Smith Island Restoration Project

Dike Crossing at Williams Pipeline
Preliminary Settlements Analysis

TO: Bill Derry / SEA
FROM: Ken Green / SEA
Joel Theodore / SEA
DATE: May 21, 2007 (Revised Jan 15, 2008)

Introduction
A setback dike is proposed for Snohomish County's proposed Smith Island Restoration Project. The purpose of the proposed dike is to protect existing infrastructure following the breaching of the existing dikes for the purpose of tidal marsh restoration. The soils at the site are generally soft and compressible for considerable depth and will settle under the embankment loading of the proposed dike. In addition, the proposed dike alignment will cross the existing, 18-inch Williams gas pipeline. Excessive settlement of the soils beneath the pipeline will cause undesirable stresses in the pipeline. This memorandum provides preliminary estimates of settlement under the dike at the location of test boring DB-2, which was drilled within the vicinity of a potential site for the dike crossing of the Williams Pipeline. Figure 1 shows the project vicinity, boring location, and approximate location of the dike crossing of the pipeline.

Existing Conditions and Information
Prior borings and work near the western limits of the project site (along I5) and one boring DB-1 near the south central side of the Harnden property suggests that we can expect to find very soft silt and/or clayey silt with peat and organics in the top 10 to 20 feet below the ground surface in almost all areas of at least the western side of the Project. This zone has been found to be very soft and compressible and will likely account for about 75 percent or more of the total settlement experience by the proposed dike. Another soft compressible zone predominates at a depth of about 75- to 85-feet throughout much of the site. However, most of the settlement occurs in the upper layer because of the greater increase in stress influence from the dike within this zone.

Test boring DB-2 was drilled for this project on September 28th, 2006 at the location shown in Figure 1. The boring was located in the field based on client specification, equipment access, and maintaining safe clearance distance from the existing Williams gas pipeline. The client specified that the boring location was within 1,000 feet of the planned crossing; however the exact crossing location was undetermined at the time of the exploration. The boring was drilled to a depth of 151.5 feet below the ground surface (bgs). The boring log is included as Attachment A to this memorandum.
The soils in boring DB-2 generally consisted of an upper layer of interbedded very soft to soft silt with varying amounts of organics and very loose to loose sand that consisted of fine-grained sand to about 25 feet bgs, underlain by loose to dense poorly graded sand with varying amounts of silt content to about 76 feet bgs. The poorly graded sand became medium dense at 22 feet bgs and dense at 60 feet bgs. At 76 feet bgs, a layer of very soft, fat clay was encountered to about 86 feet bgs, underlain by stiff silt with varying amounts of sand content to about 110 feet bgs. From 110 feet to about 128 feet bgs, dense poorly graded sand consisting of fine-grained sand and varying amounts of silt content was encountered. This was underlain by dense to very dense, well graded sand with varying amounts of gravel, silt, and scattered organics to the bottom of the boring at 151.5 feet bgs. The well graded sand with gravel became very dense at 140 feet bgs.

Groundwater was encountered at about 6.5 feet bgs at the time of drilling which was about the same elevation as the surrounding wetland areas.

**Settlement Estimate**

As a part of this work, a settlement estimate was evaluated based on the new test boring, DB-2. Subsurface data collected from this boring was used to estimate the settlement based on the current proposed dike configurations. Proposed dike configurations are shown in Figure 2. This evaluation considered configurations Type 1 and 2, but did not consider Type 1A or Type 2B. Note that the top elevation of the Type 1 dike is at 9.2 feet (NGVD29) while the corresponding elevation is 10.6 feet for the Type 2 dike.

Up to approximately 3 feet of existing fill is present in the vicinity of the dike crossing. However, the exact location and elevation of the fill relative to the dike crossing is not currently known. In addition, the elevation of the boring was not known at the time of the analyses. If present at the pipeline crossing, any existing fill will tend to reduce the dike-induced settlement because of its preloading benefits. Therefore, in order to evaluate the potential impact of the existing fill on settlement, two settlement estimates were completed for each dike configuration considered. One estimate assumed the fill is located at the pipeline crossing and a second estimate assumed it is not located at the pipeline crossing. Results of the settlement estimates are provided in Table 1.

<table>
<thead>
<tr>
<th>Dike Type (See Figure 2)</th>
<th>Assumed Existing Fill Height (ft)</th>
<th>Assumed Fill Height Required (ft)</th>
<th>Estimated Dike Settlement (in)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type 1</td>
<td>0</td>
<td>9.2</td>
<td>25</td>
</tr>
<tr>
<td>Type 1</td>
<td>3</td>
<td>6.2</td>
<td>16</td>
</tr>
<tr>
<td>Type 2</td>
<td>0</td>
<td>10.6</td>
<td>30</td>
</tr>
<tr>
<td>Type 2</td>
<td>3</td>
<td>7.6</td>
<td>21</td>
</tr>
</tbody>
</table>

Note: Secondary compression was not evaluated and is not included in the estimated dike settlement.

The analysis indicates the magnitude of the dike settlement is on the order of 16-inches to 30 inches. The lower values of Table 1 for each dike type is based on the presence of 3 feet of existing fill at the pipeline crossing site while the higher values assume it is absent. This
estimate is based on placing new fill (the amount of fill depends upon if the existing fill is assumed present or absent), determining the settlement, adding additional fill to keep the top of dike elevation at the design level, and then determining the settlement again. The second addition of fill resulted in 2 to 4 inches of settlement for the case where the initial 3 feet of fill was considered present and 3 to 5 inches where it was omitted. The estimated dike settlement presented in Table 1 includes these second-cycle settlements. In reality, this cycle (of settlement and addition of fill) would continue until settlements are negligible. Although secondary settlement was not evaluated in this study, it is anticipated to be less than 30 percent of the primary settlement provided in Tables 1 and 2 and is expected to occur over a period of 30 years or more.

Various other settlement estimates from previous projects in the vicinity have also concluded that about 18- to 24-inches of total settlement can be expected for the proposed dike in most locations, with 13- to 18-inches being attributed to the soft surficial zone. The total settlement will be influenced by the height of the dike, rate of loading, and depth and characteristics of the compressible soils.

The estimate of 16- to 30-inches includes settlement of compressible soils from the existing ground surface to over 80 feet below grade. However, settlements occurring above the pipeline are not anticipated to adversely impact the pipeline. It is only the settlement occurring below the pipeline that will tend to bend and elongate the pipeline, inducing additional stresses. Based on the assumption that the bottom of the pipeline is 8.5 feet below existing grade (assuming 30-inch diameter pipe + 5-feet cover), settlement below the pipe for the same loading cases as before were estimated and are presented in Table 2.

**TABLE 2**

Estimated Settlement Below Gas Pipeline

<table>
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<tr>
<th>Dike Type (See Figure 2)</th>
<th>Assumed Existing Fill Height (ft)</th>
<th>Assumed Fill Height Required (ft)</th>
<th>Estimated Dike Settlement (in)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type 1</td>
<td>0</td>
<td>9.2</td>
<td>15</td>
</tr>
<tr>
<td>Type 1</td>
<td>3</td>
<td>6.2</td>
<td>12</td>
</tr>
<tr>
<td>Type 2</td>
<td>0</td>
<td>10.6</td>
<td>17</td>
</tr>
<tr>
<td>Type 2</td>
<td>3</td>
<td>7.6</td>
<td>14</td>
</tr>
</tbody>
</table>

Note: Secondary compression was not evaluated and is not included in the estimated dike settlement.

It is anticipated that this settlement would be the largest directly under the center of the dike and approach zero settlement at a distance of approximately 50 feet on either side of the dike centerline. This zone would likely broaden if the flatter slopes of Types 1A and 2A are constructed. In addition, settlement estimates using Type 1A or Type 2A geometry would be larger than those presented in Tables 1 and 2.

**Other Considerations**

Two standard dike cross sections have been proposed as possible design sections but the configuration, exact layout and details have not been determined yet to our knowledge. The two standard dike sections considered in the preliminary design consist of the following:
• U.S. Army Corps of Engineers design for a 5-year flood plus 1 foot (Figure 2, type 1 dike). This dike would have a top elevation of 9.2 NGVD29). Type 1A as shown in Figure 2 would modify this section for a flatter water-side slope in many areas.

• U.S. Army Corps of Engineers design for a 10-year flood plus 2 feet (Figure 2, Type 2 dike). This dike would have a top elevation of 10.6 (NGVD29). Type 2A as shown in Figure 2 would modify this section for a flatter water-side slope in many areas.

The settlement of the ground surface and pipeline is expected to vary somewhat depending upon the height of and slopes of the proposed new dike. The estimates of this evaluation assumed top of the dike at approximate elevation 9.2 feet (NGVD29) for Type 1 and 10.6 feet for Type 2. A taller and/or wider dike will induce larger settlements. Accurate elevations of the existing ground surface must be established at the proposed dike crossing location. Accurate elevations of the gas pipeline, type of backfill used, and deformation limits for the pipe must be determined from Williams.

If a surcharge is applied to accelerate the total settlement of the dike to minimize future settlement, the impact and initial settlement to the pipeline is also expected to be greater. It is assumed that the dike construction would be staged to allow strength gain and consolidation of the foundation soils prior to completing the embankment to full height. If lateral spreading of the foundation occurs, this could lead to additional stress or movement within the pipe zone.

A more detailed settlement analysis is recommended once the dike geometry and the pipeline crossing location have been determined.

**Construction Sequencing**

In order to limit deformations and prevent global stability failure of the dike, staged construction will likely be required. Stability analysis performed for construction of the I-5 embankments which are similar in height to the proposed dike suggests that embankments more than about 9 feet high could induce lateral spreading of foundations. This condition can be controlled by construction of fills under controlled loading conditions. The embankments would be constructed to partial height and then cease additional filling to allow consolidation and strength gain within the foundation soils prior to completing the embankment to full height. This is similar to the construction method used for the new dikes recently construction by the City of Everett.

In the course of dike construction, surcharging the dikes with additional fill height could accelerate the consolidation of foundation soils. Later when the surcharge is removed, the surcharging would be expected to have accelerated settlement, reducing the future settlement and maintenance associated with maintaining the dike elevation as settlement slowly occurs.

Further analyses are required to determine construction sequencing requirements. It is recommended these analyses be completed once the dike geometry and pipeline crossing locations have been determined.
Limitations

This report has been prepared for the exclusive use of Snohomish County for specific application to the Smith Island Restoration Project in accordance with generally accepted geotechnical engineering practice. No other warranty, express or implied, is made.

The boring log and related information depict subsurface conditions only at the specific locations and times indicated. Subsurface conditions and water levels at other locations may differ from conditions occurring at these indicated locations. Also, the passage of time may result in a change in the conditions at these locations. It does not necessarily reflect site-wide strata variations that may exist. If variations in subsurface condition from those described are noted during construction, recommendations in this report must be re-evaluated.

The exploratory activities, testing procedures, and evaluative approaches used in this exploration are consistent with those normally used in geotechnical engineering for facilities of this type. In a very real sense, however, the information obtained is fragmentary. The dispersed borings and tests represent a small sampling from the entire soil volume. Although fragmentary, design guidelines have been developed from these data.

In the event that any changes in the nature, design, or location of the facilities are planned, the conclusions and recommendations contained in this report should not be considered valid unless the changes are reviewed and conclusions of this report modified or verified in writing by CH2M HILL. CH2M HILL is not responsible for any claims, damages, or liability associated with interpretation of subsurface data or reuse of the subsurface data or engineering analyses without the express written authorization of CH2M HILL.

The scope of services did not include an environmental assessment for the presence or absence of wetlands or hazardous or toxic materials in the soil, surface water, groundwater, or air, on or below or around this site. Any statement in this report or on the boring logs regarding odors, colors, or unusual or suspicious items or conditions are strictly for the information of the client. Prior to development of this site, an environmental assessment may be necessary.

References

Washington State Department of Transportation (1965). L-1635 Snohomish River to Marysville, Union Slough Bridge, C.S. 3113, PHS No. 1 (SR-5), Station 448 Foundation Investigation, December.


### Soil Boring Log

**Project:** Smith Island Restoration  
**Elevation:** ~4 feet  
**Location:** ~100’ E of 51st, 400’ N of 12th  
**Drilling Contractor:** Gregory Drilling, Inc.  
**Drilling Method and Equipment:** CME 85 truck, mud rotary, SPT, 140-lb auto-trip hammer  
**Water Levels:** See log  
**Start:** 09/28/06  
**Finish:** 09/28/06  
**Logger:** S. McGinnis

<table>
<thead>
<tr>
<th>Depth Below Ground Surface</th>
<th>Sample</th>
<th>Standard Penetration Test Results</th>
<th>Soil Description</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>6”-6”-6” (N)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ground Surface</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S-1 SS 7 3-3-2 (5)</td>
<td></td>
<td>(0-1”): <strong>Silty Sand (SM)</strong>, light brown, dry, loose, fine sand</td>
<td>2.5’: SPT at 07:52</td>
<td></td>
</tr>
<tr>
<td>S-2 SS 9 2-1-0 (1)</td>
<td></td>
<td><strong>Poorly Graded Sand (SP)</strong>, gray, moist, loose, fine sand</td>
<td>5’: Bottom of sampler wet, est. groundwater at 6.5’ bgs while drilling.</td>
<td></td>
</tr>
<tr>
<td>S-3 SS 0 0-1-1 (2)</td>
<td></td>
<td><strong>Poorly Graded Sand (SP)</strong>, Same as above but saturated</td>
<td>7.5’: Assume same as above, but sample fell out because loose and saturated.</td>
<td></td>
</tr>
<tr>
<td>S-4 SS 13 0-0-0 (0)</td>
<td></td>
<td>Sample A (0-6”): <strong>Poorly Graded Sand (SP)</strong>, same as above, saturated, very loose, grades to: Sample B (6-13”): <strong>Organic Silt, OH</strong>, brown, saturated, very soft, wood fibers</td>
<td>10’: SPT at 08:06</td>
<td></td>
</tr>
</tbody>
</table>
| Shel-1 Shel 24 N/A |                                  | Pushed Shelby: **Poorly Graded Sand (SP)**, dark gray, wet, very loose, very fine sand at top of Shelby tube and **Organic Silt, OH**, brown, saturated, very soft, wood fibers at the bottom of the Shelby tube | Sample S-4B Test Results:  
  - **WC** = 78.7%  
  - **LL** = 92%  
  - **PL** = 59%  
  - **PI** = 33%  
| Shel-2 Shel 0 N/A |                                  | **No Recovery**  
  A small bit of **Poorly Graded Sand (SP)** same as above around edge of sampler | Middle (10-20”): WC = 22.3%  
  Wet Density = 119.6%  
  Dry Density = 97.8%  
  Bottom (20-30”): **WC** = 193.4%  
  Wet Density = 81.9%  
  Dry Density = 27.9%  
| S-6 SS 0 0-0-1 (1) |                                  | **No Recovery**  
  Sample A (0-6”): **Poorly Graded Sand (SP)**, same as above  
  Sample B (6-8”): **Elastic Silt, MH**, gray-dark brown, saturated, very soft, woody fibers | 17.5’: Pushed Shelby, no recovery. Took SPT for sample, no recovery.  
  Sample S-5B Test Results:  
  - **WC** = 53.8%  
  - **LL** = 58%  
  - **PL** = 32%  
  - **PI** = 26%  
| Shel-1 Shel 24 N/A |                                  | Pushed Shelby, no recovery. Took SPT for sample, no recovery.  
  Sample S-5B Test Results:  
  - **WC** = 53.8%  
  - **LL** = 58%  
  - **PL** = 32%  
  - **PI** = 26%  |
# SOIL BORING LOG

**Project Number:** 349874  
**Boring Number:** DB-2  
**Sheet:** 2 of 8  

**Project:** Smith Island Restoration  
**Location:** ~100' E of 51st, 400' N of 12th  
**Elevation:** ~4 feet  
**Drilling Contractor:** Gregory Drilling, Inc.  
**Drilling Method and Equipment:** CME 85 truck, mud rotary, SPT, 140-lb auto-trip hammer  
**Water Levels:** See log  
**Start:** 09/28/06  
**Finish:** 09/28/06  
**Logger:** S. McGinnis

<table>
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<tr>
<th>Depth Below Ground Surface</th>
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<th>Standard Penetration Test Results</th>
<th>Soil Description</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>6&quot;-6&quot;-6&quot; (N)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20'</td>
<td>Shel-3</td>
<td>Shel 0</td>
<td>NO RECOVERY</td>
<td></td>
</tr>
<tr>
<td></td>
<td>S-7</td>
<td>SS 0</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>S-8</td>
<td>SS 15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25'</td>
<td>S-9</td>
<td>SS 8</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>S-10</td>
<td>SS 10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>30'</td>
<td>S-11</td>
<td>SS 12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>35'</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>40'</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Sample S-8B Test Results:**  
  - WC = 178.6%  
  - P200 = 39%

- **Sample S-10 Test Results:**  
  - WC = 24.4%  
  - Gravel = 0%  
  - Sand = 90.7%  
  - P200 = 9.2%

- **Sample S-11 Test Results:**  
  - WC = 178.6%  
  - P200 = 39%

- **Sample S-10 Test Results:**  
  - WC = 24.4%  
  - Gravel = 0%  
  - Sand = 90.7%  
  - P200 = 9.2%

- **Switch to mud rotary at 09:40.**
- **Switch to mud rotary at 09:40.**
- **Switch to mud rotary at 09:40.**
- **Switch to mud rotary at 09:40.**
SOIL BORING LOG

PROJECT: Smith Island Restoration
ELEVATION: ~4 feet
DRILLING METHOD AND EQUIPMENT: CME 85 truck, mud rotary, SPT, 140-lb auto-trip hammer
WATER LEVELS: See log

LOCATION: ~100' E of 51st, 400' N of 12th
DRILLING CONTRACTOR: Gregory Drilling, Inc.

START: 09/28/06  FINISH: 09/28/06  LOGGER: S. McGinnis

<table>
<thead>
<tr>
<th>DEPTH BELOW GROUND SURFACE</th>
<th>SAMPLE</th>
<th>STANDARD PENETRATION TEST RESULTS</th>
<th>SOIL DESCRIPTION</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>40'</td>
<td>S-12 SS</td>
<td>10 9-8-6 (14)</td>
<td>POORLY GRADED SAND WITH SILT, SP-SM</td>
<td>Similar to above but no organics, &quot;clean&quot;</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>40': SPT at 10:15. SP sample has drill mud mixed in from sidewalls of sampler. Appears &quot;clean&quot; but test results may come back silty.</td>
</tr>
<tr>
<td>50'</td>
<td>S-13 SS</td>
<td>11 11-11-15 (25)</td>
<td>POORLY GRADED SAND (SP)</td>
<td>Similar to above, no organics, &quot;clean&quot;</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>45': SPT at 10:22</td>
</tr>
<tr>
<td>55'</td>
<td>S-14 SS</td>
<td>10 11-11-13 (24)</td>
<td>POORLY GRADED SAND (SP)</td>
<td>Similar to above but finer grained, &quot;clean&quot;</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>50': SPT at 10:32</td>
</tr>
<tr>
<td>60</td>
<td>S-15 SS</td>
<td>13 12-13-15 (28)</td>
<td>POORLY GRADED SAND (SP)</td>
<td>Same as previous samples, gray, wet (saturated), medium dense, fine sand, scattered woody organics, &quot;clean&quot;</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>55': SPT at 10:41</td>
</tr>
</tbody>
</table>

Sample S-12 Test Results:
WC = 22%
P200 = 8.4%

Sample S-14 Test Results:
WC = 28.2%
Gravel = 0%
Sand = 82.5%
P200 = 17.5%
## Soil Boring Log

**Project:** Smith Island Restoration  
**Location:** ~100' E of 51st, 400' N of 12th  
**Elevation:** ~4 feet  
**Drilling Contractor:** Gregory Drilling, Inc.  
**Drilling Method and Equipment:** CME 85 truck, mud rotary, SPT, 140-lb auto-trip hammer  
**Water Levels:** See log  
**Start:** 09/28/06  
**Finish:** 09/28/06  
**Logger:** S. McGinnis

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</tr>
</thead>
<tbody>
<tr>
<td>60'</td>
<td>S-16</td>
<td>13-18-18 (36)</td>
<td>Poorly Graded Sand (SP)</td>
<td>60': SPT at 10:50</td>
</tr>
</tbody>
</table>
| 65'                        | S-17   | 12-15-17 (33)                   | Poorly Graded Sand with Silts, SP-SM | 65': SPT at 11:01  
|                            |        |                                  | Sample S-17 Test Results:  
|                            |        |                                  | WC = 20.8%  
|                            |        |                                  | P200 = 8.3%  
| 70'                        | S-18   | 15-18-14 (32)                   | Poorly Graded Sand (SP) | 70': SPT at 11:13  
| 75'                        |        |                                  | 76': Driller reports soft drilling |
PROJECT: Smith Island Restoration  
LOCATION: ~100' E of 51st, 400' N of 12th  
ELEVATION: ~4 feet  
DRILLING CONTRACTOR: Gregory Drilling, Inc.  
DRILLING METHOD AND EQUIPMENT: CME 85 truck, mud rotary, SPT, 140-lb auto-trip hammer  
WATER LEVELS: See log  
START: 09/28/06  
FINISH: 09/28/06  
LOGGER: S. McGinnis

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<tr>
<th>DEPTH BELOW GROUND SURFACE</th>
<th>SAMPLE NUMBER</th>
<th>TYPE</th>
<th>RECOVERY (IN)</th>
<th>STANDARD PENETRATION TEST RESULTS</th>
<th>SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY</th>
<th>COMMENTS</th>
</tr>
</thead>
</table>
| 80'                       | S-19 SS       | 18   | 0/18''        | 0/18'' (0)                        | FAT CLAY, CH  
Dark gray, wet, very soft, scattered fine organics, no dilatancy, high plasticity, low to medium toughness | 80': Sample smears when scraped |
|                           |               |      |               |                                   | Sample S-19 Test Results:  
WC = 50.6%  
LL = 58  
PL = 29  
PI = 29 | |
| 85'                       |               |      |               |                                   | 86': Driller reports out of soft soils |
| 90'                       | S-20 SS       | 15   | 9-9-8         | 9-9-8 (17)                        | SANDY SILT, ML  
Dark gray, wet (saturated), very stiff, very fine grained sand to non plastic silt that crumbles, grades to SILT (ML), non plastic, no dry strength, doesn't stick together | 90': SPT at 11:52 |
|                           |               |      |               |                                   | Sample S-20 Test Results:  
WC = 30.2%  
P200 = 59.1% | |
| 95'                       |               |      |               |                                   | 93': Driller reports clay |
| 100'                      |               |      |               |                                   | |
### Soil Boring Log

**Project:** Smith Island Restoration  
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**Elevation:** ~4 feet  
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<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Number</strong></td>
<td><strong>Type</strong></td>
<td><strong>Recovery (in)</strong></td>
<td>6''-6''-6'' (N)</td>
<td><strong>Soil Name, USCS Group Symbol, Color, Moisture Content, Relative Density or Consistency, Soil Structure, Mineralogy</strong></td>
</tr>
</tbody>
</table>
| 100' | S-21 | SS | 18 | 5-4-9 (13) | SILT (ML)  
Same as bottom of above, gray, wet, stiff, nonplastic, doesn't stick together, crumbles, no dry strength, slow dilatancy | 100': SPT at 12:09 |
| 110' | S-22 | SS | 13 | 19-18-18 (36) | POORLY GRADED SAND (SP)  
Gray, saturated, dense, fine sand, same as other SP samples | 110': SPT at 12:29 |
## SOIL BORING LOG

### Project Information
- **Project:** Smith Island Restoration
- **Location:** ~100'E of 51st, 400' N of 12th
- **Elevation:** ~4 feet
- **Drilling Contractor:** Gregory Drilling, Inc.
- **Drilling Method and Equipment:** CME 85 truck, mud rotary, SPT, 140-lb auto-trip hammer
- **Water Levels:** See log
- **Start Date:** 09/28/06
- **Finish Date:** 09/28/06
- **Logger:** S. McGinnis

### Soil Boring Log

<table>
<thead>
<tr>
<th>Depth Below Ground Surface</th>
<th>Sample Number</th>
<th>Type</th>
<th>Recovery (in)</th>
<th>Standard Penetration Test Results</th>
<th>Soil Description</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>125</td>
<td>S-23</td>
<td>SS</td>
<td>11</td>
<td>15-16-19 (35)</td>
<td><strong>Poorly Graded Sand with Silト, SP-SM</strong></td>
<td>Similar to above</td>
</tr>
<tr>
<td>130</td>
<td>S-24</td>
<td>SS</td>
<td>8</td>
<td>13-8-30 (38)</td>
<td><strong>Well Graded Sand (SW), gray, saturated, dense, fine to coarse sand, trace scattered organics, subrounded to subangular sand</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>Poorly Graded Sand (SP), gray, wet, dense, fine sand, organic lenses, &quot;clean&quot;</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>Silty Sand with Gravel (SM), gray, wet, dense, fine to coarse sand, fine subrounded to subangular gravel, est. 10-15% fines, 15-20% gravel (TILL-LIKE)</strong></td>
<td></td>
</tr>
</tbody>
</table>

**Sample S-23 Test Results:**
- WC = 7.4%
- P200 = 9.0%

128': Driller reports harder drilling
130': STP at 1:15
132': Sounds like gravel
133': Driller reports very hard drilling
**PROJECT NUMBER:** 349874  
**BORING NUMBER:** DB-2  
**Sheet:** 8 of 8

**SOIL BORING LOG**

**PROJECT:** Smith Island Restoration  
**LOCATION:** ~100' E of 51st, 400' N of 12th  
**ELEVATION:** ~4 feet  
**DRILLING CONTRACTOR:** Gregory Drilling, Inc.  
**DRILLING METHOD AND EQUIPMENT:** CME 85 truck, mud rotary, SPT, 140-lb auto-trip hammer  
**WATER LEVELS:** See log  
**START:** 09/28/06  
**FINISH:** 09/28/06  
**LOGGER:** S. McGinnis

<table>
<thead>
<tr>
<th>DEPTH BELOW GROUND SURFACE (F)</th>
<th>SAMPLE</th>
<th>STANDARD PENETRATION TEST RESULTS</th>
<th>SOIL DESCRIPTION</th>
<th>COMMENTS</th>
</tr>
</thead>
</table>
| S-25                           | SS     | 5                                 | 50/6" (50/6")   | WELL GRADED GRAVEL WITH SILT AND SAND (SW-SM)  
Similar to above, gray, wet, very dense, fine to coarse sand, fine to coarse subrounded to subangular gravel, est. 60-65% gravel, 30% sand, 5-10% fines |
| S-26                           | SS     | 12                                | 21-30-34 (64)    | WELL GRADED SAND WITH SILT AND GRAVEL, SW-SM  
Similar in appearance to above, gray, wet, very dense, fine to coarse sand, fine to coarse subrounded to subangular gravel, gravel to 1" diameter (TILL-LIKE but fewer fines)  
|                                  |        |                                   |                  | BOTTOM OF BORING |

**Sample S-26 Test Results:**  
WC = 9.5%  
P200 = 8.3%  
150': SPT 2:22

Bottom of boring at 151.5' bgs at 2:28 on 09-28-06. Piezometer not installed. Boring backfilled with cuttings and bentonite chips.