-In Check List

Client Name:	**SW**	Work Order Number:	**1301017**
Logged by:	**Troy Zehr**	Date Received:	**1/4/2013 3:10:00 PM**

Chain of Custody

1.	Were custodial seals present?	Yes ☐	No ☐	Not Required ☑
2.	Is Chain of Custody complete?	Yes ☑	No ☐	Not Present ☐
3.	How was the sample delivered?	Client		

Log In

4.	Coolers are present?	Yes ☑	No ☐	NA ☐
5.	Was an attempt made to cool the samples?	Yes ☑	No ☐	NA ☐
6.	Were all coolers received at a temperature of >0° C to 10.0°C	Yes ☑	No ☐	NA ☐
7.	Sample(s) in proper container(s)?	Yes ☑	No ☐	
8.	Sufficient sample volume for indicated test(s)?	Yes ☑	No ☐	
9.	Are samples properly preserved?	Yes ☑	No ☐	
10.	Was preservative added to bottles?	Yes ☐	No ☑	NA ☐
11.	Is there headspace present in VOA vials?	Yes ☐	No ☐	NA ☑
12.	Did all sample containers arrive in good condition?(unbroken)	Yes ☑	No ☐	
13.	Does paperwork match bottle labels?	Yes ☑	No ☐	
14.	Are matrices correctly identified on Chain of Custody?	Yes ☑	No ☐	
15.	Is it clear what analyses were requested?	Yes ☑	No ☐	
16.	Were all holding times able to be met?	Yes ☑	No ☐	

Special Handling (if applicable)

17.	Was client notified of all discrepancies with this order?	Yes ☐	No ☐	NA ☑

Person Notified: Date:
By Whom: Via: ☐ eMail ☐ Phone ☐ Fax ☐ In Person
Regarding:
Client Instructions:

18. Additional remarks/Disrepancies

Item Information

Item #	Temp ºC	Condition
Cooler	6.8	Good

1301017

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS
CORPORATE HEADQUARTERS
400 N. 34th Street, Suite 100
Seattle, WA 98103
(206) 632-8020

CHAIN-OF-CUSTODY RECORD

Page 1 of 1
Laboratory Fremont Analytical
Attn:

(include preservative if used)
Analysis Parameters/Sample Container Description

Sample Identity	Lab No.	Time	Date Sampled	Comp.	Grab	As						Total Number of Containers	Remarks/Matrix
B-2-13:2.5		1510	1/3/13			X							
B-2-13:10		1530	↓			X							

Project Information

Project No.:
Project Name: Smith Island
Contact: Cody Johnson
Ongoing Project? Yes ☐ No ☑
Sampler: CJ

Sample Receipt

Total No. of Containers:
COC Seals/Intact? Y/N/NA
Received Good Cond./Cold
Delivery Method:
(attach shipping bill, if any)

Instructions

Requested Turnaround Time: 24 hr (b, m-ly)
Special Instructions:

Distribution: White - w/shipment - returned to Shannon & Wilson w/ laboratory report
Yellow - w/shipment - for consignee files
Pink - Shannon & Wilson - job file

Reliquished By: 1.	Reliquished By: 2.	Reliquished By: 3.
Signature: [signature] Time: 15:10	Signature: Time:	Signature: Time:
Printed Name: Josh Lee Date: 1-4-13	Printed Name: Date:	Printed Name: Date:
Company: S&W	Company:	Company:

Received By: 1.	Received By: 2.	Received By: 3.
Signature: [signature] Time: 15:10	Signature: Time:	Signature: Time:
Printed Name: Troy Zehr Date: 1/4/13	Printed Name: Date:	Printed Name: Date:
Company: FAI	Company:	Company:

No. 666

3600 Fremont Ave. N.
Seattle, WA 98103
T: (206) 352-3790
F: (206) 352-7178
info@fremontanalytical.com

Shannon & Wilson
Cody Johnson
400 N. 34th Street, Suite 100
Seattle, Washington 98103

RE: Smith Island
Lab ID: 1301029

March 05, 2013

Attention Cody Johnson:

Fremont Analytical, Inc. received 2 sample(s) on 1/8/2013 for the analyses presented in the following report.

Sample Moisture (Percent Moisture)

Total Metals by EPA Method 6020

This report consists of the following:

- Case Narrative
- Analytical Results
- Applicable Quality Control Summary Reports
- Chain of Custody

All analyses were performed consistent with the Quality Assurance program of Fremont Analytical, Inc. Please contact the laboratory if you should have any questions about the results.

Thank you for using Fremont Analytical.

Sincerely,

Michelle Clements
Sr. Chemist / Lab Manager

Fremont Analytical

Date: *03/05/2013*

CLIENT: Shannon & Wilson
Project: Smith Island
Lab Order: 1301029

Work Order Sample Summary

Lab Sample ID	Client Sample ID	Date/Time Collected	Date/Time Received
1301029-001	B-1:13:2.5	01/07/2013 1:03 PM	01/08/2013 11:40 AM
1301029-002	B-1:13:10	01/07/2013 1:34 PM	01/08/2013 11:40 AM

Note: If no "Time Collected" is supplied, a default of 12:00AM is assigned

Case Narrative

WO#: **1301029**

Date: **3/5/2013**

CLIENT: Shannon & Wilson
Project: Smith Island

I. SAMPLE RECEIPT:
All samples were received intact. The internal ice chest temperatures were measured on receipt and are recorded on the attached Sample Receipt Checklist.

II. GENERAL REPORTING COMMENTS:
Results are reported on a wet weight basis unless dry-weight correction is denoted in the units field on the analytical report ("mg/kg-dry" or "ug/kg-dry").

Matrix Spike (MS) and MS Duplicate (MSD) samples are tested from an analytical batch of "like" matrix to check for possible matrix effect. The MS and MSD will provide site specific matrix data only for those samples which are spiked by the laboratory. The sample chosen for spike purposes may or may not have been a sample submitted in this sample delivery group. The validity of the analytical procedures for which data is reported in this analytical report is determined by the Laboratory Control Sample (LCS) and the Method Blank (MB). The LCS and the MB are processed with the samples and the MS/MSD to ensure method criteria are achieved throughout the entire analytical process.

III. ANALYSES AND EXCEPTIONS:
Exceptions associated with this report will be footnoted in the analytical results page(s) or the quality control summary page(s) and/or noted below.

Analytical Report

Fremont Analytical

WO#: **1301029**
Date Reported: **3/5/2013**

CLIENT: Shannon & Wilson
Project: Smith Island

Lab ID: 1301029-001 **Collection Date:** 1/7/2013 1:03:00 PM
Client Sample ID: **B-1:13:2.5** **Matrix:** Soil

Analyses	Result	RL	Qual	Units	DF	Date Analyzed
Total Metals by EPA Method 6020				Batch ID: 3917		Analyst: MC
Arsenic	32.8	0.132		mg/Kg-dry	1	1/9/2013 7:28:00 PM
Lead	12.3	0.265		mg/Kg-dry	1	1/9/2013 7:28:00 PM
Sample Moisture (Percent Moisture)				Batch ID: R7115		Analyst: EM
Percent Moisture	39.1			wt%	1	1/10/2013 8:30:21 AM

Lab ID: 1301029-002 **Collection Date:** 1/7/2013 1:34:00 PM
Client Sample ID: **B-1:13:10** **Matrix:** Soil

Analyses	Result	RL	Qual	Units	DF	Date Analyzed
Total Metals by EPA Method 6020				Batch ID: 3917		Analyst: MC
Arsenic	19.4	0.120		mg/Kg-dry	1	1/9/2013 7:37:45 PM
Sample Moisture (Percent Moisture)				Batch ID: R7115		Analyst: EM
Percent Moisture	40.3			wt%	1	1/10/2013 8:30:21 AM

Qualifiers:

B	Analyte detected in the associated Method Blank	D	Dilution was required
E	Value above quantitation range	H	Holding times for preparation or analysis exceeded
J	Analyte detected below quantitation limits	ND	Not detected at the Reporting Limit
RL	Reporting Limit	S	Spike recovery outside accepted recovery limits

Fremont Analytical

Date: *3/5/2013*

Work Order: 1301029
CLIENT: Shannon & Wilson
Project: Smith Island

QC SUMMARY REPORT
Total Metals by EPA Method 6020

Sample ID: **MB-3917** SampType: **MBLK** Units: **mg/Kg** Prep Date: **1/9/2013** RunNo: **7119**
Client ID: **MBLKS** Batch ID: **3917** Analysis Date: **1/9/2013** SeqNo: **141224**

Analyte	Result	RL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Arsenic	ND	0.100									
Lead	ND	0.200									

Sample ID: **LCS-3917** SampType: **LCS** Units: **mg/Kg** Prep Date: **1/9/2013** RunNo: **7119**
Client ID: **LCSS** Batch ID: **3917** Analysis Date: **1/9/2013** SeqNo: **141225**

Analyte	Result	RL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Arsenic	112	0.200	102.0	0	109	83.43	115.7				
Lead	76.7	0.400	71.80	0	107	84.26	115.7				

Sample ID: **1301029-002ADUP** SampType: **DUP** Units: **mg/Kg-dry** Prep Date: **1/9/2013** RunNo: **7119**
Client ID: **B-1:13:10** Batch ID: **3917** Analysis Date: **1/9/2013** SeqNo: **141229**

Analyte	Result	RL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Arsenic	19.3	0.118						19.39	0.591	30	
Lead	6.27	0.236						6.350	1.33	30	

Sample ID: **1301029-002AMS** SampType: **MS** Units: **mg/Kg-dry** Prep Date: **1/9/2013** RunNo: **7119**
Client ID: **B-1:13:10** Batch ID: **3917** Analysis Date: **1/9/2013** SeqNo: **141231**

Analyte	Result	RL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Arsenic	76.3	0.114	56.97	19.39	99.9	75	125				
Lead	32.4	0.228	28.48	6.350	91.4	75	125				

Qualifiers:

B	Analyte detected in the associated Method Blank	D	Dilution was required	E	Value above quantitation range
H	Holding times for preparation or analysis exceeded	J	Analyte detected below quantitation limits	ND	Not detected at the Reporting Limit
R	RPD outside accepted recovery limits	RL	Reporting Limit	S	Spike recovery outside accepted recovery limits

Date: *3/5/2013*

Work Order: 1301029
CLIENT: Shannon & Wilson
Project: Smith Island

QC SUMMARY REPORT

Total Metals by EPA Method 6020

Sample ID: **1301029-002AMSD** SampType: **MSD** Units: **mg/Kg-dry** Prep Date: **1/9/2013** RunNo: **7119**
Client ID: **B-1:13:10** Batch ID: **3917** Analysis Date: **1/9/2013** SeqNo: **141232**

Analyte	Result	RL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Arsenic	80.3	0.120	60.25	19.39	101	75	125	76.30	5.13	30	
Lead	33.7	0.241	30.12	6.350	90.9	75	125	32.37	4.07	30	

Qualifiers:

B	Analyte detected in the associated Method Blank	D	Dilution was required	E	Value above quantitation range
H	Holding times for preparation or analysis exceeded	J	Analyte detected below quantitation limits	ND	Not detected at the Reporting Limit
R	RPD outside accepted recovery limits	RL	Reporting Limit	S	Spike recovery outside accepted recovery limits

Fremont Analytical

Sample Log-In Check List

Client Name: **SW**

Logged by: **Clare Griggs**

Work Order Number: **1301029**

Date Received: **1/8/2013 11:40:00 AM**

Chain of Custody

1. Were custodial seals present? Yes ☐ No ☐ Not Required ☑
2. Is Chain of Custody complete? Yes ☑ No ☐ Not Present ☐
3. How was the sample delivered? Client

Log In

4. Coolers are present? Yes ☑ No ☐ NA ☐
5. Was an attempt made to cool the samples? Yes ☑ No ☐ NA ☐
6. Were all coolers received at a temperature of >0° C to 10.0°C Yes ☑ No ☐ NA ☐
7. Sample(s) in proper container(s)? Yes ☑ No ☐
8. Sufficient sample volume for indicated test(s)? Yes ☑ No ☐
9. Are samples properly preserved? Yes ☑ No ☐
10. Was preservative added to bottles? Yes ☐ No ☑ NA ☐
11. Is there headspace present in VOA vials? Yes ☐ No ☐ NA ☑
12. Did all sample containers arrive in good condition?(unbroken) Yes ☑ No ☐
13. Does paperwork match bottle labels? Yes ☑ No ☐
14. Are matrices correctly identified on Chain of Custody? Yes ☑ No ☐
15. Is it clear what analyses were requested? Yes ☑ No ☐
16. Were all holding times able to be met? Yes ☑ No ☐

Special Handling (if applicable)

17. Was client notified of all discrepancies with this order? Yes ☐ No ☐ NA ☑

Person Notified:

Date:

By Whom:

Via: ☐ eMail ☐ Phone ☐ Fax ☐ In Person

Regarding:

Client Instructions:

18. Additional remarks/Disrepancies

Item Information

Item #	Temp ºC	Condition
Cooler	8.9	Good

130029

Shannon & Wilson, Inc.

400 N. 34th Street, Suite 100
Seattle, WA 98103
(206) 632-8020

11500 Olive Blvd., Suite 276
St. Louis, MO 63141
(314) 872-8170

2055 Hill Road
Fairbanks, AK 99707
(907) 479-0600

5430 Fairbanks Street, Suite 3
Anchorage, AK 99518
(907) 561-2120

Chain of Custody Record

Page 1 of 1
Laboratory Fremont
Attn: ____

Analysis Parameters/Sample Container Description
(Include preservative if used)

Sample Identity	Lab No.	Time	Date Sampled	Comp.	Grab	Arsenic						Total Number of Containers	Remarks/Matrix
B-1-13:2.5		13:03	1/7/13		X	X						1	
B-1-13:10		13:34	1/7/13		X	X						1	

Project Information	
Project Number:	
Project Name:	Smith Island
Contact:	CMJ@shanwil.com
Ongoing Project?	Yes ☐ No ☐
Sampler:	EAS

Sample Receipt	
Total Number of Containers	2
COC Seals/Intact? Y/N/NA	
Received Good Cond./Cold	
Delivery Method: (attach shipping bill, if any)	

	Relinquished By: 1.	Relinquished By: 2.	Relinquished By: 3.
Signature:	[signature]		
Time:	11:40		
Printed Name:	Josh Lee		
Date:	1-8-13		
Company:	S&W		

	Received By: 1.	Received By: 2.	Received By: 3.
Signature:	[signature]		
Time:	11:40		
Printed Name:	Clare Griggs		
Date:	1813		
Company:			

Instructions

Requested Turn Around Time: 48 hours

Special Instructions:

Distribution: White - w/shipment - returned to Shannon & Wilson w/ Laboratory report
Yellow - w/shipment - for consignee files
Pink - Shannon & Wilson - Job File

F-19-91/UR

APPENDIX D

LIQUEFACTION ANALYSES AND RESULTS

APPENDIX D

LIQUEFACTION ANALYSES AND RESULTS

TABLE OF CONTENTS

Page

FIGURES

APPENDIX D

LIQUEFACTION ANALYSES AND RESULTS

D-1 INTRODUCTION

We evaluated liquefaction susceptibility of the foundation soils along the proposed setback levee using a ground motion level corresponding to a 50 percent probability of exceedence in 75 years, or about a 100-year return period. The determination of the site ground motion and the liquefaction analyses results are discussed in the main text of this report. The analytical approach used in our evaluation is discussed in the following section. Plots of the factors of safety (FSs) against liquefaction versus depth are presented as Figures D-1 through D-13.

D-2 LIQUEFACTION ANALYSIS APPROACH

We evaluated the liquefaction potential along the proposed setback levee alignment using the empirical procedures outlined in NCEER (Youd and Idriss, 1997), and the subsequent alternative procedures and updates by:

- Youd and others (2001)
- Cetin and others (2004)
- Idriss and Boulanger (2006)
- Robertson and Wride (1997)

For empirical liquefaction evaluation, the Standard Penetration Test N-value and the Cone Penetration Test cone tip resistance are correlated to the liquefaction resistance of the soil (expressed as cyclic resistance ratio). Other factors affecting the liquefaction resistance include the fines content for a granular soil and the Atterberg Limits plasticity index for a cohesive soil. The soil resistance is compared to the earthquake-induced loading (expressed as cyclic stress ratio), and a corresponding FS against liquefaction is calculated.

The U.S. Army Corps of Engineers EC 1110-2-6067 recommends the river median annual water level (MAWL) be used for seismic analyses. However, based on visual observations at the site, a groundwater level at the ground surface, which is higher in elevation than the MAWL, was used for our liquefaction analyses.

D-3 REFERENCES

American Association of State Highway and Transportation Officials (AASHTO), 2012, AASHTO guide specifications for LRFD seismic bridge design: Washington, D.C., American Association of State Highway and Transportation Officials, 1 v.

Cetin, K.O., Seed, R.B., Der Kiureghian, Armen; and others, 2004, Standard penetration test-based probabilistic and deterministic assessment of seismic soil liquefaction potential: Journal of Geotechnical and Geoenvironmental Engineering, v. 130, no. 12, p. 1314-1340.

Idriss, I.M., and Boulanger, R.W., 2006, Semi-empirical procedures for evaluating liquefaction potential during earthquakes: Soil Dynamics and Earthquake Engineering, v. 26, no. 2-4, p. 115-130.

Petersen, M.D., Frankel, A.D., Harmsen, S.C., and others, 2008, Documentation for the 2008 update of the national seismic hazard maps: U.S. Geological Survey Open-File Report 08-118, available: http://pubs.usgs.gov/of/2008/1128.

Robertson, P.K., and Wride, C.E., 1997, "Cyclic liquefaction and its evaluation based on the SPT and CPT," Proc. NCEER Workshop on Evaluation of Liquefaction Resistance of Soils, Youd, T.L., and Idriss, I.M., eds., Technical Report NCEER 97-0022, p. 41-88.

U.S. Army Corps of Engineers (USACE), Engineering and Design, 2010, USACE Process for the National Flood Insurance Program (NFIP) Levee System Evaluation, Engineering Circular 1110-2-6067: Washington, D.C., August.

U.S. Geological Survey (USGS), 2012b, 2008 Interactive Deaggregations (Beta): available: https://geohazards.usgs.gov/deaggint/2008/.

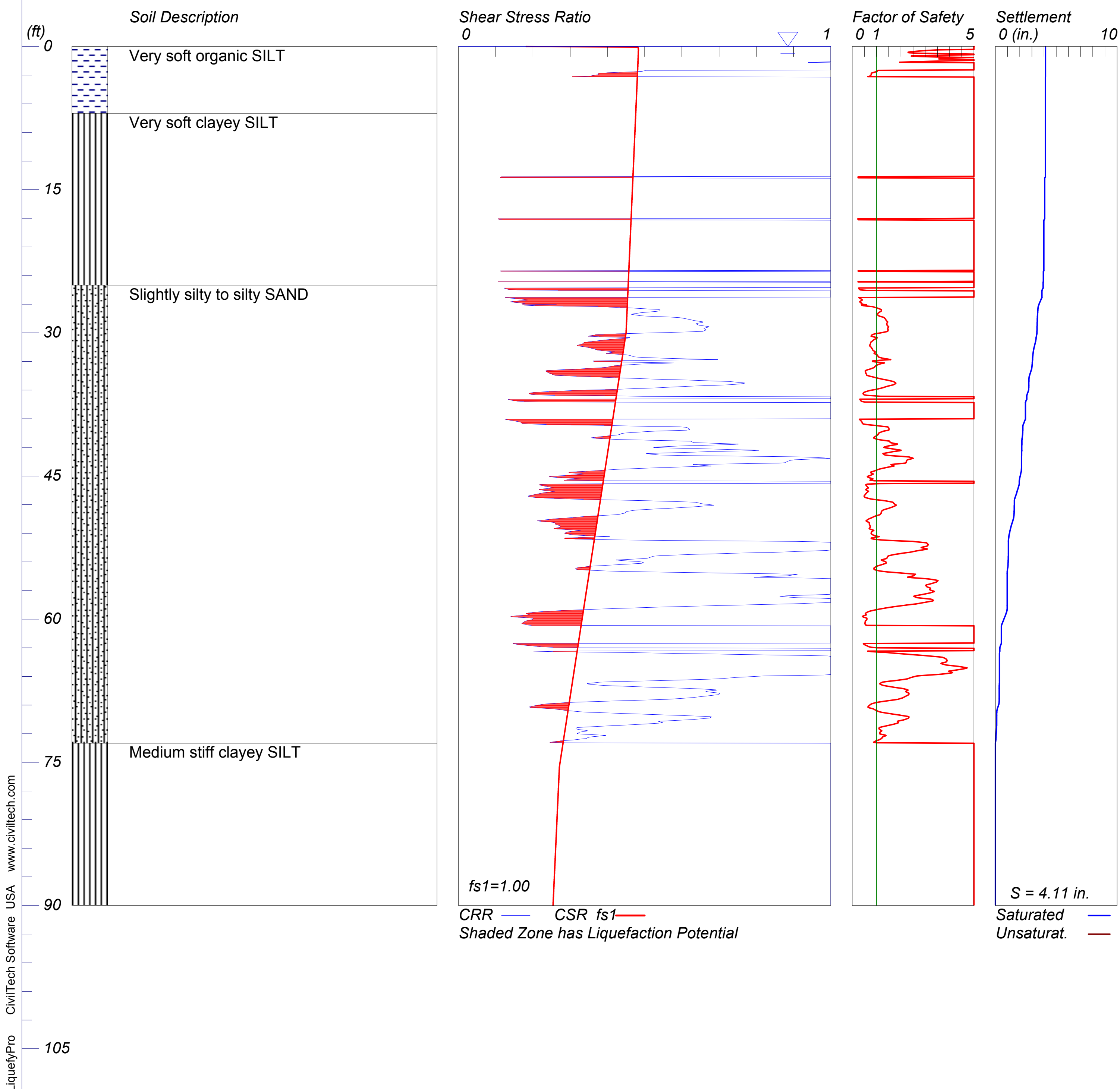
Youd, T.L., and Idriss, I.M., 1997, Proceeding of the NCEER workshop on evaluation of liquefaction resistance of soils: Buffalo, N.Y., National Center for Earthquake Engineering Research, Technical Report no. NCEER-97-0022.

Youd, T.L., Idriss, I.M., Andrus, R.D., and others, 2001, Liquefaction resistance of soils: summary report from the 1996 NCEER and 1998 NCEER/NSF workshops on evaluation of liquefaction resistance of soils: Journal of Geotechnical and Geoenvironmental Engineering, v. 127, no. 10, p. 817-833.

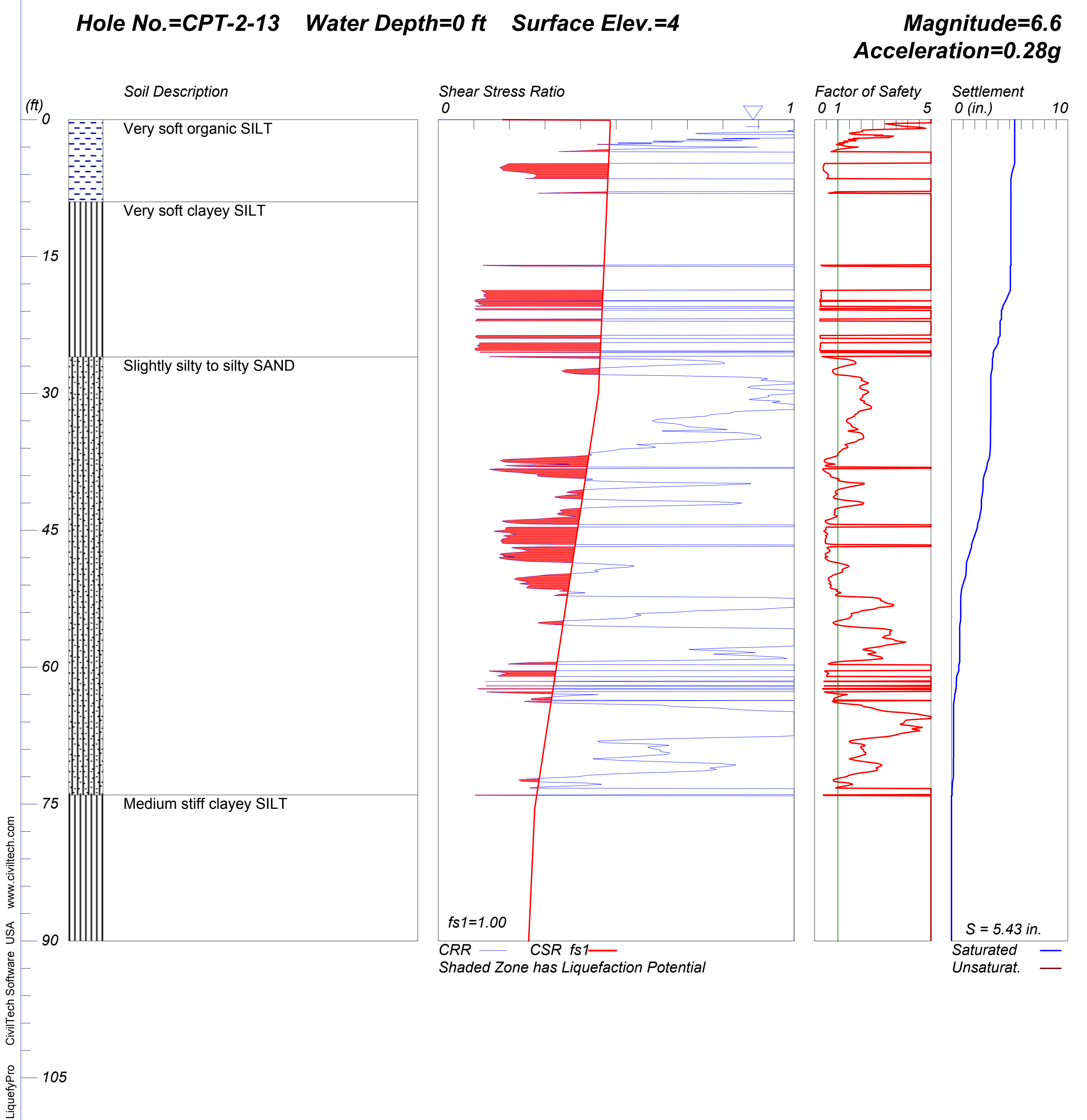
LIQUEFACTION ANALYSIS
SMITH ISLAND RESTORATION

Hole No.=CPT-1-13 Water Depth=0 ft Surface Elev.=4

Magnitude=6.6
Acceleration=0.28g



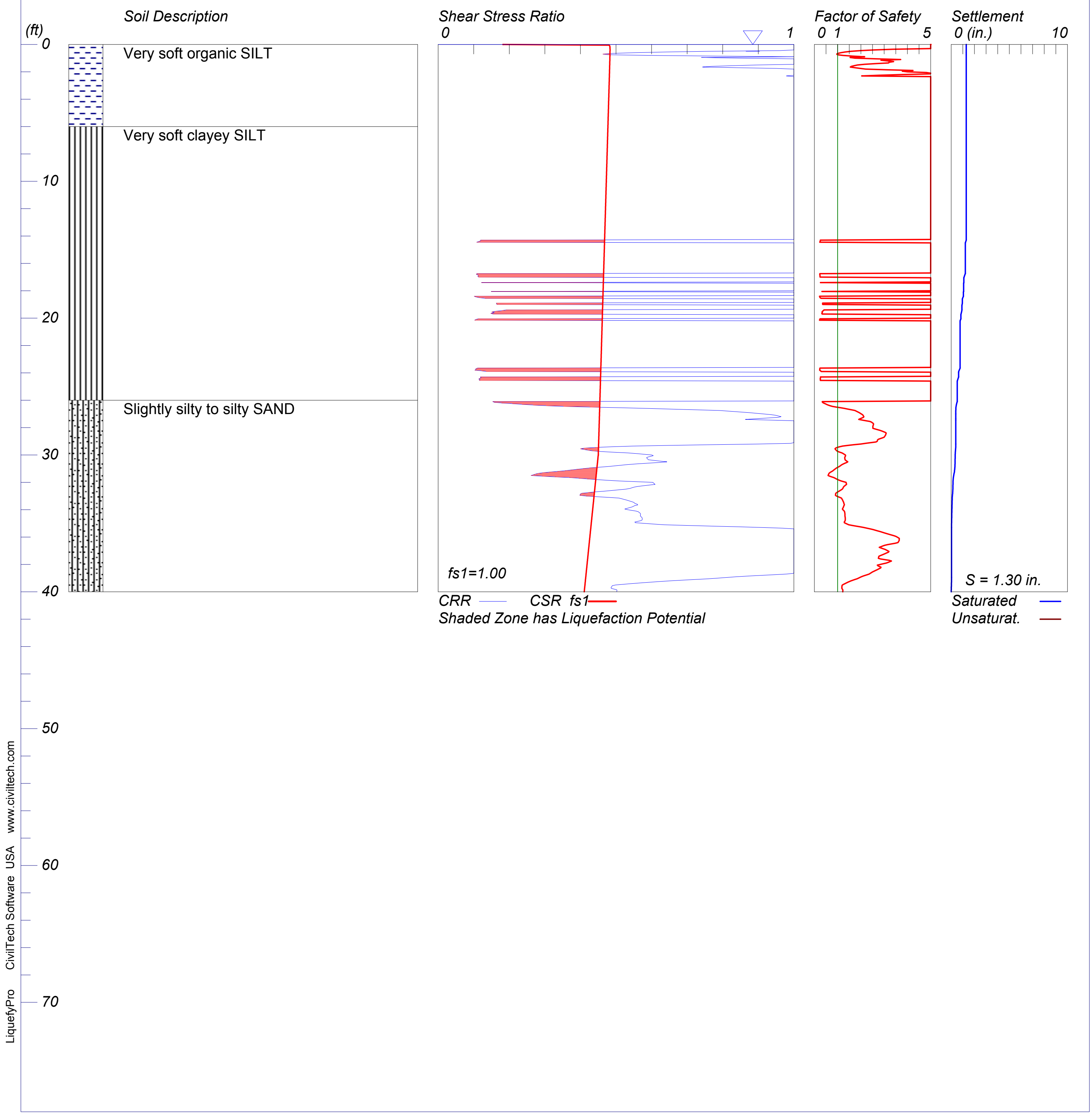
LIQUEFACTION ANALYSIS
SMITH ISLAND RESTORATION



LIQUEFACTION ANALYSIS
SMITH ISLAND RESTORATION

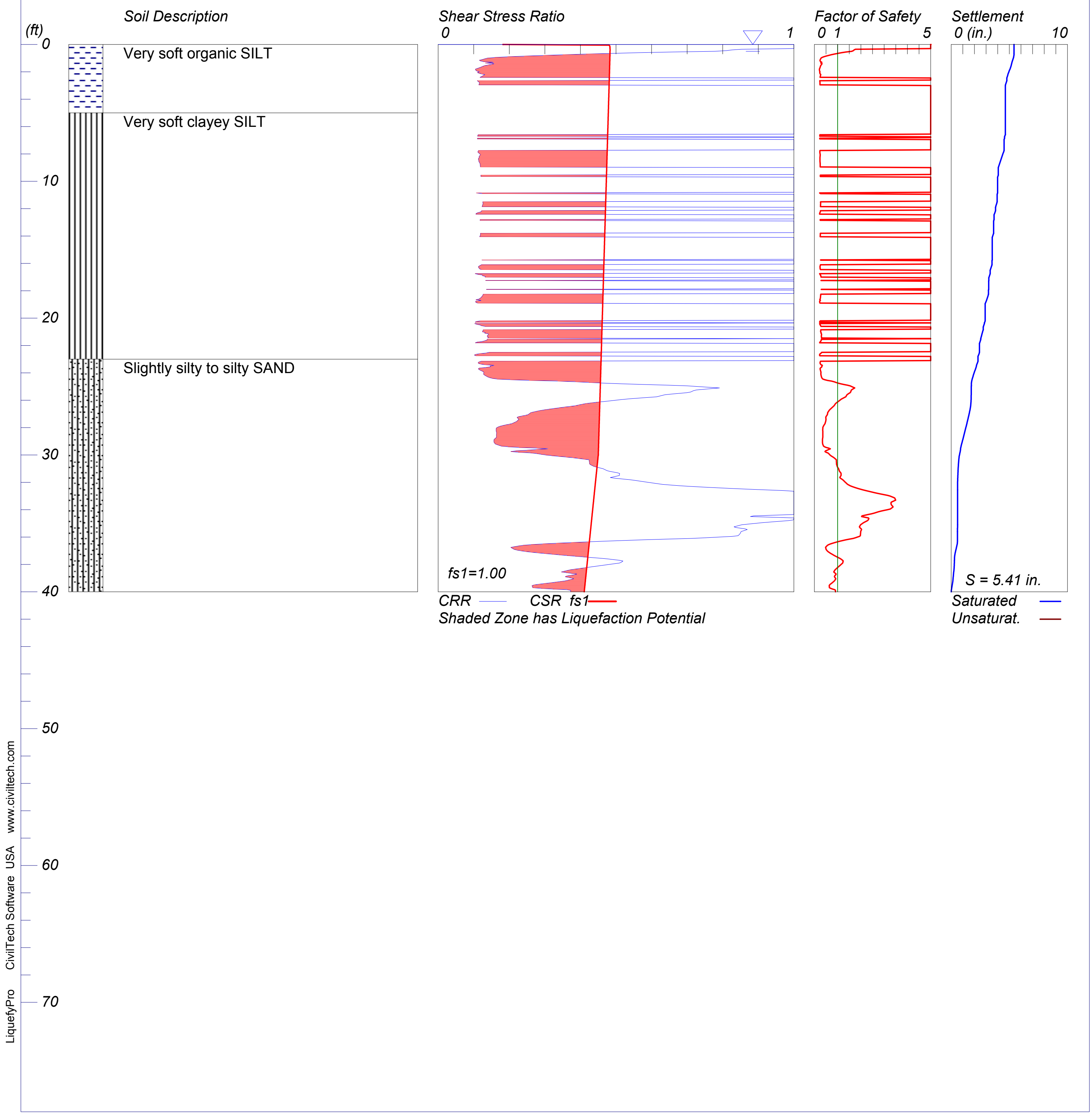
Hole No.=CPT-3-13 Water Depth=0 ft Surface Elev.=4

Magnitude=6.6
Acceleration=0.28g



LIQUEFACTION ANALYSIS
SMITH ISLAND RESTORATION

Hole No.=CPT-4-13 **Water Depth=0 ft** **Surface Elev.=4** **Magnitude=6.6**
Acceleration=0.28g

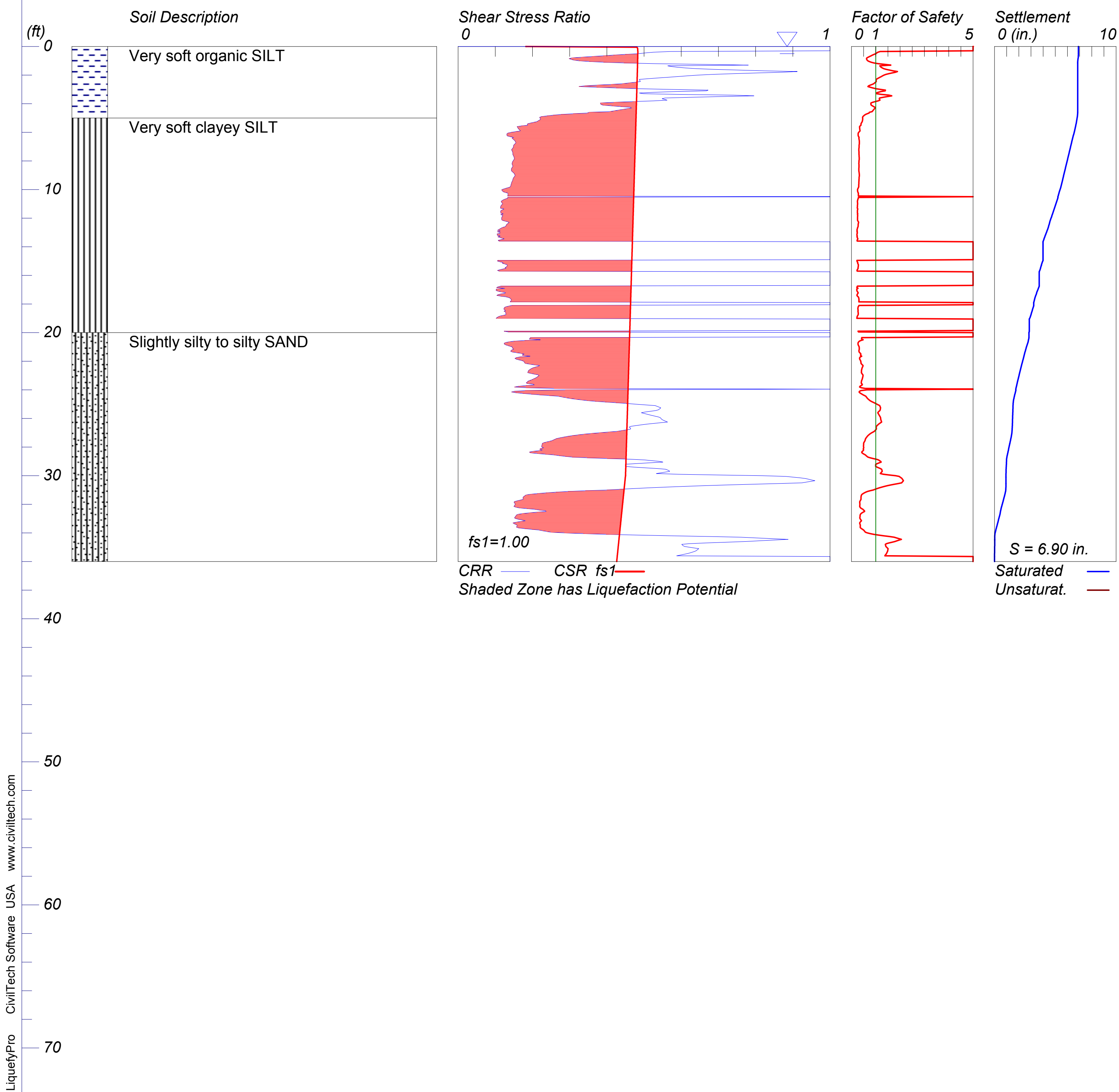


LIQUEFACTION ANALYSIS

SMITH ISLAND RESTORATION

Hole No.=CPT-5-13   Water Depth=0 ft   Surface Elev.=4

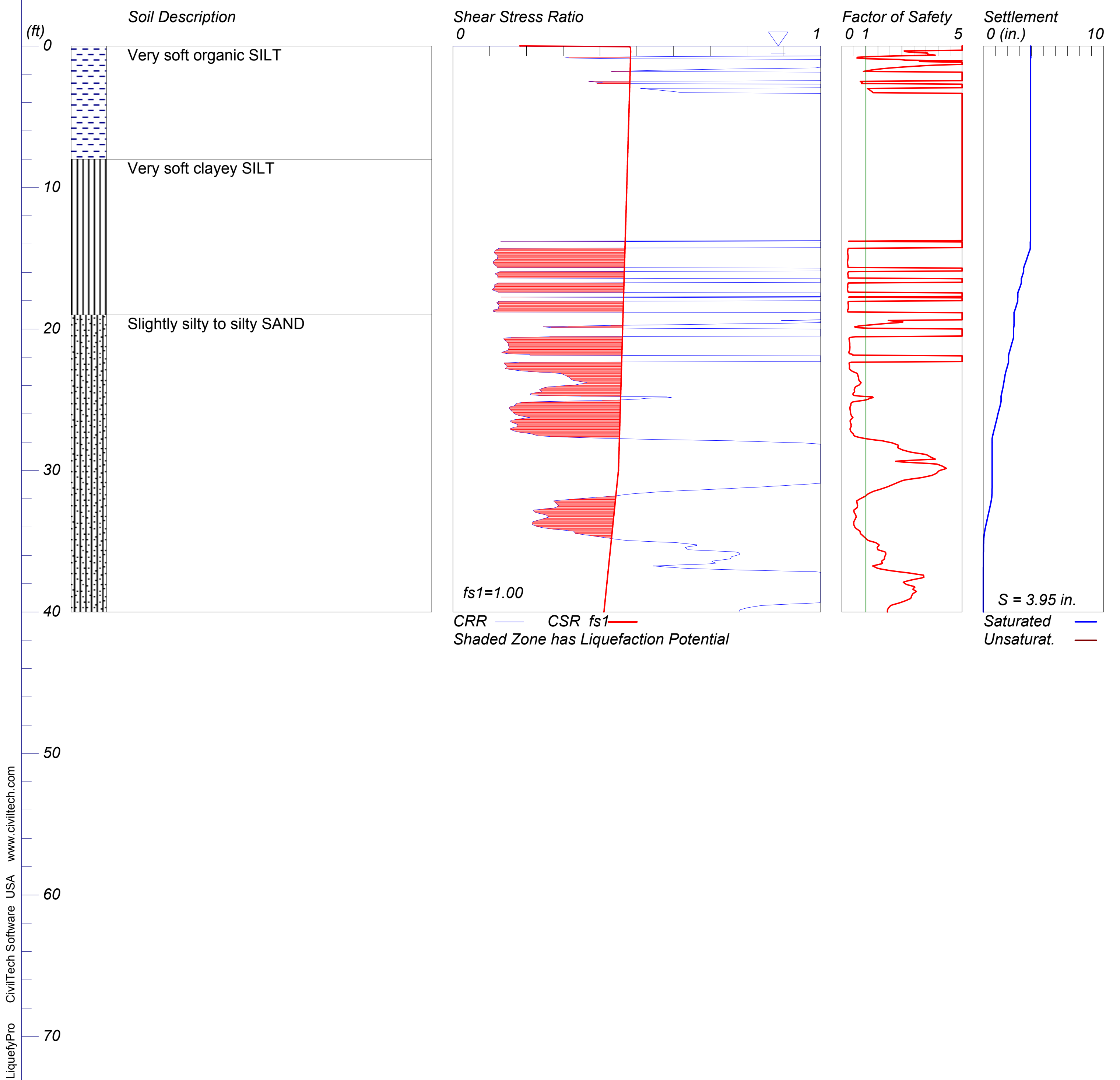
Magnitude=6.6
Acceleration=0.28g



LIQUEFACTION ANALYSIS
SMITH ISLAND RESTORATION

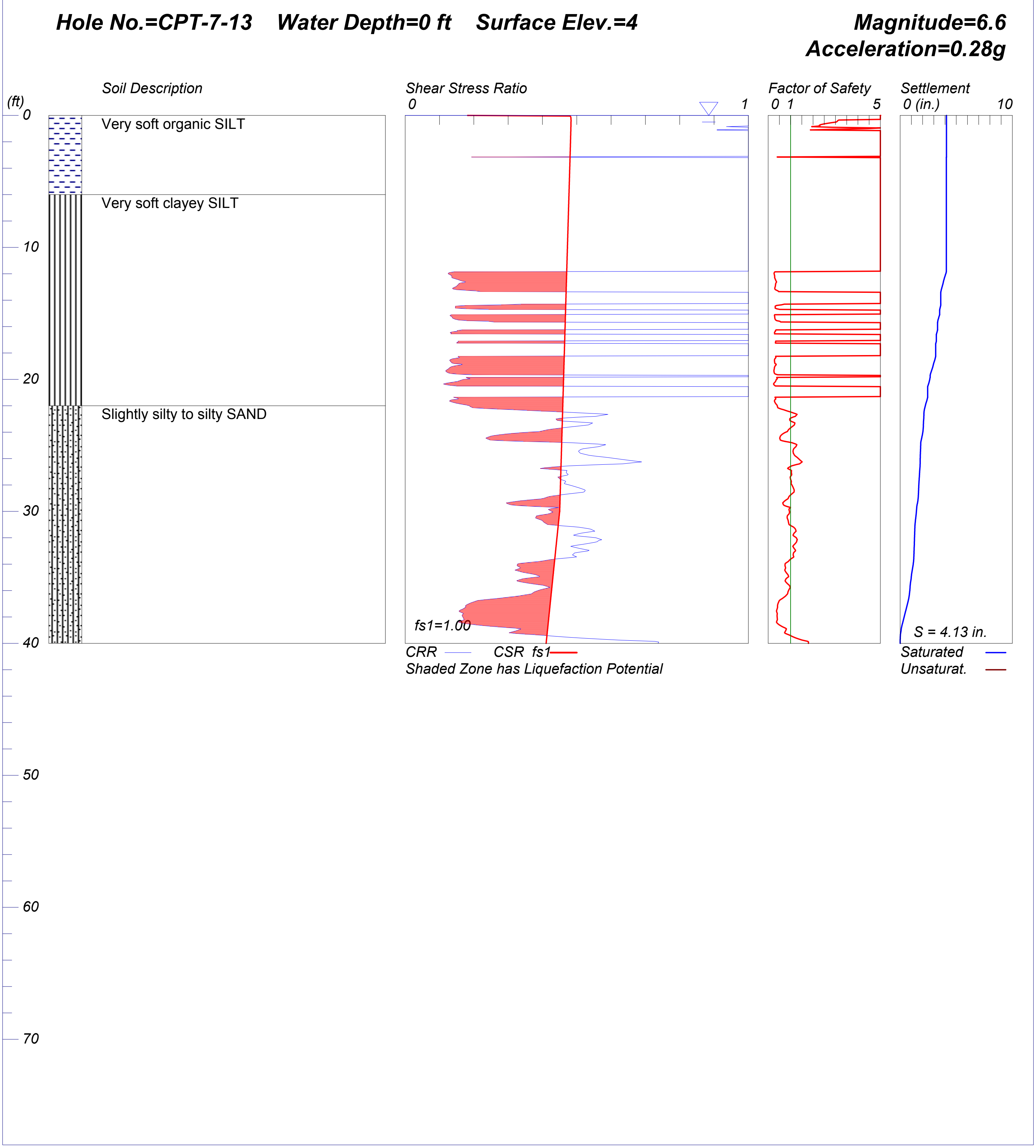
Hole No.=CPT-6-13   Water Depth=0 ft   Surface Elev.=4

Magnitude=6.6
Acceleration=0.28g



LIQUEFACTION ANALYSIS

SMITH ISLAND RESTORATION

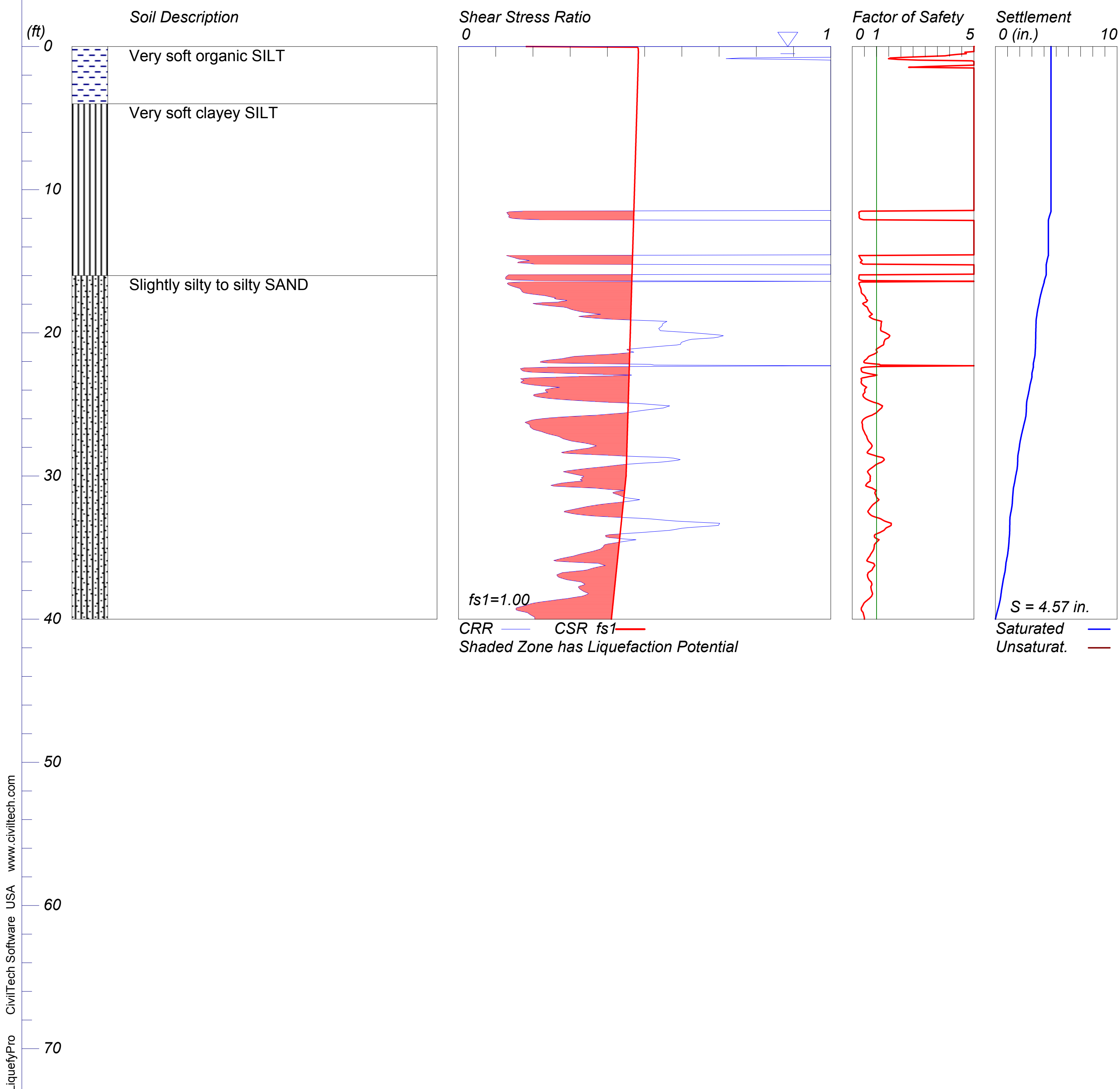


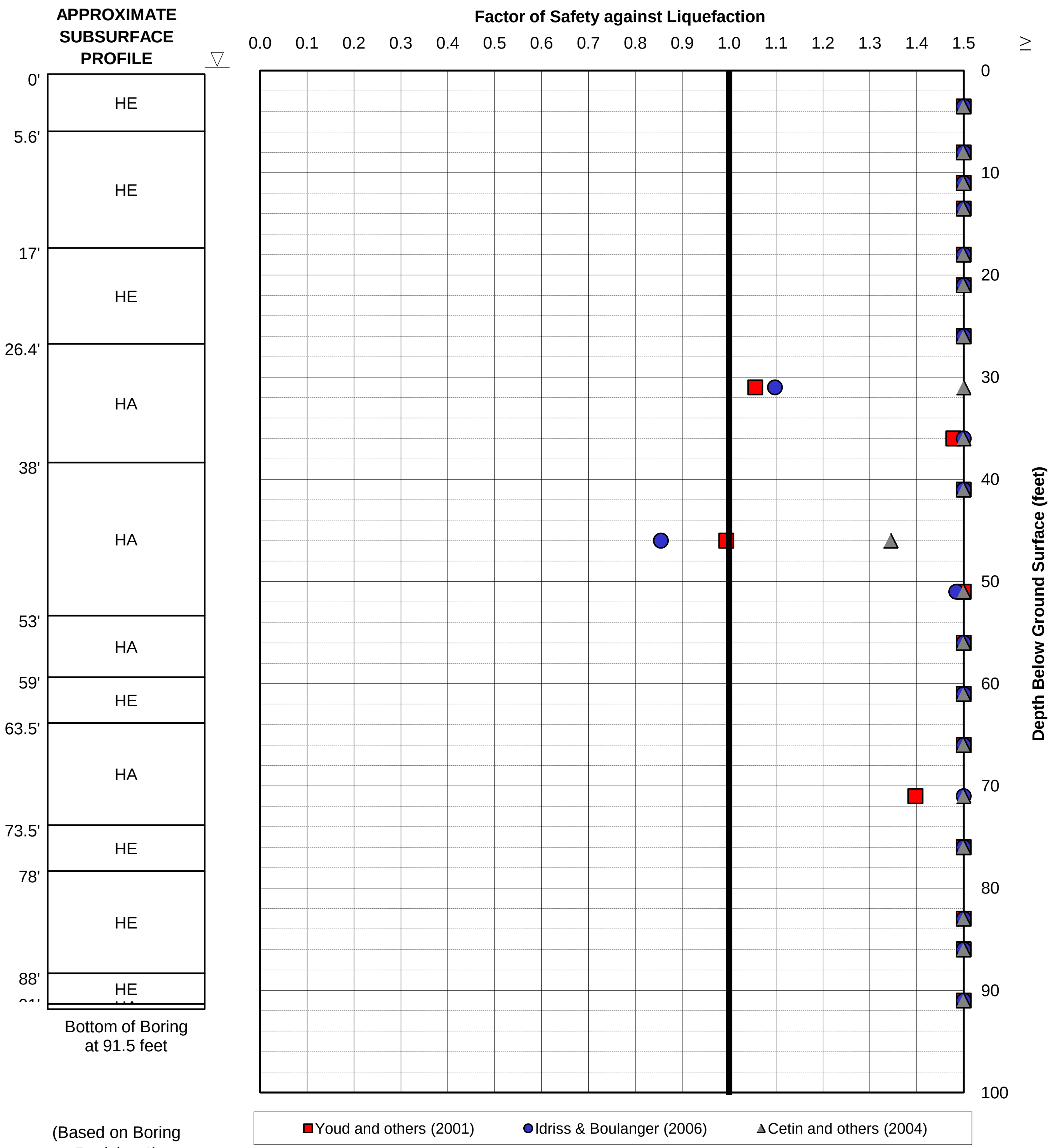
Shannon & Wilson, Inc. **21-1-12405-030** **Figure D-7**

LIQUEFACTION ANALYSIS
SMITH ISLAND RESTORATION

Hole No.=CPT-8-13 Water Depth=0 ft Surface Elev.=4

Magnitude=6.6
Acceleration=0.28g





(Based on Boring Revision 1)

NOTES

1. See main text for references.
2. The liquefaction resistance of a soil is based on its density and fines content. We used the results of the standard penetration testing to estimate the density, and the results of selected laboratory tests to estimate the fines content.

Smith Island Site Restoration
Snohomish County, Washington

RESULTS OF LIQUEFACTION ANALYSES
BORING B-1-13
M = 6.6, PGA = 0.28

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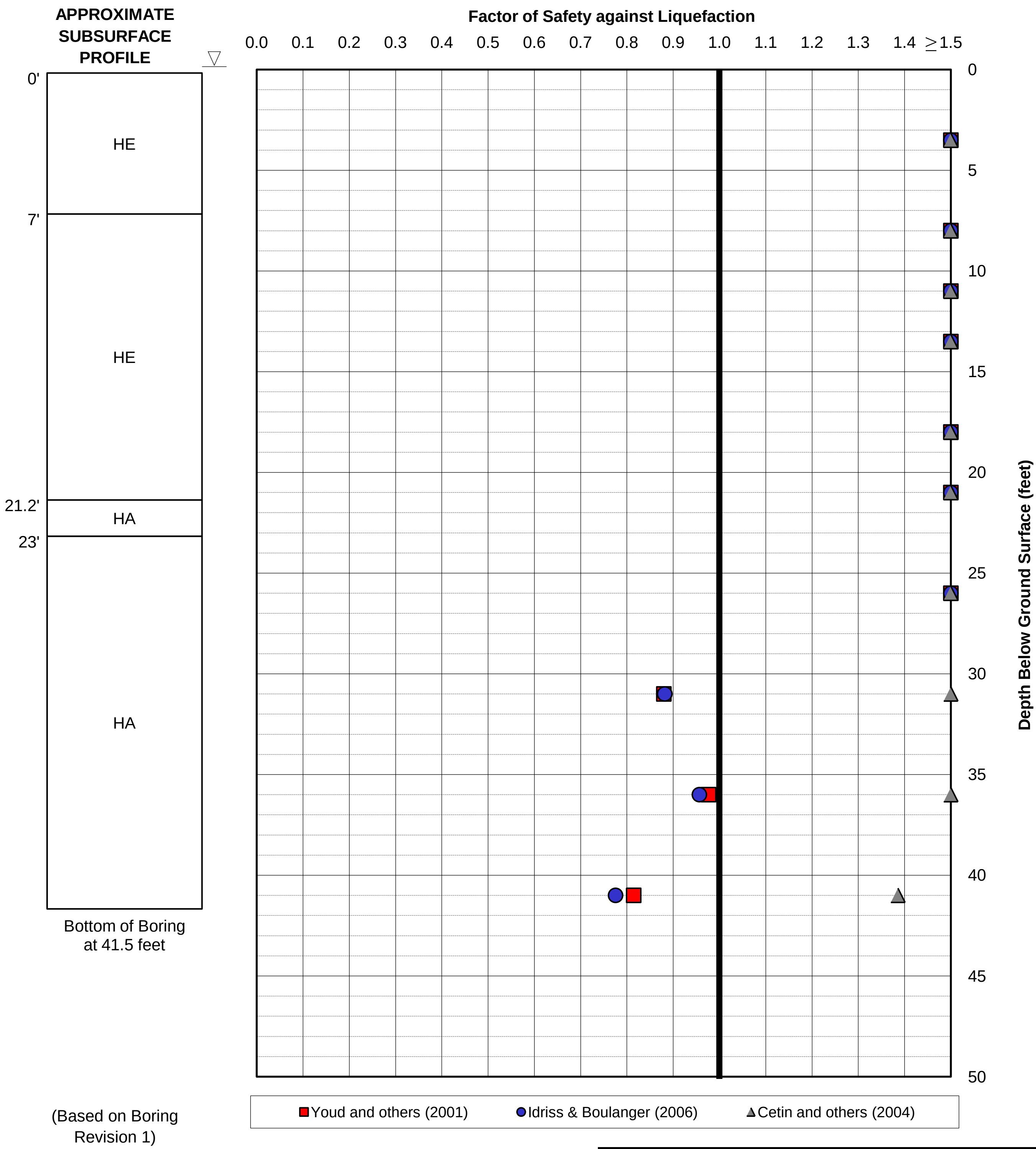
FIG. D-9



NOTES

1. See main text for references.
2. The liquefaction resistance of a soil is based on its density and fines content. We used the results of the standard penetration testing to estimate the density, and the results of selected laboratory tests to estimate the fines content.

Smith Island Site Restoration
Snohomish County, Washington

RESULTS OF LIQUEFACTION ANALYSES
BORING B-2-13
M = 6.6, PGA = 0.28

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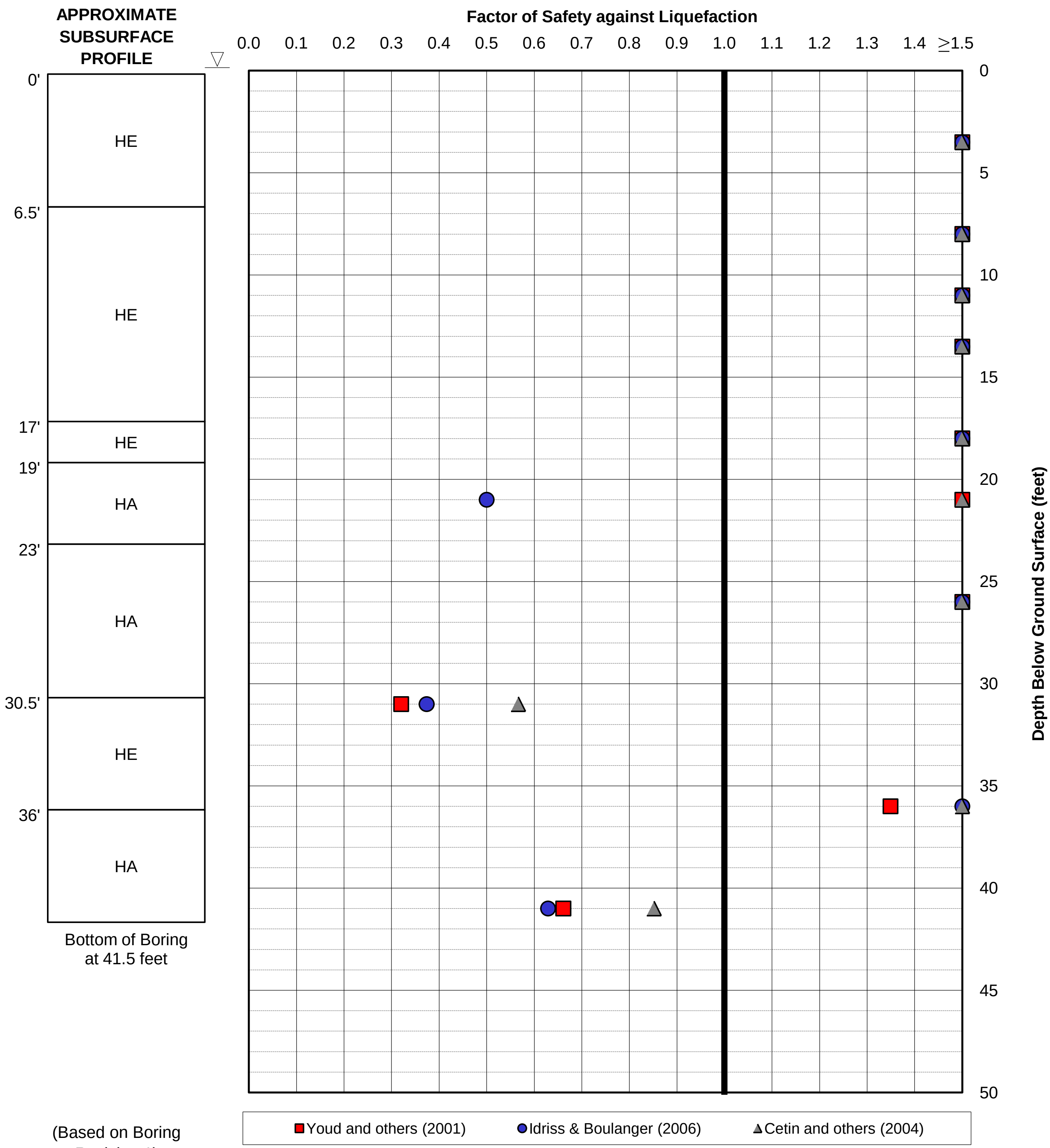
FIG. D-10



(Based on Boring Revision 1)

NOTES

1. See main text for references.
2. The liquefaction resistance of a soil is based on its density and fines content. We used the results of the standard penetration testing to estimate the density, and the results of selected laboratory tests to estimate the fines content.

Smith Island Site Restoration
Snohomish County, Washington

RESULTS OF LIQUEFACTION ANALYSES
BORING B-3-13
M = 6.6, PGA = 0.28

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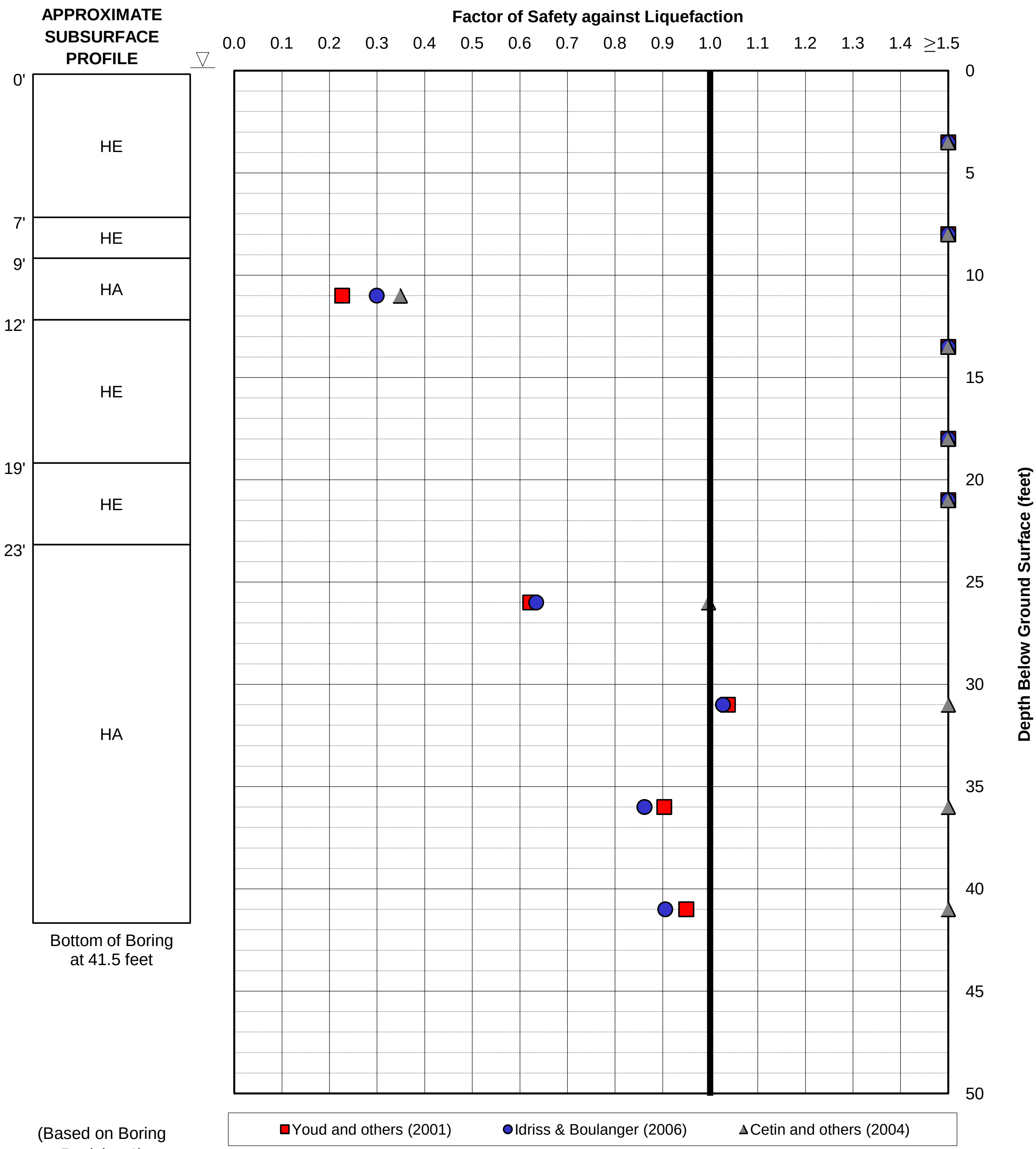
FIG. D-11



(Based on Boring Revision 1)

NOTES

1. See main text for references.
2. The liquefaction resistance of a soil is based on its density and fines content. We used the results of the standard penetration testing to estimate the density, and the results of selected laboratory tests to estimate the fines content.

Smith Island Site Restoration
Snohomish County, Washington

RESULTS OF LIQUEFACTION ANALYSES
BORING B-4-12
M = 6.6, PGA = 0.28

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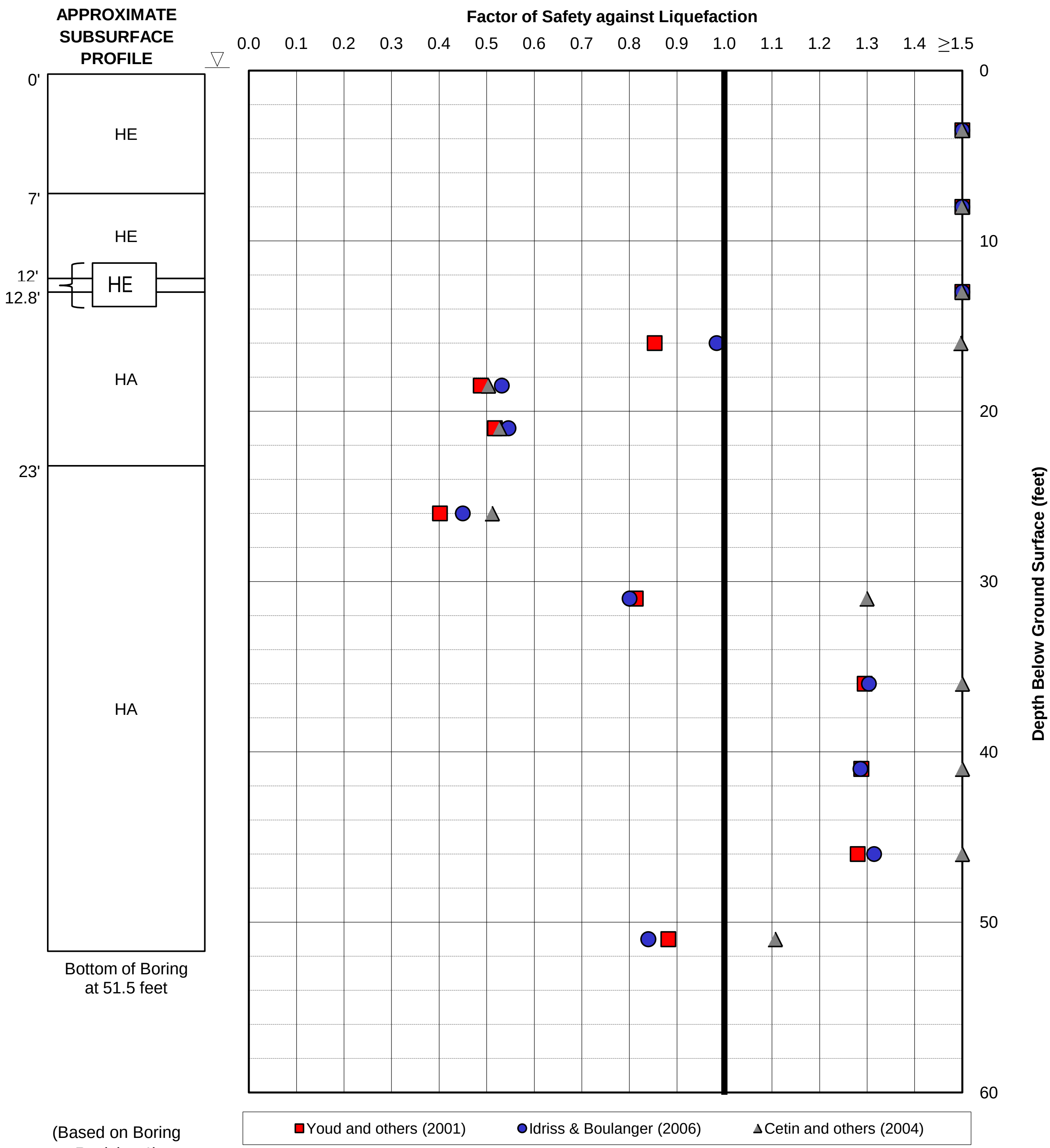
FIG. D-12



(Based on Boring Revision 1)

NOTES

1. See main text for references.
2. The liquefaction resistance of a soil is based on its density and fines content. We used the results of the standard penetration testing to estimate the density, and the results of selected laboratory tests to estimate the fines content.

Smith Island Site Restoration
Snohomish County, Washington

RESULTS OF LIQUEFACTION ANALYSES
BORING B-5-12
M = 6.6, PGA = 0.28

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FIG. D-13

APPENDIX E

SLOPE STABILITY AND SEEPAGE ANALYSES AND RESULTS

APPENDIX E

SLOPE STABILITY AND SEEPAGE ANALYSES AND RESULTS

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TABLES

FIGURES

FIGURES (cont.)

APPENDIX E

SLOPE STABILITY AND SEEPAGE ANALYSES AND RESULTS

E-1 INTRODUCTION

Four levee cross sections were selected for seepage and global stability analyses. One cross section, A-A', was located at the Puget Sound Energy (PSE) pipeline crossing near the south end of the proposed setback levee. The remaining three cross sections (B-B', C-C', and D-D') were selected to represent typical soil conditions along the levee alignment, differing levee geometries with respect to height and slope, anticipated scour, and proximity to tidal channels. The selected levee cross sections are shown in Figure 2 of the main report and the approximate levee station, levee design height, and base widths for each section are presented in Tables E-2 and E-3.

For each levee cross section, we prepared a coupled global stability and seepage computer model using the software suite Geostudio Version 8 (Geo-Slope, 2012). The seepage module of Geostudio, SEEP/W, is a two-dimensional, finite-element seepage analysis program that simulates fluid flow and pressure distribution in saturated and unsaturated materials such as soil and rock. The global stability module of Geostudio, SLOPE/W, uses limit equilibrium analysis methods to calculate a factor of safety (FS) against global instability. Geostudio allows porewater pressures calculated by SEEP/W to be imported into SLOPE/W analyses.

E-2 SUBSURFACE CONDITIONS

Our interpretation of the subsurface conditions along the proposed levee alignment is presented in Figure 3. The profile indicates generalized subsurface soil layering and contact elevations based on our subsurface explorations, laboratory test results, and historical records research. The following generalized geologic soil layers were categorized beneath the proposed setback levee:

- Organic estuarine clayey silt (He_1)
- Estuarine clayey silt with few organics (He_2)
- Clean to slightly silty alluvial sand (Ha)
- Deep estuarine clayey silt (He_3)

Subsurface layering for the individual analyses (Sections A-A' through D-D') are based on Figure 3, and shown in Figures E-1 through E-17. Figure 4 presents a generalized subsurface profile along the PSE/Williams pipeline which crosses the alignment at the location of Section A-A'.

Based on available subsurface information near the levee alignment, the subsurface layering was modeled with a constant elevation for each analysis cross section except for the Section B-B'. Based on Figure 5, Ha Layer Elevation Plan, there is an area on the landside of the levee near Section B-B' where the Ha is locally higher than the majority of the project site. This "sand mound" was incorporated into the Section B-B' analysis.

E-3 SOIL PARAMETERS

Soil parameters used in our slope stability and seepage analyses are summarized in Table E-1. Strength parameters for slope stability analyses were estimated using available: (1) existing and current geotechnical boring logs, (2) existing and current geotechnical laboratory test results, (3) Cone Penetration Test (CPT) sounding results, and (4) published correlations and parameters.

Effective stress internal friction angles were used for the Ha layer and the He layers for long-term loading conditions. For the end-of-construction condition (analysis Case 1), undrained strengths (S_U) were used. Total stress strength parameters derived from current consolidated-undrained (CU) triaxial tests were incorporated into multi-stage drawdown analyses following a procedure presented in the U.S. Army Corps of Engineers' (USACE's) *Slope Stability Manual EM 1110-2-1902* (USACE, 2003) and Duncan, Wright and Wong (1990). Soil strengths were estimated using CPT correlations, current CU triaxial tests, a database of 135 unconsolidated-undrained (UU), and 121 unconfined compression (UC) triaxial tests from previous projects located in or near the project site. End-of-construction undrained shears strengths (S_U) were estimated using a correlation that uses in situ vertical effective stress, σ'_{v0}, and over-consolidation ratio, OCR (OCR = current σ'_{v0} divided by the maximum past vertical effective stress or preconsolidation pressure, σ'_P) developed by Ladd (1991). Initial OCR values were estimated from 111 consolidation tests (6 current tests and 105 existing tests from projects within or adjacent to the project site). In estimating the end-of-construction σ'_{v0} values, we assumed that the levee would take at least 2 months to construct and that each fill lift would be completed over the entire levee length prior to beginning the next lift. Based on the settlement analyses, we estimate that at least 50 percent of the increase in effective stress from the levee fill load would have developed by the time the levee is completed.

Hydraulic conductivities used in seepage analyses were estimated using: (1) CPT dissipation tests, (2) correlations with grain size distribution, (3) consolidation test data, and (4) CPT correlations. Water contents and coefficient of compressibility (m_v), used in the development of water content versus pore pressure function development in SEEP/W were developed using moisture content tests, consolidation tests, and CPT correlations.

E-4 DESIGN CASES

The following conditions, following guidelines presented in the USACE Engineering Manuals 1110-2-1902 and 1110-2-1913, were evaluated for each of the four levee cross sections:

- Case 1 – End of construction
- Case 2a – Rapid drawdown from full flood stage
- Case 2b – Daily tidal drawdown from the Mean Higher High Water (MHHW) level to the Mean Lower Low Water (MLLW) level.
- Case 3 – Steady-state seepage from full flood stage

The Case 1 model geometry was based on the existing ground surface with the proposed levee and an additional over-build height, ΔH, of 3 feet to account for anticipated settlement (see report text). The landside drainage ditch and permanent access road were included. The levee was modeled with a 15-foot-wide crest and embankment side slopes inclined at 3H horizontal to H+ΔH vertical. The resulting pre-settlement slope angles would vary from 2.2H:1V to 2.4H:1V. The groundwater level was assumed to be at the ground surface.

For Cases 2a, 2b and 3, we assumed that the estimated long-term settlement had occurred (i.e., the additional over-build height is not present) and that the levee crest is at elevation +15 feet (North American Vertical Datum of 1988).

Rapid drawdown seepage and global stability were evaluated for both the design flood condition (Case 2a) and the daily high tide condition (Case 2b). For Case 2a analyses, four methods were used to estimate the in situ porewater pressures at the end of the drawdown:

Method A - Multi-stage drawdown analysis following procedure detailed in USACE EM1110-2-1902 (2003) and Duncan, Wright and Wong (1990). Assumes instantaneous drawdown with hydrostatic water pressure and uses both effective and total stress soil strengths. See Table 1 for total stress strength parameters.

Method B - Drawdown from steady state seepage condition with the water level at +15 feet (design flood elevation) to the Mean Tide Level (MTL) of +4.5 feet over a period of 4 days (calculated using SEEP/W transient analysis).

Method C - Water rising from the MTL to +15 feet over 4 days, held at +15 feet for 1 day, and then drawdown back to MTL over a period of 4 days (9-day total flood) (calculated using SEEP/W transient analysis).

Method D - User-defined groundwater level using the mounded groundwater surface from Day 4 of the Method A analysis. This analysis assumes hydrostatic groundwater pressures (no flow).

The transient analysis drawdown durations (Methods B and C) are based on U.S. Geological Survey (USGS) Snohomish River gage data recorded during the January 2009 high-flow event.

We evaluated four drawdown methods for Case 2a because the SEEP/W transient drawdown analysis from steady-state conditions (Method B) indicated that significant "excess" porewater pressures would be present in the He_1 and He_2 layers after the floodwater had receded. This caused low effective stress conditions to persist in the foundation soil, which affected our global stability results using the SLOPE/W models. The porewater pressures exist in the SEEP/W model because the program calculates changes in water content due to changes in porewater pressure. In other words, as the porewater pressure increases, the water content increases due to expansion of the pore spaces between the soil skeleton. Therefore, during the flood stage (especially if steady-state conditions are assumed) the volume of water per unit volume of soil in the He soil on the waterside of the levee is increased. As the water recedes and the water pressure boundary conditions at the ground surface and in the underlying Ha sand decrease, the additional stored volume of water cannot instantaneously flow out of the He (due to the low hydraulic conductivity of the unit) and, therefore, the elevated porewater pressures decrease gradually with time. Based on our engineering judgment, it was our opinion that the lingering excess porewater pressures in the He_1 and He_2 layers calculated using Method B were too high and produced unrealistic global stability failure surfaces in SLOPE/W. Method C, using a finite flood duration based on USGS river gage data, was implemented to reduce the level of porewater pressure buildup on the waterside of the levee during the flood to a more realistic level. FS values from the four methods are summarized in Table E-3. The Case 2a analyses figures in this Appendix represent the lowest FS result of the four methods.

For Case 2b, we evaluated the tidal drawdown from the MHHW level to the MLLW level over a period of 6 hours (one half tidal cycle) using a transient SEEP/W analysis. According to USGS records for Everett, Washington, the MHHW and MLLW are approximately elevation +11 feet and -2 feet, respectively.

For Section D-D', Case 2a was also performed for scoured conditions. This condition is applicable to the northernmost section of the proposed levee that intersects Union Slough. In our analysis we assumed that a launchable scour apron will be installed and designed to leave a 50 foot unscoured bench on the waterside of the levee. We assumed that the lower erosion slopes would be 2H:1V down to scour elevation.

E-5 SLOPE STABILITY ANALYSIS METHODOLOGY

Slope stability analyses were performed in accordance with the USACE *Levee Design and Construction Manual EM 1110-2-1913* (USACE, 2000) and the *Slope Stability Manual EM 1110-2-1902* (USACE, 2003). The analyses used traditional limit equilibrium slope stability analysis methods and the computer program SLOPE/W (Geo-Slope, 2012b). Circular failure surfaces were analyzed at four levee cross sections using the Spencer method-of-slices to calculate the FS. An automated search routine was used to identify the failure surface with the lowest FS (critical failure surface). The critical failure surface was then modified using the optimization feature in SLOPE/W as a non-circular surface and a revised FS calculated. The SLOPE/W optimization technique was employed for all static analyses cases, except Case 1 of the Section A-A' analysis (Figure E-1) and Case 2a (Method B) for the scour condition of the Section D-D' analysis. For these two analyses, the "optimization" routines resulted in kinematically inadmissible slip surfaces and were rejected. The Morgenstern and Price (1965) and Spencer (1967) methods of analysis, which satisfy both moment and force equilibrium, were used to search for the location of the most critical slip surfaces and their corresponding FS.

Due to the soft foundation soil (He_1 and He_2 layers), global stability was facilitated by using a basal reinforcing geotextile. The minimum tensile strengths assumed in our analyses are summarized in Table 2 of the main text. In general, Case 1 was found to control the basal reinforcement tensile strength design.

E-6 SEEPAGE AND GLOBAL STABILITY ANALYSIS RESULTS

Results of our seepage and global stability analyses are discussed in the main text of this report. Seepage results for the upward exit hydraulic gradient and seepage flow rates for steady state flow conditions during a design flood are summarized in Table E-2. Global stability results for the four cases and the four methods evaluated for the rapid drawdown case are summarized in Table E-3. Global stability results are presented graphically as Figures E-1 through E-17. For the Case 2a analyses, only the lowest FS results were included as a Figure.

E-7 REFERENCES

Duncan, J.M., Wright S.G. and Wong, K.S., 1990, "Slope Stability during Rapid Drawdown," Proceedings of H. Bolton Seed Memorial Symposium, v. 2.

Geo-Slope International Ltd., 2012a, Seepage modeling with SEEP/W 2012 version 8.0.10.6504.

Geo-Slope International Ltd., 2012b, Stability modeling with SLOPE/W 2012 version 8.0.10.6504.

Morgenstern, N.R., and Price, V.E., 1965, The analysis of the stability of general slip surfaces, Geotechnique, v. 15, p. 79-93.

Spencer, E., 1967, A method of analysis of the stability of embankments assuming parallel inter-slice forces: Geotechnique, v. 17, no. 1, p. 11-26.

U.S. Army Corps of Engineers (USACE), Engineering and Design, 2000, Design and Construction of Levees, Engineer Manual 1110-2-1913: Washington, D.C., April.

U.S. Army Corps of Engineers (USACE), Engineering and Design, 2003, Slope Stability, Engineering Manual 1110-2-1902: Washington, D.C., October.

U.S. Army Corps of Engineers (USACE), Engineering and Design, 2005, Design Guidance for Levee Underseepage, Technical Letter ETL 1110-2-569: Washington, D.C., May.

TABLE E-1
INTERPRETED RANGE OF ENGINEERING SOIL PARAMETERS

			Shear Strength					Deformation				Hydraulic Parameters
		Saturated Unit Weight	Effective Stress (Drained)		Total Stress (Undrained)		Undrained Shear Strength	Constrained Modulus	Compression Index	Recompression Index	Overconsolidation Ratio	Saturated Hydraulic Conductivity
Geologic Unit	USCS [3]	γ_{sat} *(pcf)*	c' *(psf)*	ϕ' *(deg)*	c' *(psf)*	ϕ' *(deg)*	S_u *(psf)*	$D' = 1/m_v$ *(ksf)*	C_c *(in/in)*	C_r *(in/in)*	$OCR = \sigma'_p/\sigma'_{v0}$	k *(ft/day)*
Levee Fill	ML, CL-ML, CL, SM, SM-SC, SC	120 *(100 - 125)*	*0* *(n/a)*	*32* *(25 - 34)*	*0* *(n/a)*	*32* *(25 - 34)*	*n/a*	335 *(20 - 500)*	- -	- -	- -	1.7 *(0.03 - 11)*
Organic Estruarine Deposit (He_1)	OL, OH, ML, MH, CL	90 *(70 - 125)*	50 *(0-100)*	30 *(24 - 38)*	80 *(60-100)*	19 *(12 - 29)*	$Su = 0.25 \cdot \sigma'_{v0} \times OCR^{0.88(1-Cr/Cc)}$ (Ladd, 1991)	80 *(40 - 200)*	1.0 *(0.3 - 2.5)*	0.20 *(0.02 - 0.4)*	6 *(4 - 8)*	0.014 *($3x10^{-4}$ - 0.3)*
Upper Estruarine Deposit (He_2)	ML, MH, CL, CH	110 *(85 - 125)*	50 *(0 to 100)*	29 *(25 - 35)*	230 *(200- 360)*	10 *(10- 15)*		60 *(20 - 500)*	0.25 *(0.1 - 0.45)*	0.06 *(0.02 - 0.15)*	2 *(1.5 - 6)*	0.014 *($3x10^{-5}$ - 3)*
Alluvium (Ha)	SP, SP-SM, SM	120 *(110 - 130)*	0 *(n/a)*	33 *(32- 42)*	0 *(n/a)*	33 *(32- 42)*	*n/a*	1,200 *(600 - 2,600)*	0.1 *(0.04 - 0.2)*	0.02 *(0.009 - 0.09)*	- -	50 *(6 - 300)*
Lower Estruarine Deposit (He_3)	ML, MH, CL, CH	110 *(100 - 125)*	0 *(0 - 100)*	26 *(19 - 30)*	*not estimated*	*not estimated*	*see He1 and He2*	120 *(70 - 330)*	0.25 *(0.1 - 0.45)*	0.06 *(0.01 - 0.09)*	1 *(1 - 2)*	0.014 *(0.08 - 1)*

Notes:

1. The parameters above were based on statistical averages of index properties, laboratory tests, published correlations, testing from previous projects, and engineering judgement. Please refer to the text of the report for additional information.

2. The key to the ranges and values shown above is as follows: The single value shown represents the preliminary design value. The ranges shown in parentheses represent the potential variability of the property. For analyses performed at specific locations, values other than the design value may be used if warranted by test data (i.e. SPT blowcount or lab tests).

3. See text for an explanation of geologic units. The Unified Soil Classification System (USCS) definitions are as follows: CL = low plasticity clay; CH = high plasticity clay; ML = low plasticity silt; MH = high plasticity silt; OL = low plasticity organic silt or clay; OH = high plasticity organic silt or clay; SM = silty sand; SP = poorly graded sand; SP-SM = poorly graded sand with 5 to 12 percent silt.

"n/a" or "-" = for "not applicable"

S_U = undrained shear strength

σ'v0 = in situ vertical effective stress

TABLE E-2
SEEPAGE ANALYSIS SUMMARY

Analysis Location	Analysis Geometry		Design Flood Level Steady State Seepage Analysis			
	Levee Design Height, H[1] (ft)	Levee Base Width (ft)	E_{LS} (ft)	E_{WS} (ft)	Q (ft^3/day/ft)	i_V [2, 3] (ft/ft)
A-A' (Station 11+03)	9	69	4.5	15	4	0.18
B-B' (Station 29+11)	9	69	4.5	15	4	0.17
C-C' (Station 51+86)	11	81	4.5	15	10	0.30
D-D' (Station 65+75)	10	75	4.5	22.5[4]	4	0.23[4]

Notes:

[1] Design levee crest elevation is fixed at +15 feet (North American Vertical Datum of 1988). Levee design height is a function of existing ground surface elevation.

[2] U.S. Army Corps of Engineers Technical Letter ETL 1110-2-569 (2005) recommends that levees should be designed to maintain a factor of safety against a quick (piping) condition of 1.6. Based on the density of the He_1 layer, this corresponds to a required maximum upward exit gradient (i_v) of 0.30.

[3] Exit gradients presented in this table occur at the base of a proposed drainage trench on the land side of the permanent access road (west of the levee). Our analyses indicate that this trench must be filled with free draining material. A perforated pipe may be installed in the trench if additional flow capacity is required.

[4] Analysis assumes scoured conditions and incorporates the effect of the 90-degree bend in the levee where the proposed levee meets the existing levee. At this corner on the land side, seepage would be coming from two directions (i.e., from both legs of the bend). To account for this, we artificially increased the pressure head on the water side by 75 percent (based on past experience and engineering judgment).

ft = feet

i_V = upward hydraulic gradient averaged over depth of anpticipated piping in front of the levee toe

E_{LS} = surface water elevation on land side of the levee

E_{WS} = surface water elevation on the flood side of the levee (east side)

LS (Land-side) = side of the levee protected from flooding by the levee (west side)

Q = Estimated groundwater flow per foot of levee length from the WS to the LS of the levee that is anticipated to enter

WS (Water-side) = side of the levee subject to flooding (east side)

TABLE E-3
RAPID DRAWDOWN GLOBAL STABILITY ANALYSIS SUMMARY

Analysis Location	Assumed Base Reinforcement Fabric Long Term Strength, $T_{LTDS'}$[1] (lb/ft)	Factor of Safety Against Global Instability			
		Case 2a: Multi Stage Drawdown from Steady State Design Flood [2]	Case 2a: 4-day Transient Drawdown from Steady State Design Flood [2]	Case 2a: Drawdown from 9-Day Transient Design Flood [2]	Case 2a: Drawdown Assuming Hydrostatic Pressure from Mounded Water[2]
A-A' (Station 11+03)	2,100	1.5	1.4	1.5	2.2
B-B' (Station 29+11)	2,100	1.6	1.6	1.7	1.9
C-C' (Station 51+86)	2,100	1.4	1.5	1.5	1.8
D-D' (Station 65+75)	1,900	1.4	1.2 / 1.1[3]	1.4	1.8
USACE Recommended FS	**-**	**1.0-1.2**	**1.0-1.2**	**1.0-1.2**	**1.0-1.2**

Notes:

[1] A base reinforcement geogrid was included to improve stability. Long-term strength includes reduction factors for chemical degradation, creep strain, etc. (if applicable). Short-term includes 60-day creep and construction damage reductions must be accounted for in material selection.

[2] Three rapid flood level rapid drawdown conditions were evaluated:

(A) Multi-stage drawdown analysis following procedure detailed in U.S. Army Corps of Engineers EM1110-2-1902 (2003) and Duncan, Wright, and Wong (1990). Assumes instantaneous drawdown with hydrostatic water pressure and uses both effective and total stress soil strengths.

(B) Drawdown from steady state seepage condition with the water level at +15 feet to the Mean Tide Level (MTL) of +4.5 feet over a period of 4 days (calculated using SEEP/W transient analyis)

(C) Water rises from the MTL to +15 feet over 4 days, hold at +15 feet for 1 day, and drawdown back to MTL over a period of 4 days (9 day flood total) (calculated using SEEP/W transient analyis)

(D) User-defined groundwater level using the mounded groundwater surface from Day 4 of the (B) analysis. This analysis assumes hydrostatic groundwater pressures (no flow).

Flood duration and water drawup and drawdown rates are based on U.S. Geological Survey river flow data from the January 2009 high-flow event in the Snohomish River.

[3] Analysis applies to area near Union Slough subject to scour during the design flood event.

ft = feet

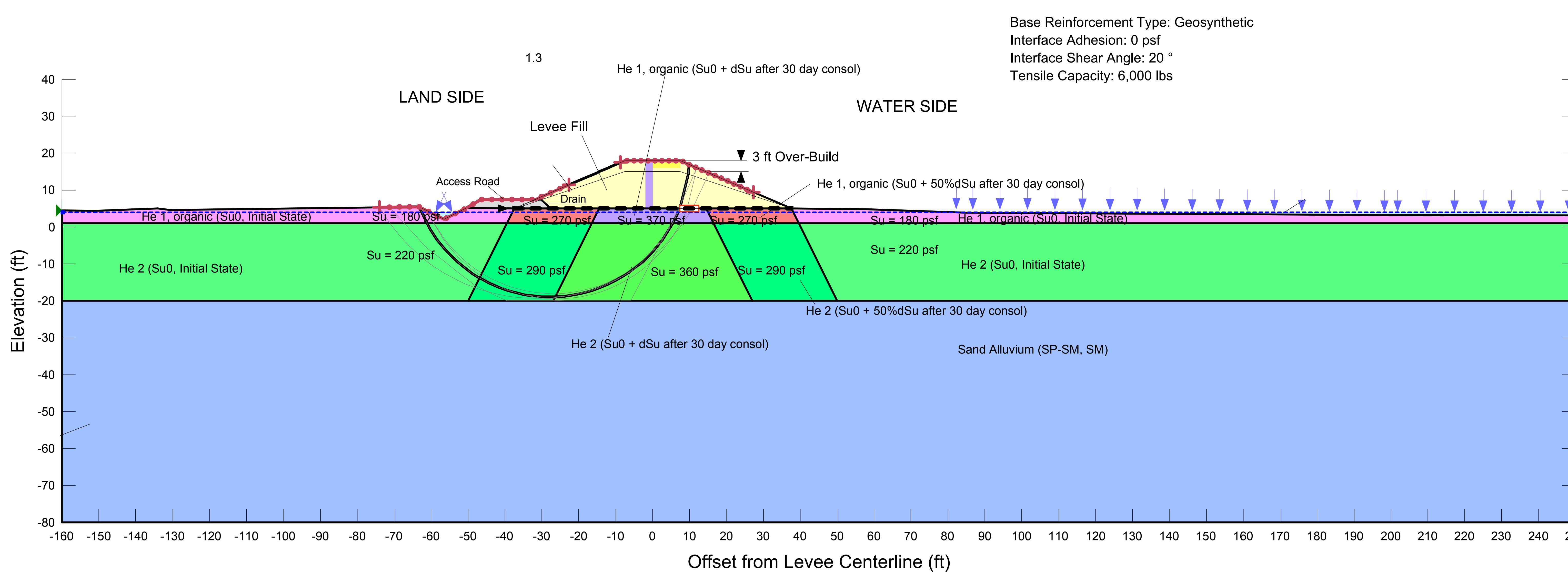
lb = pound

- = case not analyzed

Smith Island Restoration
21-1-12405-030
File Name: Section A-A' (Pipeline)_REV7.gsz
Analysis Name: Case 1, EOC (LS) w/ fabric
Print Date: 4/11/2013
Last Edited By: Oliver Hoopes
GeoStudio Version 8.0.10.6504
Method: Spencer

Name: Sand Alluvium (SP-SM, SM) Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion': 0 psf Phi': 34 ° Piezometric Line: 1
Name: Sand & Gravel Fill Model: Mohr-Coulomb Unit Weight: 125 pcf Cohesion': 0 psf Phi': 34 ° Piezometric Line: 1
Name: Levee Fill Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion': 0 psf Phi': 32 ° Piezometric Line: 1
Name: Levee Fill (Short Term) Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion': 100 psf Phi': 28 ° Piezometric Line: 1
Name: He 2 (Su0, Initial State) Model: Undrained (Phi=0) Unit Weight: 110 pcf Cohesion': 220 psf Piezometric Line: 1
Name: He 2 (Su0 + dSu after 30 day consol) Model: Undrained (Phi=0) Unit Weight: 110 pcf Cohesion': 360 psf Piezometric Line: 1
Name: He 1, organic (Su0, Initial State) Model: Undrained (Phi=0) Unit Weight: 90 pcf Cohesion': 180 psf Piezometric Line: 1
Name: He 1, organic (Su0 + dSu after 30 day consol) Model: Undrained (Phi=0) Unit Weight: 90 pcf Cohesion': 370 psf Piezometric Line: 1
Name: He 1, organic (Su0 + 50%dSu after 30 day consol) Model: Undrained (Phi=0) Unit Weight: 90 pcf Cohesion': 270 psf Piezometric Line: 1
Name: He 2 (Su0 + 50%dSu after 30 day consol) Model: Undrained (Phi=0) Unit Weight: 110 pcf Cohesion': 290 psf Piezometric Line: 1

Base Reinforcement Type: Geosynthetic
Interface Adhesion: 0 psf
Interface Shear Angle: 20 °
Tensile Capacity: 6,000 lbs



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Filename: Section A-A' (Pipeline)_REV7.gsz

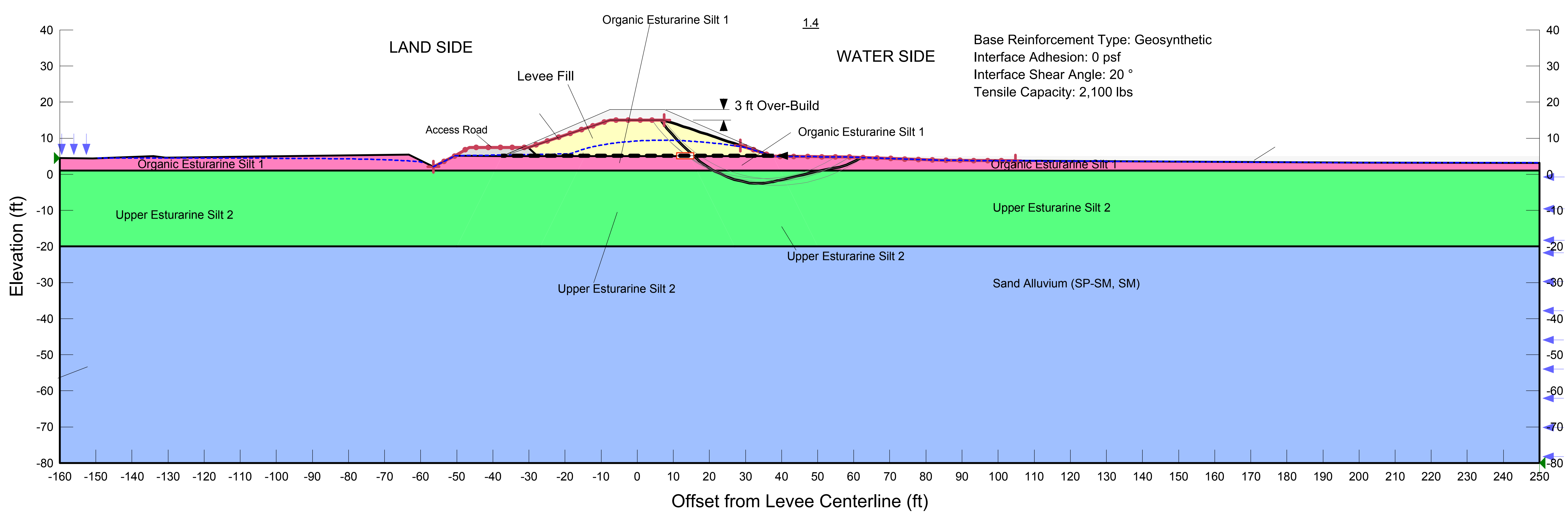
Figure E-1

Smith Island Restoration
21-1-12405-030
File Name: Section A-A' (Pipeline)_REV7.gsz
Analysis Name: Case 2a, DD from 15' Stability (WS) (medium fabric)
Print Date: 4/4/2013
Last Edited By: Oliver Hoopes
GeoStudio Version 8.0.10.6504
Method: Spencer

Parent Analysis = Name: DD from H = 15' (Kind: SEEP/W)

Method B: 4-Day Transient Drawdown from Steady State

Name: Sand Alluvium (SP-SM, SM) Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion': 0 psf Phi': 34 °
Name: Sand & Gravel Fill Model: Mohr-Coulomb Unit Weight: 125 pcf Cohesion': 0 psf Phi': 34 °
Name: Levee Fill Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion': 0 psf Phi': 32 °
Name: Upper Esturarine Silt 2 Model: Mohr-Coulomb Unit Weight: 110 pcf Cohesion': 50 psf Phi': 29 °
Name: Organic Esturarine Silt 1 Model: Mohr-Coulomb Unit Weight: 90 pcf Cohesion': 50 psf Phi': 31 °



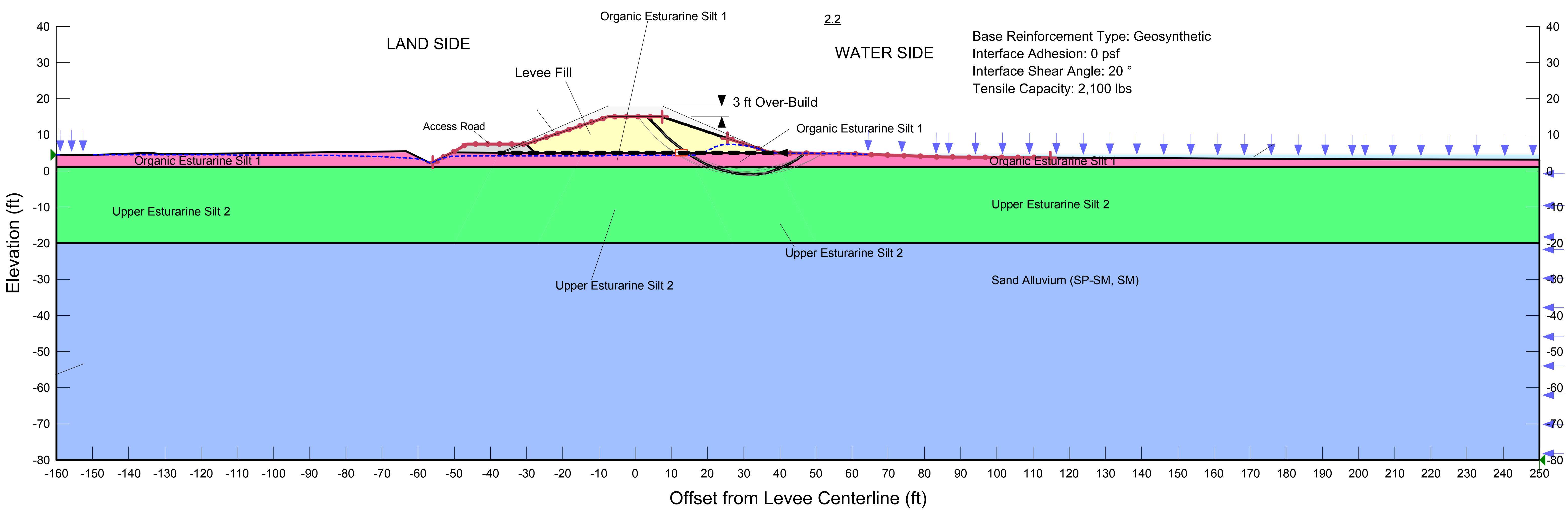
Directory: I:\WIP\21-1\12405 Smith Island (Snohomish Cty)\030. GEOTECH\GEOSTUDIO\
Filename: Section A-A' (Pipeline)_REV7.gsz

Figure E-2

Smith Island Restoration
21-1-12405-030
File Name: Section A-A' (Pipeline)_REV7.gsz
Analysis Name: Case 2b, High Tide DD (WS), w/ HS fabric
Print Date: 4/4/2013
Last Edited By: Oliver Hoopes
GeoStudio Version 8.0.10.6504
Method: Morgenstern-Price

Parent Analysis = Name: High Tide DD from H = 11.1' (Kind: SEEP/W)

Name: Sand Alluvium (SP-SM, SM) Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion': 0 psf Phi': 34 °
Name: Sand & Gravel Fill Model: Mohr-Coulomb Unit Weight: 125 pcf Cohesion': 0 psf Phi': 34 °
Name: Levee Fill Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion': 0 psf Phi': 32 °
Name: Upper Esturarine Silt 2 Model: Mohr-Coulomb Unit Weight: 110 pcf Cohesion': 50 psf Phi': 29 °
Name: Organic Esturarine Silt 1 Model: Mohr-Coulomb Unit Weight: 90 pcf Cohesion': 50 psf Phi': 31 °



Directory: I:\WIP\21-1\12405 Smith Island (Snohomish Cty)\030. GEOTECH\GEOSTUDIO\
Filename: Section A-A' (Pipeline)_REV7.gsz

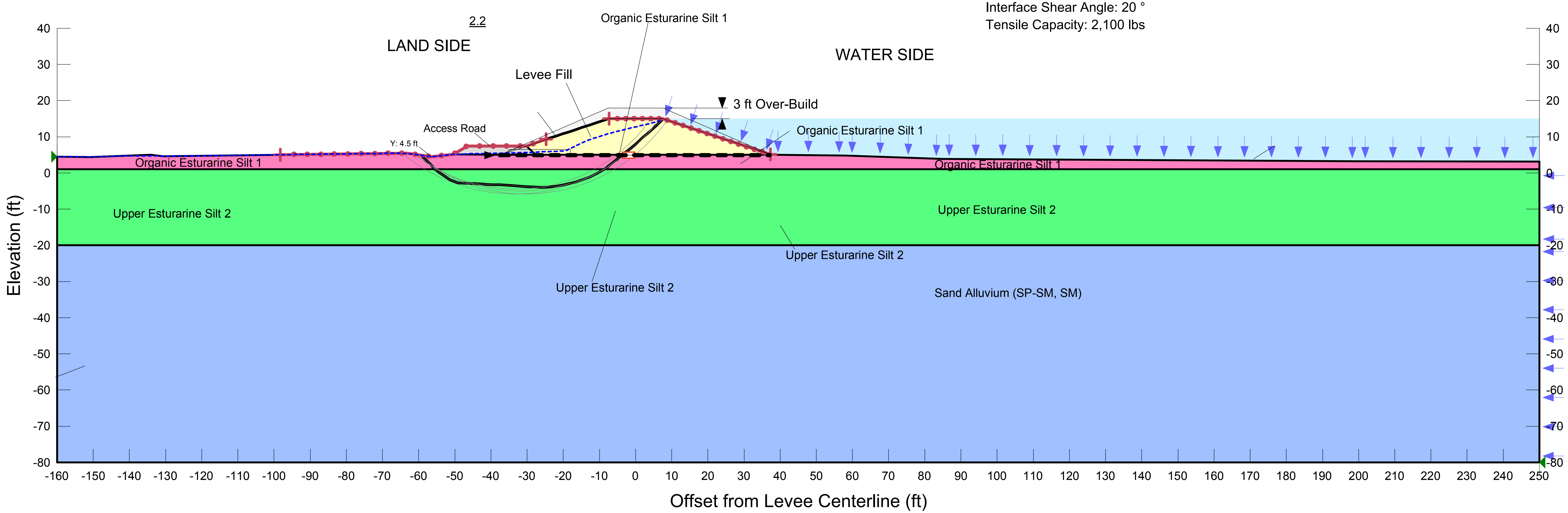
Figure E-3

Smith Island Restoration
21-1-12405-030
File Name: Section A-A' (Pipeline)_REV9.gsz
Analysis Name: Case 3, SS Seepage Stability (WS) (w/Fabric)
Print Date: 4/22/2013
Last Edited By: Oliver Hoopes
GeoStudio Version 8.0.10.6504
Method: Morgenstern-Price

Parent Analysis = Name: Case 2a & 3 St. State Seepage (H = 15') (Kind: SEEP/W)

Name: Sand Alluvium (SP-SM, SM) Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion': 0 psf Phi': 34 °
Name: Sand & Gravel Fill Model: Mohr-Coulomb Unit Weight: 125 pcf Cohesion': 0 psf Phi': 34 °
Name: Levee Fill Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion': 0 psf Phi': 32 °
Name: Upper Esturarine Silt 2 Model: Mohr-Coulomb Unit Weight: 110 pcf Cohesion': 50 psf Phi': 29 °
Name: Organic Esturarine Silt 1 Model: Mohr-Coulomb Unit Weight: 90 pcf Cohesion': 50 psf Phi': 31 °

Base Reinforcement Type: Geosynthetic
Interface Adhesion: 0 psf
Interface Shear Angle: 20 °
Tensile Capacity: 2,100 lbs

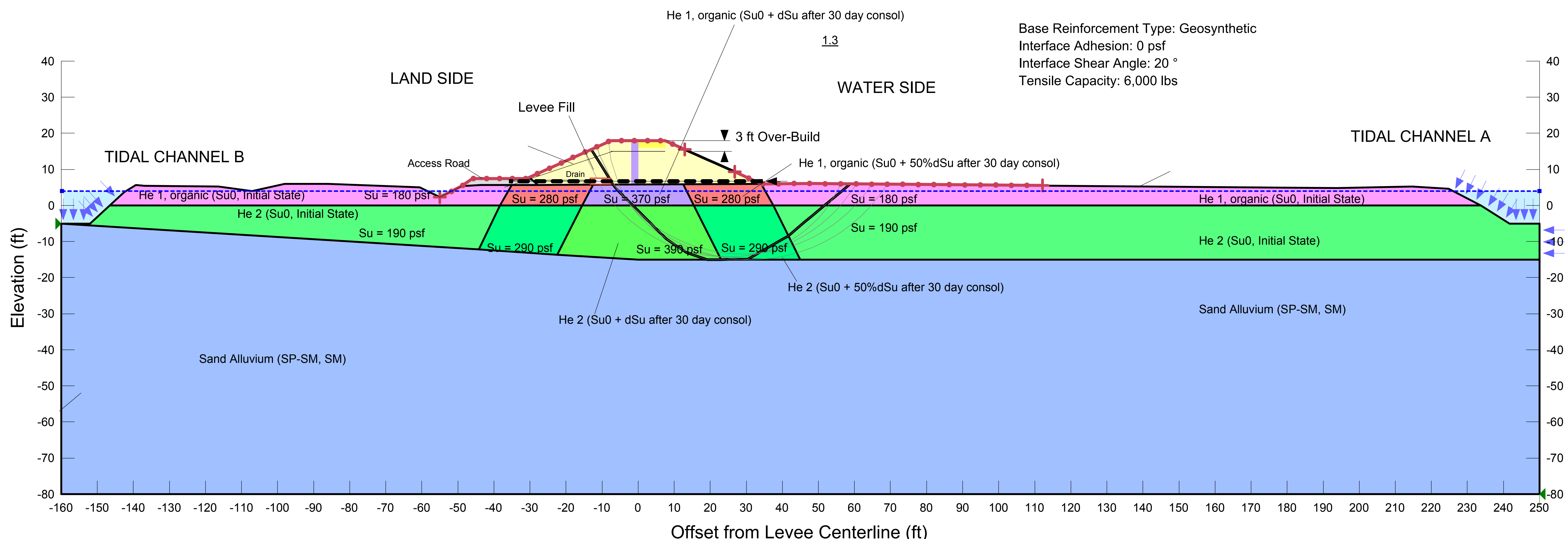


Directory: I:\WIP\21-1\12405 Smith Island (Snohomish Cty)\030. GEOTECH\GEOSTUDIO\
Filename: Section A-A' (Pipeline)_REV9.gsz

Figure E-4

Smith Island Restoration
21-1-12405-030
File Name: Section B-B' (Sta 29+11)_REV7.gsz
Analysis Name: A Case 1, EOC (WS) w/ fabric
Print Date: 4/11/2013
Last Edited By: Oliver Hoopes
GeoStudio Version 8.0.10.6504
Method: Morgenstern-Price

Name: Sand Alluvium (SP-SM, SM) Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion': 0 psf Phi': 33 ° Piezometric Line: 1
Name: Sand & Gravel Fill Model: Mohr-Coulomb Unit Weight: 125 pcf Cohesion': 0 psf Phi': 34 ° Piezometric Line: 1
Name: Levee Fill Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion': 0 psf Phi': 32 ° Piezometric Line: 1
Name: Levee Fill (Short Term) Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion': 100 psf Phi': 28 ° Piezometric Line: 1
Name: He 2 (Su0, Initial State) Model: Undrained (Phi=0) Unit Weight: 110 pcf Cohesion': 190 psf Piezometric Line: 1
Name: He 2 (Su0 + dSu after 30 day consol) Model: Undrained (Phi=0) Unit Weight: 110 pcf Cohesion': 390 psf Piezometric Line: 1
Name: He 1, organic (Su0, Initial State) Model: Undrained (Phi=0) Unit Weight: 90 pcf Cohesion': 180 psf Piezometric Line: 1
Name: He 1, organic (Su0 + dSu after 30 day consol) Model: Undrained (Phi=0) Unit Weight: 90 pcf Cohesion': 370 psf Piezometric Line: 1
Name: He 1, organic (Su0 + 50%dSu after 30 day consol) Model: Undrained (Phi=0) Unit Weight: 90 pcf Cohesion': 280 psf Piezometric Line: 1
Name: He 2 (Su0 + 50%dSu after 30 day consol) Model: Undrained (Phi=0) Unit Weight: 110 pcf Cohesion': 290 psf Piezometric Line: 1



Directory: I:\WIP\21-1\12405 Smith Island (Snohomish Cty)\030. GEOTECH\GEOSTUDIO\
Filename: Section B-B' (Sta 29+11)_REV7.gsz

Figure E-5

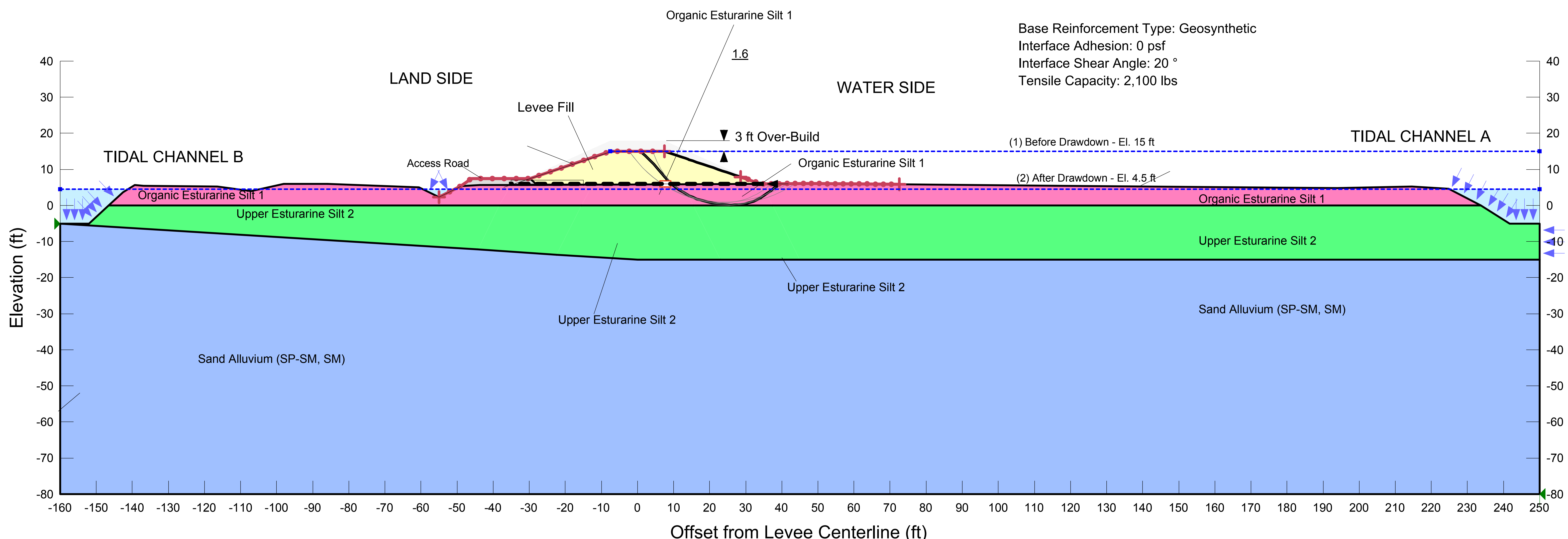
Smith Island Restoration
21-1-12405-030
File Name: Section B-B' (Sta 29+11)_REV7.gsz
Analysis Name: Case 2a, Multi Stage DD from 15'
Print Date: 4/11/2013
Last Edited By: Oliver Hoopes
GeoStudio Version 8.0.10.6504
Method: Morgenstern-Price

Method A: Multi Stage Drawdown

Parent Analysis = Name: A Case 2a & 3 SS Seepage (FLOOD, H = 15') (Kind: SEEP/W)

Name: Sand Alluvium (SP-SM, SM) Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion': 0 psf Phi': 33 ° Total Cohesion: 0.1 psf Total Phi: 32.99 ° Piezometric Line: 1 Piezometric Line After Drawdown: 2
Name: Sand & Gravel Fill Model: Mohr-Coulomb Unit Weight: 125 pcf Cohesion': 0 psf Phi': 34 ° Total Cohesion: 0.1 psf Total Phi: 33.99 ° Piezometric Line: 1 Piezometric Line After Drawdown: 2
Name: Levee Fill Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion': 0 psf Phi': 32 ° Total Cohesion: 0.1 psf Total Phi: 31.99 ° Piezometric Line: 1 Piezometric Line After Drawdown: 2
Name: Upper Esturarine Silt 2 Model: Mohr-Coulomb Unit Weight: 110 pcf Cohesion': 50 psf Phi': 29 ° Total Cohesion: 230 psf Total Phi: 10 ° Piezometric Line: 1 Piezometric Line After Drawdown: 2
Name: Organic Esturarine Silt 1 Model: Mohr-Coulomb Unit Weight: 90 pcf Cohesion': 50 psf Phi': 31 ° Total Cohesion: 80 psf Total Phi: 19 ° Piezometric Line: 1 Piezometric Line After Drawdown: 2

Base Reinforcement Type: Geosynthetic
Interface Adhesion: 0 psf
Interface Shear Angle: 20 °
Tensile Capacity: 2,100 lbs



Directory: I:\WIP\21-1\12405 Smith Island (Snohomish Cty)\030. GEOTECH\GEOSTUDIO\
Filename: Section B-B' (Sta 29+11)_REV7.gsz

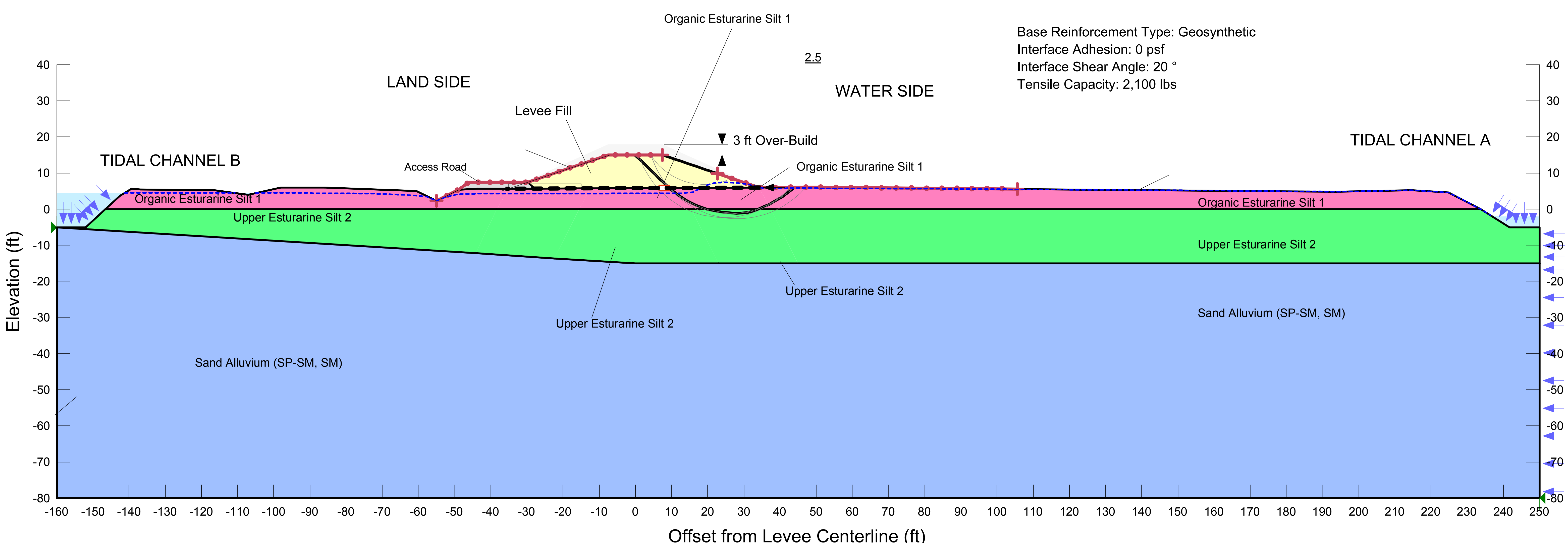
Figure E-6

Smith Island Restoration
21-1-12405-030
File Name: Section B-B' (Sta 29+11)_REV7.gsz
Analysis Name: Case 2b, High Tide DD Stability (WS)
Print Date: 4/11/2013
Last Edited By: Oliver Hoopes
GeoStudio Version 8.0.10.6504
Method: Morgenstern-Price

Parent Analysis = Name: A High Tide DD from H = 11.1' (Kind: SEEP/W)

Name: Sand Alluvium (SP-SM, SM) Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion': 0 psf Phi': 33 °
Name: Sand & Gravel Fill Model: Mohr-Coulomb Unit Weight: 125 pcf Cohesion': 0 psf Phi': 34 °
Name: Levee Fill Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion': 0 psf Phi': 32 °
Name: Upper Esturarine Silt 2 Model: Mohr-Coulomb Unit Weight: 110 pcf Cohesion': 50 psf Phi': 29 °
Name: Organic Esturarine Silt 1 Model: Mohr-Coulomb Unit Weight: 90 pcf Cohesion': 50 psf Phi': 31 °

Base Reinforcement Type: Geosynthetic
Interface Adhesion: 0 psf
Interface Shear Angle: 20 °
Tensile Capacity: 2,100 lbs



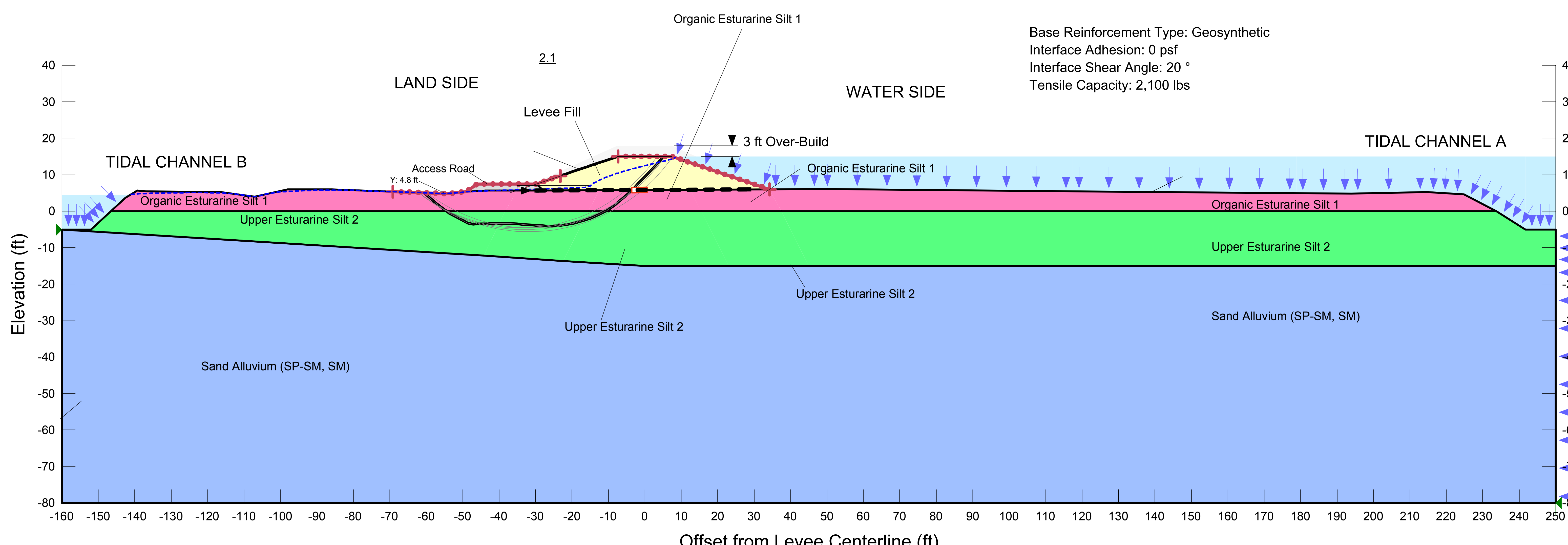
Directory: I:\WIP\21-1\12405 Smith Island (Snohomish Cty)\030. GEOTECH\GEOSTUDIO\
Filename: Section B-B' (Sta 29+11)_REV7.gsz

Figure E-7

Smith Island Restoration
21-1-12405-030
File Name: Section B-B' (Sta 29+11)_REV9.gsz
Analysis Name: Case 3, SS Seepage Stability (WS)
Print Date: 4/22/2013
Last Edited By: Oliver Hoopes
GeoStudio Version 8.0.10.6504
Method: Morgenstern-Price

Parent Analysis = Name: A Case 2a & 3 SS Seepage (FLOOD, H = 15') (Kind: SEEP/W)

Name: Sand Alluvium (SP-SM, SM) Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion': 0 psf Phi': 33 °
Name: Sand & Gravel Fill Model: Mohr-Coulomb Unit Weight: 125 pcf Cohesion': 0 psf Phi': 34 °
Name: Levee Fill Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion': 0 psf Phi': 32 °
Name: Upper Esturarine Silt 2 Model: Mohr-Coulomb Unit Weight: 110 pcf Cohesion': 50 psf Phi': 29 °
Name: Organic Esturarine Silt 1 Model: Mohr-Coulomb Unit Weight: 90 pcf Cohesion': 50 psf Phi': 31 °

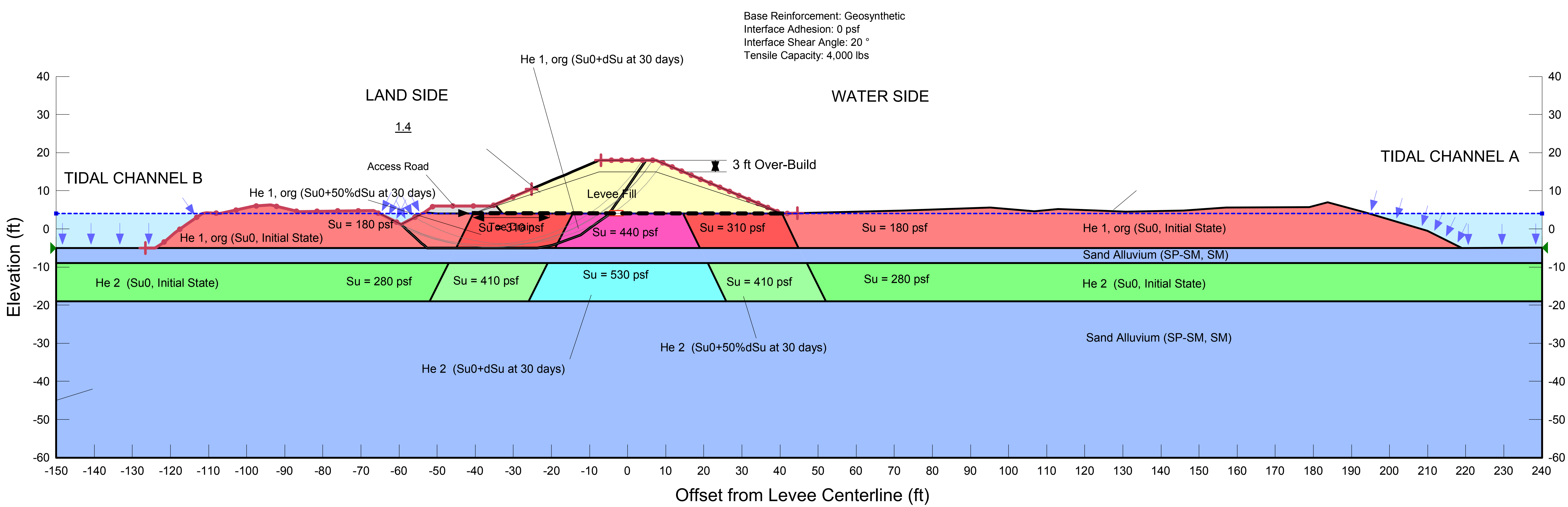


Directory: I:\WIP\21-1\12405 Smith Island (Snohomish Cty)\030. GEOTECH\GEOSTUDIO\
Filename: Section B-B' (Sta 29+11)_REV9.gsz

Figure E-8

Smith Island Restoration
21-1-12405-030
File Name: Section C-C' (Sta 51+86)_REV7.gsz
Analysis Name: Case 1b, EOC (LS), w/ fabric
Print Date: 4/11/2013
Last Edited By: Oliver Hoopes
GeoStudio Version 8.0.10.6504
Method: Morgenstern-Price

Name: Sand Alluvium (SP-SM, SM) Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion': 0 psf Phi': 33 ° Piezometric Line: 1
Name: Sand & Gravel Fill Model: Mohr-Coulomb Unit Weight: 125 pcf Cohesion': 0 psf Phi': 34 ° Piezometric Line: 1
Name: Levee Fill Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion': 0 psf Phi': 32 ° Piezometric Line: 1
Name: He 1, org (Su0, Initial State) Model: Undrained (Phi=0) Unit Weight: 90 pcf Cohesion': 180 psf Piezometric Line: 1
Name: He 1, org (Su0+dSu at 30 days) Model: Undrained (Phi=0) Unit Weight: 90 pcf Cohesion': 440 psf Piezometric Line: 1
Name: He 1, org (Su0+50%dSu at 30 days) Model: Undrained (Phi=0) Unit Weight: 90 pcf Cohesion': 310 psf Piezometric Line: 1
Name: He 2 (Su0, Initial State) Model: Undrained (Phi=0) Unit Weight: 110 pcf Cohesion': 280 psf Piezometric Line: 1
Name: He 2 (Su0+dSu at 30 days) Model: Undrained (Phi=0) Unit Weight: 110 pcf Cohesion': 530 psf Piezometric Line: 1
Name: He 2 (Su0+50%dSu at 30 days) Model: Undrained (Phi=0) Unit Weight: 110 pcf Cohesion': 410 psf Piezometric Line: 1



Directory: I:\WIP\21-1\12405 Smith Island (Snohomish Cty)\030. GEOTECH\GEOSTUDIO\
Filename: Section C-C' (Sta 51+86)_REV7.gsz

Figure E-9

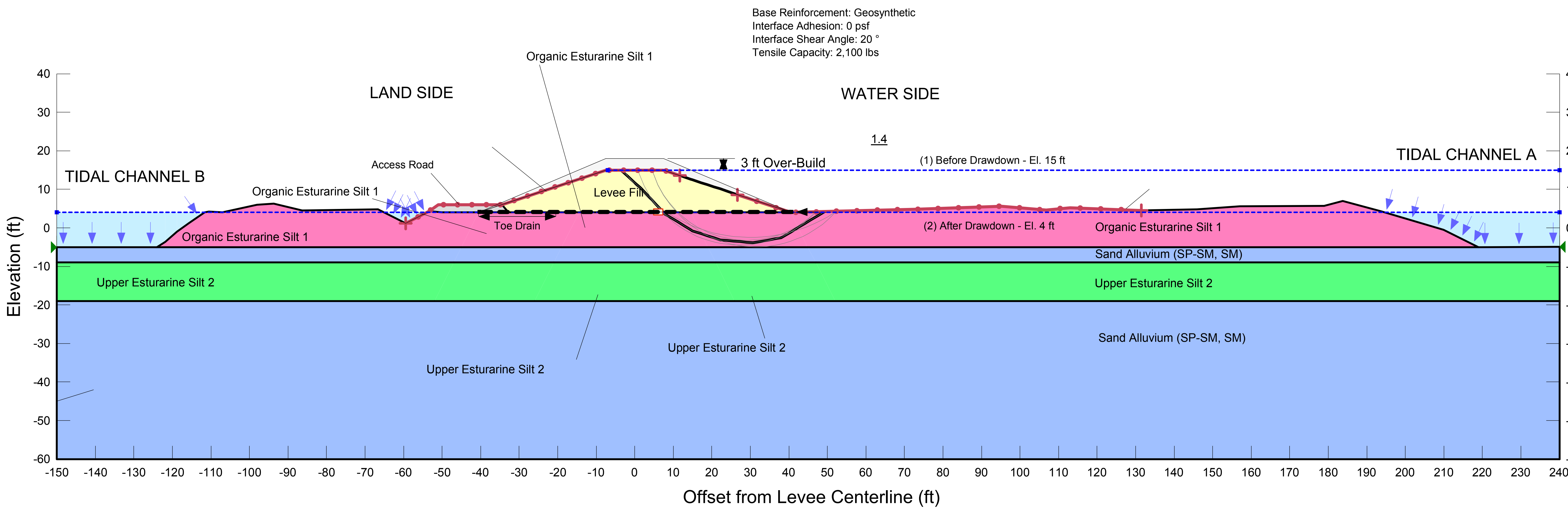
Smith Island Restoration
21-1-12405-030
File Name: Section C-C' (Sta 51+86)_REV7.gsz
Analysis Name: Case 2A, Multi Stage f rom SS
Print Date: 4/11/2013
Last Edited By: Oliver Hoopes
GeoStudio Version 8.0.10.6504
Method: Morgenstern-Price

Method A: Multi Stage Drawdown

Parent Analysis = Name: Case 2a, 3 SS Seepage (FLOOD, H = 15') (Kind: SEEP/W)

Name: Sand Alluvium (SP-SM, SM) Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion': 0 psf Phi': 33 ° Total Cohesion: 0.1 psf Total Phi: 32.99 ° Piezometric Line: 1 Piezometric Line After Drawdown: 2
Name: Sand & Gravel Fill Model: Mohr-Coulomb Unit Weight: 125 pcf Cohesion': 0 psf Phi': 34 ° Total Cohesion: 0.1 psf Total Phi: 33.99 ° Piezometric Line: 1 Piezometric Line After Drawdown: 2
Name: Levee Fill Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion': 0 psf Phi': 32 ° Total Cohesion: 0.1 psf Total Phi: 31.99 ° Piezometric Line: 1 Piezometric Line After Drawdown: 2
Name: Upper Esturarine Silt 2 Model: Mohr-Coulomb Unit Weight: 110 pcf Cohesion': 50 psf Phi': 29 ° Total Cohesion: 230 psf Total Phi: 10 ° Piezometric Line: 1 Piezometric Line After Drawdown: 2
Name: Organic Esturarine Silt 1 Model: Mohr-Coulomb Unit Weight: 90 pcf Cohesion': 50 psf Phi': 31 ° Total Cohesion: 80 psf Total Phi: 19 ° Piezometric Line: 1 Piezometric Line After Drawdown: 2

Base Reinforcement: Geosynthetic
Interface Adhesion: 0 psf
Interface Shear Angle: 20 °
Tensile Capacity: 2,100 lbs



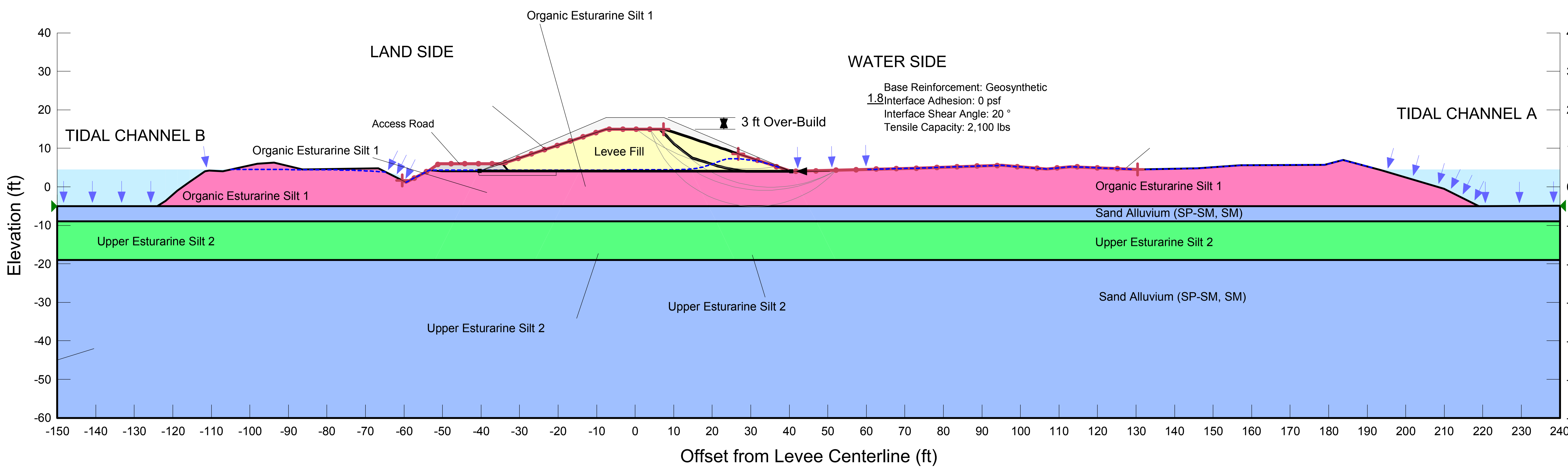
Directory: I:\WIP\21-1\12405 Smith Island (Snohomish Cty)\030. GEOTECH\GEOSTUDIO\
Filename: Section C-C' (Sta 51+86)_REV7.gsz

Figure E-10

Smith Island Restoration
21-1-12405-030
File Name: Section C-C' (Sta 51+86)_REV7.gsz
Analysis Name: Case 3b, High Tide DD, (RS), drained, w/ fabric
Print Date: 4/4/2013
Last Edited By: Oliver Hoopes
GeoStudio Version 8.0.10.6504
Method: Morgenstern-Price

Parent Analysis = Name: High Tide DD Transient Seepage from H = 11.1' (Kind: SEEP/W)

Name: Sand Alluvium (SP-SM, SM) Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion': 0 psf Phi': 33 °
Name: Sand & Gravel Fill Model: Mohr-Coulomb Unit Weight: 125 pcf Cohesion': 0 psf Phi': 34 °
Name: Levee Fill Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion': 0 psf Phi': 32 °
Name: Upper Esturarine Silt 2 Model: Mohr-Coulomb Unit Weight: 110 pcf Cohesion': 50 psf Phi': 29 °
Name: Organic Esturarine Silt 1 Model: Mohr-Coulomb Unit Weight: 90 pcf Cohesion': 50 psf Phi': 31 °



Directory: I:\WIP\21-1\12405 Smith Island (Snohomish Cty)\030. GEOTECH\GEOSTUDIO\
Filename: Section C-C' (Sta 51+86)_REV7.gsz

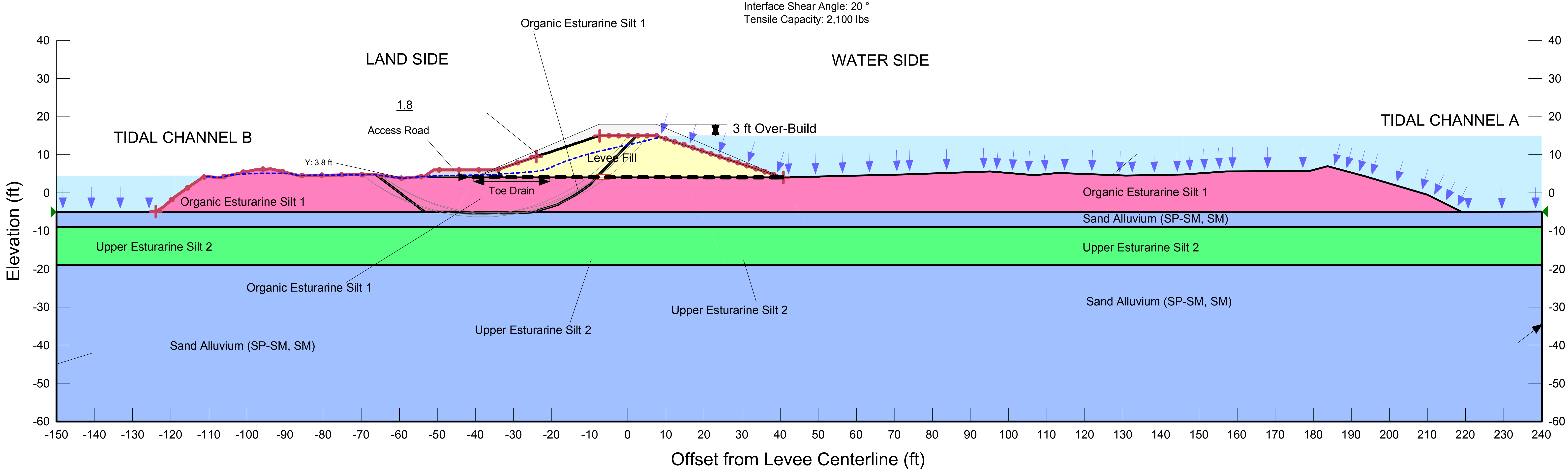
Figure E-11

Smith Island Restoration
21-1-12405-030
File Name: Section C-C' (Sta 51+86)_REV9.gsz
Analysis Name: Case 3, SS (LS), w/ fabric
Print Date: 4/22/2013
Last Edited By: Oliver Hoopes
GeoStudio Version 8.0.10.6504
Method: Morgenstern-Price

Parent Analysis = Name: Case 2a, 3 SS Seepage (FLOOD, H = 15') (Kind: SEEP/W)

Name: Sand Alluvium (SP-SM, SM) Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion': 0 psf Phi': 33 °
Name: Sand & Gravel Fill Model: Mohr-Coulomb Unit Weight: 125 pcf Cohesion': 0 psf Phi': 34 °
Name: Levee Fill Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion': 0 psf Phi': 32 °
Name: Upper Esturarine Silt 2 Model: Mohr-Coulomb Unit Weight: 110 pcf Cohesion': 50 psf Phi': 29 °
Name: Organic Esturarine Silt 1 Model: Mohr-Coulomb Unit Weight: 90 pcf Cohesion': 50 psf Phi': 31 °

Base Reinforcement: Geosynthetic
Interface Adhesion: 0 psf
Interface Shear Angle: 20 °
Tensile Capacity: 2,100 lbs

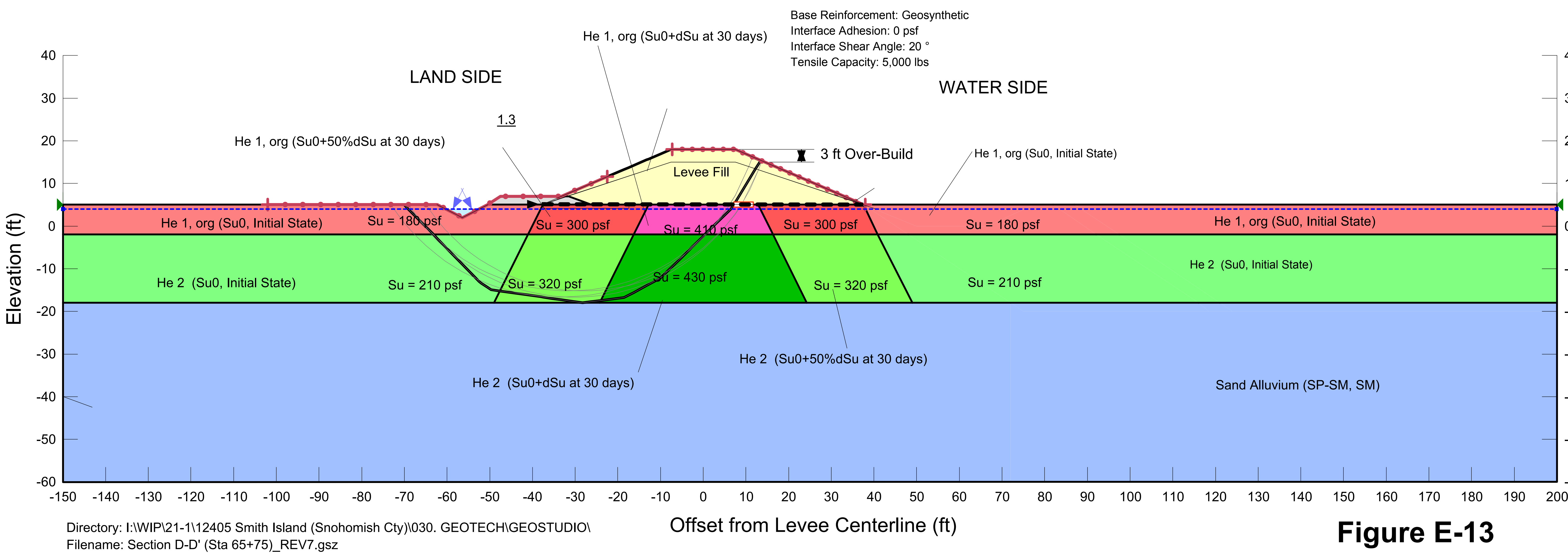


Directory: I:\WIP\21-1\12405 Smith Island (Snohomish Cty)\030. GEOTECH\GEOSTUDIO\
Filename: Section C-C' (Sta 51+86)_REV9.gsz

Figure E-12

Smith Island Restoration
21-1-12405-030
File Name: Section D-D' (Sta 65+75)_REV7.gsz
Analysis Name: Case 1, EOC (LS), w/ fabric
Print Date: 4/11/2013
Last Edited By: Oliver Hoopes
GeoStudio Version 8.0.10.6504
Method: Morgenstern-Price

Name: Sand Alluvium (SP-SM, SM) Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion': 0 psf Phi': 33 ° Piezometric Line: 1
Name: Sand & Gravel Fill Model: Mohr-Coulomb Unit Weight: 125 pcf Cohesion': 0 psf Phi': 34 ° Piezometric Line: 1
Name: Levee Fill Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion': 0 psf Phi': 32 ° Piezometric Line: 1
Name: He 1, org (Su0, Initial State) Model: Undrained (Phi=0) Unit Weight: 90 pcf Cohesion': 180 psf Piezometric Line: 1
Name: He 1, org (Su0+dSu at 30 days) Model: Undrained (Phi=0) Unit Weight: 90 pcf Cohesion': 410 psf Piezometric Line: 1
Name: He 1, org (Su0+50%dSu at 30 days) Model: Undrained (Phi=0) Unit Weight: 90 pcf Cohesion': 300 psf Piezometric Line: 1
Name: He 2 (Su0, Initial State) Model: Undrained (Phi=0) Unit Weight: 110 pcf Cohesion': 210 psf Piezometric Line: 1
Name: He 2 (Su0+dSu at 30 days) Model: Undrained (Phi=0) Unit Weight: 110 pcf Cohesion': 430 psf Piezometric Line: 1
Name: He 2 (Su0+50%dSu at 30 days) Model: Undrained (Phi=0) Unit Weight: 110 pcf Cohesion': 320 psf Piezometric Line: 1



Directory: I:\WIP\21-1\12405 Smith Island (Snohomish Cty)\030. GEOTECH\GEOSTUDIO\
Filename: Section D-D' (Sta 65+75)_REV7.gsz

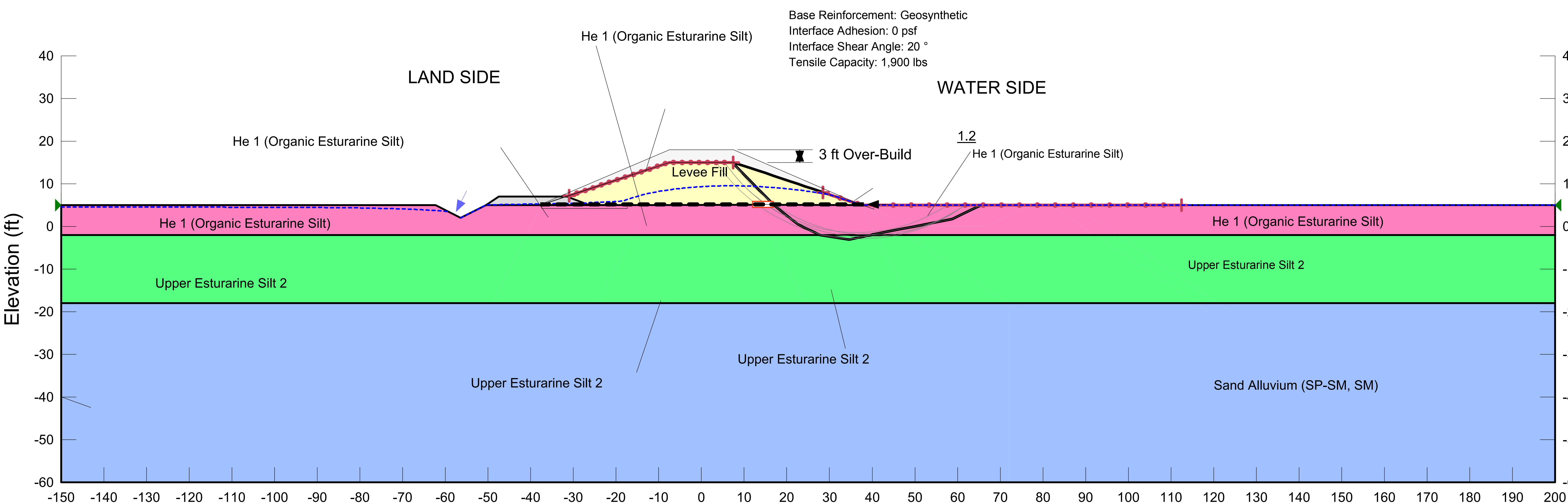
Figure E-13

Smith Island Restoration
21-1-12405-030
File Name: Section D-D' (Sta 65+75)_REV7.gsz
Analysis Name: Case 2a, FLOOD DD (RS), w/fabric
Print Date: 4/4/2013
Last Edited By: Oliver Hoopes
GeoStudio Version 8.0.10.6504
Method: Spencer

Parent Analysis = Name: Case 2a FLOOD DD Seepage from H = 15' (Kind: SEEP/W)

Method B: 4-Day Transient Drawdown from Steady State

Name: Sand Alluvium (SP-SM, SM) Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion': 0 psf Phi': 33 °
Name: Sand & Gravel Fill Model: Mohr-Coulomb Unit Weight: 125 pcf Cohesion': 0 psf Phi': 34 °
Name: Levee Fill Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion': 0 psf Phi': 32 °
Name: Upper Esturarine Silt 2 Model: Mohr-Coulomb Unit Weight: 110 pcf Cohesion': 50 psf Phi': 29 °
Name: He 1 (Organic Esturarine Silt) Model: Mohr-Coulomb Unit Weight: 90 pcf Cohesion': 50 psf Phi': 31 °



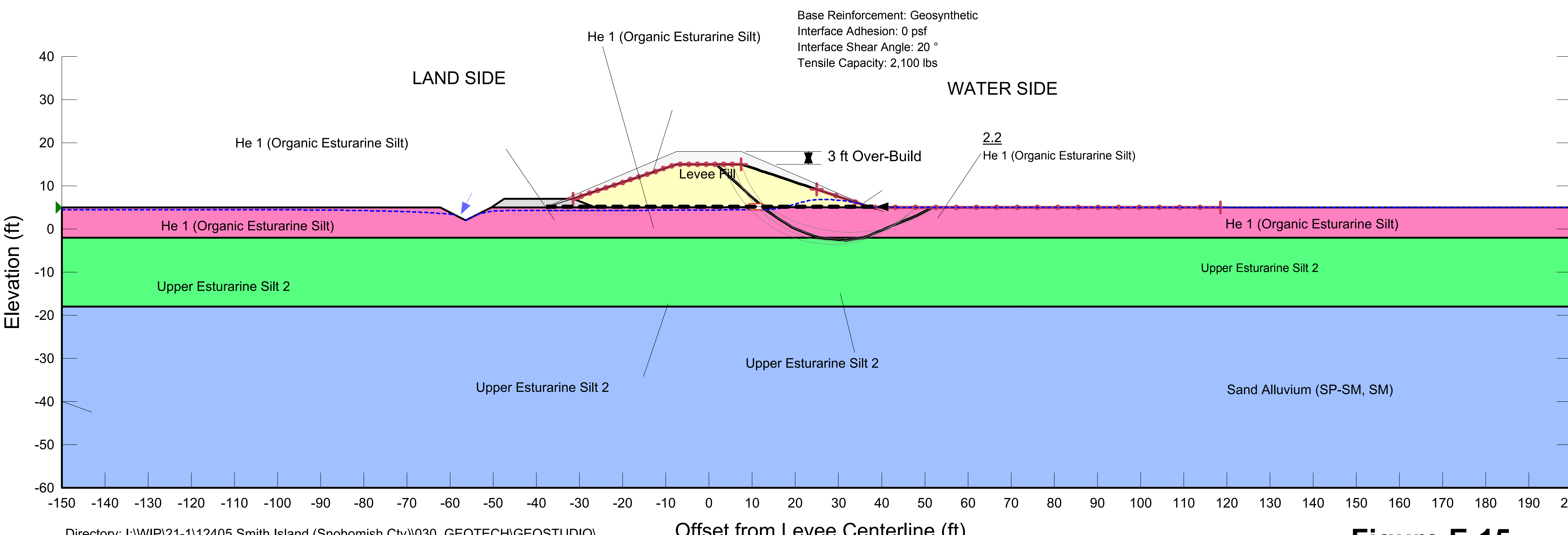
Directory: I:\WIP\21-1\12405 Smith Island (Snohomish Cty)\030. GEOTECH\GEOSTUDIO\
Filename: Section D-D' (Sta 65+75)_REV7.gsz

Figure E-14

Smith Island Restoration
21-1-12405-030
File Name: Section D-D' (Sta 65+75)_REV7.gsz
Analysis Name: Case 2b, High Tide DD (RS), w/ fabric
Print Date: 4/4/2013
Last Edited By: Oliver Hoopes
GeoStudio Version 8.0.10.6504
Method: Spencer

Parent Analysis = Name: Case 2b High Tide DD Seepage from H = 11.1' (Kind: SEEP/W)

Name: Sand Alluvium (SP-SM, SM) Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion': 0 psf Phi': 33 °
Name: Sand & Gravel Fill Model: Mohr-Coulomb Unit Weight: 125 pcf Cohesion': 0 psf Phi': 34 °
Name: Levee Fill Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion': 0 psf Phi': 32 °
Name: Upper Esturarine Silt 2 Model: Mohr-Coulomb Unit Weight: 110 pcf Cohesion': 50 psf Phi': 29 °
Name: He 1 (Organic Esturarine Silt) Model: Mohr-Coulomb Unit Weight: 90 pcf Cohesion': 50 psf Phi': 31 °



Directory: I:\WIP\21-1\12405 Smith Island (Snohomish Cty)\030. GEOTECH\GEOSTUDIO\
Filename: Section D-D' (Sta 65+75)_REV7.gsz

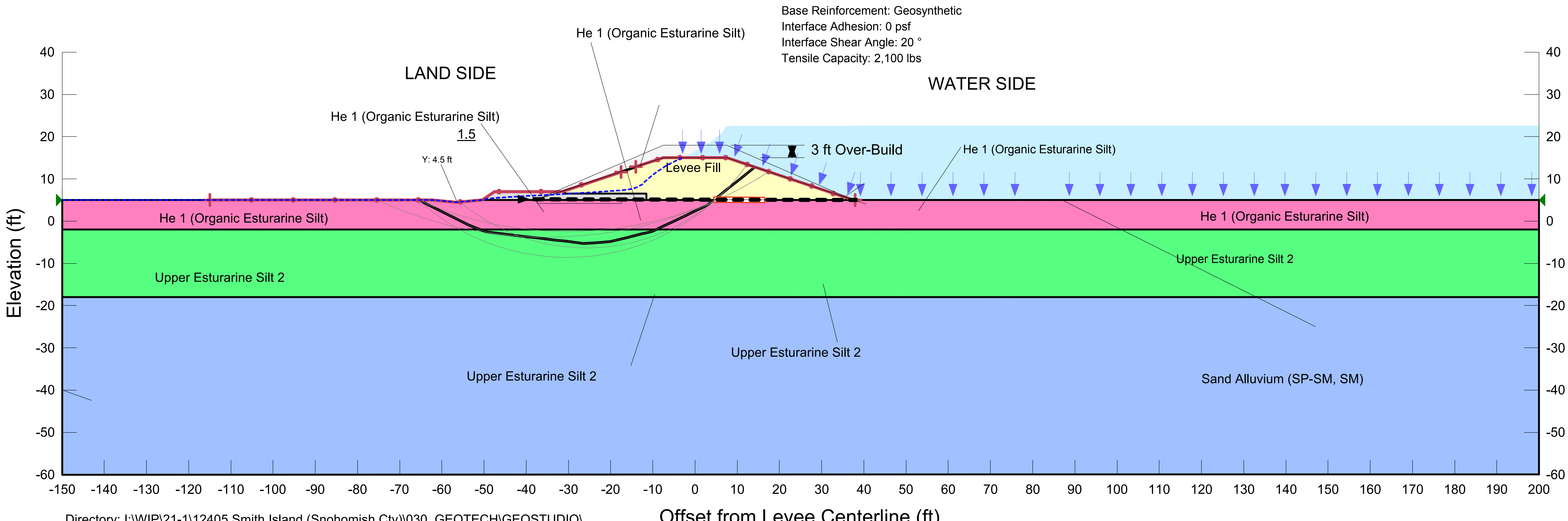
Figure E-15

Smith Island Restoration
21-1-12405-030
File Name: Section D-D' (Sta 65+75)_REV9.gsz
Analysis Name: Case 3A, SS (LS) at 90 deg Bend (Double Seepage)
Print Date: 4/22/2013
Last Edited By: Oliver Hoopes
GeoStudio Version 8.0.10.6504
Method: Spencer

Parent Analysis = Name: Case 3A FLOOD SS Double Seepage at 90 deg Bend (H = 22.5') (Kind: SEEP/W)

NOTE:
This analysis was performed to address the potential impact that the 90 degree bend in the proposed levee at its north may have on the underseepage flows. The 90 degree would occur where the new levee ties into the existing levee at the north end of the project. To account for the flow coming from 2 directions rather than just one, the head on the water side was increased by about 75% (from 10 feet above the ground surface to 17.5 feet above the ground surface, or a total head of 22.5 feet).

Name: Sand Alluvium (SP-SM, SM) Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion': 0 psf Phi': 33 °
Name: Sand & Gravel Fill Model: Mohr-Coulomb Unit Weight: 125 pcf Cohesion': 0 psf Phi': 34 °
Name: Levee Fill Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion': 0 psf Phi': 32 °
Name: Upper Esturarine Silt 2 Model: Mohr-Coulomb Unit Weight: 110 pcf Cohesion': 50 psf Phi': 29 °
Name: He 1 (Organic Esturarine Silt) Model: Mohr-Coulomb Unit Weight: 90 pcf Cohesion': 50 psf Phi': 31 °



Directory: I:\WIP\21-1\12405 Smith Island (Snohomish Cty)\030. GEOTECH\GEOSTUDIO\
Filename: Section D-D' (Sta 65+75)_REV9.gsz

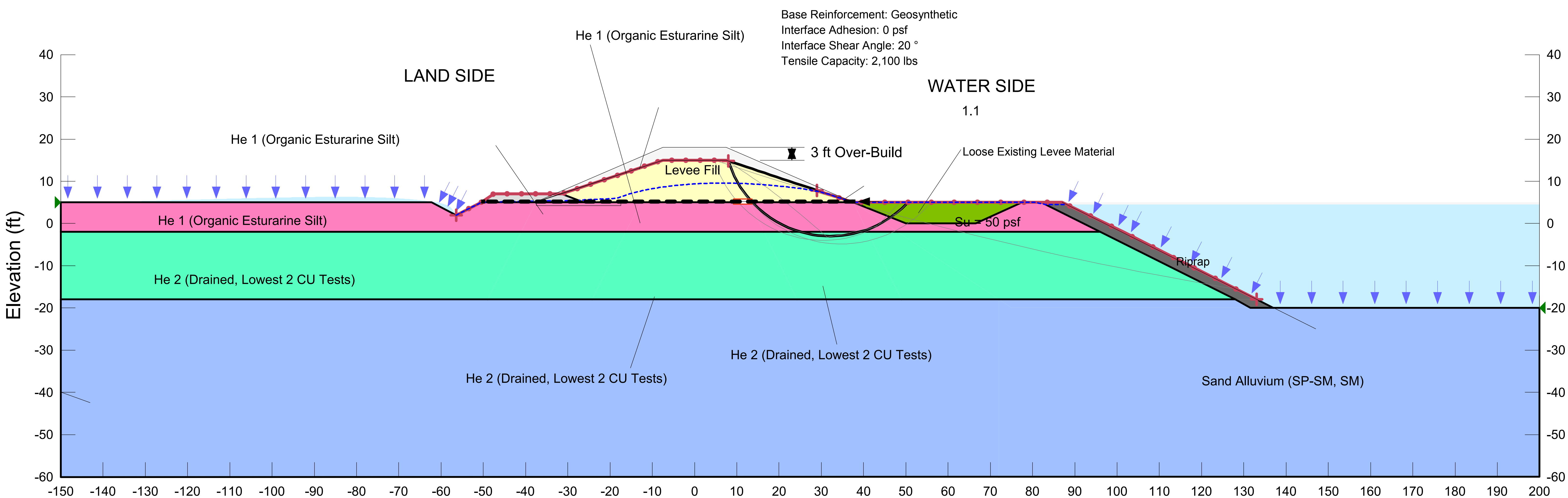
Figure E-16

Smith Island Restoration
21-1-12405-030
File Name: Section D-D' (Sta 65+75)_REV7.gsz
Analysis Name: Case 2a, SCOUR ZONE DD (RS), w/fabric
Print Date: 4/11/2013
Last Edited By: Oliver Hoopes
GeoStudio Version 8.0.10.6504
Method: Spencer

Parent Analysis = Name: Case 2a Transient Seepage from H = 15', Scour (Kind: SEEP/W)

Method B: 4-Day Transient Drawdown from Steady State

Name: Sand Alluvium (SP-SM, SM) Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion': 0 psf Phi': 33 °
Name: Sand & Gravel Fill Model: Mohr-Coulomb Unit Weight: 125 pcf Cohesion': 0 psf Phi': 34 °
Name: Levee Fill Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion': 0 psf Phi': 32 °
Name: He 1 (Organic Esturarine Silt) Model: Mohr-Coulomb Unit Weight: 90 pcf Cohesion': 50 psf Phi': 31 °
Name: Riprap Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion': 0 psf Phi': 45 °
Name: He 2 (Drained, Lowest 2 CU Tests) Model: Mohr-Coulomb Unit Weight: 110 pcf Cohesion': 50 psf Phi': 29 °
Name: Loose Existing Levee Material Model: Mohr-Coulomb Unit Weight: 115 pcf Cohesion': 50 psf Phi': 28 °



Directory: I:\WIP\21-1\12405 Smith Island (Snohomish Cty)\030. GEOTECH\GEOSTUDIO\
Filename: Section D-D' (Sta 65+75)_REV7.gsz

Figure E-17

APPENDIX F

GROUNDWATER STUDY UPDATES AND RESULTS

APPENDIX F

GROUNDWATER STUDY UPDATES AND RESULTS

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APPENDIX F

GROUNDWATER STUDY UPDATES AND RESULTS

F.1 INTRODUCTION

The Smith Island Estuary Restoration project (the project) is east of Interstate 5 (I-5) and south of Union Slough in the Snohomish River Delta (Figure F-1). The project involves constructing a setback levee; breaching an existing levee; and restoring historical farm to natural, tidal, and flood inundated marsh areas. This seepage assessment is part of continuing salt-water intrusion and groundwater studies intended to understand the project's likely hydrologic and water quality impacts to adjacent farm properties. The possible impacts to groundwater conditions include increased seepage flows into Tidal Channel "B," which could affect local groundwater levels, drainage and pumping (Figure F-2). Increased seepage into Tidal Channel "B" could also result in increases in salt-water intrusion into local groundwater wells, the underlying farm groundwater and soils.

A previous report published by Shannon & Wilson (S&W, 2012) described the likely groundwater quality effects in nearby groundwater supply wells during flood conditions. At present, only two groundwater supply wells are believed to exist in the project area. These wells are owned by Hima Farm. However, the owner has not pumped groundwater from either well to date since their installation. One well was installed in April 2010 to a depth of 74 feet. The driller's log for the well reported that the groundwater was brackish. The S&W 2012 report indicated that the project would likely reduce salinity at the well location as a result of increased flooding and infiltration of lower salinity flood waters on the restored marsh areas.

This report appendix presents the following:

- Analysis of groundwater and surface water monitoring data from recently installed pressure transducers and data loggers.
- Use of these monitoring and other hydrogeologic data to update the existing numerical groundwater flow/transport model (that was previously developed for the salt-water intrusion study for the Environmental Impact Statement [EIS]; S&W, 2012). This model uses the U.S. Geological Survey code *MODFLOW-2005* (Harbaugh, 2005).
- Model-predicted seepage and salt-water intrusion estimates into Tidal Channel "B" and the surrounding farm areas resulting from the proposed Smith Island, levee setback and estuary restoration project.

F.2 GROUNDWATER AND SURFACE WATER MONITORING

In mid-July 2013, Snohomish County (the County) installed a series of groundwater and surface water depth (pressure), temperature and conductivity data loggers in three existing shallow monitoring wells (SW-01, SW-02, and SW-08) and at four channel sites at the project site. The installations were designed to evaluate existing groundwater and surface water conditions, and monitor long-term conditions along Union Slough, the proposed marsh restoration area, and Tidal Channels "A" and "B" (Figure F-2). The County installed and operates (calibrating, maintaining, and downloading ground and surface water data) the instruments and data loggers in accordance with the project's Quality Assurance Project Plan developed in July 2013. Table F-1 summarizes the groundwater and surface water loggers and parameters being collected for the project.

The County monitored these instruments and processed the data between July 18 and August 8, 2013. The County compiled these data to establish baseline existing conditions during a typical summer-time tidal period, and for use in updating the MODFLOW model calibration. Access to the private Hima Farm property for land surveying was through an agreement with the landowner. Table F-2 summarizes the monitoring results. Figures F-3 through F-6 illustrate the observed surface and groundwater elevations and salinity conditions.

The following observations were made on the July and August 2013 data.

- Union Slough tidal elevations ranged from -3.05 to +9.94 feet, with an average tidal water surface elevation of +4.43 feet.
- Union Slough showed daily tidal cycling for which salinity conditions were considered "brackish" ranging between 1.21 and 17.59 practical salinity units (psu) with an average salinity of 9.13 psu (Figure F-6). The lowest daily salinity levels coincided with the low tides, indicating a relatively high river flow influence on the Slough. Conversely, the higher salinity occurred at high tide.
- The highest annual salinity levels in Union Slough have been documented to occur during summer tidal conditions (Battelle – Pacific Northwest Division [Battelle], 2007, and Rowse, 2003). This is due to the Snohomish River flow contribution to Union Slough being relatively low during the summer. Conversely, lower salinity levels occur during the fall/winter flood and spring runoff seasons due to the much higher river flows.
- The recorded Tidal Channel "A" water surface elevations ranged between a low of -0.9 foot for the County's Lower Tidal Channel "A" monitoring location, to a high of +1.0 foot for the County's Upper Tidal Channel "A" monitoring location (Figure F-3).
- The Tidal Channel "A" salinity monitoring showed slightly brackish conditions with observed salinity ranging between 2.7 and 5.4 psu (Figure F-6).

- The recorded Upper Tidal Channel "B" water surface elevations (upstream from the Hima Farm earth dam) ranged from -2.2 to -1.9 feet (Figure F-4). The recorded Lower Tidal Channel "B" water surface elevations (downstream from the Hima Farm earth dam) ranged from +0.3 to +0.6 foot. The local farm property owner intermittently pumps Upper Tidal Channel "B" to manage local groundwater and drainage conditions. During this monitoring period, the owner indicated that they had drawdown Tidal Channel "B" earlier in the summer and were not actively pumping during the County's monitoring period.
- The Upper Tidal Channel "B" salinity monitoring indicates mildly brackish water, with salinity ranging between 2.1 to 2.5 psu (Figure F-6).
- The groundwater elevation in the County's monitoring well SW-01 (which is located 350 feet west of Union Slough) ranged between +2.36 and +6.0 feet, with an average of +4.38 feet, during the monitoring period (Figure F-5). The difference between the average water surface elevations in Union Slough and the average groundwater elevation in well SW-01 was 0.05 foot.
- The groundwater elevation in the County's monitoring well SW-08 (which is located 1,000 feet east of Tidal Channel "A" and 1,850 feet west of Union Slough) ranged between +3.31 and +4.44 feet, with an average of +3.81 feet, during the monitoring period (Figure F-5). Union Slough tidal conditions also influence the groundwater behavior in SW-08. The difference between the average water surface elevations in Union Slough and the average groundwater elevation in well SW-08 was 0.62 foot. Therefore, the tidal influence of Union Slough reduces landwards (to the west).
- The groundwater elevation in the County's monitoring well SW-02 (which is located between the lower reaches of Tidal Channels "A" and "B," and 550 feet from Union Slough) ranged between +2.67 and +3.55 feet, with an average of +3.16 feet, during the monitoring period (Figure F-5). This observed range is less than for well SW-08 despite SW-02 being located closer to Union Slough. The difference between the average water surface elevations in Union Slough and the average groundwater elevation in well SW-02 was 1.27 feet.
- The County recorded salinity levels in well SW-08. The screened section in SW-08 (between 20 and 30 feet below grade) is adjacent to the upper part of the near-shore marine sand aquifer The average recorded salinity was 16.12 psu, which is higher than the salinity in the Union Slough surface water gage (9.23 psu).
- The average salinity for Upper Tidal Channel "A" and Upper Tidal Channel "B" gages were 3.90 and 2.29 psu, respectively (Figure F-6). These salinity levels are indicative of mildly brackish water. [The general guidance for drinking freshwater is 0.1 psu, the freshwater limit is considered 0.5 psu, and the irrigation salinity limit is considered 2.0 psu.] A gradual increase in salinity in Tidal Channel "A" occurred during the monitoring period. We suspect this trend was a result of evaporation as there was very little flow/drainage from Upper Tidal Channel "A" and a slightly decreasing water elevations during this hot, dry time period.

F.3 GROUNDWATER FLOW AND SALINITYMODELING

F.3.1 Background

The groundwater impact study for the EIS involved quantitatively evaluating the long-term, average effects that the proposed project would have on the local groundwater conditions. Specifically, the assessment focused on predicting potential groundwater level and salinity changes to potential groundwater users. The impact assessment was based on the use of a numerical groundwater flow and transport model of the Smith Island area. The model was based on the County's hydrogeologic conceptual model (see Snohomish County Department of Public Works, 2013) and was calibrated to existing, pre-restoration hydrologic (baseline) conditions. The model domain is bounded by the Everett Water Pollution Control Facility pond in the south, the Snohomish River on the west, and the Union Slough channel on the east and north. The calibrated model simulated the effects of the proposed dike breaching on this baseline to predict likely changes in groundwater flow, levels and salinity. The initial groundwater modeling was performed and summarized in a report by S&W, *Groundwater Flow and Seawater Impacts Assessment, Smith Island Restoration Project, Snohomish County, Washington, October 2012.* The following section of this report presents the updates made to the groundwater model since the October 2012 report.

F.3.2 MODFLOW Model Updates

F.3.2.1 Model Mesh

The previous model employed a spatially varying computational mesh to calculate groundwater levels and flows. The individual cells ranged in dimensions between 100 feet by 100 feet at the model's outer boundary to 20 feet by 20 feet at and near the Hima Farm well (Figure F-7).

The model was updated to use a uniform cell of 25 feet by 25 feet (Figure F-8). This enabled the model to more accurately represent internal draining features previously not included in the model and the new surface topography (see later).

F.3.2.2 Land Surface

The original model's upper surface was solely based on the 2-foot LIDAR data for the area, which uses a NAVD88 survey datum. We updated the model's surface and bathymetric data using additional bathymetric survey information for Tidal Channel "B," and Federal Emergency Management Agency Flood Insurance Study HEC-RAS model bathymetry for Tidal Channels "A" and Union Slough, all of which were provided by Snohomish County in 2013.

F.3.2.3 Tidal Channels

The original model did not explicitly represent the interior drainage features. Therefore, the model did not previously simulate the interchange between shallow groundwater and Tidal Channels "A" and "B" that now are within the levee system and have tidegates and other drainage controls.

The model update included the two tidal channel's bathymetry as discrete head-dependent internal boundaries. This consisted of assigning MODFLOW *Drain* functions to cells coincident with the channels. This function permits groundwater to discharge to the channel at a rate dependent on (a) the local hydraulic gradient between drain cells and the adjacent non-Drain cells and (b) the conductivity assigned to *Drain* cell. The assigned *Drain* elevations are +4.3 feet in Tidal Channel "A" due to lack of bathymetry and -0.6 foot (Tidal Channel "B").

F.3.2.4 Drain Tiles

During the summer of 2013, the County was allowed to access the Hima Farm property to survey drain tiles that drain to Tidal Channel "B" and west towards Tidal Channel "C" along I-5. Drain tiles were added to the updated model to represent the discharge of shallow groundwater from farm areas mostly located in the southwest area of the farm near I-5 and 12^{th} Avenue NE. Figure F-9 shows the locations of the drain tiles surveyed and input to the updated MODFLOW model. The model also uses the MODFLOW *Drain* function to simulate the tiles. The assigned *Drain* elevations are 0.0 foot for the western group of tiles and +1.5 feet for the eastern group of tiles.

F.3.2.5 Model Layering and Unit Surfaces

The original model used four discrete layers to represent the subsurface soils, and two hydrogeologic units: the uppermost layer (layer 1) represented the estuarine sediments, and layers 2 through 4 represented the near-shore marine sand aquifer (to a base elevation of -75 feet). The boundary surface between the two hydrogeologic units across the model area was based on interpretation from the County's logs for the observation wells and 58 test pits in the project area.

The updated model uses seven discrete layers to represent the two hydrogeologic units (Figure F-10).

- Layers 1 through 3 represent the future setback levee (layer 1) and the estuarine sediments (layers 2 and 3). Each layer has a thickness of up to 10 feet. This change allows the model to more accurately represent internal surface water features and shallow groundwater seepage (in layers 2 and 3), and the planned levee.
- Layers 4 through 7 represent the near-shore marine sand aquifer. Each layer has equal thickness at any point, and the total aquifer thickness ranges between 40 and 60 feet.
- The base of the model remained unchanged (at elevation -75 feet), and no groundwater flow occurs across this lower surface (no flow boundary).

We also updated the elevation of the model's upper hydrostratigraphic boundary between the estuarine sediment deposits and underlying marine sand aquifer deposits. This new surface (the interface between model layers 3 and 4) accounted for the existing surface and the recent geotechnical field exploration soil layer interpretations identified in the Geotechnical Engineering Report (Figure 6 in main body of this Geotechnical Report). Some additional interpretation of this modeled surface was necessary towards the outer modeled areas. The revised elevation of the interface between the two hydrogeologic units ranges from -5 feet in the northeast to -22.5 feet in the southeast (Figure F-11).

F.3.2.6 Hydraulic Properties

The original model was assigned a horizontal hydraulic conductivity of 50 feet per day (ft/day) for the sand aquifer. This parameter value was based on the grain-size analysis data for ten soil samples that the County collected between the depths of 20 and 30 feet in the borings for wells SW-02, SW-04, SW-06, SW-07, and SW-08. Sensitivity testing of the model-predicted salt-water intrusion impacts was conducted using a horizontal hydraulic conductivity range between 25 and 125 ft/day. The modeled hydraulic conductivity of the shallow estuarine sediments was between 0.1 and 0.5 ft/day (Figure F-12); the higher value was assigned to area of this unit that indicted a higher fraction of sand lenses and occurrence of water seeps in the County's test pits. These values were estimated based on observed soil conditions and were not directly calibrated.

For the updated model, we tested a range of hydraulic conductivities for these two units to improve the model calibration targets using information from the surface and groundwater observation data collected in July and August 2013. These updates include new groundwater elevations and estimated seepage rates into Tidal Channel "B."

F.3.2.7 Union Slough and Snohomish River Boundaries

The original model represented the two main surface water features as external boundaries, with elevations based on historical level estimates. These elevations ranged from +3.8 to +5.5 feet for Union Slough, and +4.0 to +5.5 feet for the Snohomish River.

The updated model revised these boundary elevations based on the July-August 2013 monitoring data to represent current, tidal (summer) conditions. Table F-3 presents the updated boundary conditions. The new elevations are:

- Union Slough: +4.0 to +5.2 feet (downstream to upstream) resulting in an average decrease of 0.25 foot compared to the original model version.
- Snohomish River: +4.3 to +5.7 feet (downstream to upstream. As the County did not collect river level data and no permanent gage exists in the area, we lowered the modeled river level also by 0.25 foot.

F.3.2.8 Simulation of City of Everett's Wastewater Treatment Plant (WWTP)

Dike District 5, Hima Farm, and their consultants have requested clarification concerning how the model represents the City of Everett's WWTP pond. The original (and updated) model simulates the northern 64 acres of the WWTP pond along the model's southern boundary as a recharge source. Currently, no information has been provided by the City of Everett to County regarding the pond's daily water elevations, historic pond construction methods and materials, local groundwater elevations adjacent to the pond, or the current condition of the pond bedding and soil conditions.

The MODFLOW model simulates the hydraulic effect of the pond as follows:

- In model layers 1 through 3, the hydraulic conductivity of the soils coinciding with the pond area are assumed the same as the underlying near-marine sand aquifer (that is, 50 ft/day); and
- The fixed recharge rate applied to the model's uppermost active layer is 2.2 inches per year (which equates to a total annual recharge flux of 12 acre-feet, or 7.5 gallons per minute [gpm]).

Therefore, the model assumes that the pond acts as a recharge source for both the shallow estuarine soils and the underlying marine aquifer. However, no changes were made to these parameters as part of the model update.

F.3.3 Updated Model Calibration

The original model used average groundwater levels from the County's 11 monitoring wells (8 shallow and 3 deep) recorded manually between January 17 and July 17, 2012 (21 values per well), as calibration targets for the near-shore marine sand aquifer. These average levels ranged between elevation +4.31 feet (DW-02) and elevation +5.11 feet (DW-03). No calibration data were available for the groundwater elevations in the overlying estuarine sediments or seepage into the tidal channels or drain tiles. The updated model used the following groundwater and seepage data for calibration targets.

F.3.3.1 Groundwater Elevations

The updated model was calibrated to match the average observed groundwater elevations in wells SW-01 (+4.38 feet), SW-02 (+3.16 feet), and SW-08 (+3.81 feet) between July 18 and August 8, 2013 (Figure F-13). These levels are between 0.48 and 1.31 feet lower than the equivalent levels used for the original model calibration. No new calibration groundwater levels were available for the remaining eight observation wells.

F.3.3.2 Tidal "B" Channel Seepage

Based on the water level data collected in July and August 2013, we estimated that Tidal Channels "A" receives between 20 and 40 gpm from shallow groundwater seepage. This estimate was performed by observing the volume of channel filling during the tidegate closure period when no precipitation was present and discounts evapotranspiration losses. We were unable to estimate the inflow seepage rate to Tidal Channel "B" due to the relatively constant elevation that may be related to pumping operations that occurred earlier in the season with low water conditions remaining in the channel. Average surface water levels for Union Slough, Tidal Channel "A" and Tidal Channel "B" were input as head boundary conditions.

We adjusted the soil permeability parameters in the upper soil layer and made iterative adjustments to the properties of new channels and drain tile cells to better match with the observed groundwater level and seepage targets. We adjusted the hydraulic properties of the lower part of this unit (layer 3) to have a higher conductivity than the upper half, reflecting the observed sand lenses and groundwater seeps in the test pits and recent field explorations.

Figure F-13 shows the updated steady-state (tidal) groundwater elevations in the near-shore marine sand aquifer (model layer 4). Table F-4 summarizes the comparison of observed to modeled water surface elevations. Table F-5 summarizes the revised and original model calibrated water budgets by hydrologic feature.

F.3.4 Seepage Modeling Scenarios

The primary purpose of updating the model was to predict changes in groundwater seepage rates and salinity levels under future dike breaching and new levee setback conditions (tidal and flood). As discussed above, the model's main outer (Union Slough and Snohomish River) and internal (Tidal Channels "A" and "B") hydrologic boundaries under current conditions were adjusted to reflect observed daily average tidal elevations from the July-August 2013 monitoring period. The following is a summary of the seepage modeling scenarios simulated and hydrologic boundary conditions for the updated model.

- For flood conditions (for the existing and proposed dike/levee conditions), the boundary condition heads were increased to match the Corps of Engineers' PL84-99 design flood elevation equal to +13.5 feet (NAVD88) (Figure F-14).
- For tidal conditions (for the existing and proposed dike/levee conditions), the boundary condition heads were set at +4.3 feet (NAVD88) to match the mean tide elevation (Figure F-15).
- For flood and tidal conditions, a pond was simulated north of Tidal Channel "B" with a base (modeled *Drain*) elevation of -0.6 foot (Figure F-9).
- For flood and tidal conditions, the *Drain* elevations for Tidal Channel "B" under the proposed flood condition was set at -0.6 foot (per the agreed operational water surface elevation between the County and Hima Farm), and to +0.46 foot for the lower Tidal Channel B downstream from the earthen berm and crossing area (Figure F-14).
- For flood and tidal conditions, Tidal Channel "A" was excluded as a hydrologic feature under the proposed flood conditions as the area east of the new setback dike will be inundated.

F.3.5 Seepage Modeling Results

Tables F-6 through F-10 present the modeling results for existing and proposed, tidal and flood seepage conditions to Tidal Channel "B." SEEP-W modeling was performed as part of the geotechnical levee stability analyses (Geo-Slope, 2012a). The SEEP-W model was used to estimate levee through and under seepage rates into the drainage trench, and residual seepage to Tidal Channel "B" (USACE, 2005). The SEEP-W drainage trench flow modeling was combined with the MODFLOW seepage rates to estimate a net seepage flow to Tidal Channel "B." Seepage flows to Tidal Channel "B" are expected to decrease by between 3 and 11 gpm for tidal conditions, and to decrease by between 15 and 23 gpm for flood conditions.

The new setback levee will include a drainage trench feature which is designed to intercept levee under and through seepage and redirect flows northward along the setback levee and access road to the storage pond and away from Tidal Channel "B." Our estimates from the

SEEP-W modeling, performed in support of the geotechnical stability analyses, indicate that the drainage trench will be 75 to 95 percent efficient in capturing levee through seepage and underseepage in the drain. Drainage conveyance efficiency is related to the drain pipe design, slope configuration, and soils surrounding the drainage trench. Therefore, the analyses predict that the groundwater seepage rate into Tidal Channel "B" will decrease from the levee setback if appropriate surface and groundwater drainage and seepage control measures are included in the design.

F.3.6 Salinity Modeling

Potential increases in salinity in Tidal Channel "B" due to the proposed dike breaching and levee setback are of concern to the neighboring farm. The updated MODFLOW modeling indicates that Union Slough will becomes a more predominate source of groundwater recharge to the underlying aquifer and Tidal Channel "B" for the proposed levee setback condition. Existing conditions modeling indicates that the Snohomish River and groundwater sources from the south currently have a stronger influence.

Modeling and data collection indicate that recharge and discharge to/from the Union Slough and the underlying aquifer are strongly controlled by tidal fluctuations. Under high tide, the slough acts as a recharge source to the sand aquifer and the project area. Under low tides, the hydraulic gradient between the aquifer and the slough reverses and the aquifer discharges to the slough. This concept is an important consideration when evaluating the salinity effects on Tidal Channel "B."

S&W's 2012 saltwater intrusion analysis demonstrated that, under average seasonal/daily tidal conditions, salinity levels will likely decrease in relation to Snohomish River and Union Slough flood and levee setback conditions.

The updated model evaluated salinity transport pathways by using particle tracking function in MODFLOW and modeling salt particle transport across the levee setback area to Tidal Channel "B. Our analysis shows recharge sources and salinity pathways shifting from the Snohomish River and areas south of the project to the east along Union Slough. We used the predicted high tide, recharge salinity conditions adapted from Battelle (2007) for a late summer, high salinity period to perform hydrodynamic modeling studies. The results indicate that Union Slough and the restored marsh areas will have lower salinities than both the Snohomish River during the restored condition, and lower salinities than existing conditions along the Snohomish River and Union Slough, for high tide aquifer recharge periods of the tidal cycle. This finding, combined with the MODFLOW results regarding the shift in groundwater recharge and salinity pathways from the Snohomish River and southern areas to predominately Union Slough indicate that the project will likely have lower salinity aquifer source recharge conditions than existing conditions.

These findings indicate that (a) recharge sources would likely have lower salinity conditions than existing conditions, and (b) seepage flows would likely be intercepted by the design drainage trench. Based on these findings, we conclude that increases in seepage and salinity in Tidal Channel “B” are not likely.

F.4 SUMMARY OF FINDINGS

The following is a summary of findings related to existing surface and groundwater conditions, and updated groundwater modeling for existing and proposed conditions at the project site.

- The existing salinity conditions in Tidal Channel “A” and “B,” and in the underlying groundwater, are above drinking water and agricultural irrigation water standards.
- Installing a drainage trench to convey seepage water to the north into the storage pond would likely result in a net decrease in seepage flow to Tidal Channel “B.”
- Aquifer recharge sources would likely shift from the Snohomish River and southern areas towards the east along Union Slough, which will have lower salinity than existing conditions.
- Seepage and salinity increases to Tidal Channel B resulting from the levee setback project are not likely.

F.5 RECOMMENDATIONS

The following recommendations are provided to the County and the design team for consideration of groundwater, seepage, and saltwater intrusion management and design for the project.

- The drainage trench should be designed to convey seepage flows north to the storage pond facility. We recommend installing the drainage trench structure with backflow preventers to limit backwater flooding from the pond.
- The Hima Farm Tidal Channel “B” water surface elevations should be managed to lower the local groundwater elevation conditions and improve drainage. Tidal Channel “B” water elevations were observed at an average elevation of -2.14 feet in July and August 2013. Hima Farm has agreed to the operating elevation of -0.6 foot used in the design. Lowering the local groundwater water elevations is beneficial in maintaining dry soils for plant roots. The farm currently lowers groundwater levels by a significant depth below farm grade and root zone depths. One concern is that sump pumping and groundwater pumping and drainage operations lower the freshwater elevation (and head) in Tidal Channel “B.” These groundwater pumping activities increase the potential for saltwater

intrusion into to the local groundwater table by reducing the freshwater head on top of the underlying salt water. Therefore, we recommend modifying future Tidal Channel "B" operations to maintain the highest acceptable water surface level to the extent practical. Allowing for increases in fresh water elevations will reduce the potential for saltwater intrusion over the long-term and further protect the farm from salt water intrusion.

F.6 LIMITATIONS

This appendix was prepared for the exclusive use of Otak and the County, and other members of the design team for specific application to the design of the Smith Island Estuary Restoration Project as it relates to groundwater and surface water monitoring, and groundwater modeling as discussed in this appendix. The data contained in this appendix are based upon site conditions as they existed at the time this appendix was prepared and were provided to S&W by the County. Within the limitations of the scope, schedule, and budget, the data presented in this appendix were presented in accordance with generally accepted professional engineering practice in this area at the time this appendix was prepared. No warranty, express or implied, is made.

We have performed limited review of the data provided to S&W, and assume that the data and modeling output provided by others is accurate and that it comprises reliable information to perform the analysis. S&W cannot make claims regarding the correctness or accuracy of these models and data provided by others. Facts and conditions referenced in this appendix may change over time. Facts and conditions set forth here are applicable as described only at the time this appendix was written. We believe that the conclusions stated here are factual, but no guarantee is made or implied.

This appendix was prepared for the exclusive use of Otak and the County and its representatives and in no way guarantees that any agency or its staff will reach the same conclusions as S&W.

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TABLE F-1
SURFACE WATER GAGE AND GROUNDWATER OBSERVATION WELL SUMMARY

Well/Gage ID	Latitude	Longtitude	Type	Gage Parameters (L, T, C)[1]
Shallow Well - 01 (SW-01)	N48°01'03.6116"	W122°09'29.4904"	Groundwater	L, T
Shallow Well - 08 (SW-08)	N48°00'56.2049"	W122°09'52.8051"	Groundwater	L, T, C
Shallow Well - 02 (SW-02)	N48°01'13.3061"	W122°10'17.8181"	Groundwater	L, T
(SW) Upper Tidal Channel “A”	N48°00'53.9701"	W122°10'01.3936"	Surface Water	L, T, C
(SW) Lower Tidal Channel “A”	N48°01'15.7927"	W122°10'13.0187"	Surface Water	L, T
(SW) Upper Tidal Channel “B”	N48°00'57.4260"	W122°10'12.9959"	Surface Water	L, T, C
(SW) Lower Tidal Channel “B”	N48°01'03.6116"	W122°09'29.4904"	Surface Water	L, T
(SW) Union Slough	N48°01'17.7828"	W122°10'07.2389"	Surface Water	L, T, C

Note:

[1] (C) = Conductivity; (L) = Level; (T) = Temperature.

TABLE F-2
SURFACE WATER AND GROUNDWATER OBSERVATION DATA SUMMARY

Well/Gage ID	Water Surface Elevation (NAVD88-ft)			Salinity (psu)		
	Minimum	Average	Maximum	Mininum	Average	Maximum
Shallow Well - 01 (SW-01)	2.36	4.38	6.01	N/A	N/A	N/A
Shallow Well - 08 (SW-08)	3.31	3.81	4.44	13.63	16.12	18.76
Shallow Well - 02 (SW-02)	2.67	3.16	3.55	N/A	N/A	N/A
(SW) Upper Tidal Chan. “A”	-0.87	-0.68	-0.43	N/A	N/A	N/A
(SW) Lower Tidal Channel “A”	-0.10	0.05	0.97	2.67	3.90	5.38
(SW) Upper Tidal Channel “B”	0.34	0.46	0.63	N/A	N/A	N/A
(SW) Lower Tidal Channel “B”	-2.17	-2.09	-1.93	2.11	2.29	2.51
(SW) Union Slough	-3.05	4.43	9.94	1.21	9.13	17.59

Notes:

Data collection period - July 18 to August 8, 2013.

N/A = Not applicable (no sample)

NAVD88 = North American Vertical Datum of 1988

psu = Practical Salinity Units

TABLE F-3
GROUNDWATER MODEL
HYDROLOGIC BOUNDARY CONDITIONS

Location / Feature	Model Input Water Elevation (NAVD88-ft)				
	Calibration	Existing Condition		Proposed Condition	
	Water Level	Tidal Water Level	Flood Water Level	Tidal Water Level	Flood Water Level
Union Slough	3.96-5.21 (avg 4.3)	3.96-5.21 (avg 4.3)	12.46-13.71 (avg 13.5)	3.96-5.21 (avg 4.3)	12.46-13.71 (avg 13.5)
Snohomish River	4.25-5.69	4.25-5.69	13.5	4.25-5.69	13.5
Lower Tidal Channel A	-0.68	-0.68	-0.68	4.3	13.5
Upper Tidal Channel A	0.05	0.05	0.05	4.3	13.5
Lower Tidal Channel B	0.46	0.46	0.46	0.46	0.46
Upper Tidal Channel B	-2.09	-2.09 (design -0.6)	-2.09 (design -0.6)	-2.09 (design -0.6)	-2.09 (design -0.6)
Pond	NA	NA	NA	-0.6	-0.6
Drain Tile - West	-0.6	-0.6	-0.6	-0.6	-0.6
Drain Tile - East	-0.6	-0.6	-0.6	-0.6	-0.6

Notes:

avg = average

Elevation (North American Vertical Datum of 1988

NA = not applicable

TABLE F-4
GROUNDWATER ELEVATION CALIBRATION

Well ID	Observed Mean Groundwater Elevation		Model Simulated Groundwater Elevation and Calibration Residual	
	2012	2013	2013	
	El. (NAVD88-ft)		El. (NAVD88-ft)	Residual (ft)
SW-01	4.86	4.38	4.87	-0.49
SW-02	4.47	3.16	4.11	-0.95
SW-03	4.38	4.38	3.79	0.59
SW-04	4.33	4.33	3.67	0.66
SW-05	4.63	4.63	3.74	0.89
SW-06	4.75	4.75	4.10	0.65
SW-07	4.87	4.87	4.74	0.13
SW-08	4.64	3.81	4.03	-0.22
DW-01	4.99	4.99	4.10	0.89
DW-02	4.31	4.31	4.10	0.21
DW-03	5.11	5.11	4.74	0.37

Notes:

blue cells indicate 2012 values used.

NAVD88 = North American Vertical Datum of 1988

TABLE F-5
WATER BUDGET CALIBRATION

Feature	Model Simulated Total flow	
	gpm	cfs
Recharge-precipitation	21	0.05
Recharge-WWTP	7	0.01
Union Slough	45	0.10
Snohomish River	36	0.08
Tidal A	-59	-0.13
Tidal B	-18	-0.04
Pond	NA	NA
Drain Tiles - west	-25	-0.06
Drain Tiles - east	-7	-0.02

Notes:

Blue cell indicates estimated seepage into Tidal Channel "B"

cfs = cubic feet per second

gpm = gallons per minute

NA = not applicable

WWTP = wastewater treatment plant

TABLE F-6
MODFLOW RESULTS
EXISTING CONDITIONS - TIDAL REGIME

Feature	Total flow	
	gpm	cfs
Recharge-precipitation	21	0.05
Recharge-WWTP	7	0.01
Union Slough	43	0.09
Snohomish River	35	0.08
Tidal A	-59	-0.13
Tidal B	-13	-0.03
Pond	NA	NA
Drain Tiles - west	-26	-0.06
Drain Tiles - east	-7	-0.02

Notes:

Blue cell indicates estimated seepage in Channel "B"

cfs = cubic feet per second

gpm = gallons per minute

NA = not applicable

WWTP = wastewater treatment plant

TABLE F-7
MODFLOW RESULTS
EXISTING CONDITIONS - FLOOD REGIME

Feature	Total flow	
	gpm	cfs
Recharge-precipitation	21	0.05
Recharge-WWTP	7	0.01
Union Slough	139	0.31
Snohomish River	93	0.21
Tidal A	-150	-0.33
Tidal B	-33	-0.07
Pond	NA	NA
Drain Tiles - west	-60	-0.13
Drain Tiles - east	-16	-0.04

Notes:

Blue cell indicates estimated seepage into Tidal Channel "B"

cfs = cubic feet per second

gpm = gallons per minute

NA = not applicable

WWTP = wastewater treatment plant

TABLE F-8
MODFLOW RESULTS
PROPOSED CONDITIONS - TIDAL REGIME

Feature	Total flow	
	gpm	cfs
Recharge-precipitation	21	0.05
Recharge-WWTP	7	0.01
Union Slough	110	0.24
Snohomish River	29	0.07
Tidal A	-55	-0.12
Tidal B	-14	-0.03
Pond	-64	-0.14
Drain Tiles - west	-27	-0.06
Drain Tiles - east	-7	-0.02

Notes:

Blue cell indicates estimated seepage into Tidal Channel "B"

cfs = cubic feet per second

gpm = gallons per minute

NA = not applicable

WWTP = wastewater treatment plant

TABLE F-9
MODFLOW RESULTS
PROPOSED CONDITIONS - FLOOD REGIME

Feature	Total flow	
	gpm	cfs
Recharge-precipitation	21	0.05
Recharge-WWTP	7	0.01
Union Slough	85	0.19
Snohomish River	52	0.12
Tidal A	131	0.29
Tidal B	-38	-0.08
Pond	-172	-0.38
Drain Tiles - west	-66	-0.15
Drain Tiles - east	-19	-0.04

Notes:

Blue cell indicates estimated seepage into Tidal Channel "B"

cfs = cubic feet per second

gpm = gallons per minute

NA = not applicable

WWTP = wastewater treatment plant

TABLE F-10
SEEPAGE ANALYSIS SUMMARY

Flow Condition	Tidal Channel B	Proposed 75% Efficiency Drain Trench (gpm)	Proposed 75% Efficiency Drain Trench (cfs)	Proposed 95% Efficiency Drain Trench (gpm)	Proposed 95% Efficiency Drain Trench (cfs)
Tidal	Existing	46.09	0.10	46.09	0.10
	Proposed	42.51	0.09	35.82	0.08
	Change	-3.58	-0.01	-10.28	-0.02
Flood	Existing	110.22	0.25	110.22	0.25
	Proposed	95.09	0.21	87.46	0.19
	Change	-15.13	-0.03	-22.76	-0.05

Notes:

cfs = cubic feet per second

gpm = gallons per minute

% = percent

0 1 2

Scale in Miles

NOTE

Map adapted from aerial imagery provided by Google Earth Pro, reproduced by permission granted by Google Earth ™ Mapping Service.

Smith Island Estuary Restoration Project
Snohomish County, Washington

VICINITY MAP

October 2013 21-1-12405-060

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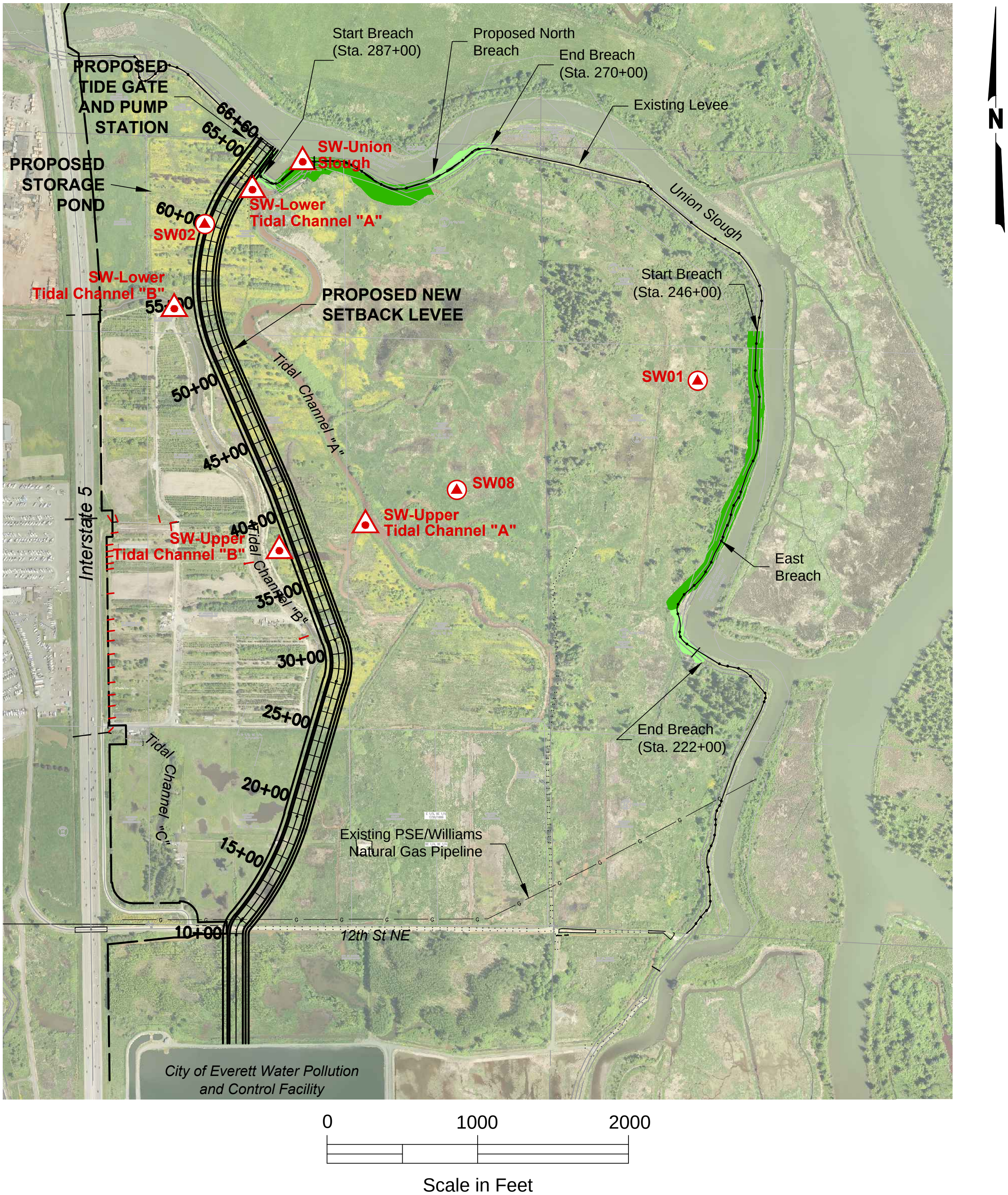
FIG. F-1

Filename: I:\WIP\21-1\12405 Smith Island (Snohomish Cty)\CAD_FIGURES\-060\21-1-12405-060 Fig 1.dwg Date: 11-27-2013 Login: SAC



LEGEND

SW-..... Surface Water Observation Gauge Designation and Approximate Location

SW08 Groundwater Monitoring Well Designation and Approximate Location

Drain Tile (Pipe) Outlet

NOTE

Figure adapted from electronic files provided by Otak.

Smith Island Estuary Restoration Project
Snohomish County, Washington

GROUNDWATER AND SURFACE WATER MONITORING PLAN

October 2013 | 21-1-12405-060

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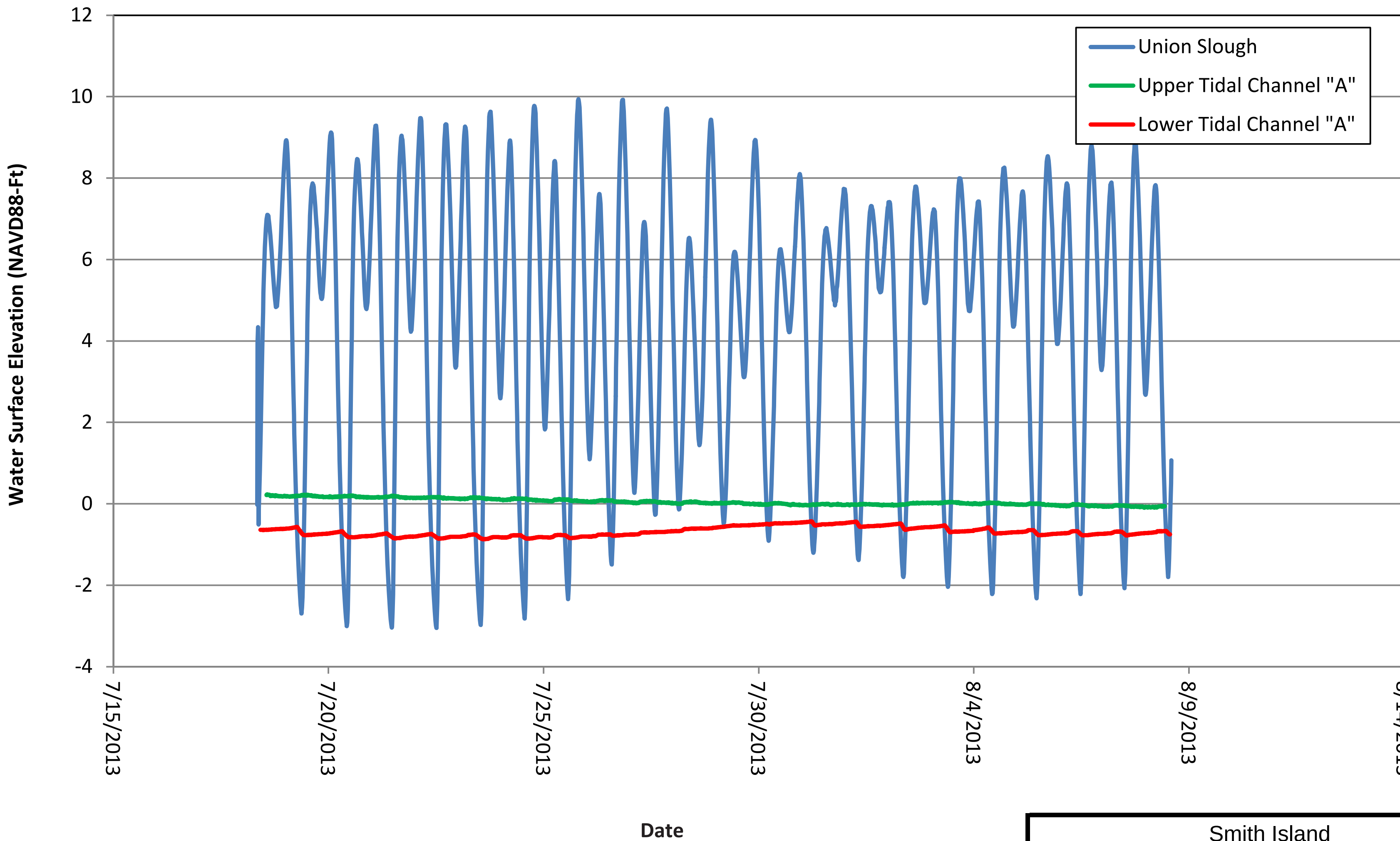
Geotechnical and Environmental Consultants

FIG. F-2

Filename: I:\WIP\21-1\12405 Smith Island (Snohomish Cty)\CAD_FIGURES\-060\21-1-12405-060 Appendix F-2.dwg Date: 11-27-2013 Login: SAC



Smith Island

Snohomish County, WA

Union Slough / Tidal Channel "A"
WATER LEVELS
JULY 2013 - AUGUST 2013

October 2013 21-1-12405-060

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FIG. F-3

FIG. F-3

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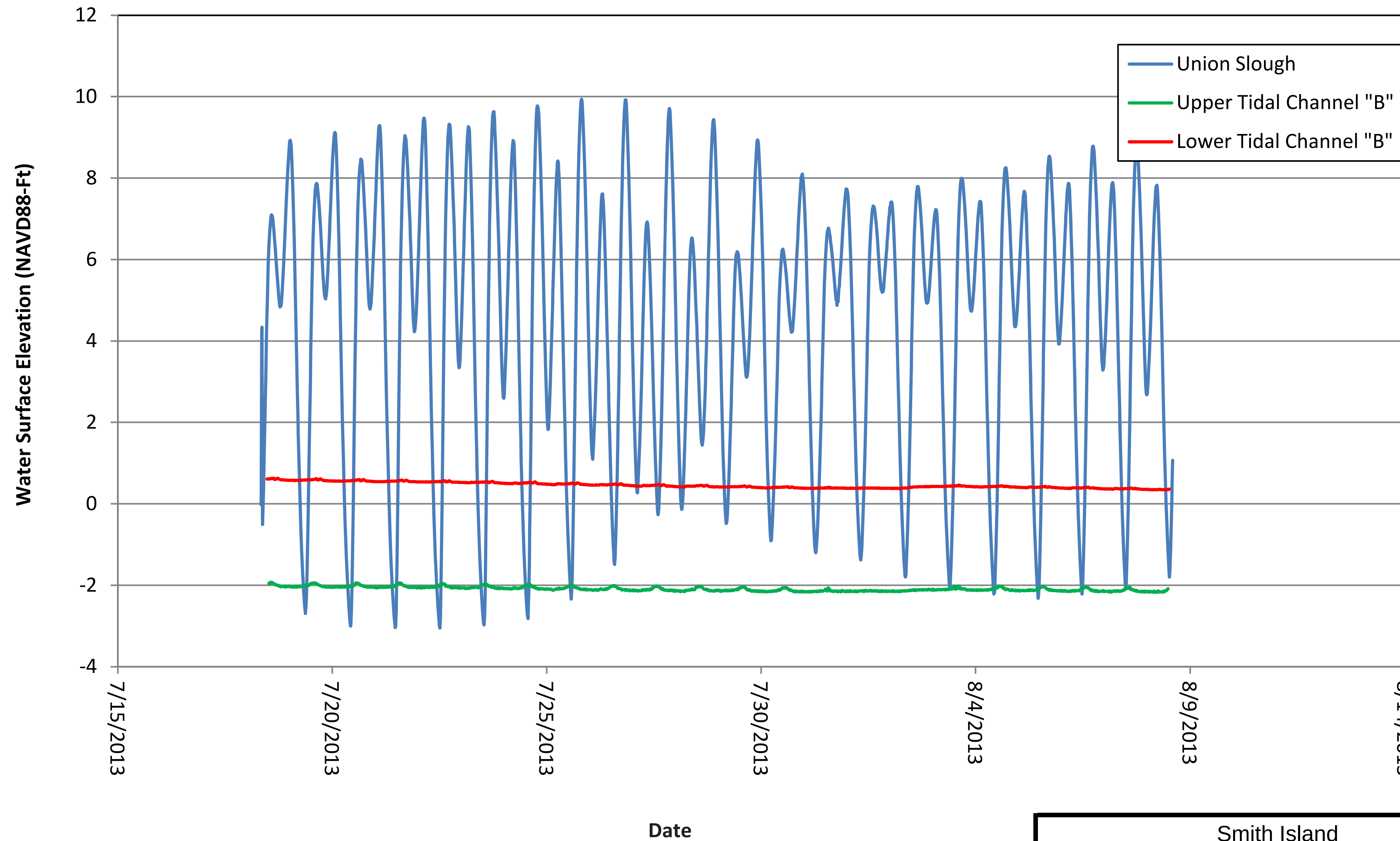

Note: Upstream Tidal Channel "B" lower water surface elevations are a result of existing conditions operations whereby adjacent landowner pumping surface water from Upper Tidal Channel "B" to Lower Tidal Channel "B". Earth dam isolates Upper and Lower Channel Tidal Channel "B".

Smith Island

Snohomish County, WA

Union Slough / Tidal Channel "B"
WATER LEVELS
JULY 2013 - AUGUST 2013

October 2013 | 21-1-12405-060

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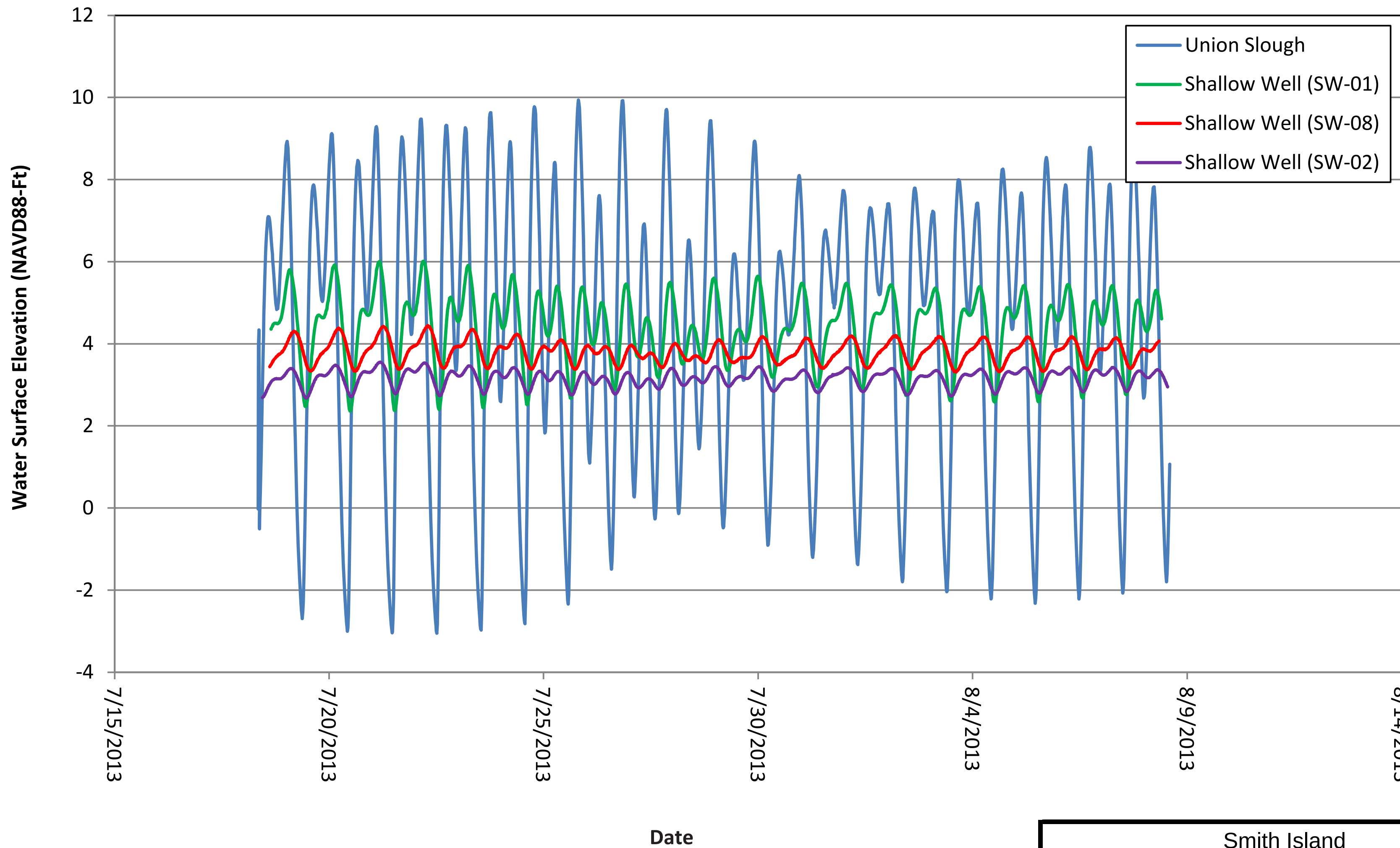
FIG. F-4

FIG. F-4



Smith Island

Snohomish County, WA

Union Slough and Shallow Well
WATER LEVELS
JULY 2013 - AUGUST 2013

October 2013 | 21-1-12405-060

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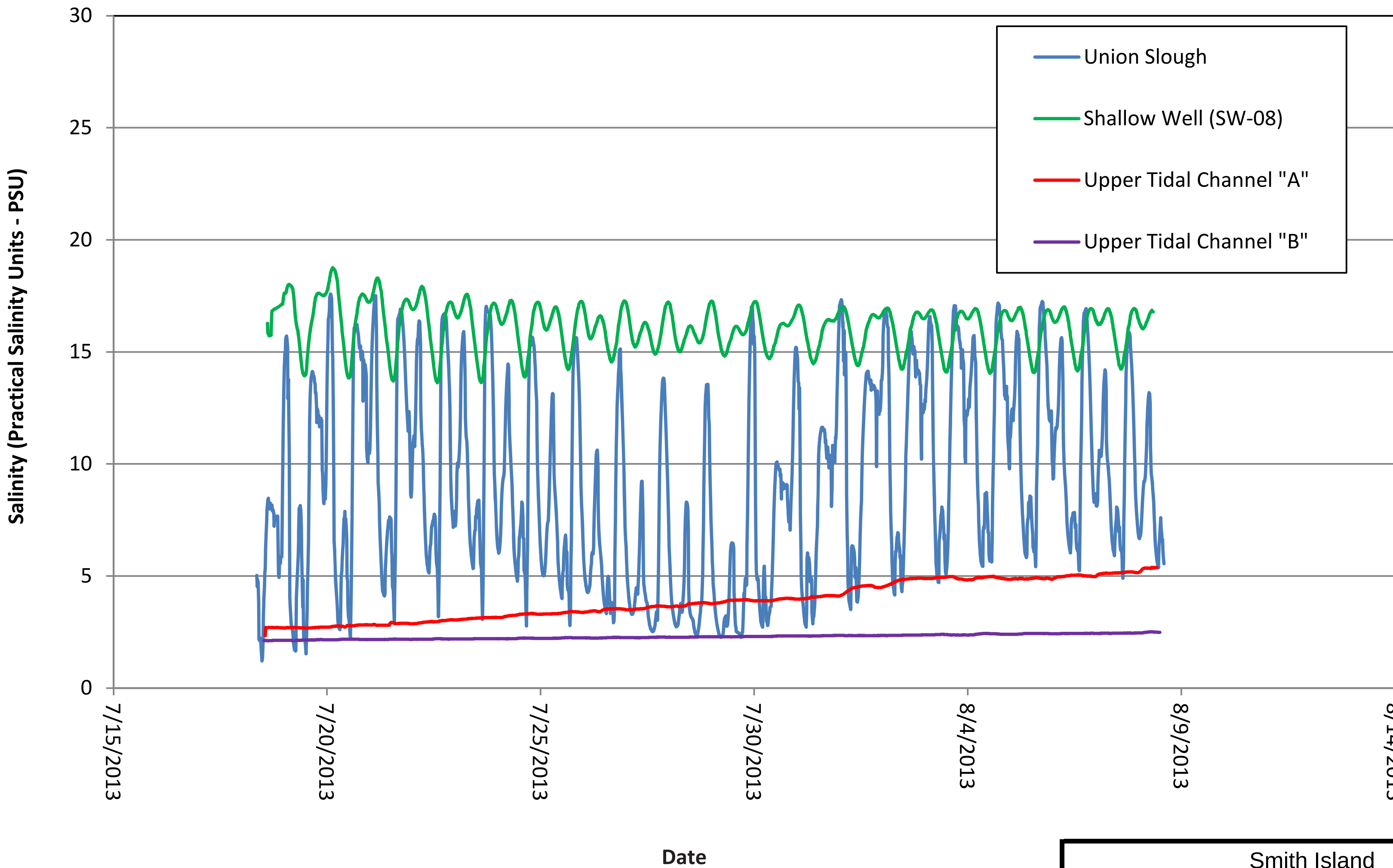
FIG. F-5

FIG. F-5



Smith Island

Snohomish County, WA

SURFACE AND GROUNDWATER SALINITY

JULY 2013 - AUGUST 2013

October 2013 | 21-1-12405-060

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FIG. F-6

FIG. F-6

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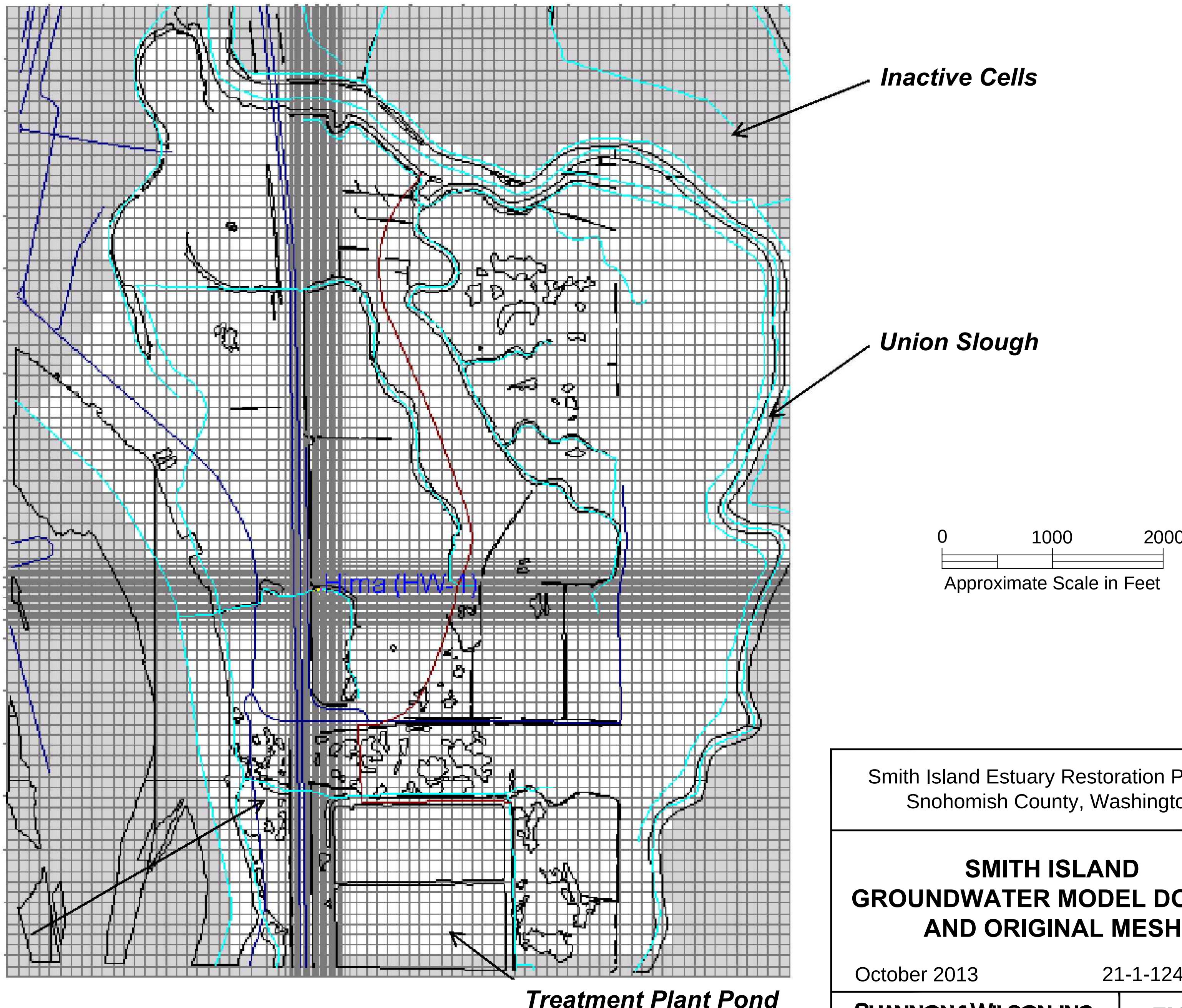

Smith Island Estuary Restoration Project
Snohomish County, Washington

SMITH ISLAND GROUNDWATER MODEL DOMAIN AND ORIGINAL MESH

October 2013   21-1-12405-060

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FIG. F-7

FIG. F-7

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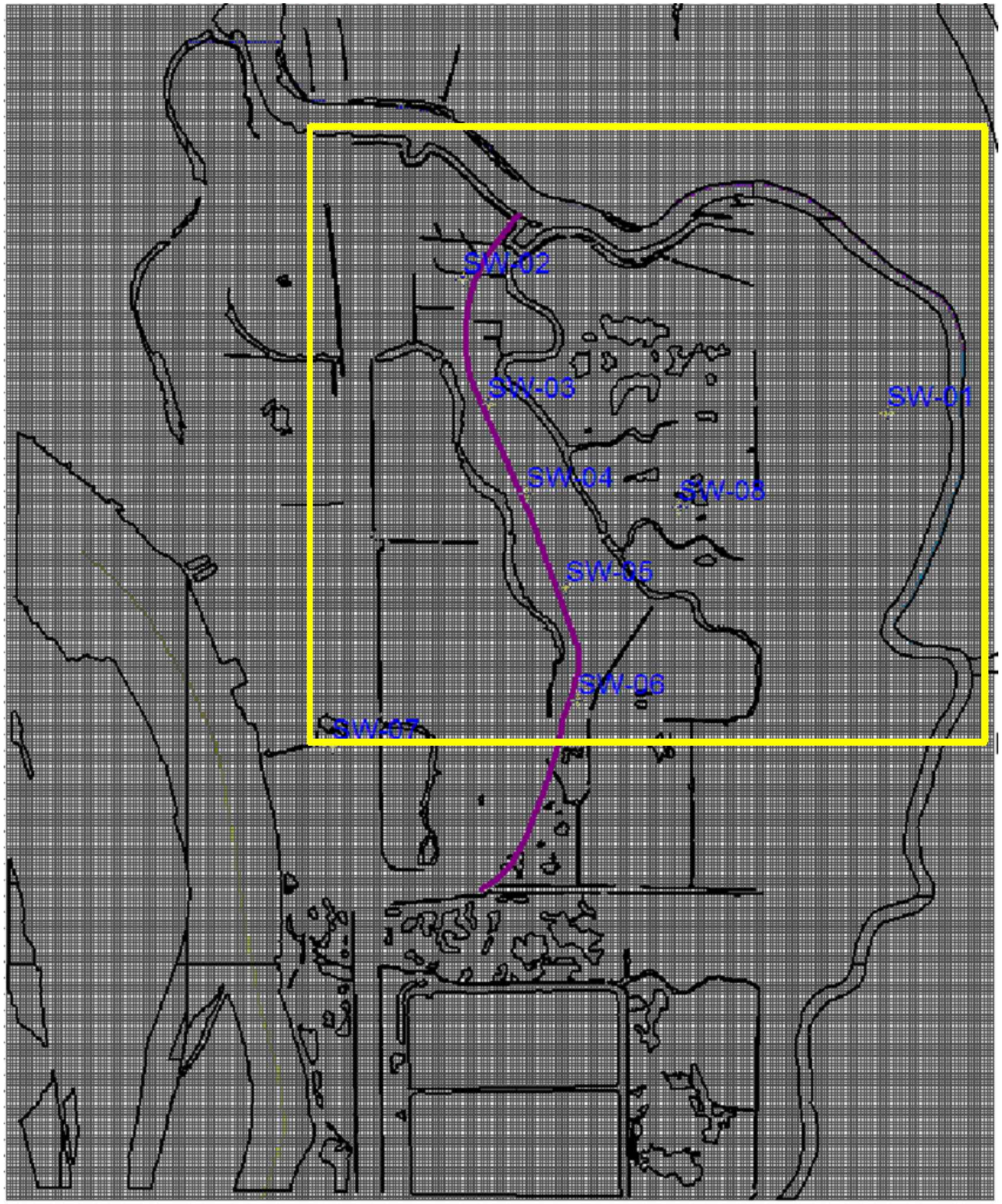

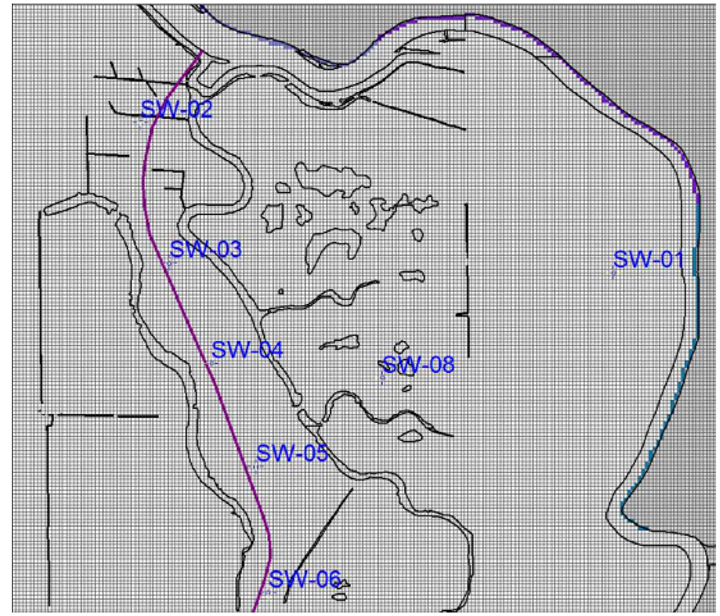

No Scale

0 1000 2000

Approximate Scale in Feet

Smith Island Estuary Restoration Project
Snohomish County, Washington

UPDATED MODEL MESH

October 2013 21-1-12405-060

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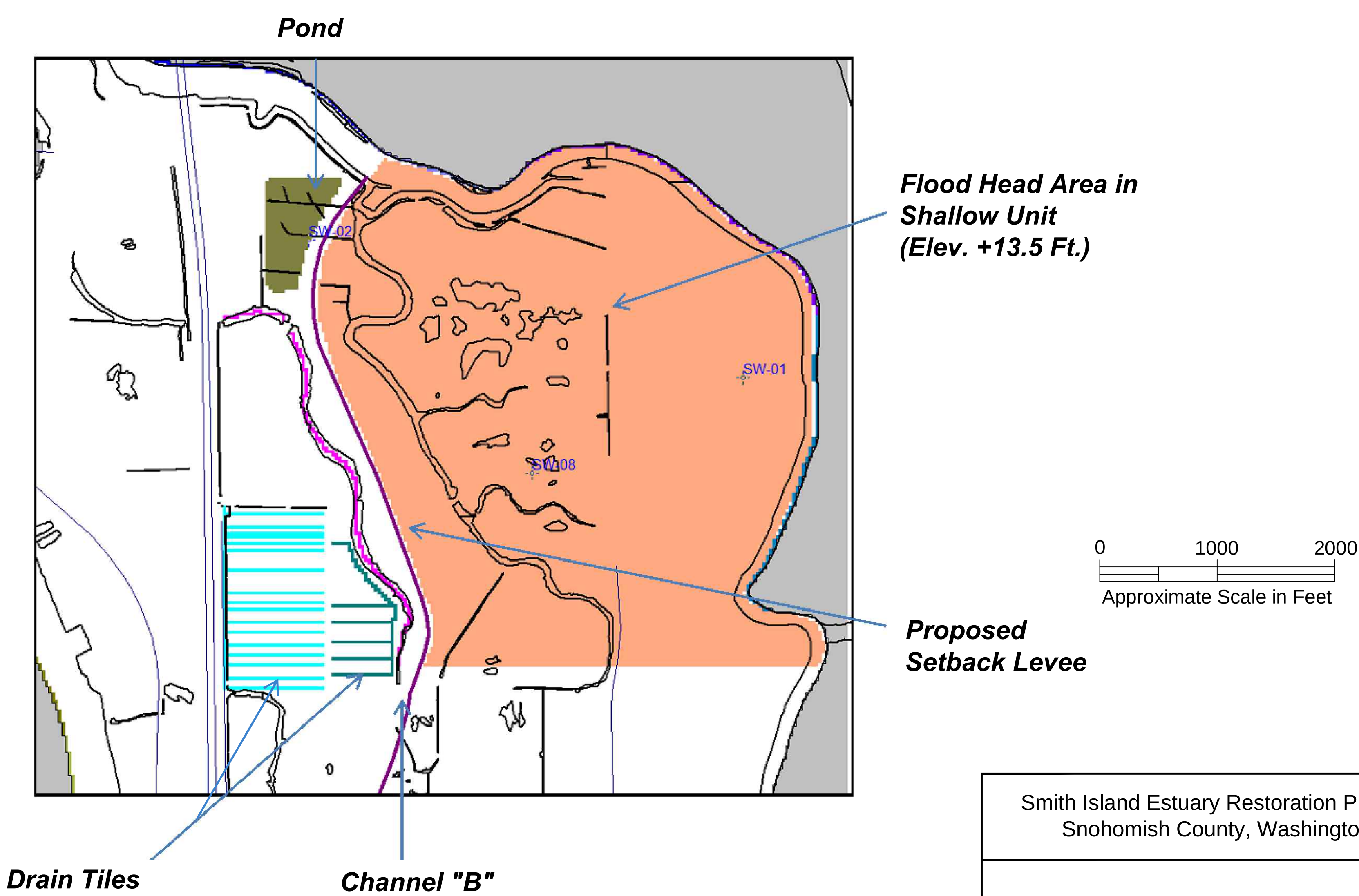
FIG. F-8

FIG. F-8

Filename: I:\WIP\21-1\12405 Smith Island (Snohomish Cty)\CAD_FIGURES\-060\21-1-12405-060 Appendix F Figures.dwg Date: 11-27-2013 Login: SAC



Smith Island Estuary Restoration Project
Snohomish County, Washington

INTERNAL BOUNDARIES FOR CHANNELS - FLOOD CONDITION

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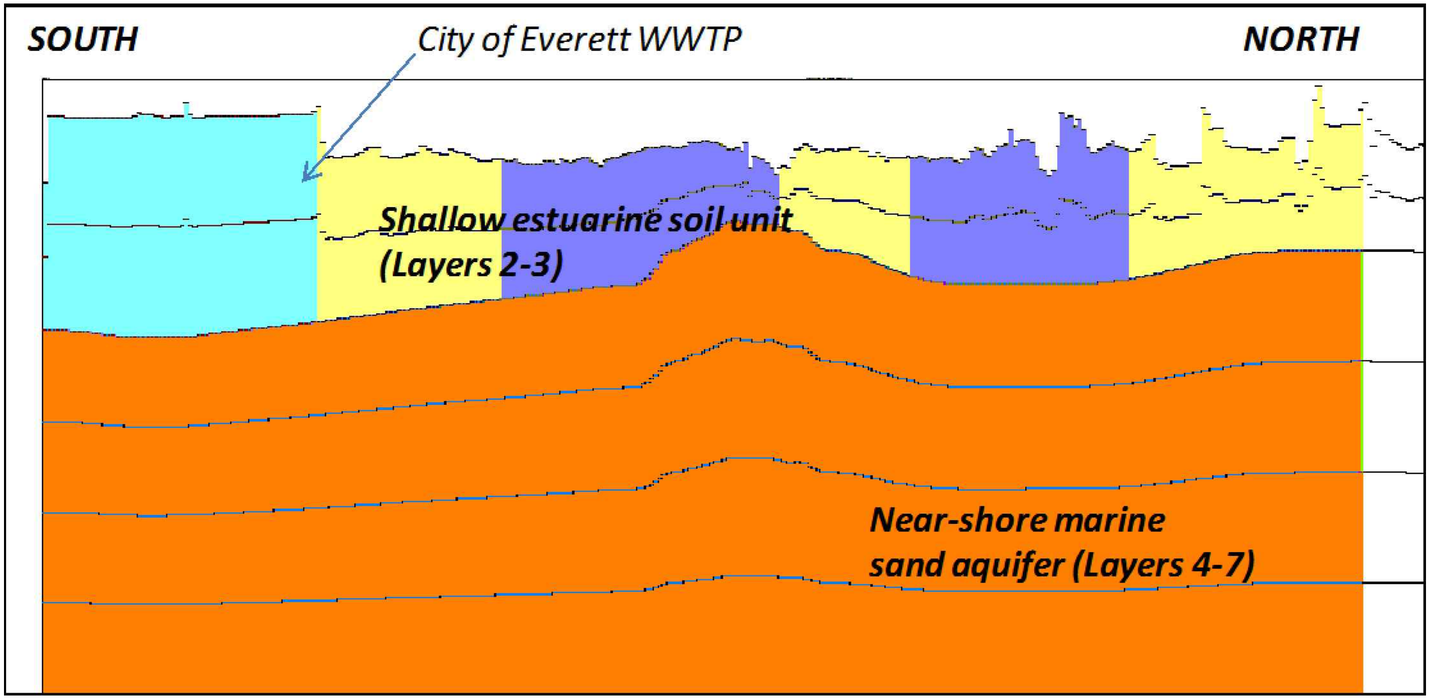
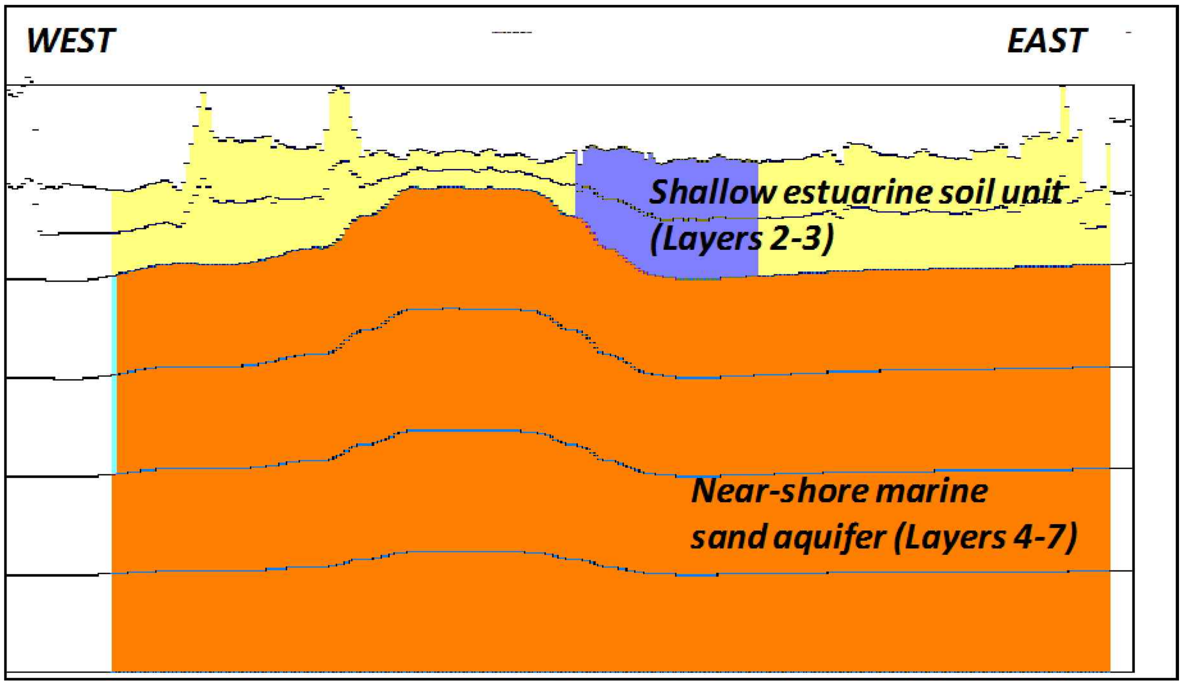
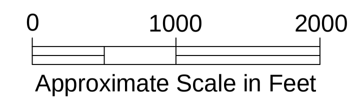
FIG. F-9

FIG. F-9







Smith Island Estuary Restoration Project
Snohomish County, Washington

UPDATED MODEL LAYERING

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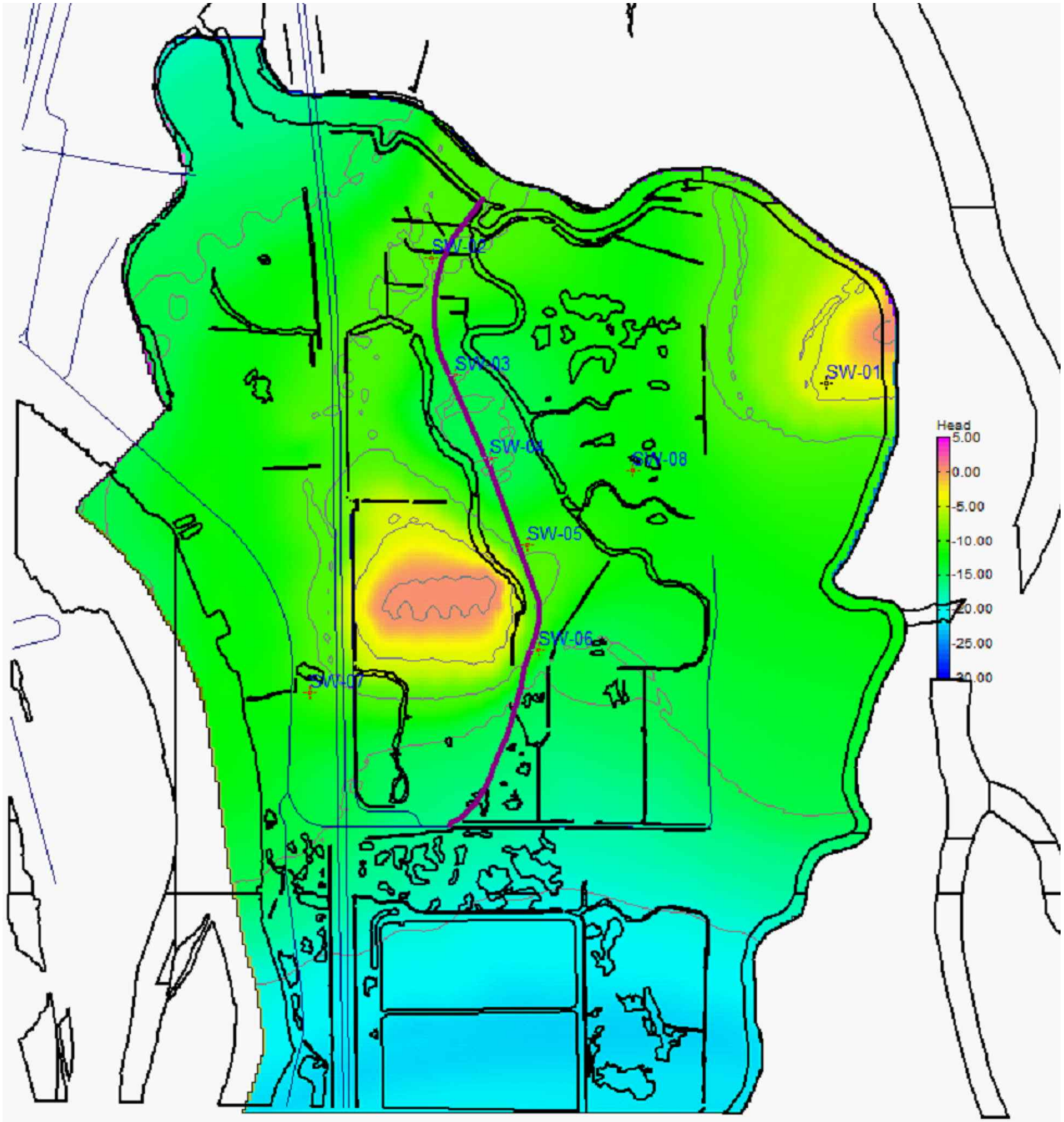
FIG. F-10

FIG. F-10

Filename: I:\WIP\21-1\12405 Smith Island (Snohomish Cty)\CAD_FIGURES\-060\21-1-12405-060 Appendix F Figures.dwg Date: 11-27-2013 Login: SAC



0 1000 2000

Approximate Scale in Feet

Smith Island Estuary Restoration Project
Snohomish County, Washington

UPDATED SAND AQUIFER UPPER SURFACE

October 2013 21-1-12405-060

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FIG. F-11

FIG. F-11

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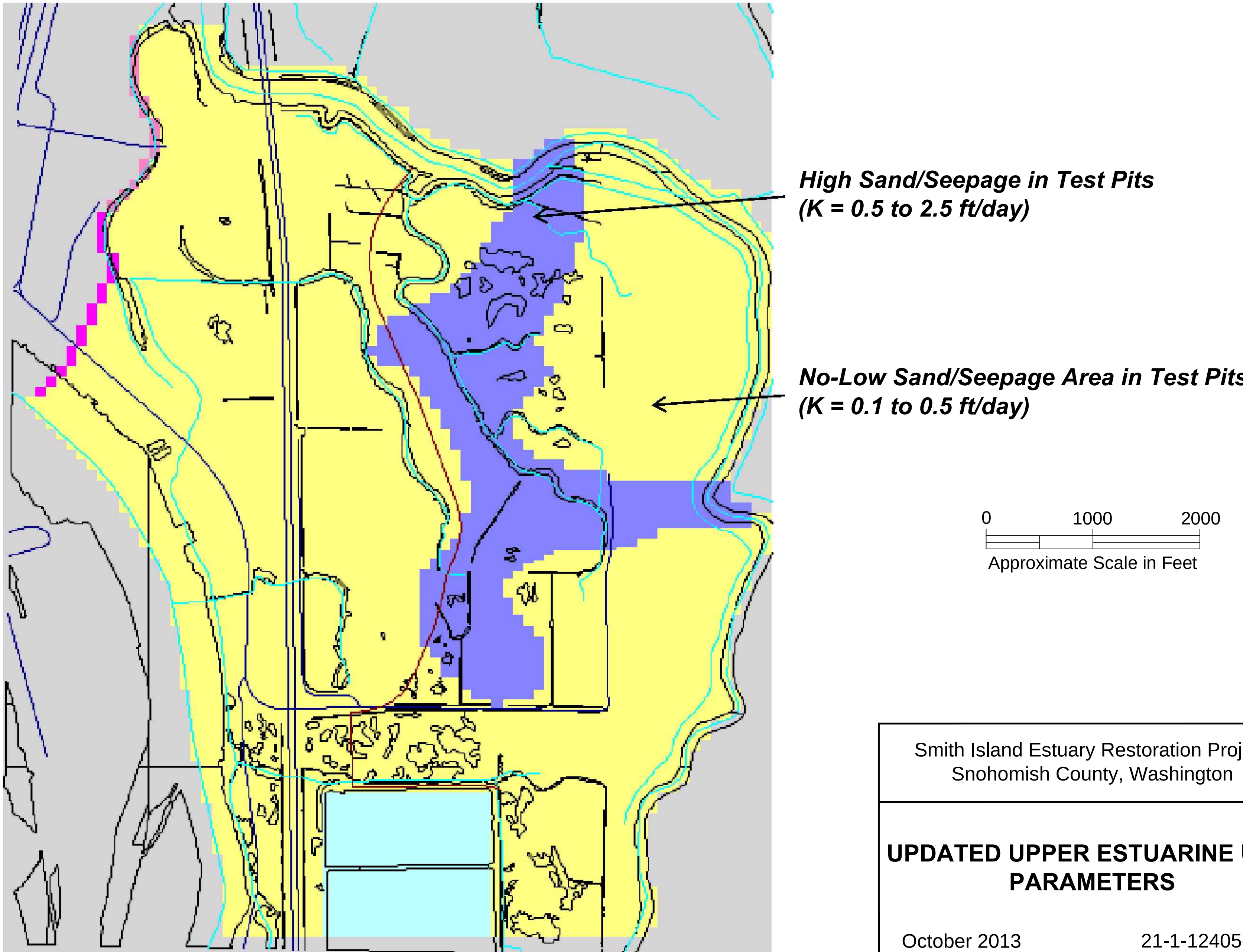

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Snohomish County, Washington

UPDATED UPPER ESTUARINE UNIT PARAMETERS

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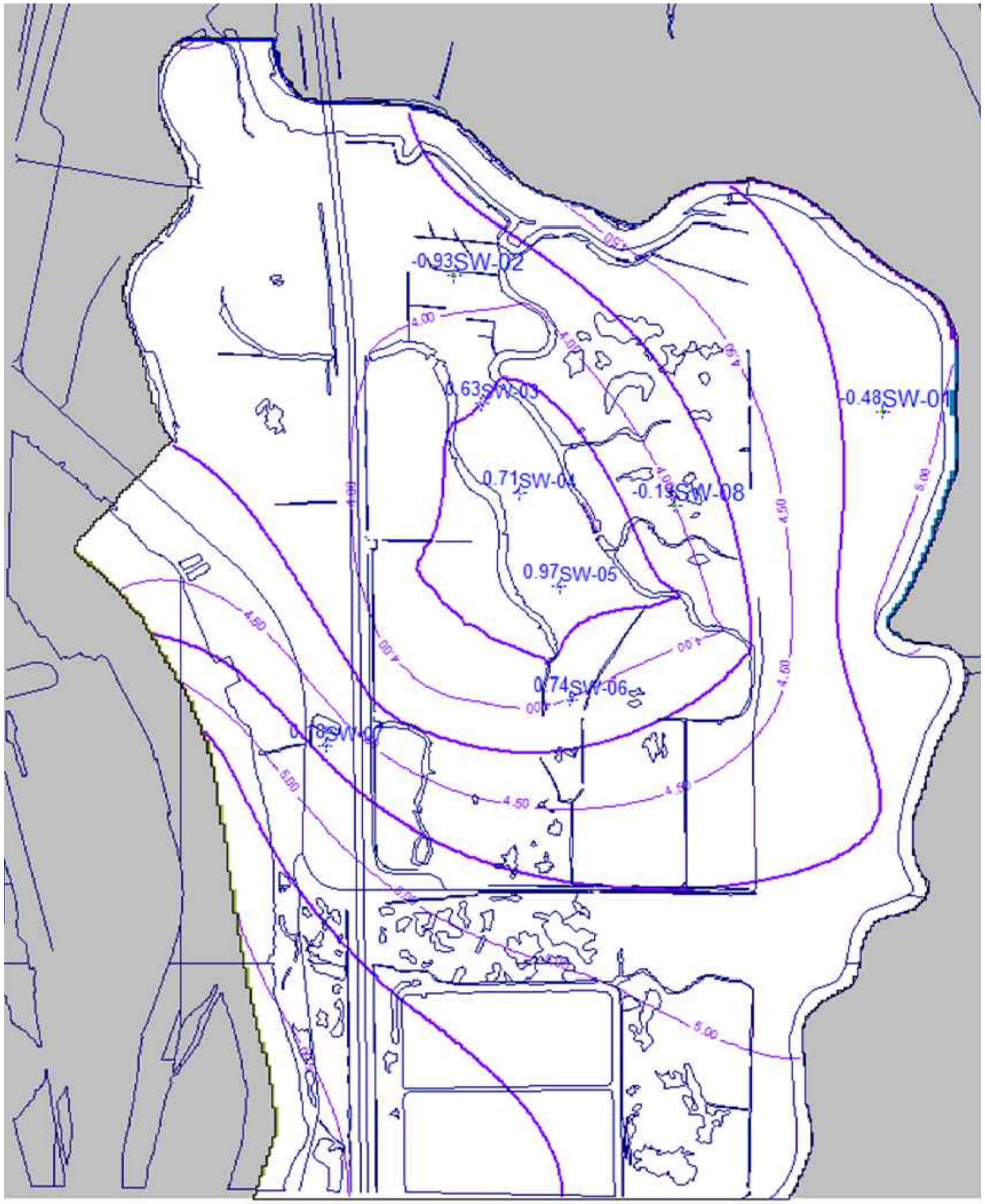
FIG. F-12

FIG. F-12

Filename: I:\WIP\21-1\12405 Smith Island (Snohomish Cty)\CAD_FIGURES\-060\21-1-12405-060 Appendix F Figures.dwg Date: 11-27-2013 Login: SAC



0 1000 2000
Approximate Scale in Feet

Smith Island Estuary Restoration Project
Snohomish County, Washington

UPDATED MODELED STEADY-STATE CALIBRATION HEADS IN THE SAND AQUIFER

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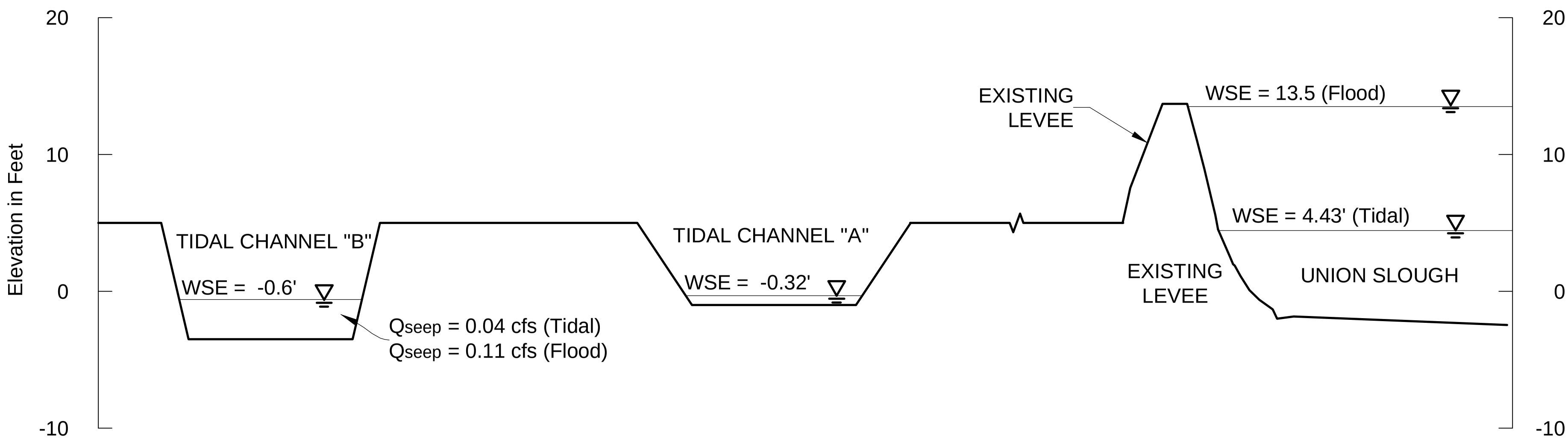
FIG. F-13

FIG. F-13



NOTE: Tidal Channel B calibration WSE's were 0.46 in the upper section and -2.17 in the lower section

Smith Island Estuary Restoration Project
Snohomish County, Washington

GROUNDWATER MODELING RUN - EXISTING CONDITIONS

October 2013 | 21-1-12405-060

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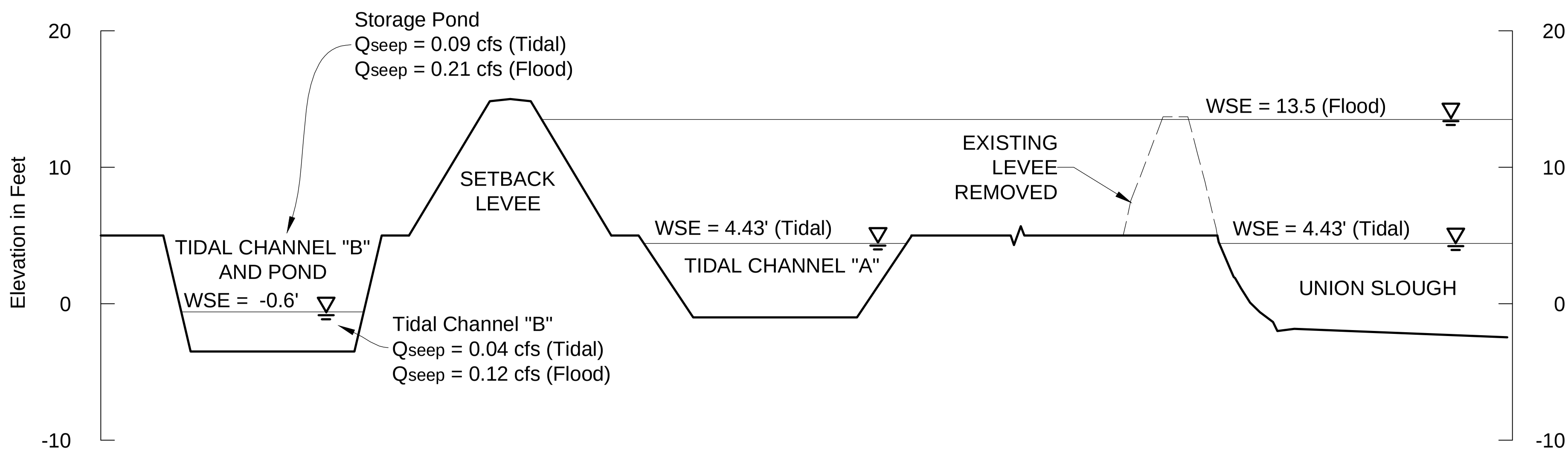
FIG. F-14



NOTE: Tidal Channel B calibration WSE's were 0.46 in the upper section and -2.17 in the lower section

Smith Island Estuary Restoration Project
Snohomish County, Washington

GROUNDWATER MODELING RUN - PROPOSED CONDITIONS

October 2013 21-1-12405-060

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FIG. F-15

APPENDIX G

U.S. ARMY CORPS OF ENGINEERS ENGINEERING DESIGN GUIDELINE REVIEW FOR LEVEES AND DAMS

APPENDIX G

U.S. ARMY CORPS OF ENGINEERS
ENGINEERING DESIGN GUIDELINE REVIEW FOR LEVEES AND DAMS

TABLE OF CONTENTS

TABLE

TABLE G-1
USACE LEVEE DESIGN GUIDELINES, REGULATIONS, STANDARDS
APPLIED TO THE SMITH ISLAND ESTUARY RESTORATION PROJECT

Design Element	U.S. Army Corps of Engineers PL 84-99 (ER 500-1-1) (EP 500-1-1)	U.S. Army Corps of Engineers Design and Construction of Levees (EM 1110-2-1913)	U.S. Army Corps of Engineers General Design and Construction Considerations for Earth and Rock-Fill Dams (EM 1110-2-2300)	Comparison of Smith Island Design to USACE Criteria
Design Height	15 feet elevation (NAVD88) (3 to 11 feet in height)	Risk-based analysis to account for hydrologic and hydraulic uncertainty.	Design height should be sufficient to prevent overtopping by wind setup, wave action, and potential settlement due to earthquakes.	Meets or exceeds USACE levee design criteria, dam criteria do not specify level of protection
Overtopping Criteria	Not designed for overtopping.	N/A	Spillway and outlet capacity must be sufficient to prevent overtopping of the embankment.	N/A, not an overtopping levee
Level of Flood Protection	100-year level 10-yr + 2 ft ≈ 13.5 feet elev. at N. end 10-yr + 2 ft ≈ 4.8 feet elev. at S. end 100-yr ≈ 15 feet elev. (FEMA)	Furnish flood protection from seasonal high water.	Maximum water surface elevation plus freeboard.	Exceeds USACE levee criteria by providing flood protection up to 15 ft, which is above seasonal high water. USACE dam design standards do not specify level of protection.
Design Flood Review / Inspection Frequency	N/A	N/A	Dam inflow design flood must be reviewed and updated every 5 years.	N/A
Top Width	15 feet	Depends on roadway requirements and emergency needs; minimum 10 to 12 feet.	Governed by functional purpose top must serve; minimum 25 to 40 feet.	Exceeds USACE levee criteria, 15-ft top width is based on functional purpose
Side Slopes	3H:1V waterside and 3H:1V landside	2H:1V maximum slope accepted for construction and placement of riprap layers; 3H:1V maximum for mowing.	Maximum 3H:1V where mowing is required.	Meets or exceeds USACE dam and levee criteria
Seepage		Refers to EM 1110-2-1901; Also reference ETL 1110-2-569	Refers to EM 1110-2-1901; Also reference ETL 1110-2-569	
Vertical Exit Gradient	Ranges 0.17 to 0.30 ft/ft	$i_v \leq 0.5$ ft/ft (~FS = 1.6)	$i_v \leq 0.5$ ft/ft (~FS = 1.6)	Meets or exceeds USACE dam and levee criteria
Drainage Trench	Ranges 0.17 to 0.30 ft/ft	$i_v \leq 0.5$ ft/ft (~FS = 1.6)	$i_v \leq 0.5$ ft/ft (~FS = 1.6)	Meets or exceeds USACE dam and levee criteria
Horizontal Drainage Layer (Levee Embankment)	24 inches thick; Select granular material w/ filter design	Minimum thickness of 18 inches; select granular material with filter design.	Minimum thickness and material not indicated.	Meets or exceeds USACE levee criteria, USACE dam criteria do not specify
Stability			Refers to EM 1110-2-1902	
End of Construction	Ranges 1.3 to 1.4	FS = 1.3	FS = 1.3 (upstream and downstream slope)	Meets or exceeds USACE dam and levee criteria
Rapid (Sudden) Drawdown	Flood Drawdown: ranges 1.1 to 1.6 Tidal Drawdown: ranges 1.8 to 2.5	FS = 1.0 for pool levels not likely to persist for long periods prior to drawdown FS = 1.2 for pool levels likely to persist for long periods prior to drawdown.	FS = 1.1 applies to drawdown from maximum surcharge pool. (Upstream slope) FS = 1.3 applies to drawdown from maximum storage pool. (Upstream slope)	Meets or exceeds USACE dam and levee criteria

TABLE G-1
USACE LEVEE DESIGN GUIDELINES, REGULATIONS, STANDARDS
APPLIED TO THE SMITH ISLAND ESTUARY RESTORATION PROJECT

Design Element	U.S. Army Corps of Engineers PL 84-99 (ER 500-1-1) (EP 500-1-1)	U.S. Army Corps of Engineers Design and Construction of Levees (EM 1110-2-1913)	U.S. Army Corps of Engineers General Design and Construction Considerations for Earth and Rock-Fill Dams (EM 1110-2-2300)	Comparison of Smith Island Design to USACE Criteria
Long-term Steady State Seepage	Ranges 1.5 to 2.2 (water at elevation 15 feet)	FS = 1.4	FS = 1.4 applies to a pool thrust from maximum surcharge level. (Downstream slope) FS = 1.5 applies to steady seepage, max. storage pool level, spillway crest, or top of gates. (Downstream slope)	Meets or exceeds USACE dam and levee criteria
Seismic (ER 1110-2-6067) USACE Process for the National Flood Insurance Program (NFIP) Levee System Evalaution	Foundation soils potentially liquefiable, resulting in an estimated 2 to 14 inches of settlement. Other potential hazards due to liquefaction include a reduction in soil shear strength, potential embankment instability, and lateral spreading. Levee will be overbuilt, maintained to a 15-ft elevation, and sections will be repaired in case of seismic activity.	If the peak ground acceleration is greater than 0.10g for the 100-year return period, the levee and its foundation should be checked for liquefaction. Where liquefaction is determined likely to occur, post-earthquake limit equilibrium stability analyses should be performed. If the post-earthquake stability FS is less than 1.2, a seismic deformation analysis should be performed to determine how the levee will perform during a seismic event.	If the peak ground acceleration is greater than 0.10g for the 100-year return period, the levee and its foundation should be checked for liquefaction. Where liquefaction is determined likely to occur, post-earthquake limit equilibrium stability analyses should be performed. If the post-earthquake stability FS is less than 1.2, a seismic deformation analysis should be performed to determine how the levee will perform during a seismic event.	USACE EM 1110-2-1913 indicates earthquake loadings are not normally considered in analyzing the stability of levees. Seismic standards for dams are not applicable due to only periodic inundation of the levee slope. Levee will be overbuilt, maintained to a 15-ft elevation, and sections will be repaired in case of seismic activity. Seismic-related liquefaction settlement was evaluated with an estimated 0.1 to 1.2 ft of settlement, which could leave lower sections of levee at elevations 13.8 ft, which provide protection from tides, highest astronomical tides (extreme), and most flooding. Seismic-related stability was not analyzed, in accordance with the indication in the guidelines that this is not typically performed.

TABLE G-1
USACE LEVEE DESIGN GUIDELINES, REGULATIONS, STANDARDS
APPLIED TO THE SMITH ISLAND ESTUARY RESTORATION PROJECT

Design Element	U.S. Army Corps of Engineers PL 84-99 (ER 500-1-1) (EP 500-1-1)	U.S. Army Corps of Engineers Design and Construction of Levees (EM 1110-2-1913)	U.S. Army Corps of Engineers General Design and Construction Considerations for Earth and Rock-Fill Dams (EM 1110-2-2300)	Comparison of Smith Island Design to USACE Criteria
Seismic (ER-1110-2-1806) Earthquake Design and Evaluation for Civil Works Projects	Foundation soils potentially liquefiable resulting in an estimated 2 to 14 inches of settlement. Other potential hazards due to liquefaction include a reduction in soil shear strength, potential embankment instability, and lateral spreading. Levee will be overbuilt, maintained to a 15-ft elevation, and sections will be repaired in case of seismic activity.	EM 1110-2-1913 indicates earthquake loadings are not normally considered in analyzing the stability of levees. Depending on the severity of the expected earthquake and the importance of the levee, seismic analyses to determine liquefaction susceptibility may be required. However, if earthquake design is to be considered, EM 1110-2-1913 references EM 1110-2-1806 for guidance.	EM 1110-2-1902 references EM 1110-2-1806 for earthquake loading guidance. Based on EM 1110-2-1806, design earthquakes are based on the Maximum Credible Earthquake (MCE), Maximum Design Earthquake (MDE), and Operating Basis Earthquake (OBE). The MCE is a deterministic seismic hazard analysis (DSHA) based on the greatest earthquake that can reasonably be expected to be generated by a specific source. The MDE is the maximum level of ground motion for which a structure is designed, is performance based, and characterized by DSHA or probabilistic seismic hazard analysis (PSHA). The MDE is equal to or less than the MCE. The OBE is an earthquake that can reasonably be expected within the service life of the project, is performance based, and characterized by PSHA. The OBE has a 50% probability of exceedence during the service life, corresponds to a return period of 144 years for a project with a service life of 100 years.	USACE EM 1110-2-1913 indicates earthquake loadings are not normally considered in analyzing the stability of levees. Seismic standards for dams are not applicable due to only periodic inundation of the levee slope. Levee will be overbuilt, maintained to a 15-ft elevation, and sections will be repaired in case of seismic activity. Seismic-related liquefaction settlement was evaluated with an estimated 0.1 to 1.2 ft of settlement, which could leave lower sections of levee at elevations 13.8 ft, which provide protection from tides, highest astronomical tides (extreme), and most flooding. Seismic-related stability was not analyzed, in accordance with the indication in the guidelines that this is not typically performed.
Foundation Preparation				
Clear and Grub	Clear and grub in accordance with EM 1110-2-1913.	Clear all trees, timber, brush, vegetation, loose stone, abandoned structures, fencing, and debris. Remove all stumps, roots over 1.5 inches in diameter, buried logs, piling, paving, drains, and other objectional material up to a depth of 3 feet below natural ground surface and backfill.	Clear and grub to a minimum depth of 3 feet and backfill.	Meets or exceeds USACE levee criteria
Stripping	Estimated average stripping depth is 10 inches.	Strip to remove low growing vegetation and organic topsoil; typical depth 6 to 12 inches.	Strip to remove sod, topsoil, boulders, organic materials, rubbish fills, and other undesirable materials.	Meets or exceeds USACE dam and levee criteria
Exploration Trenches	A 6-foot-deep observation trench to be excavated along the waterside toe of the full levee length.	A minimum 6-foot-deep inspection trench required; trenches can be omitted where landside toe drains are to be constructed to compariable depths.	A minimum 6-foot-deep inspection trench required for dams without cutoffs.	Meets or exceeds USACE dam and levee criteria
Foundation Repairs	Soft, loose, or wet zones to be removed.	Soft or organic spots should be removed.	Highly compressible soils occuring in a thin surface layer or isolated pockets should be removed.	Meets or exceeds USACE dam and levee criteria
Dewatering	Local dewatering likely during clearing, grubbing, and stripping. Soils to be dewatered 1 foot below exposed grade during excavation and construction.	Dewatering necessary where trench or cuttoffs extend below the water table, or where moisture sensitive embankment soils are placed near the groundwater table.	Dewatering necessary where trench or cuttoffs extend below the water table, or where moisture-sensitive embankment soils are placed near the groundwater table.	Meets or exceeds USACE dam and levee criteria

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Erosion and Scour Protection	Protection from erosion using river design flow velocity. Riprap erosion protection with filter on the waterside slope. Launchable rock toe where scour anticipated.	Adequate riverside slope protection must be provided to protect against the erosional forces of waves and stream currents; Several types have been used (grass, gravel, paving, concrete mat, and riprap) and the choice depends on the degree of protection needed and the associated costs; High-class protection, such as riprap, mats, or paving, should be provided on the riverside slope beneath bridges and adjacent to structures passing through the levee embankment.	Adequate slope protection must be provided to protect against wind and wave erosion, weathering, ice damage, damage from floating debris, rainfall, and surface runoff (especially above permanent pool elevation). Slope protection should have adequate bedding and filter layers. Each erosion protection design can be optimized through the evaluation of the probability of damage and by classifying the embankment slopes. Spillways preclude the need for downstream rock protection. Vegetative cover is desired.	Meets or Exceeds USACE dam and levee criteria
Pipeline Crossings				
Considerations for Pipes Crossing Beneath and Through Levees (New and Existing)	16-inch-diameter gas pipeline exists beneath proposed alignment. Pipe encased in 2-inch-thick concrete annulus. Pipe bottom 4 feet below grade.	Must be known to be in good condition; Must have adequate strength to withstand levee loading; Must have sufficient flexibility for settlement deformation; Must have rapid closure devices for pressure pipes; Must have provisions for emergency closure for gravity pipes.	N/A	Pipeline analysis will ensure USACE levee criteria are met
Installation of Pipes Crossing Beneath and Through Levees	36-inch-diameter tide gate pipe to be installed beneath exisitng dike.	Minimum 2 feet of cover above pipe crown; do not install seepage rings; 18-inch annular thickness of drainage fill provided around the landside third of the pipe.	N/A	Meets or exceeds USACE levee criteria
Considerations for Pipes Crossing Over Levees (New and Existing)	No new or existing pipes over levee.	Must have adequate pipeline cover for vehicle crossing; Must have adequate frost protection; Must have sufficient flexibility for settlement deformation; Must have adequate protection from damages caused by debris carried by the currents; Must be designed to counteract uplift if submerged; Must have rapid closure devices for pressure pipes.	N/A	N/A
Installation of Pipes Crossing Over Levees	No new pipe installations over levee.	Minimum 1 ft of cover above pipe crown on the riverside.	N/A	N/A
Access Roads				
Access Road to Levee / Dam	15 feet wide; parallel along landward toe; crushed surfacing base course.	Provided at reasonably close intervals in cooperation with state and local authorities.	N/A	Meets or exceeds USACE levee criteria
Access Road on Levee / Dam	15 feet wide; crushed surfacing base course.	All-weather access for inspection, maintenance, flood fighting, and emergency repair; Surfaced with suitable gravel or crushed stone base course.	N/A	Meets or exceeds USACE levee Criteria
Turnouts	Turnouts located at approximately 1,200-ft intervals	Minimum 1 per 2,500 feet of levee, provided no access ramps are within the reach.	N/A	Meets or exceeds USACE levee criteria

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Turnarounds	Turnaround located at north end of levee	Required when the levee deadends and no access ramps are within the vicinity of the deadend.	N/A	Meets or exceeds USACE levee criteria
Access Ramps	Access ramps with maximum 10% grade and 3H:1V side slopes located at north and south ends of levee	Maximum 10% grade and 3H:1V side slopes; surfaced with suitable gravel or crushed stone base course; constructed by adding material to the levee crown and slopes, and not by modifying the levee section.	N/A	Meets or exceeds USACE levee criteria
Vegetation				
Vegetation	Design in progress.	Vegetation can be incorporated in the project as long as it will not diminish the integrity and functionality of the embankment system, or impede ongoing operations, maintenance and floodfighting capability; Drain outlets kept free of vegetation; References EM 1110-2-301 and ER 500-1-1 (ETL 1110-2-571 supersides EM 1110-2-301).	Grass preferable on downstream slope; Drain outlets kept free of vegetation.	Will meet or exceed USACE levee criteria
U.S. Army Corps of Engineers: Guidelines for Landscape Planting and Vegetation Management at Levees, Floodwalls, Embankment Dams, and Appurtenant Structures (ETL 1110-2-571)	Design in Progress	Vegetation-free zone (VFZ) includes a minimum width of the levee prism, plus 15 feet on each side, measured from the outermost critical structure. The VFZ also includes a minimum 8-ft height clearance, measured vertically from the ground. The only acceptable vegetative ground cover in the VFZ is perennial grasses; The use of suitable vegetation riverward of the VFZ is encouraged to moderate the erosive potential of water currents and wave action.	VFZ includes a minimum width of the embankment dam, plus 50 feet on each side for a "dry" reservoir or 50 feet on the downstream side for a "normal pool" reservoir, measured from the outermost critical structure. At a minimum, the VFZ shall extend for a horizontal distance of 15 feet beyond the embankment/abutment contact. At a minimum, the VFZ shall include the entire outlet channel, outlet structure headwalls and wingwalls, and surrounding areas to a distance of 50 feet from the top of the bank of the outlet channel. The VFZ also includes a minimum 8-foot height clearance, measured vertically from the ground. The only acceptable vegetative ground cover in the VFZ is perennial grasses, and the maximum allowable height for the grasses is 12 inches; The use of suitable vegetation riverward of the VFZ is encouraged to moderate the erosive potential of water currents and wave action.	Will meet or exceed USACE levee criteria

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Design Element	U.S. Army Corps of Engineers	U.S. Army Corps of Engineers	U.S. Army Corps of Engineers	Comparison of Smith Island Design to USACE Criteria
	PL 84-99 (ER 500-1-1) (EP 500-1-1)	Design and Construction of Levees (EM 1110-2-1913)	General Design and Construction Considerations for Earth and Rock-Fill Dams (EM 1110-2-2300)	

Notes:
ft = foot
FS = factor of safety
H:V = horizontal to vertical
N. = north
N/A = not applicable
NAVD88 = North American Vertical Datum of 1988
yr = year
USACE = U.S. Army Corps of Engineers
~ = approximately

APPENDIX H

IMPORTANT INFORMATION ABOUT YOUR GEOTECHNICAL/ENVIRONMENTAL REPORT

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

Attachment to and part of Report 21-1-12405-060

Date: October 10, 2013
To: Mr. Greg Laird, P.E.
Otak

IMPORTANT INFORMATION ABOUT YOUR GEOTECHNICAL/ENVIRONMENTAL REPORT

CONSULTING SERVICES ARE PERFORMED FOR SPECIFIC PURPOSES AND FOR SPECIFIC CLIENTS.

Consultants prepare reports to meet the specific needs of specific individuals. A report prepared for a civil engineer may not be adequate for a construction contractor or even another civil engineer. Unless indicated otherwise, your consultant prepared your report expressly for you and expressly for the purposes you indicated. No one other than you should apply this report for its intended purpose without first conferring with the consultant. No party should apply this report for any purpose other than that originally contemplated without first conferring with the consultant.

THE CONSULTANT'S REPORT IS BASED ON PROJECT-SPECIFIC FACTORS.

A geotechnical/environmental report is based on a subsurface exploration plan designed to consider a unique set of project-specific factors. Depending on the project, these may include: the general nature of the structure and property involved; its size and configuration; its historical use and practice; the location of the structure on the site and its orientation; other improvements such as access roads, parking lots, and underground utilities; and the additional risk created by scope-of-service limitations imposed by the client. To help avoid costly problems, ask the consultant to evaluate how any factors that change subsequent to the date of the report may affect the recommendations. Unless your consultant indicates otherwise, your report should not be used: (1) when the nature of the proposed project is changed (for example, if an office building will be erected instead of a parking garage, or if a refrigerated warehouse will be built instead of an unrefrigerated one, or chemicals are discovered on or near the site); (2) when the size, elevation, or configuration of the proposed project is altered; (3) when the location or orientation of the proposed project is modified; (4) when there is a change of ownership; or (5) for application to an adjacent site. Consultants cannot accept responsibility for problems that may occur if they are not consulted after factors which were considered in the development of the report have changed.

SUBSURFACE CONDITIONS CAN CHANGE.

Subsurface conditions may be affected as a result of natural processes or human activity. Because a geotechnical/environmental report is based on conditions that existed at the time of subsurface exploration, construction decisions should not be based on a report whose adequacy may have been affected by time. Ask the consultant to advise if additional tests are desirable before construction starts; for example, groundwater conditions commonly vary seasonally.

Construction operations at or adjacent to the site and natural events such as floods, earthquakes, or groundwater fluctuations may also affect subsurface conditions and, thus, the continuing adequacy of a geotechnical/environmental report. The consultant should be kept apprised of any such events, and should be consulted to determine if additional tests are necessary.

MOST RECOMMENDATIONS ARE PROFESSIONAL JUDGMENTS.

Site exploration and testing identifies actual surface and subsurface conditions only at those points where samples are taken. The data were extrapolated by your consultant, who then applied judgment to render an opinion about overall subsurface conditions. The actual interface between materials may be far more gradual or abrupt than your report indicates. Actual conditions in areas not sampled may differ from those predicted in your report. While nothing can be done to prevent such situations, you and your consultant can work together to help reduce their impacts. Retaining your consultant to observe subsurface construction operations can be particularly beneficial in this respect.

A REPORT'S CONCLUSIONS ARE PRELIMINARY.

The conclusions contained in your consultant's report are preliminary because they must be based on the assumption that conditions revealed through selective exploratory sampling are indicative of actual conditions throughout a site. Actual subsurface conditions can be discerned only during earthwork; therefore, you should retain your consultant to observe actual conditions and to provide conclusions. Only the consultant who prepared the report is fully familiar with the background information needed to determine whether or not the report's recommendations based on those conclusions are valid and whether or not the contractor is abiding by applicable recommendations. The consultant who developed your report cannot assume responsibility or liability for the adequacy of the report's recommendations if another party is retained to observe construction.

THE CONSULTANT'S REPORT IS SUBJECT TO MISINTERPRETATION.

Costly problems can occur when other design professionals develop their plans based on misinterpretation of a geotechnical/environmental report. To help avoid these problems, the consultant should be retained to work with other project design professionals to explain relevant geotechnical, geological, hydrogeological, and environmental findings, and to review the adequacy of their plans and specifications relative to these issues.

BORING LOGS AND/OR MONITORING WELL DATA SHOULD NOT BE SEPARATED FROM THE REPORT.

Final boring logs developed by the consultant are based upon interpretation of field logs (assembled by site personnel), field test results, and laboratory and/or office evaluation of field samples and data. Only final boring logs and data are customarily included in geotechnical/environmental reports. These final logs should not, under any circumstances, be redrawn for inclusion in architectural or other design drawings, because drafters may commit errors or omissions in the transfer process.

To reduce the likelihood of boring log or monitoring well misinterpretation, contractors should be given ready access to the complete geotechnical engineering/environmental report prepared or authorized for their use. If access is provided only to the report prepared for you, you should advise contractors of the report's limitations, assuming that a contractor was not one of the specific persons for whom the report was prepared, and that developing construction cost estimates was not one of the specific purposes for which it was prepared. While a contractor may gain important knowledge from a report prepared for another party, the contractor should discuss the report with your consultant and perform the additional or alternative work believed necessary to obtain the data specifically appropriate for construction cost estimating purposes. Some clients hold the mistaken impression that simply disclaiming responsibility for the accuracy of subsurface information always insulates them from attendant liability. Providing the best available information to contractors helps prevent costly construction problems and the adversarial attitudes that aggravate them to a disproportionate scale.

READ RESPONSIBILITY CLAUSES CLOSELY.

Because geotechnical/environmental engineering is based extensively on judgment and opinion, it is far less exact than other design disciplines. This situation has resulted in wholly unwarranted claims being lodged against consultants. To help prevent this problem, consultants have developed a number of clauses for use in their contracts, reports and other documents. These responsibility clauses are not exculpatory clauses designed to transfer the consultant's liabilities to other parties; rather, they are definitive clauses that identify where the consultant's responsibilities begin and end. Their use helps all parties involved recognize their individual responsibilities and take appropriate action. Some of these definitive clauses are likely to appear in your report, and you are encouraged to read them closely. Your consultant will be pleased to give full and frank answers to your questions.

The preceding paragraphs are based on information provided by the
ASFE/Association of Engineering Firms Practicing in the Geosciences, Silver Spring, Maryland