Technical Memorandum 1.3 –
Geotechnical Baseline Study
WDFW – Fir Island Farm Snow Goose Reserve
Skagit County, Washington

January 11, 2011

Draft

Submitted To:
Mr. Brian Williams
Washington Department of Fish and Wildlife
Natural Resources Building
1111 Washington Street SE
Olympia, Washington 98501

By:
Shannon & Wilson, Inc.
400 N 34th Street, Suite 100
Seattle, Washington 98103

21-1-12318-001

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

ALASKA
CALIFORNIA
COLORADO
FLORIDA
MINNESOTA
MISSOURI
OREGON
WASHINGTON

January 11, 2011

Mr. Brian Williams
Washington Department of Fish and Wildlife
Natural Resources Building
1111 Washington Street SE
Olympia, WA 98501

RE: TECHNICAL MEMORANDUM 1.3 – GEOTECHNICAL BASELINE STUDY, WDFW – FIR ISLAND FARM SNOW GOOSE RESERVE, SKAGIT COUNTY, WASHINGTON

Draft

Dear Mr. Williams:

This Technical Memorandum 1.3 presents a geotechnical baseline study for the Fir Island Farm, Snow Goose Reserve, Fish Habitat Restoration Feasibility Study. The project location is shown in the Vicinity Map (Figure 1). The intent of this technical memorandum is to document existing surface and subsurface soil conditions to support an evaluation of setting back the existing coastal levee (dike) system. We use the term "dike" to reflect the coastal flood protection nature of the project structures. This is in contrast to the levee, which in the Pacific Northwest typically refers to river flood protection structures. The proposed setback dike is planned as part of restoration of the historical tidal marsh for the endangered juvenile Chinook salmon.

This technical memorandum presents preliminary geotechnical studies that included the following tasks:

- Research background information including geologic records, historical maps and aerial photographs, and as-built drawings.
- Interview with Dike District 22 personnel regarding dike construction, repair, and embankment stability issues.
- Perform a field reconnaissance of the existing dike system to identify evidence of recent erosion, overtopping, seepage, settlement, and slope instability. We looked for evidence of water seepage and general soil conditions that could affect setback dike design.
- Perform 12 subsurface explorations using geoprobes.

400 NORTH 34TH STREET, SUITE 100
P.O. BOX 300303
SEATTLE, WASHINGTON 98103
206-632-8020 FAX 206-695-6777
TDD 1-800-833-6388draft
www.shannonwilson.com

- Perform soil index and strength testing on select soil samples to characterize soil geotechnical and hydrogeologic properties, including strength, compressibility, and hydraulic conductivity.
- Perform preliminary stability and settlement analyses to develop concept-level dike design recommendations. Identify major risks that may be associated with any of the potential alternatives.

BACKGROUND INFORMATION

Research of historical information included reviewing existing geologic maps, records and studies, and aerials, and interviewing Dike District 22 (DD22) personnel. We were not able to obtain as-built drawings for our record review. However, the DD22 interview provided insightful information regarding the history of the levee, coastal flood dike protection system.

Geologic Setting

The Skagit River delta is located in the northern portion of the Puget Lowland, which is an elongated, north-south depression situated between the Olympic Mountains and the Cascade Range. The Puget Lowland was subjected to six or more major glacial advances over the past several million years. The most recent of these advances, termed "Vashon," covered the region between about 18,000 and 13,500 years ago. Extensive erosion and sedimentation during the Vashon glaciation produced many of the deposits and landforms that make up the surface of the Puget Lowland.

Among the more prominent glacially derived landforms in the Puget Lowland are north-south-trending troughs, like those now occupied by Puget Sound and Lake Washington. These troughs were scoured by meltwater streams that flowed beneath Vashon ice (Booth, 1994). Skagit River deltaic deposits likely occupy a trough eroded by subglacial meltwater streams (Dragovich and others, 2002).

The trough existed as a marine embayment following retreat of the Vashon ice sheet north of the Strait of Juan de Fuca. Relatively rapid deltaic sedimentation of the Skagit River subsequently filled the marine embayment. Within the past 5,000 years, the Skagit River delta front is thought to have prograded about 5 miles from Mount Vernon to its current position (Dragovich and others, 2002). High depositional rates may be attributed, in part, to sediment input from volcanic debris flows (*lahars*) originating from Glacier Peak volcano (Dragovich and others, 2000; 2002).

Draft

Surficial geologic maps show that Skagit Valley deltaic deposits consist of Holocene marsh, estuarine, tidal flat, alluvial, and lahar-derived deposits (Figure 2) (Wunder, 1976; Pessl and others, 1989; Dragovich and others, 2002). In the subsurface, these deposits form complex sequences that interfinger with one another and which have soil characteristics that vary laterally and vertically. Marsh, estuarine, and tidal flat deposits in the Skagit River delta sequence typically consist of soft clay and silt and/or loose fine sand. These deposits are mapped as unit Qn by Dragovich and others (2002) in the vicinity of Fir Island Farm (Figure 2). Alluvial and lahar-derived deposits typically consist of loose sand and gravel.

The Devils Mountain fault extends east-west across the Skagit River delta approximately 2 miles north of the project site. This left-lateral oblique fault extends for at least 80 miles between the Cascade Mountains and eastern Strait of Juan de Fuca. The fault is considered to be active, which implies that the levee and dike structures will likely be subject to seismic events during the life of the structure (Johnson and others, 2001).

Historical Maps and Aerial Photographs

We reviewed a number of historical maps and aerial photographs to document the progression of levee and dike construction on the Skagit Delta. A more comprehensive discussion and historical maps and aerial photographs are provided in Technical Memo 1.1.2 Geomorphology. Settlement of Skagit County began in the early 1850s. Michael Sullivan and Samuel Calhoun were two settlers responsible for early diking of Skagit marshy flat lands (History Link, 2007). Settlements on Fir Island occurred throughout the 1860s and 1870s. T-sheet (historic land survey) maps from 1889 show that dikes were constructed along Brown's and Dry Slough and portions of the current bay-front dike alignment. The dike alignment shown on the 1889 map runs along the southwest bay-front dike near the mouth of Brown's Slough and is similar to the current dike alignment. It is likely that this section of dike is 130 years old. In addition to diking activities, local residents engaged in river logging operations that included the removing massive log jams on the Skagit River to allow for boat navigation. The aerial photographs indicate that the bay-front dike was moved bayward prior to 1937 and Dry Slough was cut off in 1962.

Draft

Dike District 22 Interview and Site Reconnaissance Visit

An interview and site reconnaissance visit was performed with Stan Nelson, Dike District 22 commissioner, on August 31, 2010. Project notes, maps, and photographs pertaining to the interview are included in Appendix A.

The interview and site reconnaissance focused on the following general topics:

- Dike design and construction
- Dike flood performance and repair history
- Seepage and salt-water intrusion
- Participation of DD22 in the U.S. Army Corps of Engineers (Corps) PL84-99 and NRCS rehabilitation and repair programs
- Current operation and maintenance program

Dike Design and Construction

The (dikes) were initially constructed in the mid to late 1800s. The dikes were constructed using on-site borrow material, which the locals refer to as a "blue-clay." Laboratory testing of local surface soils (Appendix C) and a single test in the dike (GP-01-10) indicate that the surficial soils are typically clayey silts and silty sand deposits (see laboratory analysis) and not actually a true clay material.

The Claude O'Davis Slough tidegate installation and reclamation of the farm area between the Claude O'Davis and Dry Slough distributaries occurred in 1913 (Technical Memo 1.1.2 – Geomorphologic Characterization). The culverts currently leak and allow for salt-water intrusion into the interior drainage areas contributing to brackish water quality in the interior farm drainage channels.

Dike Flood Performance and Repair History

The dikes have experienced overtopping and bank erosion as the primary failure mechanisms. The southwest corner of the dikes near the mouth of Brown's Slough has overtopped a number of times during extreme high tides and deep low pressure systems. Both the DD22 and Washington Department of Fish and Wildlife (WDFW) staff have reported observing water

Draft

flowing over the section of the dike near the second locked gate in the lower southwest corner of the project site. There are no historical observations indicating that the remaining sections of the dikes are frequently overtopped. However, it is noted that the sections of dike near Claude O'Davis Slough and MacDonald Slough to the east have failed and been manually breached during the 1990 flood. We do not believe these were caused by overtopping events.

The dikes have experienced several breaches. DD22 has indicated that these are a result of overtopping near the southwest corner of the project and breaching (manmade and natural) in other locations. The breach locations are as follows:

- Brown's Slough west dike breach in 1990 – this resulted in the installation of the current tidegate complex due to access issues for the dike repair (see notes in Appendix C).
- Claude O'Davis breach in 1990 (natural breach; see Appendix C).
- McDonald Slough manmade breach in 1990 to drain Fir Island floodwater.

Breach repairs made by DD22 included backfilling the breach with large riprap rock and then reconstructing the dikes with fill once a rock barrier was established. DD22 indicated that the dike repairs were performed with assistance from the Natural Resources Conservation Service (NRCS, also referred to as the Soil Conservation Service).

Riprap rock bank protection has been added at a number of locations where local hydraulics were causing erosion and embankment scour. The riprap typically appears to be approximately 2 to 3 feet in diameter, and placed from the toe of the dike up to about one-half the height of the structure. A partial list of these areas include (see Appendix C):

- Upstream along east dike from Brown's Slough replacement section and culverts
- Southwest corner overtopping area
- Claude O'Davis breach and repair areas

DD22 was asked about salt-water intrusion through the dike system. DD22 indicated that they thought the Claude O'Davis tidegates leaked, and identified a number of areas with evidence of salt-water. They report that adjacent farm areas show evidence of reduced crop production due to salt-water influence. It is likely that the low crop production also occurs near overtopping and breach areas, which were inundated and the salt-water degraded soil conditions. It is not currently known what level of influence the tidegate leakage and underseepage of salt-water

Draft

influence or degrade farm crop production, compared with these other overtopping and breach events. DD22 is of the opinion that the Claude O'Davis tidegates need to be replaced to prevent continued salt-water intrusion into the interior drainage system.

Annual operations and maintenance for the dike include:

- Mowing of the top and upper sides of the dike.
- Occasional repairs from overtopping or breaching.
- Occasional inspection, repairs, and replacement of tidegate structures.
- Opening and closing of the Brown's Slough screw-gate for flood protection and fish passage.
- Wood debris removal and disposal from the tidegates.

The final element of the interview with DD22 was to assess what federal and state programs they participate in to receive funding for levee and dike repairs. Stan Nelson indicated that DD22 participates in the Corps PL84-99 program for river levees, but not for coastal and marine dikes. However, DD22 did receive federal funding assistance from the NRCS Emergency Watershed Protection Section 216, P.L.81-516 EWP program for repairing the 1990 flood damage repairs.

SUBSURFACE EXPLORATIONS

Subsurface explorations at the site included performing 12 geoprobes, designated GP-01-10 through GP-12-10, from October 5 through 7, 2010. Locations of the geoprobes are shown in the Site and Exploration Plan (Figure 3). Geoprobe GP-01-10 was advanced to 40 feet below ground surface (bgs). Geoprobes GP-02-10 through GP-12-10 were advanced to 30 feet bgs. A representative from Shannon & Wilson, Inc. was present throughout the subsurface explorations to observe sampling, collect representative samples for subsequent laboratory testing, and prepare descriptive field logs of the geoprobes. Appendix B presents a discussion of the subsurface exploration and sampling methods. A Soil Log and Classification Key is presented in Figure B-1 in Appendix B. Logs of geoprobes GP-01-10 through GB-12-10 are presented in Figures B-2 through B-13 in Appendix B.

Draft

LABORATORY TESTING

Samples retrieved from the geoprobes were returned to the Shannon & Wilson, Inc. laboratory in Seattle for reclassification and index property testing. Index property tests performed on selected samples included water contents, grain size analyses, and Atterberg Limits. Test results and procedures are discussed in detail in Appendix C.

SUBSURFACE CONDITIONS

Our interpretation of subsurface conditions is based on historical information we reviewed and on samples recovered from the geoprobe explorations. In general, we encountered what we interpret to be five soil units: dike fill (Hf), an agricultural layer, Holocene mudflat deposits (Hm), Holocene alluvium (Ha), and Holocene estuarine deposits (He). A general description of the subsurface conditions is presented below. Detailed soil descriptions are presented in the boring logs in Appendix B, Figures B-2 through B-13.

Dike fill (Hf) at the site primarily consists of local, near-surface native materials that were pushed into place during dike construction. These soils generally consist of slightly clayey to clayey silt that resembles Holocene mudflat deposits, as observed in geoprobe GP-01-10 on the east side of Dry Slough (Figure 3). Portions of the dike have been repaired using imported riprap, sand, and gravel.

Native deltaic deposits at the site are overlain by an agricultural layer. The layer generally consists of a 1- to 2-foot-thick layer of silt that locally appears disturbed. The disturbance is likely the result of farming practices, such as tilling.

The agricultural layer is underlain by a 2- to 7-foot-thick layer of slightly clayey to clayey silt locally interbedded with layers of silty fine sand and fine sandy silt. In this memorandum, we assign the geologic unit *Holocene mudflat* (Hm) to these deposits. Hm represents deposits that may have accumulated from a combination of tidal flat, estuarine, and alluvial overbank deposition. The unit is analogous to the Quaternary nearshore (Qn) unit of Dragovich and others (2002) (Figure 2).

Holocene alluvium (Ha) typically underlies Hm to the bottom of the geoprobes. The Ha typically consists of clean to slightly silty sand. Locally, the deposits contain layers of silty sand,

Draft

scattered shell fragments, and wood debris. The dark gray color of the sand suggests its origin is largely volcanic, and that the Ha may be related to lahars from Glacier Peak.

Holocene estuarine (He) deposits form 1- to 3-foot-thick layers of silt, slightly clayey to clayey silt, and silty clay that are interlayered with Ha. We observed shells and shell fragments in some He layers.

Groundwater Conditions

Groundwater and hydrogeologic information will be provided in Technical Memorandum 1.4.

GEOTECHNICAL ENGINEERING ASSESSMENTS

We performed geotechnical engineering analyses to develop concept-level dike design recommendations. We evaluated dike side slope stability, settlement, soil suitability, and seepage.

Side Slopes

We used the computer program SLOPE/W (GeoStudio, 2007) to analyze the stability of several dike side slope configurations. We used the subsurface exploration and laboratory testing results to estimate stratigraphy and soil strength parameters. Figure 4 shows the typical analyzed dike configuration.

For each dike side slope configuration, we analyzed three water configurations, in accordance with Corps levee design standards:

1. Based on the results of our End of construction, corresponding to a static groundwater level at Elevation +5 feet;

2. Steady state seepage from full flood stage, corresponding to water at Elevation +9.7 feet (mean higher high water [MHHW] in NAVD88) on the dike seaward side, and Elevation +5 feet on the landward side; and

3. Sudden drawdown, in which the dike is saturated from a MHHW event, then the water level rapidly drops.

Draft

Based on the results of our analyses, we recommend a maximum dike side slope of 3 horizontal to 1 vertical (3H:1V) for initial planning purposes. In future project phases, we recommend performing additional subsurface explorations, laboratory testing, and geotechnical analyses to verify this conclusion or justify steeper side slopes.

Settlement

We evaluated settlement for an 11-foot-high, 15-foot-wide (at the crest) dike, with 3H:1V side slopes. We estimated settlement beneath the dikes using elastic theory. We used the subsurface exploration and laboratory testing results to estimate soil elastic parameters. We then used elastic stress distributions to estimate the stress increase with depth below the dikes. Based on our analyses, we estimate about ½ to 1 foot of settlement may occur beneath the dikes. Because the soil is mostly granular, this settlement would occur during dike construction. Dike design should account for this settlement.

Our settlement estimate is based on soil conditions interpreted from the preliminary soil explorations. Subsurface explorations during future project phases could discover relatively thick deposits of compressible soil (e.g., silt or clay), which could change the magnitude and duration of our settlement estimate.

Soil Suitability

In situ soils generally comprise a sequence of 1 to 2 feet of agricultural soil, 2 to 7 feet of Hm, and Ha (encountered to the bottom of the explorations). The existing dike fill consists of local, near-surface native materials. The following describes each soil layer's suitability for use in dike construction:

- The agricultural soil is unsuitable for use in dike construction because of its organic content. However, it may be suitable a vegetative topsoil layer over the proposed dikes.
- The Hm soil and the existing dike fill could be suitable; however, moisture conditioning and/or amendments will likely be necessary to properly compact the soil, which can add cost. Recent levee construction projects in the Skagit Delta (such as Fisher Slough) had significant challenges related to soil moisture control and treatment of on-site borrow soil. The on-site soil had a relatively high moisture content and was slow-drying.

Draft

- Use of Ha in the proposed dike is unsuitable. The fines content of the sandy layers are too low (less than 10 percent) to produce a relatively lowly permeable dike. Mixing of higher silt content materials may be possible; however, the price would likely be greater than import materials.

Therefore, we recommend that for planning purposes the study team assume that dike construction materials will need to be imported to complete the project as the on-site materials. Future geotechnical engineering studies will further evaluate methods for optimizing soil borrowing and use on the project, and opportunities for reducing costs of the planned coastal flood protection structures. Future studies should include additional subsurface explorations to sample possible borrow material, as well as soil suitability tests like compaction, admixture, and moisture-content tests.

Seepage

Seepage affects the project in two ways:

1. Seepage through dikes can cause instability, and
2. Salt water seepage through and/or beneath the dikes can cause brackish groundwater.

We considered (1) in our dike stability analyses. Future analyses could consider dike seepage using more sophisticated analysis procedures, including transient groundwater flow analyses or a steady-state seepage model.

Based on salinity monitoring, a salt-water intrusion wedge appears to exist on the interior side of the dikes. About 1,000 feet inside the dikes, brackish water conditions exist about 15 feet bgs. In our opinion, a similar wedge would exist after new dike construction.

We recommend considering a pervious toe trench/ditch to mitigate the effects of the salt-water intrusion wedge. A fresh-water-filled dike toe ditch would reduce the salt-water intrusion wedge impacts by providing a freshwater barrier. We considered a toe ditch in our stability analyses. Based on our experience, a dike toe ditch could mitigate salt-water intrusion effects.

Draft

CONCLUSIONS AND RECOMMENDATIONS

We have a number of general conclusions and recommendations for feasibility level, geotechnical design:

- Based on the results of our analyses, we recommend a maximum levee side slope of 3H:1V for initial planning purposes.
- For future project engineering phases, we recommend performing additional subsurface explorations, laboratory, and geotechnical analyses testing to justify steeper side slopes (or steeper).
- Based on salinity monitoring, a salt-water intrusion wedge appears to exist on the interior side of the levees. In our opinion, a similar wedge would occur for the new levee setback alignments. Two main options exist for mitigating the effects of the salt-water intrusion wedge: a cut-off wall and a fresh-water-filled levee toe ditch.
- For soil suitability, we recommend that for planning purposes the study team assume that dike construction materials will need to be imported to complete the project as the on-site materials.
- Future geotechnical engineering studies may further evaluate methods for optimizing soil borrowing and use on the project, and opportunities for reducing costs of the planned coastal flood protection structures.
- Based on our observations of current dike conditions and interview with DD22, we recommend that more frequent dike maintenance repair be performed, and that future designs and maintenance be performed in such a fashion to remain eligible and active in federal funding assistance programs.

CLOSURE

This technical memorandum was prepared for the exclusive use of WDFW and their authorized agents for the Fir Island Farm project. This technical memorandum presents the data from field explorations and field and laboratory testing of subsurface conditions at the specific locations and depths indicated, using the means and methods described in this technical memorandum. No other representation is made. Unanticipated soil conditions are commonly encountered and cannot fully be determined by merely taking soil samples from borings and test pits. This technical memorandum should be made available to the prospective contractors for information on factual data only. Subsurface conditions that are interpreted from the data included in this

Draft

technical memorandum may not be construed as a guarantee or warranty of such interpreted conditions. Depending upon the contractor's intended means and methods of construction, additional geotechnical data may be necessary. Shannon & Wilson, Inc. has prepared the enclosure "Important Information About Your Geotechnical Report," to assist you and others in understanding the use and limitations of our reports. This enclosure is included as Appendix D.

Sincerely,

SHANNON & WILSON, INC.

David R. Cline, P.E.
Associate

DRC/drc

Enc: References
Figure 1 – Vicinity Map
Figure 2 – Surficial Geologic Map
Figure 3 – Site and Exploration Plan
Figure 4 – Slope Stability Analysis Geometry
Appendix A – Field Reconnaissance and Dike District 22 Interview
Appendix B – Subsurface Explorations
Appendix C – Geotechnical Laboratory Testing
Appendix D – Important Information About Your Geotechnical/Environmental Report

Draft

REFERENCES

Booth, D.B., 1994, Glaciofluvial infilling and scour of the Puget Lowland, Washington, during ice-sheet glaciations: Geology, v. 22, n. 8, p. 695-698.

Dragovich, J.D., McKay, D.T., Jr., Dethier, D.P., Beget, J.E., 2000, Voluminous laharic inundation of the lower Skagit River valley, Washington – a product of a single large mid-Holocene Glacier Peak eruptive episode: Geological Society of America Abstracts with Programs, v. 32, no. 6, p. A-11.

Dragovich, J.D., Gilbertson, L.A., Norman, D.K., Anderson, G., and Petro, G.T., 2002, Geologic map of the Utsalady and Conway quadrangles, Skagit, Snohomish, and Island Counties, Washington: Washington Division of Geology and Earth Resources, OF 2002-5, scale 1:24,000.

Geo-Slope, 2007, Documentation for the SLOPE\W Version 7 Software, Geo-Slope International Ltd., Calgary, Alberta.

History Link, 2007, Skagit County—Thumbnail History, Electronic Document, http://www.historylink.org/essays/output.cfm?file_id=5663

Johnson, S.A., Nelson, A.R., Personius, S.F., Wells, R.E., Kelsey, H.M., Sherrod, B.L., Okumura, K., Koehler III, R., Witter, R.C., Bradley, L., and Harding, D.J., 2001, Evidence for late Holocene earthquakes on the Utsalady Point Fault, Northern Puget Lowland, Washington: Bulletin of the Seismological Society of America, v. 94, n. 6, p. 2299–2316.

Pessl, F., Dethier, D.P., Booth, D.B., and Minard, J.P., 1989, Surficial geologic map of the Port Townsend 30- by 60-minute quadrangle, Puget Sound Region, Washington: USGS Geological Investigation Series I-1198-F, scale 1:100,000.

Wunder, J., 1976, Preliminary geologic map of the Utsalady Quadrangle, Skagit and Snohomish Counties: Washington Division of Geology and Earth Resources, OF 76-5, scale 1:24,000.

Draft

0 2 4

Approximate Scale in Miles

NOTE

Map adapted from aerial imagery provided by Google Earth Pro, Image U.S. Geological Survey , Image Island County, reproduced by permission granted by Google Earth ™ Mapping Service.

DRAFT

Fir Island Farm Restoration
Skagit Wildlife Area
Skagit County, Washington

VICINITY MAP

January 2011 21-1-12318-001

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. 1

Filename: I:\WIP\21-1\12318 FIR ISLAND\CAD\21-1-12318-001 Vicmap.dwg Date: 01-06-2011 Login: cnt

Filename: I:\WIP\21-1\12318 FIR ISLAND\CAD\21-1-12318-001 Geologic Map.dwg Date: 01-06-2011 Login: cnt

Geologic Units

QUATERNARY SEDIMENTARY AND VOLCANIC DEPOSITS

Holocene Nonglacial Deposits

- af — Fill
- Qn — Nearshore deposits (Holocene)
- Qm — Marsh deposits (Holocene)
- Qas — Skagit River alluvium, undivided (Holocene)
- Qasl — Sand levees (Holocene) - Overbank sand deposits of the Skagit River

Pleistocene Glacial and Nonglacial Deposits

- Qgdme — Everson glaciomarine drift, undivided (Pleistocene)

TERTIARY SEDIMENTARY AND VOLCANIC ROCKS

- ΦEcbcg — Rocks of Bulson Creek, lower conglomeratic lithofacies (Oligocene to Eocene)
- Ecb — Chuckanut Formation, Bellingham Bay Member (Eocene)

Geologic Symbols

- Contact - Dashed were Inferred
- Fault - Dashed where Inferred; Dotted where Concealed
- Strike-slip fault - Arrows show relative horizontal movement; dotted where concealed
- Syncline - Showing direction of plunge; dotted where concealed
- Stike and dip of Quarternary bedding
- inclined; 'f' adjacent to symbol indicates foreset bedding

Fir Island Farm Restoration
Skagit Wildlife Area
Skagit County, Washington

SURFICIAL GEOLOGIC MAP

January 2011 21-1-12318-001

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. 2

NOTE

Modified from Dragovich and others (2002).

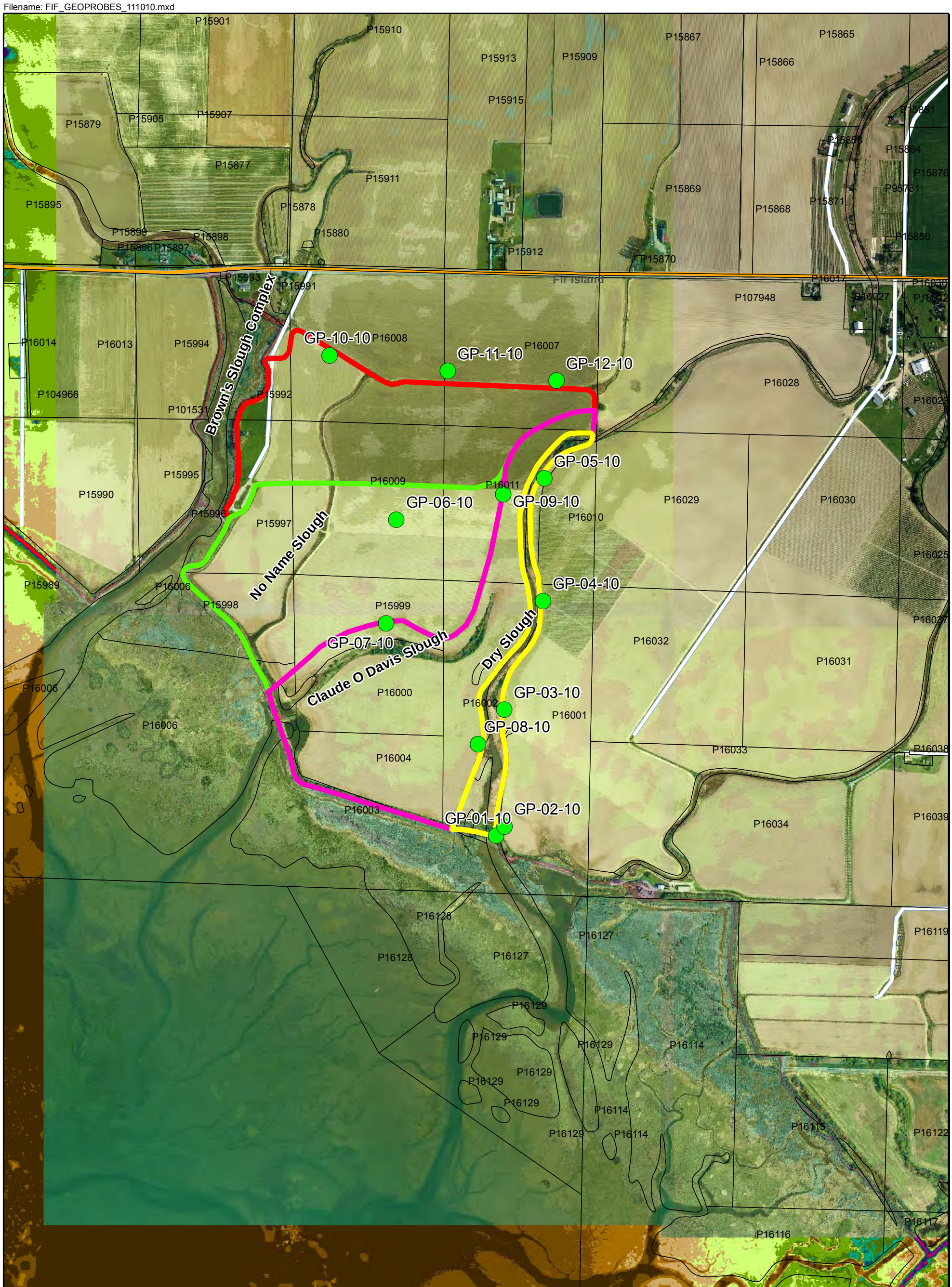
0 1/2 1

Approximate Scale in Miles

DRAFT

FIG. 2

Filename: FIF_GEOPROBES_111010.mxd



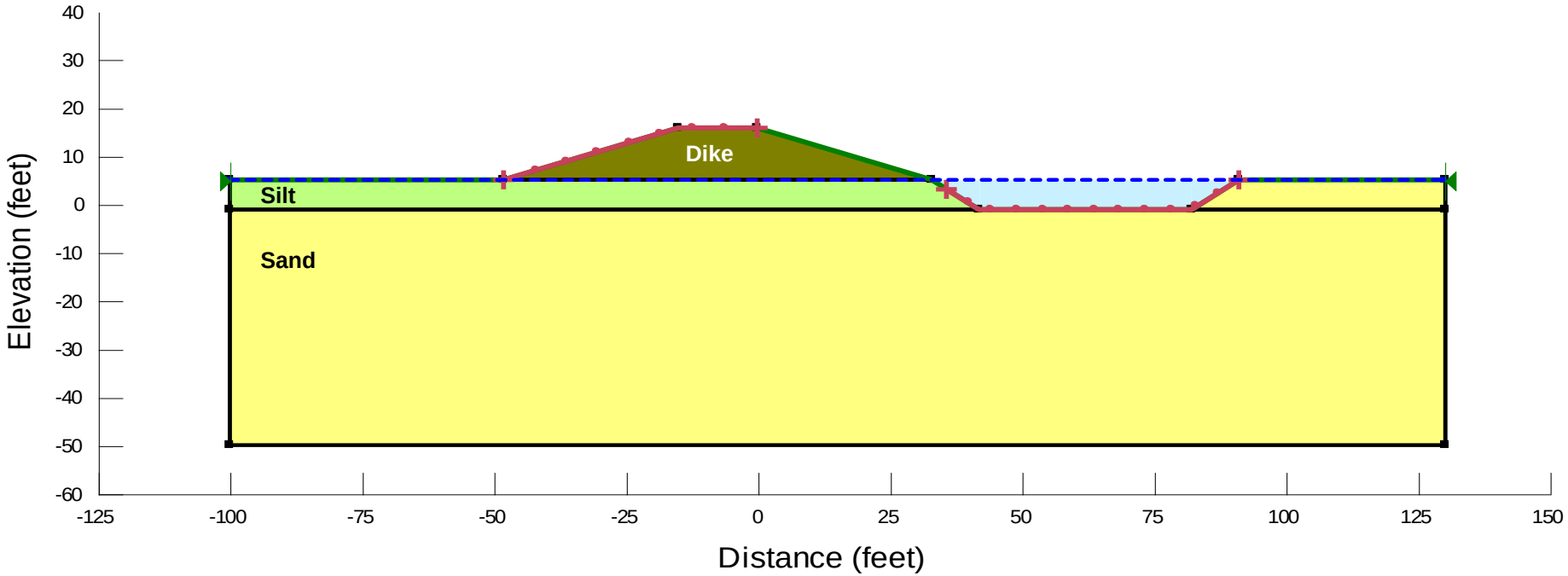
FIR ISLAND FARM RESTORATION
SKAGIT SNOW GOOSE PRESERVE
SKAGIT COUNTY, WA

SITE AND EXPLORATION PLAN

January 2011 | 21-1-12318-001

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

FIG. 3



NOTES

1. We used the computer program SLOPE/W (GeoStudio, 2007) to perform the analyses.
2. The condition shown corresponds to static water levels and a dike with 3 horizontal to 1 vertical side slopes.

DRAFT

Fir Island Farm Restoration
Skagit Wildlife Area
Skagit County, Washington

SLOPE STABILITY ANALYSIS GEOMETRY

January 2011 | 21-1-12318-001

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. 4

FIG. 4

Draft

APPENDIX A

FIELD RECONNAISSANCE AND DIKE DISTRICT 22 INTERVIEW

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

DAILY FIELD ACTIVITY REPORT

PROJECT NO.:	21-1-12318-001
REPORT DATE:	August 31, 2010
REPORT NO.:	FAR-2010-08-31-BSK
SW FIELD REP.:	Brian Reznick (Dave Cline FAR Writeup)
PERMIT NO.:	

PROJECT NAME/LOCATION	Fisher Slough Tidal Marsh Restoration, Skagit County, Washington

REPORT SUBMITTED TO:		CONTRACTOR NAME AND CONTACT:		WEATHER & TEMP.	Cloudy/windy, low 70's
Client	Brian Williams, WDFW	General		TIMES OF SITE VISITS:	
CC				from 09:00	to 16:00
				from	to
				from	to

CONSTRUCTION OBSERVATIONS

NO.	TOPIC AND LOCATION	DESCRIPTION OF FIELD ACTIVITY, OBSERVATIONS AND RECOMMENDATIONS TO OWNER	FURTHER ACTION RECOMMENDED TO OWNER
1	Fir Island Farm Site Reconnaissance and DD22 Interview	A site visit was performed with Stan Nelson, DD22 to investigate coastal dike conditions and to document the history of the agricultural flood protection infrastructure. Figure 1 is overview of site map and locations visited during reconnaissance. Meeting notes are on file w/ S&W.	
2	Southwest corner, just past 2nd entrance gate	Farm area affected by salt water. Location on dike is a low spot that is frequently overtopped. Salt water inflow and soil damage most likely from overtopping (Photos 1-3).	
3	No Name Slough	Crop and soil damage from saltwater noted along area. Likely from leakage through Claude O'Davis slough tidegate and overtopping events. Appears to be a 50-100ft wide area where crops grow more slowly. Notable algae scum on water likely from nutrient load and farm drainage runoff (Photos 4-5).	
4	Claude O'Davis Slough	Stopped at Claude O'Davis Slough. Location was breached in 1990 flood. Ponds are scour areas as a result of dike breach. Repaired with NRCS EWP funds. Rock repair in breach and also rock facing along dike (Photos 6-8)	
5	East of Claude O'Davis	Tire rut depressions observed on dike (Photo 9)	
6	Browns Slough	Dike/levee system has several large cottonwood trees growing out of levee. Current section is not functioning as active dike as it is upstream from screwgate control (Photos 10-11). Section will need to be fully replaced if part of dike setback.	

ATTACHMENTS	
	Figure 1 – Site Map and Notes
	Photo 1 – Looking north from low spot on levee near second access gate
	Photo 2 – Looking northeast from low spot on levee near second access gate
	Photo 3 - Looking east along low spot on levee near second access gate

LIMITATIONS: The Shannon & Wilson field representative is present on site solely to observe the field activities of the contractor identified and keep our client informed of the progress and quality of the work. The presence and activities of the Shannon & Wilson field representative and our acceptance of any non-conforming work or failure to reject any non-conforming work does not relieve the contractor from complying with its contract documents. Shannon & Wilson does not have the authority to direct the contractor's work. Any information provided by the Shannon & Wilson field inspector is intended solely to advise the contractor of the technical requirements of the plans and specifications and/or design concept. The contractor is solely responsible for its means, methods, sequences, procedures, construction site safety, quality of work, and adherence to the contract documents.

REVIEW BY (PM initial/date)
DRC, 09/05/10

CONSTRUCTION OBSERVATIONS (continued)

Photo 4 - Looking north at crop damage area at No Name Slough.

Photo 5 - Looking north at crop damage area at No Name Slough.

Photo 6 – Looking east toward Claude O'Davis breach and scour pond.

Photo 7 – Looking east along rock facing of Claude O'Davis repair

Photo 8 – Looking southeast along coastal face of dike at 2-3ft diameter rock repair

Photo 9 – Looking west towards tire rut depressions at position east of Claude O'Davis Slough

Photo 10 – Looking east at east Browns Slough levee with cottonwoods growing within dike.

Photo 11 – Looking west at backside of east Browns Slough levee with blackberries.

LIMITATIONS: The Shannon & Wilson field representative is present on site solely to observe the field activities of the contractor identified and keep our client informed of the progress an quality of the work. The presence and activities of the Shannon & Wilson field representative and our acceptance of any non-conforming work or failure to reject any non-conforming work does not relieve the contractor from complying with its contract documents. Shannon & Wilson does not have the authority to direct the contractor's work. Any information provided by the Shannon & Wilson field inspector is intended solely to advice the contractor of the technical requirements of the plans and specifications and/or design concept. The contractor is solely responsible for its means, methods, sequences, construction site safety, quality of work, and adherence to the contract documents.

REVIEW BY (PM initial/date)

DRC, 09/05/10

CONSTRUCTION OBSERVATIONS (continued)

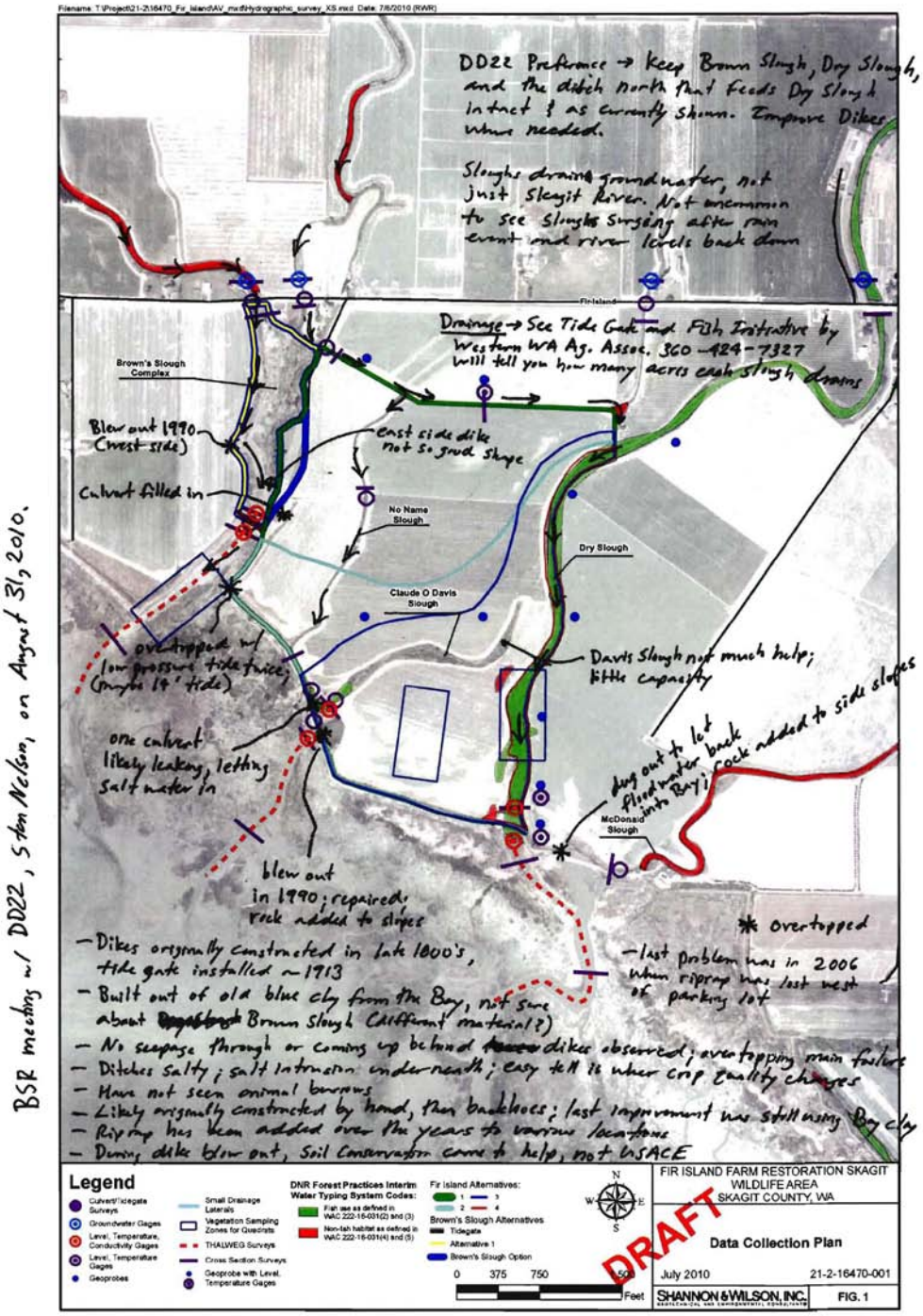


Figure 1 – Site Map and Reconnaissance Notes

CONSTRUCTION OBSERVATIONS (continued)

Photo 1 – Looking north from low spot on levee near second access gate

Photo 2 – Looking northeast from low spot on levee near second access gate

LIMITATIONS: The Shannon & Wilson field representative is present on site solely to observe the field activities of the contractor identified and keep our client informed of the progress an quality of the work. The presence and activities of the Shannon & Wilson field representative and our acceptance of any non-conforming work or failure to reject any non-conforming work does not relieve the contractor from complying with its contract documents. Shannon & Wilson does not have the authority to direct the contractor's work. Any information provided by the Shannon & Wilson field inspector is intended solely to advice the contractor of the technical requirements of the plans and specifications and/or design concept. The contractor is solely responsible for its means, methods, sequences, construction site safety, quality of work, and adherence to the contract documents.

REVIEW BY (PM initial/date)

DRC, 09/05/10

CONSTRUCTION OBSERVATIONS (continued)

Photo 3 - Looking east along low spot on levee near second access gate

Photo 4 - Looking north at crop damage area at No Name Slough.

LIMITATIONS: The Shannon & Wilson field representative is present on site solely to observe the field activities of the contractor identified and keep our client informed of the progress an quality of the work. The presence and activities of the Shannon & Wilson field representative and our acceptance of any non-conforming work or failure to reject any non-conforming work does not relieve the contractor from complying with its contract documents. Shannon & Wilson does not have the authority to direct the contractor's work. Any information provided by the Shannon & Wilson field inspector is intended solely to advice the contractor of the technical requirements of the plans and specifications and/or design concept. The contractor is solely responsible for its means, methods, sequences, construction site safety, quality of work, and adherence to the contract documents.

REVIEW BY (PM initial/date)

DRC, 09/05/10

CONSTRUCTION OBSERVATIONS (continued)

Photo 5 - Looking north at crop damage area at No Name Slough

Photo 6 – Looking east toward Claude O'Davis breach and scour pond.

LIMITATIONS: The Shannon & Wilson field representative is present on site solely to observe the field activities of the contractor identified and keep our client informed of the progress an quality of the work. The presence and activities of the Shannon & Wilson field representative and our acceptance of any non-conforming work or failure to reject any non-conforming work does not relieve the contractor from complying with its contract documents. Shannon & Wilson does not have the authority to direct the contractor's work. Any information provided by the Shannon & Wilson field inspector is intended solely to advice the contractor of the technical requirements of the plans and specifications and/or design concept. The contractor is solely responsible for its means, methods, sequences, construction site safety, quality of work, and adherence to the contract documents.

REVIEW BY (PM initial/date)

DRC, 09/05/10

CONSTRUCTION OBSERVATIONS (continued)

Photo 7 – Looking east along rock facing of Claude O'Davis repair

Photo 8 – Looking southeast along coastal face of dike at 2-3ft diameter rock repair

LIMITATIONS: The Shannon & Wilson field representative is present on site solely to observe the field activities of the contractor identified and keep our client informed of the progress an quality of the work. The presence and activities of the Shannon & Wilson field representative and our acceptance of any non-conforming work or failure to reject any non-conforming work does not relieve the contractor from complying with its contract documents. Shannon & Wilson does not have the authority to direct the contractor's work. Any information provided by the Shannon & Wilson field inspector is intended solely to advice the contractor of the technical requirements of the plans and specifications and/or design concept. The contractor is solely responsible for its means, methods, sequences, construction site safety, quality of work, and adherence to the contract documents.

REVIEW BY (PM initial/date)

DRC, 09/05/10

CONSTRUCTION OBSERVATIONS (continued)

Photo 9 – Looking west towards tire rut depressions and dike settlement section east of Claude O'Davis Slough

Photo 10 – Looking east at east Browns Slough levee with cottonwoods growing within dike.

LIMITATIONS: The Shannon & Wilson field representative is present on site solely to observe the field activities of the contractor identified and keep our client informed of the progress an quality of the work. The presence and activities of the Shannon & Wilson field representative and our acceptance of any non-conforming work or failure to reject any non-conforming work does not relieve the contractor from complying with its contract documents. Shannon & Wilson does not have the authority to direct the contractor's work. Any information provided by the Shannon & Wilson field inspector is intended solely to advice the contractor of the technical requirements of the plans and specifications and/or design concept. The contractor is solely responsible for its means, methods, sequences, construction site safety, quality of work, and adherence to the contract documents.

REVIEW BY (PM initial/date)

DRC, 09/05/10

CONSTRUCTION OBSERVATIONS (continued)

Photo 11 – Looking west at backside of east Browns Slough levee with blackberries.

LIMITATIONS: The Shannon & Wilson field representative is present on site solely to observe the field activities of the contractor identified and keep our client informed of the progress an quality of the work. The presence and activities of the Shannon & Wilson field representative and our acceptance of any non-conforming work or failure to reject any non-conforming work does not relieve the contractor from complying with its contract documents. Shannon & Wilson does not have the authority to direct the contractor's work. Any information provided by the Shannon & Wilson field inspector is intended solely to advice the contractor of the technical requirements of the plans and specifications and/or design concept. The contractor is solely responsible for its means, methods, sequences, construction site safety, quality of work, and adherence to the contract documents.

REVIEW BY (PM initial/date)

DRC, 09/05/10

APPENDIX B

SUBSURFACE EXPLORATIONS

Draft

APPENDIX B

SUBSURFACE EXPLORATIONS

TABLE OF CONTENTS

Page

B.1 GENERAL B-1

B.2 GEOPROBES B-1

B.3 MONITORING WELL INSTALLATION B-1

B.4 REFERENCE B-2

FIGURES

B-1 Soil Classification and Log Key (2 sheets)
B-2 Log of Geoprobe GP-01-10
B-3 Log of Geoprobe GP-02-10
B-4 Log of Geoprobe GP-03-10
B-5 Log of Geoprobe GP-04-10
B-6 Log of Geoprobe GP-05-10
B-7 Log of Geoprobe GP-06-10
B-8 Log of Geoprobe GP-07-10
B-9 Log of Geoprobe GP-08-10
B-10 Log of Geoprobe GP-09-10
B-11 Log of Geoprobe GP-10-10
B-12 Log of Geoprobe GP-11-10
B-13 Log of Geoprobe GP-12-10

Draft

APPENDIX B

SUBSURFACE EXPLORATIONS

B.1 GENERAL

The field exploration program for the Fir Island project consisted of advancing 12 geoprobes, designated GP-01-10 through GP-12-10. The geoprobes were pushed from October 5 through 7, 2010. Approximate locations of the explorations are shown in the Site and Exploration Plan, Figure 3, in the main text of this report.

B.2 GEOPROBES

Geoprobing was performed by Cascade Drilling, Inc. of Woodinville, Washington, under subcontract to Shannon & Wilson, Inc., using a rubber-tread Geoprobe 7730DT rig. Geoprobe GP-01-10 was pushed to a depth of 40 feet, and geoprobes GP-02-10 through GP-12-10 were pushed to 30 feet. A representative from Shannon & Wilson, Inc. was present throughout the subsurface explorations to observe the geoprobing, to collect representative samples for subsequent laboratory testing, and to prepare descriptive field logs of the borings. The terminology and symbols used in the geoprobe logs are summarized in Figure B-1. Geoprobe logs are presented in Figures B-2 and B-13.

The geoprobe is a direct-push boring rig with a 2-inch outside-diameter (O.D.) casing that is advanced using a percussive force rather than using an auger to remove soil in its path. Geoprobing involved advancing the geoprobe below the ground surface, and then driving a 5-foot-long, 2-inch O.D., plastic-lined sampler to retrieve a soil sample.

After geoprobe tubes were retrieved from the tool string, they were cut open lengthwise on site for sampling and classification. Geotechnical samples were taken from the plastic tubes at selected depth locations, as noted in the geoprobe logs in Appendix A. Geotechnical samples were stored in plastic jars and transported to the Shannon & Wilson laboratory for testing.

B.3 MONITORING WELL INSTALLATION

Monitoring wells were installed in geoprobes GP-01-10, GP-02-10, and GP-03-10 to evaluate groundwater depth and salinity. Following geoprobe sampling, a 3.5-inch O.D. steel casing fitted with a conical tip was driven to the proposed well depth. The conical tip was then detached from the casing and left in the hole. The well screen and riser pipe were installed

Draft

through the casing. The casing was then removed gradually as the annular space between the boring and well screen was filled with sand, bentonite, and concrete.

The monitoring wells were constructed of new, commercially fabricated, threaded, flush-jointed, 2-inch-diameter Schedule 40 polyvinyl chloride. Well screen consisted of 0.01-inch-wide machine slotted screen. A silica sand filter pack was poured in the annular space between the boring and well screen to a depth about 2 feet above the screen. A bentonite seal was placed in the annulus above the filter pack to within 2 feet of the ground surface. The wells were completed with flush with the elevation of the surrounding grade by placing an 8-inch-diameter flush-mount steel monument over the top of the borehole. The steel monuments were set in place with quick-set concrete.

B.4 REFERENCE

ASTM International (ASTM), 2008, Annual book of standards, Construction, v. 04.08, Soil and rock (I): D 420 – D 5611: West Conshohocken, Pa.

Draft

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	

Fir Island Farm Restoration
Skagit Wildlife Area
Skagit County, Washington

SOIL CLASSIFICATION AND LOG KEY

January 2011 21-1-12318-001

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B-1
Sheet 1 of 2

UNIFIED SOIL CLASSIFICATION SYSTEM (USCS)
(From USACE Tech Memo 3-357)

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 of 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.

Fir Island Farm Restoration
Skagit Wildlife Area
Skagit County, Washington

SOIL CLASSIFICATION AND LOG KEY

January 2011 | 21-1-12318-001

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. A-1
Sheet 2 of 2

BORING_CLASS2 21-12318.GPJ SWNEW.GDT 1/11/11

LOG OF GEOPROBE

Date Started *10/6/10*	**Location**	**Ground Elevation:** *Approx. NA feet*
Date Completed *10/6/10*		**Typical Run Length** *5 feet*
Total Depth (ft) *40.0*	**Drilling Company:** *Cascade Drilling*	**Hole Diameter:** *2 inches*

Depth (ft)	Probe Run	Soil Description	Depth, ft.	Symbol	PID, ppm	Ground Water	Sample Number, Description, and Results	Depth (ft)
	1	Brown SILT, trace of sand; moist; (Hf) ML.					S-1 (1 - 2')	
		Gray-brown, fine to medium SAND, trace of silt; dry; (Hf) SP.	2.8				S-2 (2.8 - 3.8')	
		Brown SILT, trace of fine sand; moist; iron-oxide-stained locally; (Hf) ML.	3.8				S-3 (4 - 5')	
5	2	Gray-brown, fine to medium SAND, trace of silt; dry; (Hf) SP.	5.5				S-4 (5.5 - 6.2')	5
		Gray and orange-brown, slightly clayey to clayey SILT; moist; scattered layers or pockets of fine sand, irregular iron-oxide staining; scattered tubers (marsh plants); (Hf) ML.	6.2				S-5 (7 - 8')	
10	3	Gray, SILT, trace of clay and fine sand; moist to wet; locally slightly clayey to clayey, trace tubers (marsh plants) above 11.5 feet; (Hm) ML.	10.5			10/7/2010	S-6 (11 - 12')	10
15	4	Gray, trace to slightly silty, fine to medium SAND; wet; locally coarse sand; (Ha) SP/SP-SM. - 1-inch clayey silt layer at 16.5 feet. - 1-inch clayey silt layer at 18 feet.	15.3				S-7 (16 - 17.5')	15
20	5	- 2-inch-thick slightly clayey, slightly fine sandy silt layer at 23 feet.						20
25	6	- 1-inch-diameter wood fragment at 24.5 feet. - 1.5-inch-diameter wood fragment at 27.8 feet.					S-8 (25 - 26.5')	25

Refer to the report text for a proper understanding of the subsurface materials and probing methods. The stratification lines indicated below represent the approximate boundaries between soil types. Actual boundaries may be different if soil shifted inside sample tubes during extraction.

CONTINUED NEXT PAGE

DRAFT

NOTES

1. In some cases where recovery was low in the upper part of the run, the soil sample may have slid down in the tube prior to removal from the ground.
2. Groundwater level, if indicated above, was estimated during probing and should be considered approximate.
3. Refer to KEY for definitions and explanation of symbols.
4. CT = corrosion test sample; TR = thermal resistivity sample; EN = environmental sample; GE = geotechnical sample; AR = archeological sample.

LEGEND

- 2" Plastic Tube - No Soil Recovery
- 2" Plastic Tube with Soil Recovery
- *Run No.*
- Ground Water Level in Well
- Piezometer Screen and Sand Filter
- Bentonite-Cement Grout
- Bentonite Chips/Pellets
- Bentonite Grout

Fir Island Farm Restoration
Skagit Wildlife Area
Skagit County, Washington

LOG OF GEOPROBE GP-01-10

January 2011 — 21-1-12318-001

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B-2
Sheet 1 of 2

GEOPROBE_WELL 21-12318.GPJ 21-20447.GPJ 1/11/11 Log: PHZ Rev: PHZ Typ: LKN

LOG OF GEOPROBE

Date Started *10/6/10*	**Location**	**Ground Elevation:** *Approx. NA feet*
Date Completed *10/6/10*		**Typical Run Length** *5 feet*
Total Depth (ft) *40.0*	**Drilling Company:** *Cascade Drilling*	**Hole Diameter:** *2 inches*

Depth (ft)	Probe Run	Soil Description	Depth, ft.	Symbol	PID, ppm	Ground Water	Sample Number, Description, and Results	Depth (ft)
	7							
		Gray, trace to slightly silty, fine SAND; wet; (Ha) SP/SP-SM.	32.5					
		- 1-inch-thick silt layer at 32.5 feet.					S-9 (33 - 34.5')	
35	8							35
							S-10 (38.5 - 40')	
		- 1.5-inch-diameter wood chunk at 39 feet.						
40		BOTTOM OF BORING	40.0					40
		COMPLETED 10/6/2010						
		Note: Hole diameter widened to 3.5 inches during installation of monitoring well. See Appendix B for well installation details.						
45								45
50								50
55								55

DRAFT

NOTES

1. In some cases where recovery was low in the upper part of the run, the soil sample may have slid down in the tube prior to removal from the ground.
2. Groundwater level, if indicated above, was estimated during probing and should be considered approximate.
3. Refer to KEY for definitions and explanation of symbols.
4. CT = corrosion test sample; TR = thermal resistivity sample; EN = environmental sample; GE = geotechnical sample; AR = archeological sample.

LEGEND

- 3 — 2" Plastic Tube - No Soil Recovery
- 2" Plastic Tube with Soil Recovery
- *Run No.*
- Ground Water Level in Well
- Piezometer Screen and Sand Filter
- Bentonite-Cement Grout
- Bentonite Chips/Pellets
- Bentonite Grout

Fir Island Farm Restoration
Skagit Wildlife Area
Skagit County, Washington

LOG OF GEOPROBE GP-01-10

January 2011 — 21-1-12318-001

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B-2
Sheet 2 of 2

GEOPROBE_WELL 21-12318.GPJ 21-20447.GPJ 1/11/11 Log: PHZ Rev: PHZ Typ: LKN

LOG OF GEOPROBE

Date Started *10/6/10*	**Location**	**Ground Elevation:** *Approx. NA feet*
Date Completed *10/6/10*		**Typical Run Length** *5 feet*
Total Depth (ft) *30.0*	**Drilling Company:** *Cascade Drilling*	**Hole Diameter:** *2 inches*

Depth (ft)	Probe Run	Soil Description	Depth, ft.	Symbol	PID, ppm	Ground Water	Sample Number, Description, and Results	Depth (ft)
	1	Brown SILT, trace of fine sand, trace of clay; moist; scattered roots (Agricultural layer); ML.					S-1 (0 - 1')	
		Note: Poor soil recovery in upper 5 feet. Layer thickness may be overestimated. Agricultural layer encountered in other nearby geoprobes is typically about 1.5 feet thick.				10/7/2010		
5	2	Gray to gray-brown, slightly clayey to clayey SILT, trace of fine sand; wet; scattered wood fragments; (Hm) MH/ML.	5.0				S-2 (6 - 7')	5
		Gray, trace of silt to slightly silty, fine to medium SAND; wet; locally trace of gravel; (Ha) SP-SM/SP.	7.5					
10	3	- 0.5-inch-thick layer of woody debris at 13.2 feet.					S-3 (10 - 11.5')	10
15	4	- 2-inch-thick layer of rounded woody debris at 17.8 feet. - 3/4-inch-thick piece of branch at 18.5 feet.					S-4 (15 - 16.5')	15
20	5	- 1-inch-thick layer of wood debris at 20.5 feet. - Local zones of fine sand and scattered wood fragments below 22 feet.					S-5 (20 - 21.5')	20
25	6						S-6 (25 - 26.5')	25
		Gray, silty, fine SAND; wet; scattered clayey silt laminae; (Ha) SM.	28.2				S-7 (28.5 - 29.5')	
30		BOTTOM OF BORING COMPLETED 10/6/2010	30.0					30
		Note: Hole diameter widened to 3.5 inches during installation of monitoring well. See Appendix B for well installation details.						

DRAFT

NOTES

1. In some cases where recovery was low in the upper part of the run, the soil sample may have slid down in the tube prior to removal from the ground.
2. Groundwater level, if indicated above, was estimated during probing and should be considered approximate.
3. Refer to KEY for definitions and explanation of symbols.
4. CT = corrosion test sample; TR = thermal resistivity sample; EN = environmental sample; GE = geotechnical sample; AR = archeological sample.

LEGEND

- 2" Plastic Tube - No Soil Recovery
- 2" Plastic Tube with Soil Recovery
- *Run No.*
- Ground Water Level in Well
- Piezometer Screen and Sand Filter
- Bentonite-Cement Grout
- Bentonite Chips/Pellets
- Bentonite Grout

Fir Island Farm Restoration
Skagit Wildlife Area
Skagit County, Washington

LOG OF GEOPROBE GP-02-10

January 2011 — 21-1-12318-001

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B-3

GEOPROBE_WELL 21-12318.GPJ 21-20447.GPJ 1/12/11 Log: PHZ Rev: PHZ Typ: LKN

LOG OF GEOPROBE

Date Started *10/7/10*	**Location**	**Ground Elevation:** *Approx. NA feet*
Date Completed *10/7/10*		**Typical Run Length** *4 feet*
Total Depth (ft) *30.0*	**Drilling Company:** *Cascade Drilling*	**Hole Diameter:** *2 inches*

Depth (ft)	Probe Run	Soil Description	Depth, ft.	Symbol	PID, ppm	Ground Water	Sample Number, Description, and Results	Depth (ft)
	1	Brown, slightly fine sandy SILT, trace of clay; moist; trace of roots and organics; (Agricultural layer) ML.	1.5				S-1 (0.8 - 1.2')	
		Interbedded, gray and orange-brown, slightly fine sandy, slightly clayey SILT and silty, fine SAND; moist; iron-oxide staining, mottled; (Hm) ML/SM.					S-2 (2 - 3')	
5	2	- 2-inch layer of silty sand at 2.5 feet.	5.0			10/7/2010	S-3 (5 - 6')	5
		Gray, trace of clay to slightly clayey, slightly fine sandy, SILT; moist; (Hm) ML.	6.0					
	3	Gray, trace to slightly silty, fine to medium SAND; wet; (Ha) SP/SP-SM.					S-4 (8 - 9')	
10								10
	4	- 6-inch layer of wood debris at 11.5 feet.						
15		- 2-inch layer of wood debris at 15 feet. Odor of decaying organics.					S-5 (14.5 - 15.5')	15
	5							
		Gray, fine to medium SAND, trace of silt; wet; (Ha) SP/SP-SM.	19.0					
20		Gray, trace to slightly silty, fine to medium SAND; wet; (Ha) SM.	19.5					20
	6	Gray, trace of silt to slightly silty, fine to medium SAND; wet; scattered wood debris, scattered shells at 23.5 feet; (Ha) SP/SP-SM.	20.0				S-6 (21 - 22')	
25	7							25
		Gray, silty, fine to medium SAND, trace of clay; moist to wet; (Ha) SM.	25.5				S-7 (26 - 26.5')	
			28.0					
	8	Gray, fine to medium SAND, trace of silt; wet; occasional wood fragments and shell fragments; (Ha) SP.	29.0				S-8 (29 - 30')	
30		Gray, slightly clayey SILT, trace of fine sand; moist to wet; (He) ML.	30.0					30
		BOTTOM OF BORING COMPLETED 10/7/2010 Note: Hole diameter widened to 3.5 inches during installation of monitoring well. See Appendix B for well installation details.						

DRAFT

NOTES

1. In some cases where recovery was low in the upper part of the run, the soil sample may have slid down in the tube prior to removal from the ground.
2. Groundwater level, if indicated above, was estimated during probing and should be considered approximate.
3. Refer to KEY for definitions and explanation of symbols.
4. CT = corrosion test sample; TR = thermal resistivity sample; EN = environmental sample; GE = geotechnical sample; AR = archeological sample.

LEGEND

- 2" Plastic Tube - No Soil Recovery
- 2" Plastic Tube with Soil Recovery
- *Run No.*
- Ground Water Level in Well
- Piezometer Screen and Sand Filter
- Bentonite-Cement Grout
- Bentonite Chips/Pellets
- Bentonite Grout

Fir Island Farm Restoration
Skagit Wildlife Area
Skagit County, Washington

LOG OF GEOPROBE GP-03-10

January 2011 — 21-1-12318-001

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B-4

GEOPROBE_WELL 21-12318.GPJ 21-20447.GPJ 1/12/11 Log: PHZ Rev: PHZ Typ: LKN

LOG OF GEOPROBE

Date Started *10/5/10*	**Location**	**Ground Elevation:** *Approx. NA feet*
Date Completed *10/5/10*		**Typical Run Length** *5 feet*
Total Depth (ft) *30.0*	**Drilling Company:** *Cascade Drilling*	**Hole Diameter:** *2 inches*

Depth (ft)	Probe Run	Soil Description	Depth, ft.	Symbol	PID, ppm	Ground Water	Sample Number, Description, and Results	Depth (ft)
	1	Brown SILT, trace of fine sand; moist; (Agricultural layer); ML.					S-1 (0.5 - 1')	
		Gray SILT, trace of clay, trace of fine sand; moist; locally fine sand, iron-oxide-stained, mottled; (Hm) ML.	1.0				S-2 (2 - 3')	
5	2	Gray, slightly clayey SILT, trace of fine sand; wet; increasing fine sand content with depth; (Hm) ML.	5.0			During Drilling ▽	S-3 (5 - 6')	5
		Gray, trace to slightly silty, fine to medium and medium to coarse SAND; wet; locally trace of gravel; (Ha) SP/SP-SM.	7.5					
10	3	- 3-inch-thick silty sand layer at 9 feet.					S-4 (10 - 11.5')	10
		- 2-inch-thick layer of wood debris at 13 feet.						
15	4						S-5 (15 - 16.5')	15
		Gray, silty, fine SAND; wet; laminated in upper 3 inches; (Ha) SM.	19.0					
20	5	Gray, trace of silt to slightly silty, medium to coarse SAND; wet; locally trace of fine gravel; (Ha) SP/SP-SM.	20.0				S-6 (20 - 21.5')	20
		Gray-brown, slightly clayey SILT, trace of fine sand; wet; trace of organics; (He) ML.	23.0 / 23.5					
25	6	Gray, silty, fine SAND; wet; (Ha) SM.	25.0				S-7 (25 - 26.5')	25
		Gray, slightly silty, fine to medium and fine to coarse SAND; wet; (Ha) SP-SM.	27.2					
		Gray, fine sandy SILT; wet; trace of shell fragments; (He) ML.					S-8 (29 - 30')	
30		BOTTOM OF BORING COMPLETED 10/5/2010	30.0					30

DRAFT

NOTES

1. In some cases where recovery was low in the upper part of the run, the soil sample may have slid down in the tube prior to removal from the ground.
2. Groundwater level, if indicated above, was estimated during probing and should be considered approximate.
3. Refer to KEY for definitions and explanation of symbols.
4. CT = corrosion test sample; TR = thermal resistivity sample; EN = environmental sample; GE = geotechnical sample; AR = archeological sample.

LEGEND

3 — 2" Plastic Tube - No Soil Recovery
2" Plastic Tube with Soil Recovery
Run No.
▽ Ground Water Level ATD

Fir Island Farm Restoration
Skagit Wildlife Area
Skagit County, Washington

LOG OF GEOPROBE GP-04-10

January 2011 — 21-1-12318-001

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B-5

GEOPROBE_WELL 21-12318.GPJ 21-20447.GPJ 1/11/11 Log: PHZ Rev: PHZ Typ: LKN

LOG OF GEOPROBE

Date Started *10/5/10*	**Location** *E side of dry slough*	**Ground Elevation:** *Approx. NA feet*
Date Completed *10/5/10*		**Typical Run Length** *5 feet*
Total Depth (ft) *30.0*	**Drilling Company:** *Cascade Drilling*	**Hole Diameter:** *2 inches*

Depth (ft)	Probe Run	Soil Description	Depth, ft.	Symbol	PID, ppm	Ground Water	Sample Number, Description, and Results	Depth (ft)
	1	Brown, fine sandy SILT; moist; (Agricultural layer); ML.					S-1 (0.5 - 1.3')	
		Brown, slightly clayey SILT; moist; scattered fine sand zones; (Hm) ML.	1.5				S-2 (2 - 2.5')	
		Gray, slightly silty to silty, medium to coarse SAND; wet; (Ha) SP-SM/SM.	3.5				S-3 (3.5 - 4')	
5	2	Gray, trace to slightly silty, fine to medium SAND, trace of fine gravel; wet; locally medium to coarse sand; (Ha) SP/SP-SM.	5.0			During Drilling ▽		5
		- 3-inch-thick layer of wood debris at 7.5 feet.					S-4 (8 - 9')	
10	3	- Pocket of wood debris at 11.2 feet.					S-5 (13 - 14.3')	10
15	4	- Slightly fine gravelly, medium to coarse sand between 17 and 18.5 feet.					S-6 (17 - 18.5')	15
20	5	Gray-brown, fine sandy SILT, trace of clay; wet; scattered sand interbeds, scattered tan, silty laminae, scattered shell fragments; (He) ML.	19.0				S-7 (20 - 21.5')	20
		Gray-brown, silty, fine SAND; wet; scattered shell fragments, locally trace of clay; (Ha) SM.	21.5					
		- Trace of shells below approximately 23.5 feet.						
25	6						S-8 (25 - 25.8')	25
							S-9 (29 - 30')	
30		BOTTOM OF BORING COMPLETED 10/5/2010	30.0					30

Refer to the report text for a proper understanding of the subsurface materials and probing methods. The stratification lines indicated below represent the approximate boundaries between soil types. Actual boundaries may be different if soil shifted inside sample tubes during extraction.

DRAFT

NOTES

1. In some cases where recovery was low in the upper part of the run, the soil sample may have slid down in the tube prior to removal from the ground.
2. Groundwater level, if indicated above, was estimated during probing and should be considered approximate.
3. Refer to KEY for definitions and explanation of symbols.
4. CT = corrosion test sample; TR = thermal resistivity sample; EN = environmental sample; GE = geotechnical sample; AR = archeological sample.

LEGEND

3 — 2" Plastic Tube - No Soil Recovery
2" Plastic Tube with Soil Recovery
Run No.
▽ Ground Water Level ATD

Fir Island Farm Restoration
Skagit Wildlife Area
Skagit County, Washington

LOG OF GEOPROBE GP-05-10

January 2011 — 21-1-12318-001

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B-6

GEOPROBE_WELL 21-12318.GPJ 21-20447.GPJ 1/11/11 Log: PHZ Rev: PHZ Typ: LKN

LOG OF GEOPROBE

Date Started *10/6/10*	**Location**	**Ground Elevation:** *Approx. NA feet*
Date Completed *10/6/10*		**Typical Run Length** *5 feet*
Total Depth (ft) *30.0*	**Drilling Company:** *Cascade Drilling*	**Hole Diameter:** *2 inches*

Depth (ft)	Probe Run	Soil Description	Depth, ft.	Symbol	PID, ppm	Ground Water	Sample Number, Description, and Results	Depth (ft)
	1	Brown SILT, trace of clay; moist; scattered roots; (Agricultural layer) ML.	1.3					
		Brown and orange-brown, slightly clayey to clayey SILT, trace of fine sand; moist; numerous roots, scattered organics, iron-oxide-stained; (Hm) MH/ML.				During Drilling	S-1 (2 - 3')	
5	2	Gray, silty, fine SAND; wet; (Ha) SM.	5.5				S-2 (6 - 7')	5
		Gray, slightly silty SAND; moist to wet; locally silty, locally only trace of silt; (Ha) SP-SM.	7.2					
10	3	Gray, fine to medium and fine to coarse SAND, trace of silt; wet; locally slightly silty; (Ha) SP.	9.5				S-3 (10 - 11.5')	10
15	4							15
		Gray, slightly silty, fine to medium SAND; wet; (Ha) SP-SM.	16.5				S-4 (17 - 18.5')	
		Gray-brown, trace of clay to slightly clayey, slightly sandy SILT; wet; (He) ML.	19.2				S-5 (19.2 - 20')	
20	5	Gray, slightly silty, fine to medium SAND; wet; (Ha) SP-SM.	20.0					20
		Gray-brown, silty, fine SAND; wet; scattered shell fragments; (Ha) SM.	23.0				S-6 (23 - 24.5')	
25	6	Gray, slightly silty, fine to medium SAND; wet; locally coarse sand; (Ha) SP-SM.	25.0					25
		Gray, silty, fine SAND; wet; scattered shell fragments; (Ha) SM.	27.5				S-7 (28.5 - 30')	
30		BOTTOM OF BORING COMPLETED 10/6/2010	30.0					30

DRAFT

NOTES

1. In some cases where recovery was low in the upper part of the run, the soil sample may have slid down in the tube prior to removal from the ground.
2. Groundwater level, if indicated above, was estimated during probing and should be considered approximate.
3. Refer to KEY for definitions and explanation of symbols.
4. CT = corrosion test sample; TR = thermal resistivity sample; EN = environmental sample; GE = geotechnical sample; AR = archeological sample.

LEGEND

3 — 2" Plastic Tube - No Soil Recovery
2" Plastic Tube with Soil Recovery
Run No.
Ground Water Level ATD

Fir Island Farm Restoration
Skagit Wildlife Area
Skagit County, Washington

LOG OF GEOPROBE GP-06-10

January 2011 — 21-1-12318-001

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B-7

GEOPROBE_WELL 21-12318.GPJ 21-20447.GPJ 1/11/11 Log: PHZ Rev: PHZ Typ: LKN

LOG OF GEOPROBE

Date Started *10/6/10*	**Location**	**Ground Elevation:** *Approx. NA feet*
Date Completed *10/6/10*		**Typical Run Length** *5 feet*
Total Depth (ft) *30.0*	**Drilling Company:** *Cascade Drilling*	**Hole Diameter:** *2 inches*

Depth (ft)	Probe Run	Soil Description	Depth, ft.	Symbol	PID, ppm	Ground Water	Sample Number, Description, and Results	Depth (ft)
	1	Brown SILT, trace of fine sand, trace of clay; moist; disturbed appearance; (Agricultural layer) ML.	1.8				S-1 (0.5 - 1.5')	
		Gray-brown and orange-brown, trace of clay to slightly clayey, slightly fine sandy SILT; moist; numerous roots and organics; iron-oxide-stained; (Hm) ML/MH.					S-2 (2 - 3')	
5	2	Gray-brown, silty, fine SAND, trace of clay; wet; scattered organics and twigs; (Ha) SM.	5.5			During Drilling	S-3 (6 - 7')	5
		Gray, slightly silty, fine to medium SAND; wet; trace of wood fragments, locally trace of gravel; (Ha) SP-SM.	7.5					
10	3						S-4 (10 - 11.5')	10
		Gray, fine to medium and medium to coarse SAND, trace of gravel; wet; scattered rounded wood fragments; (Ha) SP.	12.0				S-5 (13 - 14.5')	
15	4							15
							S-6 (18.5 - 20')	
20	5							20
		Gray-brown, silty CLAY; wet; trace of fine shell fragments; (He) CL.	24.0				S-7 (24 - 25')	
25	6	Gray, trace of silt to slightly silty, medium to coarse SAND, trace of gravel; wet; (Ha) SP/SP-SM.	25.0				S-8 (26 - 27.5')	25
		Gray-brown, trace of sand to slightly sandy, clayey SILT; wet; scattered shell fragments; (He) ML.	29.0				S-9 (29 - 30')	
30			30.0					30

BOTTOM OF BORING
COMPLETED 10/6/2010

DRAFT

NOTES

1. In some cases where recovery was low in the upper part of the run, the soil sample may have slid down in the tube prior to removal from the ground.
2. Groundwater level, if indicated above, was estimated during probing and should be considered approximate.
3. Refer to KEY for definitions and explanation of symbols.
4. CT = corrosion test sample; TR = thermal resistivity sample; EN = environmental sample; GE = geotechnical sample; AR = archeological sample.

LEGEND

3 — 2" Plastic Tube - No Soil Recovery
2" Plastic Tube with Soil Recovery
Run No.
Ground Water Level ATD

Fir Island Farm Restoration
Skagit Wildlife Area
Skagit County, Washington

LOG OF GEOPROBE GP-07-10

January 2011 — 21-1-12318-001

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B-8

GEOPROBE_WELL 21-12318.GPJ 21-20447.GPJ 1/11/11 Log: PHZ Rev: PHZ Typ: LKN

LOG OF GEOPROBE

Date Started *10/5/10*	**Location**	**Ground Elevation:** *Approx. NA feet*
Date Completed *10/5/10*		**Typical Run Length** *5 feet*
Total Depth (ft) *30.0*	**Drilling Company:** *Cascade Drilling*	**Hole Diameter:** *2 inches*

Depth (ft)	Probe Run	Soil Description	Depth, ft.	Symbol	PID, ppm	Ground Water	Sample Number, Description, and Results	Depth (ft)
	1	Brown, slightly fine sandy SILT, trace of clay; moist; (Agricultural layer) ML.	1.2				S-1 (1.5 - 2.5')	
		Interbedded, gray and orange, silty, fine SAND and slightly clayey to clayey SILT; moist; trace of organics; (Hm) SM and ML.	2.5					
5	2	Gray, slightly silty, fine to medium SAND, trace of fine gravel; wet; (Ha) SP-SM.				During Drilling	S-2 (5 - 6.5')	5
		Gray, medium to coarse SAND grading to fine to medium SAND, trace of fine gravel, trace of silt; wet; (Ha) SP.	7.0					
		- 3-inch-thick layer of silty, fine sand with wood fragments at 8 feet.						
10	3						S-3 (10 - 11.5')	10
15	4						S-4 (15 - 16.5')	15
20	5						S-5 (20 - 21.5')	20
		- 2-inch-thick layer of silty sand at 22.5 feet.						
		Gray-brown, fine sandy SILT to silty, fine SAND; moist; laminated, scattered organic partings; (He) ML.	24.2				S-6 (24.2 - 25')	
25	6		25.0					25
		Gray, trace of silt to slightly silty, fine to medium SAND; wet; (Ha) SP/SP-SM.						
		Dark gray-brown, clayey SILT; wet; trace of shell fragments; (He) ML.	28.0				S-7 (29 - 30')	
30		BOTTOM OF BORING COMPLETED 10/5/2010	30.0					30

Refer to the report text for a proper understanding of the subsurface materials and probing methods. The stratification lines indicated below represent the approximate boundaries between soil types. Actual boundaries may be different if soil shifted inside sample tubes during extraction.

DRAFT

NOTES

1. In some cases where recovery was low in the upper part of the run, the soil sample may have slid down in the tube prior to removal from the ground.
2. Groundwater level, if indicated above, was estimated during probing and should be considered approximate.
3. Refer to KEY for definitions and explanation of symbols.
4. CT = corrosion test sample; TR = thermal resistivity sample; EN = environmental sample; GE = geotechnical sample; AR = archeological sample.

LEGEND

3 — 2" Plastic Tube - No Soil Recovery
2" Plastic Tube with Soil Recovery
Run No.
Ground Water Level ATD

Fir Island Farm Restoration
Skagit Wildlife Area
Skagit County, Washington

LOG OF GEOPROBE GP-08-10

January 2011 — 21-1-12318-001

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B-9

GEOPROBE_WELL 21-12318.GPJ 21-20447.GPJ 1/11/11 Log: PHZ Rev: PHZ Typ: LKN

LOG OF GEOPROBE

Date Started *10/6/10*	**Location**	**Ground Elevation:** *Approx. NA feet*
Date Completed *10/6/10*		**Typical Run Length** *5 feet*
Total Depth (ft) *30.0*	**Drilling Company:** *Cascade Drilling*	**Hole Diameter:** *2 inches*

Depth (ft)	Probe Run	Soil Description	Depth, ft.	Symbol	PID, ppm	Ground Water	Sample Number, Description, and Results	Depth (ft)
	1	Brown SILT, trace of fine sand, trace of clay; moist; disturbed appearence; (Agricultural layer) ML.	1.5					
		Interbedded, gray and orange-brown, slightly clayey SILT and silty, fine SAND; moist; scattered organics and iron-oxide staining; (Hm) ML/SM.	3.5				S-1 (2 - 3')	
5	2	Gray-brown, slightly fine sandy, slightly clayey SILT grading to silty, fine SAND, trace of clay; wet; (Hm) ML/SM.				During Drilling	S-2 (4 - 5')	5
		- Trace of organics at approximately 6 feet.	7.2					
10	3	Gray, trace of silt to slightly silty, fine to medium SAND, trace of fine gravel; moist to wet; local zones of coarser sand; (Ha) SP/SP-SM. - 4-inch-thick layer with abundant wood debris and twigs at 8 feet. - Scattered wood debris at 12 feet. - Scattered wood debris at 14 feet.					S-3 (10 - 11.5')	10
15	4		16.0				S-4 (16 - 17')	15
		Gray, silty, fine to medium SAND; wet; local pockets of slightly silty sand, scattered shell fragments; (Ha) SM. - Wood fragments between 18 and 18.5 feet. - Scattered twigs between 18.5 and 19.5 feet.						
20	5	Gray, medium to coarse SAND, trace of fine gravel; moist to wet; (Ha) SP.	20.0					20
		Gray-brown, silty, fine to medium SAND; wet; numerous shell fragments; (Ha) SM. - 1-inch-thick clayey silt layers at 22.8 and 23.2 feet.	21.8				S-5 (22 - 23.5')	
25	6	- 2-inch-thick clayey silt layer at 23.4 feet. - Coarser sand between 25 and 26 feet.					S-6 (26 - 27')	25
							S-7 (29 - 30')	
30		BOTTOM OF BORING COMPLETED 10/6/2010	30.0					30

DRAFT

NOTES

1. In some cases where recovery was low in the upper part of the run, the soil sample may have slid down in the tube prior to removal from the ground.
2. Groundwater level, if indicated above, was estimated during probing and should be considered approximate.
3. Refer to KEY for definitions and explanation of symbols.
4. CT = corrosion test sample; TR = thermal resistivity sample; EN = environmental sample; GE = geotechnical sample; AR = archeological sample.

LEGEND

3 — 2" Plastic Tube - No Soil Recovery
2" Plastic Tube with Soil Recovery
Run No.
Ground Water Level ATD

Fir Island Farm Restoration
Skagit Wildlife Area
Skagit County, Washington

LOG OF GEOPROBE GP-09-10

January 2011 — 21-1-12318-001

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B-10

GEOPROBE_WELL 21-12318.GPJ 21-20447.GPJ 1/11/11 Log: PHZ Rev: PHZ Typ: LKN

LOG OF GEOPROBE

Date Started *10/5/10*	**Location**	**Ground Elevation:** *Approx. NA feet*
Date Completed *10/5/10*		**Typical Run Length** *5 feet*
Total Depth (ft) *30.0*	**Drilling Company:** *Cascade Drilling*	**Hole Diameter:** *2 inches*

Depth (ft)	Probe Run	Soil Description	Depth, ft.	Symbol	PID, ppm	Ground Water	Sample Number, Description, and Results	Depth (ft)
	1	Brown SILT, trace of fine sand; moist; disturbed appearance; (Agricultural layer) ML.	1.2					
		Gray-brown and orange-brown, slightly clayey SILT, trace of fine sand; moist; scattered to numerous organics and iron-oxide-stained pockets; (Hm) ML.	3.2				S-1 (2 - 3')	
						During Drilling ▽	S-2 (4 - 5')	
5	2	Interbedded, gray, silty, fine SAND and fine sandy SILT, trace of clay; moist to wet; numerous roots and organics; (Ha) SM/ML.	5.0					5
		Gray, slightly silty, fine to medium SAND; wet; (Ha) SP-SM. - 1-inch-thick slightly clayey silt layer at 7.5 feet. - Coarser sand between 8 to 9 feet.						
10	3						S-3 (10 - 11.5')	10
		- Coarser sand pocket from 13 to 14 feet.						
15	4						S-4 (15 -16.5')	15
		- Coarser sand with scattered shell fragments below 17 feet.						
		Gray-brown, slightly clayey SILT; wet; (He) ML.	18.5					
		Gray-brown, silty, fine SAND; wet; (Ha) SM.	19.5					
20	5	Gray, slightly silty to silty, fine SAND; wet; (Ha) SP-SM.	20.0				S-5 (20 - 21.5')	20
		Gray-brown, trace of clay to slightly clayey, slightly sandy SILT; wet; (He) ML.	23.0 23.8				S-6 (24 - 25')	
25	6	Gray to gray-brown, silty, fine SAND; wet; (Ha) SM.	25.0					25
		Gray, trace to slightly silty, medium to coarse SAND; wet; (Ha) SP/SP-SM.	26.5 27.5					
		Gray-brown, fine sandy SILT to silty, fine SAND, trace of clay; wet; (He) ML/SM.					S-7 (29 - 30')	
30		Gray-brown, silty, fine SAND; wet; trace of fine shell fragments; (Ha) SM.	30.0					30
		BOTTOM OF BORING COMPLETED 10/5/2010						

DRAFT

NOTES

1. In some cases where recovery was low in the upper part of the run, the soil sample may have slid down in the tube prior to removal from the ground.
2. Groundwater level, if indicated above, was estimated during probing and should be considered approximate.
3. Refer to KEY for definitions and explanation of symbols.
4. CT = corrosion test sample; TR = thermal resistivity sample; EN = environmental sample; GE = geotechnical sample; AR = archeological sample.

LEGEND

3 — 2" Plastic Tube - No Soil Recovery
2" Plastic Tube with Soil Recovery
Run No.
▽ Ground Water Level ATD

Fir Island Farm Restoration
Skagit Wildlife Area
Skagit County, Washington

LOG OF GEOPROBE GP-10-10

January 2011 — 21-1-12318-001

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B-11

GEOPROBE_WELL 21-12318.GPJ 21-20447.GPJ 1/11/11 Log: PHZ Rev: PHZ Typ: LKN

LOG OF GEOPROBE

Date Started *10/5/10*	**Location**	**Ground Elevation:** *Approx. NA feet*
Date Completed *10/5/10*		**Typical Run Length** *5 feet*
Total Depth (ft) *30.0*	**Drilling Company:** *Cascade Drilling*	**Hole Diameter:** *2 inches*

Depth (ft)	Probe Run	Soil Description	Depth, ft.	Symbol	PID, ppm	Ground Water	Sample Number, Description, and Results	Depth (ft)
	1	Brown SILT, trace of fine sand; moist; disturbed appearance; (Agricultural layer) ML.	1.5					
		Gray and brown, slightly clayey SILT; moist; scattered organics and iron-oxide staining; (Hm) MH.	3.0				S-1 (2 - 3')	
		Gray, fine sandy SILT, trace of clay; wet; trace of organics; (Hm) ML.					S-2 (4 - 5')	
5	2	Gray, slightly silty, fine to medium SAND; wet; (Ha) SP-SM.	5.0			During Drilling		5
		Gray-brown, slightly clayey SILT, trace of fine sand; wet; (He) ML.	7.5					
		Gray, trace of silt to slightly silty, fine to medium SAND; wet; locally medium to coarse sand; (Ha) SP-SM/SP.	8.0					
10	3						S-3 (10 - 11.5')	10
		- 1-inch-thick layer of wood debris at 13 feet.						
15	4						S-4 (15 - 16.5')	15
		- 2-inch-thick layer of wood debris at 17.5 feet.	18.0					
		Gray-brown, silty, fine SAND; wet; scattered shell fragments; (Ha) SM.						
20	5	Gray, silty, fine SAND; wet; locally trace of clay, locally trace to scattered shell fragments; (Ha) SM.	20.5				S-5 (21 - 22')	20
25	6	Gray, trace of silt to slightly silty, fine to medium SAND; wet; (Ha) SP/SP-SM.	25.0 / 25.5				S-6 (25 - 26')	25
		Gray, silty, fine SAND; wet; trace of shell fragments; (Ha) SM.						
30		BOTTOM OF BORING COMPLETED 10/5/2010	30.0				S-7 (29 - 30')	30

DRAFT

NOTES

1. In some cases where recovery was low in the upper part of the run, the soil sample may have slid down in the tube prior to removal from the ground.
2. Groundwater level, if indicated above, was estimated during probing and should be considered approximate.
3. Refer to KEY for definitions and explanation of symbols.
4. CT = corrosion test sample; TR = thermal resistivity sample; EN = environmental sample; GE = geotechnical sample; AR = archeological sample.

LEGEND

3 — 2" Plastic Tube - No Soil Recovery
2" Plastic Tube with Soil Recovery
Run No.
Ground Water Level ATD

Fir Island Farm Restoration
Skagit Wildlife Area
Skagit County, Washington

LOG OF GEOPROBE GP-11-10

January 2011 — 21-1-12318-001

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B-12

GEOPROBE_WELL 21-12318.GPJ 21-20447.GPJ 1/11/11 Log: PHZ Rev: PHZ Typ: LKN

LOG OF GEOPROBE

Date Started *10/5/10*	**Location**	**Ground Elevation:** *Approx. NA feet*
Date Completed *10/5/10*		**Typical Run Length** *5 feet*
Total Depth (ft) *30.0*	**Drilling Company:** *Cascade Drilling*	**Hole Diameter:** *2 inches*

Depth (ft)	Probe Run	Soil Description	Depth, ft.	Symbol	PID, ppm	Ground Water	Sample Number, Description, and Results	Depth (ft)
	1	Brown SILT, trace of clay, trace of fine sand; moist; trace of roots and organics; (Agricultural layer) ML.	1.5				S-1 (0.5 - 1')	
		Interbedded, gray and orange-brown, slightly sandy SILT, trace of clay and silty, fine sand; wet; locally iron-oxide-stained, mottled; (Hm) ML.					S-2 (4 - 5')	
5	2	Gray, trace to slightly silty, fine to medium SAND; wet; local pockets of medium to coarse sand with trace of gravel; (Ha) SP/SP-SM.	6.2			During Drilling		5
10	3						S-3 (10 - 11.5')	10
15	4	- 4-inch-thick layer of wood debris at 14 feet.					S-4 (14 - 15')	15
		Gray, silty, fine SAND; wet; (Ha) SM.	17.0					
		Gray, slightly silty to silty, fine to medium SAND; wet; locally interbedded with layers of silt; locally numerous shell fragments; (Ha) SP-SM/SM.	18.2					
20	5						S-5 (20 - 21.5')	20
		Gray, silty, fine to medium SAND; wet; scattered wood and shell fragments; (Ha) SM.	21.8					
25	6	Gray, trace of silt to slightly silty, fine to medium SAND; wet; pockets of medium to coarse sand, trace of fine gravel; (Ha) SP-SM/SP.	25.0				S-6 (26 - 27.5')	25
		- Grades to silty below 29 feet.	29.5				S-7 (29.5 - 30')	
30		Gray, slightly fine sandy SILT; wet; (He) ML.	30.0					30
		BOTTOM OF BORING COMPLETED 10/5/2010						

Soil Description: Refer to the report text for a proper understanding of the subsurface materials and probing methods. The stratification lines indicated below represent the approximate boundaries between soil types. Actual boundaries may be different if soil shifted inside sample tubes during extraction.

DRAFT

NOTES

1. In some cases where recovery was low in the upper part of the run, the soil sample may have slid down in the tube prior to removal from the ground.
2. Groundwater level, if indicated above, was estimated during probing and should be considered approximate.
3. Refer to KEY for definitions and explanation of symbols.
4. CT = corrosion test sample; TR = thermal resistivity sample; EN = environmental sample; GE = geotechnical sample; AR = archeological sample.

LEGEND

3 — 2" Plastic Tube - No Soil Recovery
2" Plastic Tube with Soil Recovery
Run No.
Ground Water Level ATD

Fir Island Farm Restoration
Skagit Wildlife Area
Skagit County, Washington

LOG OF GEOPROBE GP-12-10

January 2011 — 21-1-12318-001

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B-13

GEOPROBE_WELL 21-12318.GPJ 21-20447.GPJ 1/11/11 Log: PHZ Rev: PHZ Typ: LKN

Draft

APPENDIX C

GEOTECHNICAL LABORATORY TESTING

APPENDIX C

GEOTECHNICAL LABORATORY TESTING

TABLE OF CONTENTS

Page

C.1 INTRODUCTION C-1

C.2 VISUAL CLASSIFICATION C-1

C.3 WATER CONTENT DETERMINATION C-1

C.4 GRAIN SIZE ANALYSES C-1

C.5 ATTERBERG LIMITS C-2

FIGURES

C-1 Title
C-1 Grain-Size Distribution, GP-01-10, GP-02-10, and GP-03-10
C-2 Grain-Size Distribution, GP-04-10, GP-05-10, and GP-06-10
C-3 Grain-Size Distribution, GP-07-10, GP-08-10, and GP-09-10
C-4 Grain-Size Distribution, GP-10-10, GP-11-10, and GP-12-10
C-5 Plasticity Chart, GP-01-10 through GP-11-10

Draft

APPENDIX C

GEOTECHNICAL LABORATORY TESTING

C.1 INTRODUCTION

This appendix presents the results of the laboratory testing program conducted for the Fir Island Farm project. Selected soil samples were tested in Shannon & Wilson's Seattle laboratory to characterize index and engineering properties of the soil at the project site.

A description of the above tests and their purposes in this study is presented in the following paragraphs. All laboratory tests were conducted in accordance with appropriate ASTM International (ASTM) standards.

C.2 VISUAL CLASSIFICATION

Soil samples recovered from the boring were visually reclassified in our laboratory using a system based on ASTM Designation: D 2488, Standard Recommended Practice for Description of Soils (Visual-Manual Procedure). This visual classification method allows for convenient and consistent comparison of soils from widespread geographic areas. Using this method, the soils are classified using the Unified Soil Classification System (Figure B-1). The individual sample classifications have been incorporated into the boring logs, presented in Figures B-2 through B-13 in Appendix A.

C.3 WATER CONTENT DETERMINATION

Natural water content of selected soil samples was determined in general accordance with ASTM Designation: D-2216, Standard Method of Laboratory Determination of Water (Moisture) Content of Soil, Rock, and Soil-Aggregate Mixtures. Comparison of natural water content of a soil with its index properties can be useful in characterizing soil unit weight, consistency, compressibility, and strength.

C.4 GRAIN SIZE ANALYSES

Grain size analyses were performed on selected samples of granular soils in general accordance with ASTM D 422, Standard Method for Particle-Size Analysis of Soils. Results of the grain size analyses are plotted as grain size distribution curves in Figures C-1 through C-4. Grain size distribution is used to assist in classifying soils and to provide correlation with soil properties, including permeability, capillarity, susceptibility to liquefaction, and sensitivity to moisture.

Draft

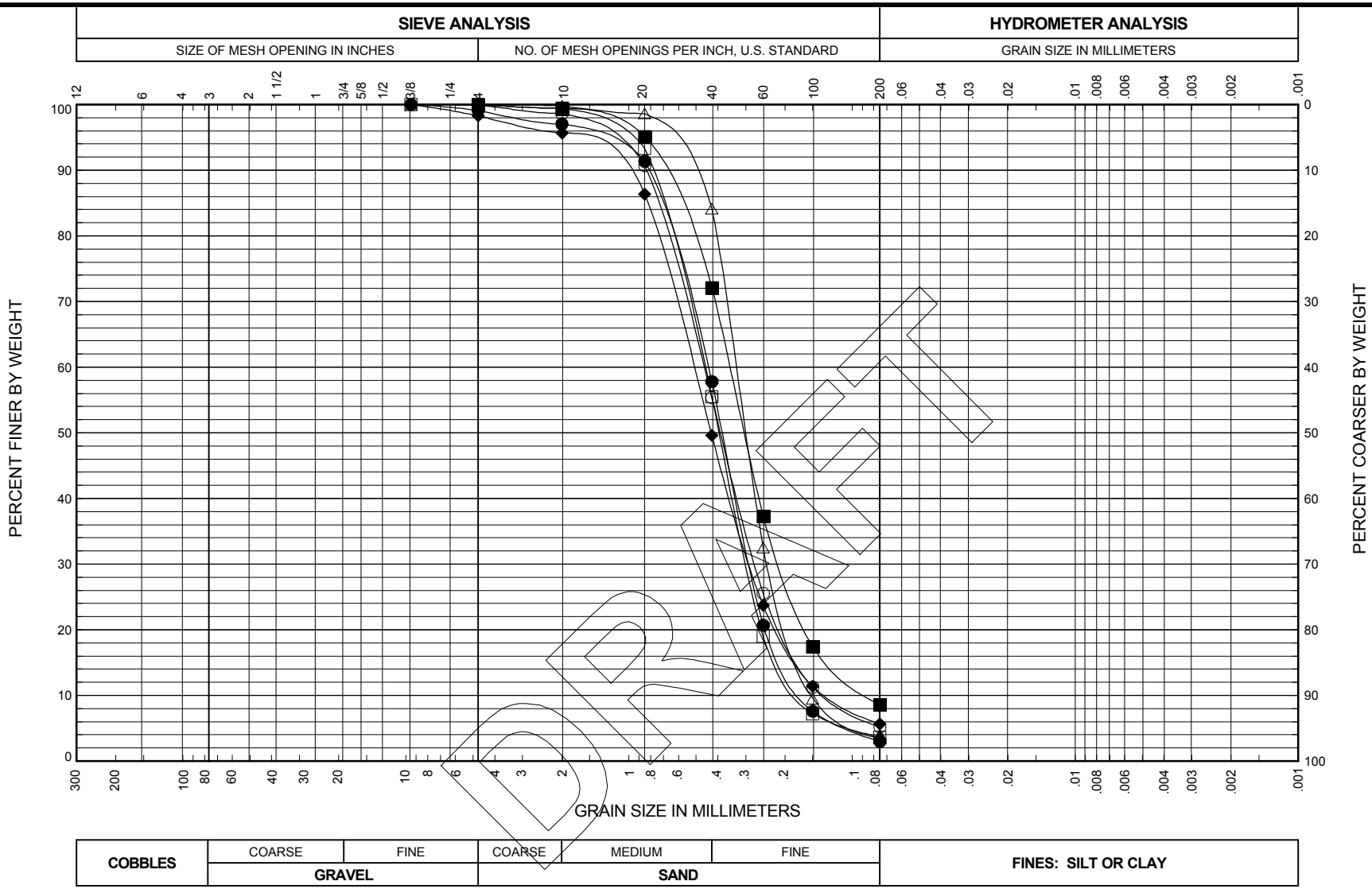
C.5 ATTERBERG LIMITS

Atterberg Limits tests were performed on selected samples in accordance with ASTM Designation: D 423-66(72), Standard Test Method of Liquid Limit of Soils, and ASTM Designation: D 424-59(71), Standard Test Method for Plastic Limit and Plasticity Index of Soils. The liquid limits and plasticity indices are presented in a Plasticity Chart, Figure C-5.

Soil at its natural water content was passed through the No. 40 sieve, and distilled water was added to bring its moisture content near the liquid limit. The liquid limit was then estimated using the one-point method. Afterwards, the remaining soil was used for the plastic limit test.

The Atterberg Limit tests the water content of a sample at which the behavior of the soil changes from that of a semi-plastic fluid to that of a plastic solid (Liquid Limit), and from a plastic solid to a non-plastic solid (Plastic Limit). This standardized test provides a measure of the plasticity of the material which, in turn, is related to the type and percentage of clay present. These tests are useful for identification and classification. Researchers have related Atterberg Limits to strength and settlement properties of clayey material. In general, the more plastic a soil is, the more sensitive it is to moisture and the more difficult it is to handle during earthwork construction.

Draft



BORING AND SAMPLE NO.	DEPTH (feet)	U.S.C.S. SYMBOL	SAMPLE DESCRIPTION	FINES %	NAT. W.C. %	LL %	PL %	PI %
● GP-01-10	16.0	SP	Gray SAND, trace of silt and fine gravel	3.0	21.5			
■ GP-01-10, S-6	25.0	SP-SM	Gray, slightly silty SAND	8.6	24.4			
▲ GP-01-10, S-7	33.0	SP	Gray, fine SAND, trace of silt; trace of organics	4.0	25.9			
◆ GP-02-10	15.0	SP-SM	Gray, slightly silty SAND, trace of fine gravel	5.7	22.2			
○ GP-02-10	25.0	SP-SM	Gray, slightly silty SAND	5.2	20.3			
□ GP-03-10	14.5	SP	Gray SAND, trace of silt	3.7	21.9			
△ GP-03-10	21.0	SP	Gray, fine to medium SAND, trace of silt	3.5	24.4			

Fir Island Farm Restoration
Skagit Wildlife Area
Skagit County, Washington

GRAIN SIZE DISTRIBUTION
GP-01-10, GP-02-10, and GP-03-10

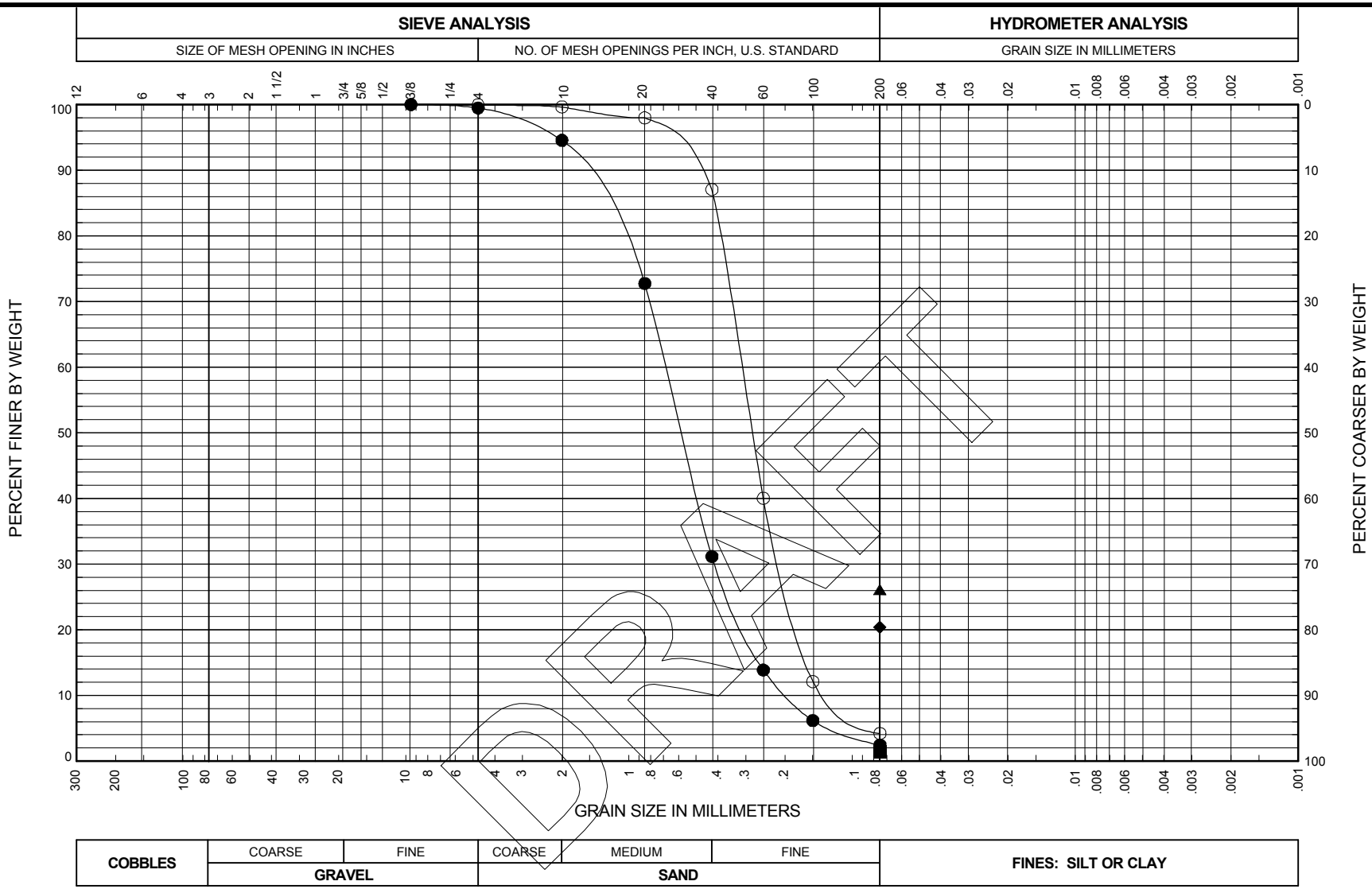
January 2011 21-1-12318-001

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. C-1

FIG. C-1

GSA_MAIN 21-12318.GPJ SHAN_WIL.GDT 1/11/11



BORING AND SAMPLE NO.	DEPTH (feet)	U.S.C.S. SYMBOL	SAMPLE DESCRIPTION	FINES %	NAT. W.C. %	LL %	PL %	PI %
● GP-04-10	10.0	SP	Gray SAND, trace of silt and fine gravel	2.5	20.5			
■ GP-05-10	8.0	SP	Gray SAND, trace of silt; trace of wood fragments	1.5	27.7			
▲ GP-05-10	25.0	SM	Gray, silty SAND; scattered organics	26.1	35.9			
◆ GP-06-10	6.0	SM	Dark gray, silty, fine to medium SAND; trace of organics	20.4	37.9			
○ GP-06-10	10.0	SP	Gray SAND, trace of silt	4.2	26.8			

Fir Island Farm Restoration
Skagit Wildlife Area
Skagit County, Washington

GRAIN SIZE DISTRIBUTION
GP-04-10, GP-05-10, and GP-06-10

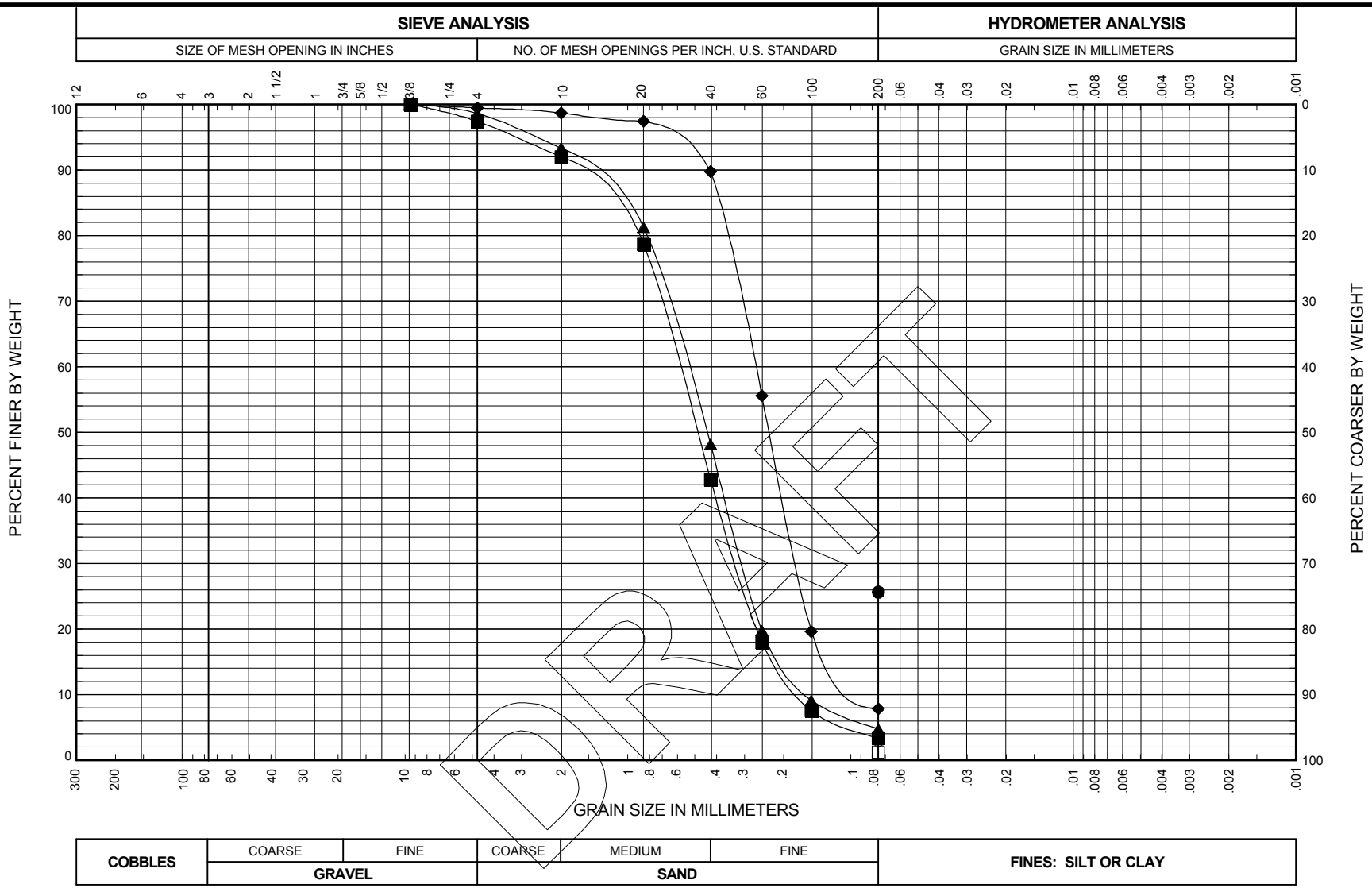
January 2011 21-1-12318-001

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. C-2

GSA_MAIN 21-12318.GPJ SHAN_WIL.GDT 1/11/11

FIG. C-2



BORING AND SAMPLE NO.	DEPTH (feet)	U.S.C.S. SYMBOL	SAMPLE DESCRIPTION	FINES %	NAT. W.C. %	LL %	PL %	PI %
● GP-07-10	6.0	SM	Gray, silty, fine SAND; scattered organics	25.6	45.0			
■ GP-07-10	13.0	SP	Gray SAND, trace of silt and fine gravel	3.4	23.0			
▲ GP-07-10	26.0	SP	Dark gray SAND, trace of silt and fine gravel	4.8	21.0			
◆ GP-08-10	5.0	SP-SM	Gray, slightly silty SAND, trace of fine gravel	7.8	27.6			
○ GP-08-10	15.0	SP	Gray SAND, trace of silt	3.0	26.3			
□ GP-09-10	10.0	SP	Gray SAND, trace of silt	1.3	23.0			

Fir Island Farm Restoration
Skagit Wildlife Area
Skagit County, Washington

GRAIN SIZE DISTRIBUTION
GP-07-10, GP-08-10, and GP-09-10

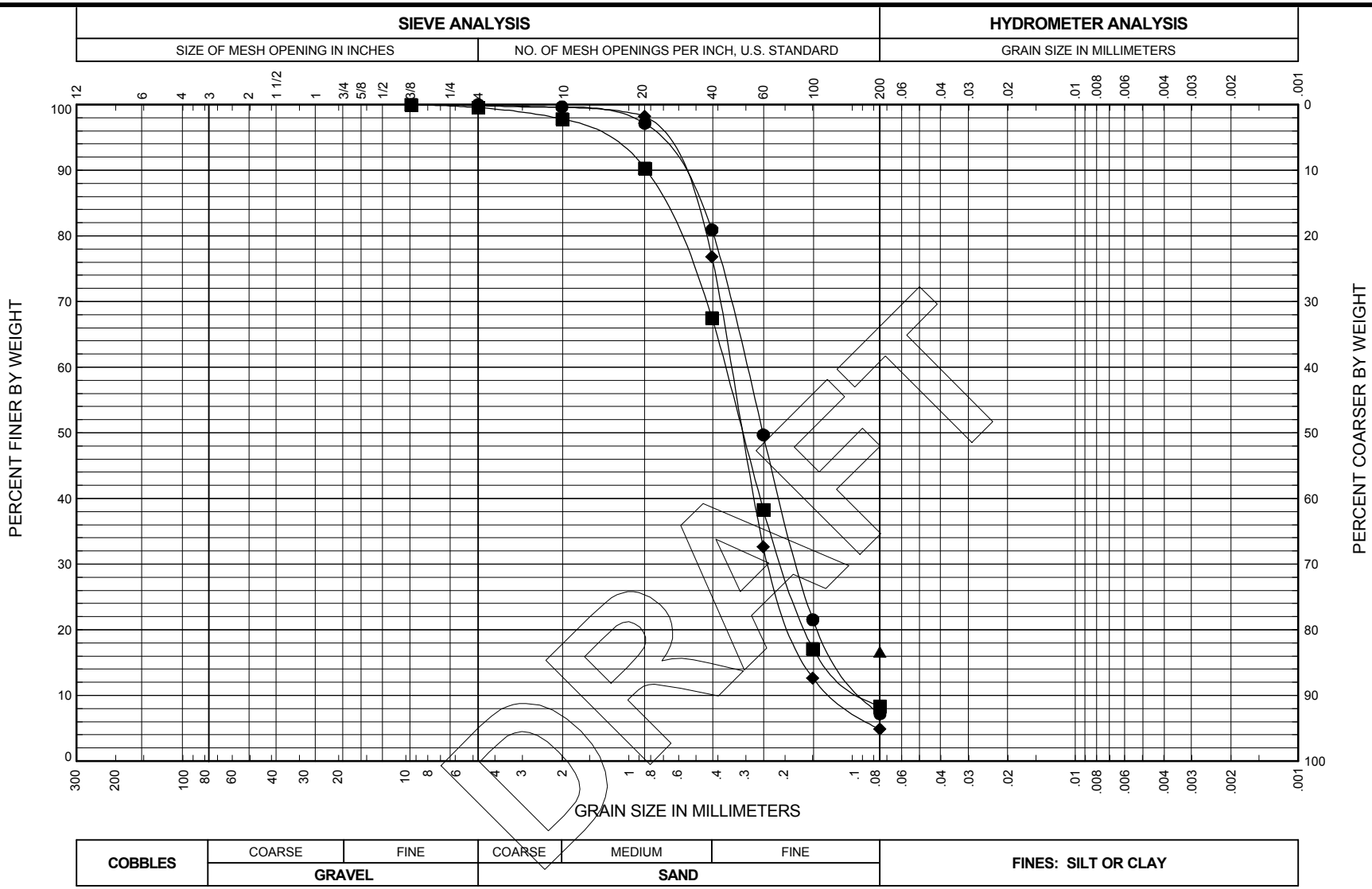
January 2011 21-1-12318-001

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. C-3

DRAFT

GSA_MAIN 21-12318.GPJ SHAN_WIL.GDT 1/11/11



BORING AND SAMPLE NO.	DEPTH (feet)	U.S.C.S. SYMBOL	SAMPLE DESCRIPTION	FINES %	NAT. W.C. %	LL %	PL %	PI %
● GP-10-10	10.0	SP-SM	Gray, slightly silty, fine to medium SAND	7.2	25.4			
■ GP-11-10	10.0	SP-SM	Gray, slightly silty SAND	8.4	23.9			
▲ GP-11-10	21.0	SM	Gray, silty, fine SAND; scattered shell fragments, trace of organics	16.6	32.9			
◆ GP-12-10	10.0	SP	Gray, fine to medium SAND, trace of silt	4.8	25.5			

Fir Island Farm Restoration
Skagit Wildlife Area
Skagit County, Washington

GRAIN SIZE DISTRIBUTION
GP-10-10, GP-11-10, and GP-12-10

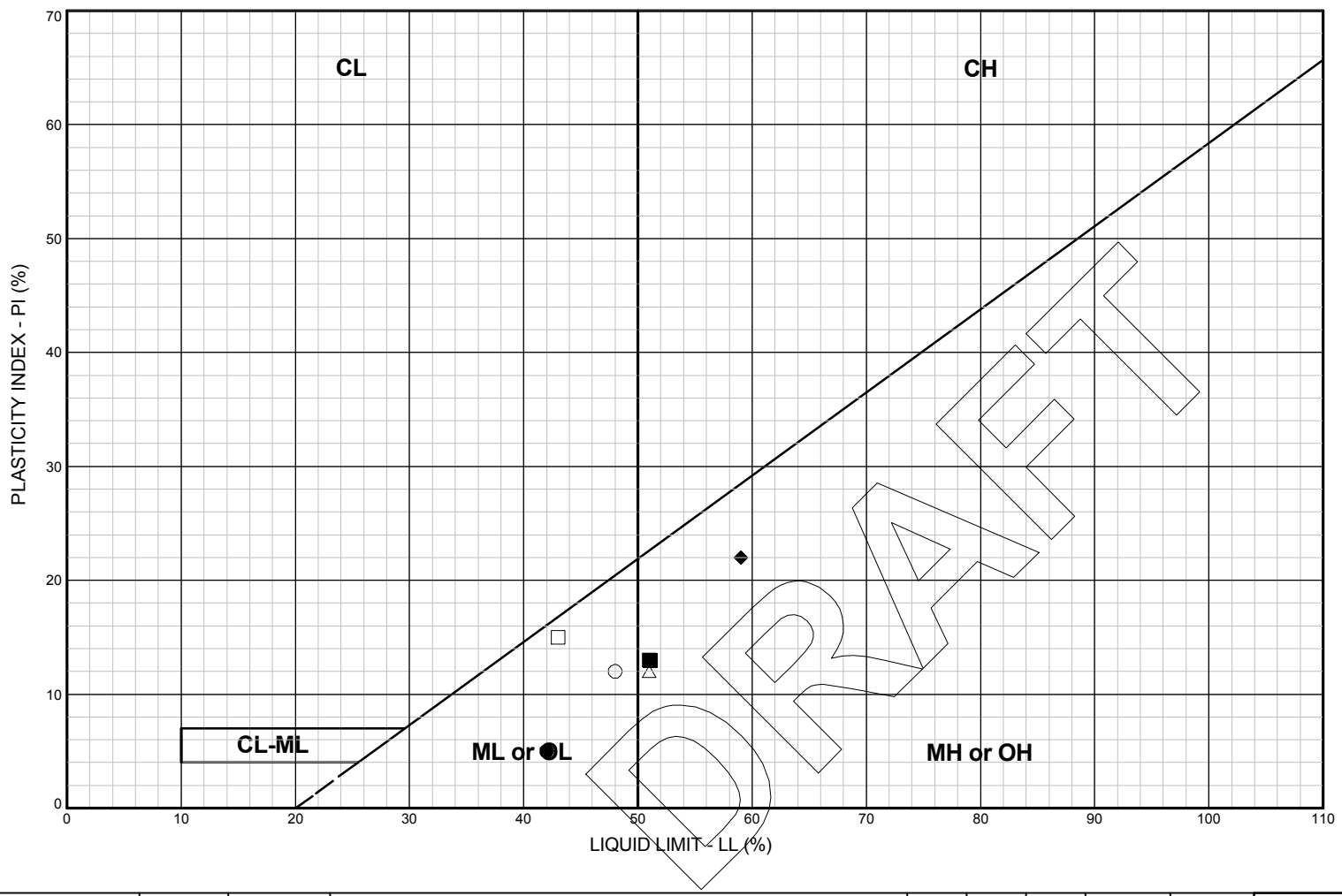
January 2011 21-1-12318-001

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. C-4

GSA_MAIN 21-12318.GPJ SHAN_WIL.GDT 1/11/11

FIG. C-4



LEGEND

CL: Low plasticity inorganic clays; sandy and silty clays

CH: High plasticity inorganic clays

ML or OL: Inorganic and organic silts and clayey silts of low plasticity

MH or OH: Inorganic and organic silts and clayey silts of high plasticity

CL-ML: Silty clays and clayey silts

BORING AND SAMPLE NO.	DEPTH (feet)	U.S.C.S. SYMBOL	SOIL CLASSIFICATION	LL %	PL %	PI %	NAT. W.C. %	PASS. #200, %
● GP-01-10	11.0	ML	Gray SILT, trace of fine sand and clay; trace of fine organics	42	37	5	46.8	
■ GP-02-10	6.0	MH	Dark brown, slightly clayey SILT, trace of sand; scattered fine organics	51	38	13	58.8	
GP-04-10	29.0	ML	Gray, fine sandy SILT; trace of shell fragments, trace of fine organics	NP	NP	NP	28.7	
◆ GP-06-10, S-1	2.0	MH	Light brown, slightly sandy, slightly clayey to clayey SILT; scattered organics, scattered iron oxide nodules	59	37	22	56.4	
○ GP-07-10	2.0	ML	Gray, clayey SILT; trace of organics, trace of iron oxide	48	36	12	53.6	
□ GP-08-10	29.0	ML	Gray, clayey SILT, trace of fine sand	43	28	15	50.3	
△ GP-11-10	2.0	MH	Light gray-brown, slightly clayey SILT, trace of fine to medium sand; scattered organics	51	39	12	53.5	

Fir Island Farm Restoration
Skagit Wildlife Area
Skagit County, Washington

PLASTICITY CHART
GP-01-10 through GP-11-10

January 2011 21-1-12318-001

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. C-5

FIG. C-5

ATT_MAIN 21-12318.GPJ SHAN WIL.GDT 1/11/11

Draft

APPENDIX D

IMPORTANT INFORMATION ABOUT YOUR GEOTECHNICAL/ENVIRONMENTAL REPORT

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