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GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

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October 26, 2016

Steve Hyland, PE
MWH Global, Inc.
806 SW Broadway, Suite 200
Portland, Oregon 97205

**RE: GROUNDWATER MONITORING PROGRAM REPORT
TRI-CITY WATER RESOURCE RECOVERY FACILITY
SOLIDS HANDLING IMPROVEMENT PROJECT
CLACKAMAS COUNTY, OREGON**

Dear Mr. Hyland:

This letter presents our field explorations, laboratory test results, and groundwater level monitoring data for the Solids Handling Improvement Project at the Tri-City Water Resource Recovery Facility (WRRF) in Clackamas County, Oregon. The project location is shown on the Vicinity Map, Figure 1. Clackamas County Water Environment Services (WES) is planning the improvements to the Tri-City WRRF with their engineering consultant, MWH Global, Inc. (MWH). As a subconsultant to MWH, Shannon & Wilson, Inc., is providing geotechnical services to support the project under Master Consulting Services Subcontract, No. MSA-S&WINC-05202011. We performed our services in accordance with Task Order T10508587-104357-OM, dated January 20, 2016. Our current scope of services, called Phase 700.2, Groundwater Monitoring Program, focused on establishing a groundwater monitoring program and included:

- Drilling two 70-foot deep borings in the vicinity of the proposed solids handling facility;
- Installing 2-inch diameter wells in the boreholes;
- Developing the wells and installing automated dataloggers in them to monitor the groundwater level through October 2016;
- Performing laboratory testing of select samples from the borings; and
- Preparing this report.

## FIELD EXPLORATIONS

The field exploration program included two geotechnical borings, designated SH-1 and SH-2. The borings were drilled to depths of 70 feet below the existing ground surface, in the vicinity of

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the proposed solids handling facility. Locations of the borings were measured in the field relative to existing site features, and their approximate locations are shown on the Site and Exploration Plan, Figure 2. Drilling was accomplished on January 27 and 28, 2016, using a track-mounted Boart Longyear Mini-Sonic drill rig provided and operated by Cascade Drilling, LP, of Clackamas, Oregon. Shannon & Wilson geology staff were on site during drilling to locate the borings, log the materials encountered, and collect samples. Observation wells were installed to depths of 50 feet below the ground surface in each boring, to allow ongoing collections of groundwater level measurements. On January 29, 2016, a Shannon & Wilson engineering geologist developed the wells and installed fully encapsulated dataloggers that were programmed to record groundwater level measurements at one hour intervals. Details of the field exploration program, including techniques used to advance and sample the borings, as well as logs and photographs of the materials encountered, are presented in Appendix A, Field Explorations. Groundwater level data recorded in the observation wells are presented in Figure 3, Groundwater Level Data.

## LABORATORY TESTING

The 4-inch diameter sonic core samples obtained during our field explorations were boxed and transported to the lower level of the Tri-City WRRF Screenings Building for further evaluation and long-term storage. During a site visit to review and photograph the sonic core, we selected representative samples for a suite of laboratory tests. The testing program included particle-size analyses and unconfined compressive strength tests. Particle-size analyses were performed by Shannon & Wilson. Unconfined compressive strength testing was performed by FEI Testing and Inspection, Inc. (FEI) of Corvallis, Oregon. All test procedures were performed in accordance with applicable ASTM International (ASTM) standards. Results of the laboratory tests and brief descriptions of the test procedures are presented in Appendix B, Laboratory Test Results.

## SUBSURFACE UNITS AND GROUNDWATER

### Subsurface Units

We grouped the materials encountered in the geotechnical borings into five geotechnical units. Generalized descriptions of the units are as follows:

- **Fill:** Soft to medium stiff Lean Clay (CL) and Silt (ML) with varying amounts of sand; trace roots and organics; few pockets of Silty Sand (SM); includes pavement sections.

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- **Fine-Grained Alluvium:** Soft to medium stiff Silt with Sand to Sandy Silt (ML); stratified with few interbeds of Silty Sand (SM); micaceous.
- **Sand Alluvium:** Loose Silty Sand (SM); micaceous.
- **Gravel Alluvium:** Medium dense to very dense Silty Gravel with Sand and Cobbles (GM) to Poorly Graded Gravel with Silt and Sand, with Cobbles (GP-GM); Well-Graded Gravel with Sand, with Cobbles; trace 12-inch-thick layers of Lean Clay (CL); trace layers of mostly cobbles.
- **Sandy River Mudstone:** Stiff to hard Lean Clay (CL), Elastic Silt (MH), and Fat Clay (CH) with varying amounts of sand; lesser amounts of Clayey Sand (SC); contains zones with relict vesicular basalt texture; contains trace strong to very strong (R4-R5) basaltic and granitic cobbles and boulders.

These geotechnical units were grouped based on their engineering properties, geologic origins, and their distribution in the subsurface as encountered in the borings. Contacts between the units may be more gradational than shown on the boring logs in Appendix A, and may vary significantly between the borings.

## Groundwater

Observation wells were installed in borings SH-1 and SH-2 to allow ongoing groundwater level measurements. Shannon & Wilson staff developed the wells to improve communication with the aquifer and then installed automated dataloggers, set to record groundwater levels at one hour intervals. Data collected from January 29, 2016 to October 13, 2016, are presented in Figure 3, Groundwater Level Data.

Based on the materials we encountered in the borings and the apparent correlation between recorded groundwater levels and nearby river gauge data, we infer that the groundwater table throughout the site is hydraulically connected to the Clackamas River. Groundwater levels should be expected to vary with changes in precipitation as well as river levels. Shallower zones of perched water may be present within the Fine-Grained Alluvium. Groundwater highs typically occur from late winter to spring, and groundwater lows typically occur in the early to mid-fall season, before the onset of significant rainfall.

## LIMITATIONS

This report provides a compilation of field exploration, laboratory data, and preliminary groundwater level data, for use by MWH in the Tri-City WRRF Solids Handling Improvement Project. Interpretations contained in this report are based on site conditions as interpreted from the explorations. We have assumed that the explorations are representative of the subsurface conditions at the site of the proposed improvements and that subsurface conditions everywhere are not significantly different from those disclosed by the explorations.

This report was prepared for the exclusive use of MWH and their design team. It should be made available to prospective contractors for data information only. This report is not a warranty of subsurface conditions, such as those interpreted from the exploration logs, including interpretations of subsurface conditions in this report. We make no warranty, either express or implied.

If, during final design and construction, subsurface conditions different from those encountered in the field explorations are observed or appear to be present, we should be advised at once so that we can review these conditions and reconsider our interpretations where necessary. If there is substantial lapse of time between the submission of this report and completion of the final design and the start of work at the site, or if conditions have changed because of natural or manmade forces, we recommend that this report be reviewed with respect to the time lapse or changed conditions. If we are not consulted after factors that were considered in the development of the report change, we cannot accept responsibility for problems that may occur.

Unanticipated soil conditions are commonly encountered and cannot fully be determined by merely taking soil samples from borings. Such unexpected conditions frequently require that additional expenditures be made to attain properly constructed projects. Therefore, some contingency fund is recommended to accommodate the potential for extra costs.

The scope of our geotechnical services did not include any environmental assessment or evaluation regarding the presence or absence of hazardous or toxic materials in the soil, surface water, groundwater, or air, on or below the site, or for evaluation of disposal of contaminated soils or groundwater, should any be encountered, except as noted in this report.

Shannon & Wilson, Inc., has prepared a document, "Important Information About Your Geotechnical/Environmental Report," to assist you and others in understanding the use and limitations of our report. This document is included in Appendix C.

Sincerely,

**SHANNON & WILSON, INC.**

CERTIFIED
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E 2210
ENGINEERING GEOLOGIST

renews
12/31/16

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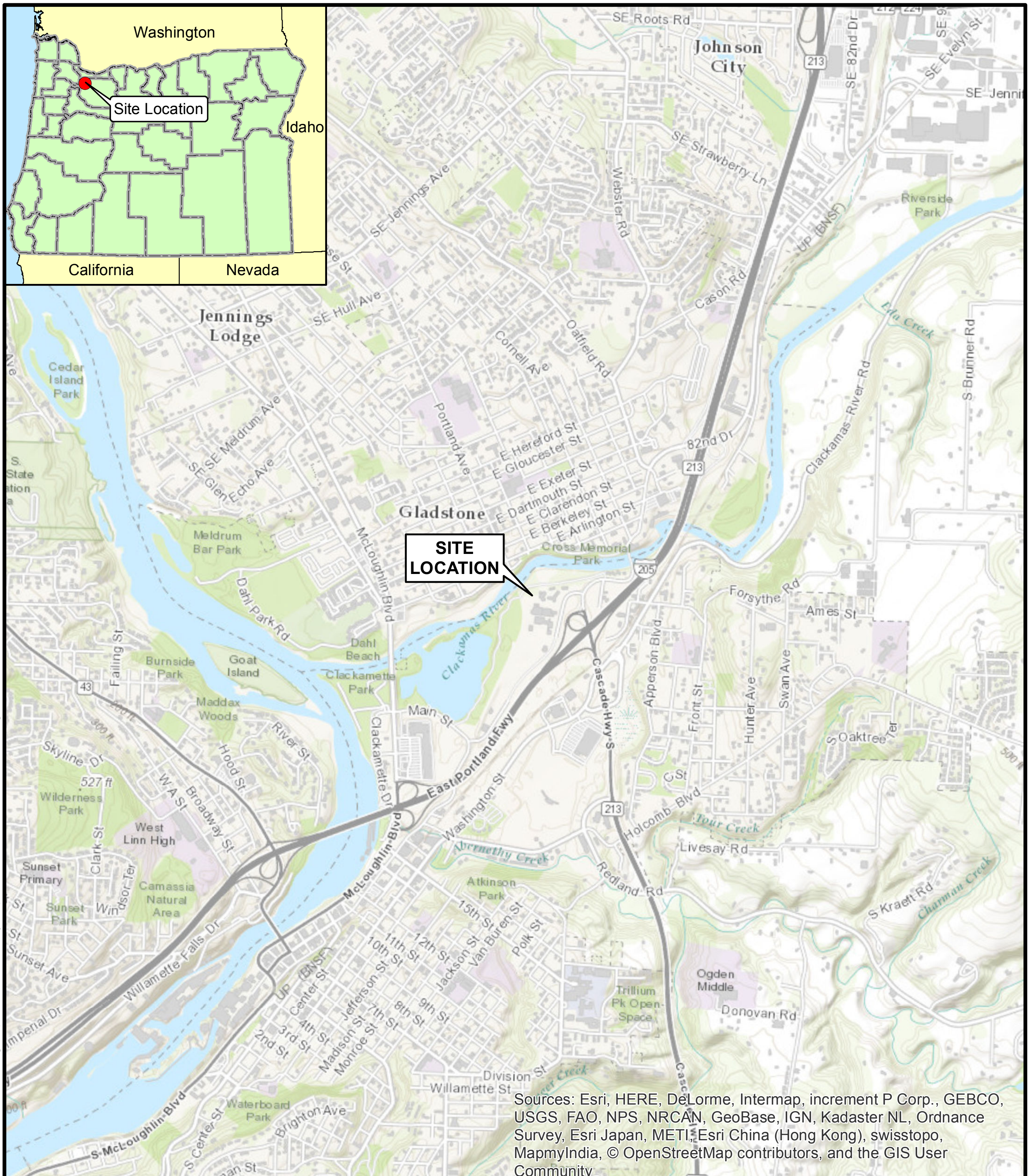
Encl.: Figure 1, Vicinity Map
Figure 2, Site and Exploration Plan
Figure 3, Groundwater Level Data
Appendix A - Field Explorations
Appendix B - Laboratory Test Results
Appendix C - Important Information About Your Geotechnical/Environmental Report




0 0.25 0.5 1

Scale in Miles

N

Tri-City WRRF Solids Handling Improvement
Clackamas County, Oregon

**VICINITY MAP**

April 2016 24-1-03996-002

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**FIG. 1**

Filename: T:\Projects\24-1\3996_Tri-City WPCP Solids Handling Impr\Avmxd\VicinityMap.mxd Date: 4/12/2016 Login: aah


LEGEND

SH-1 Designation and Approximate Location of Boring with Observation Well

Tri-City WRRF Solids Handling Improvement
Clackamas County, Oregon

## SITE AND EXPLORATION PLAN

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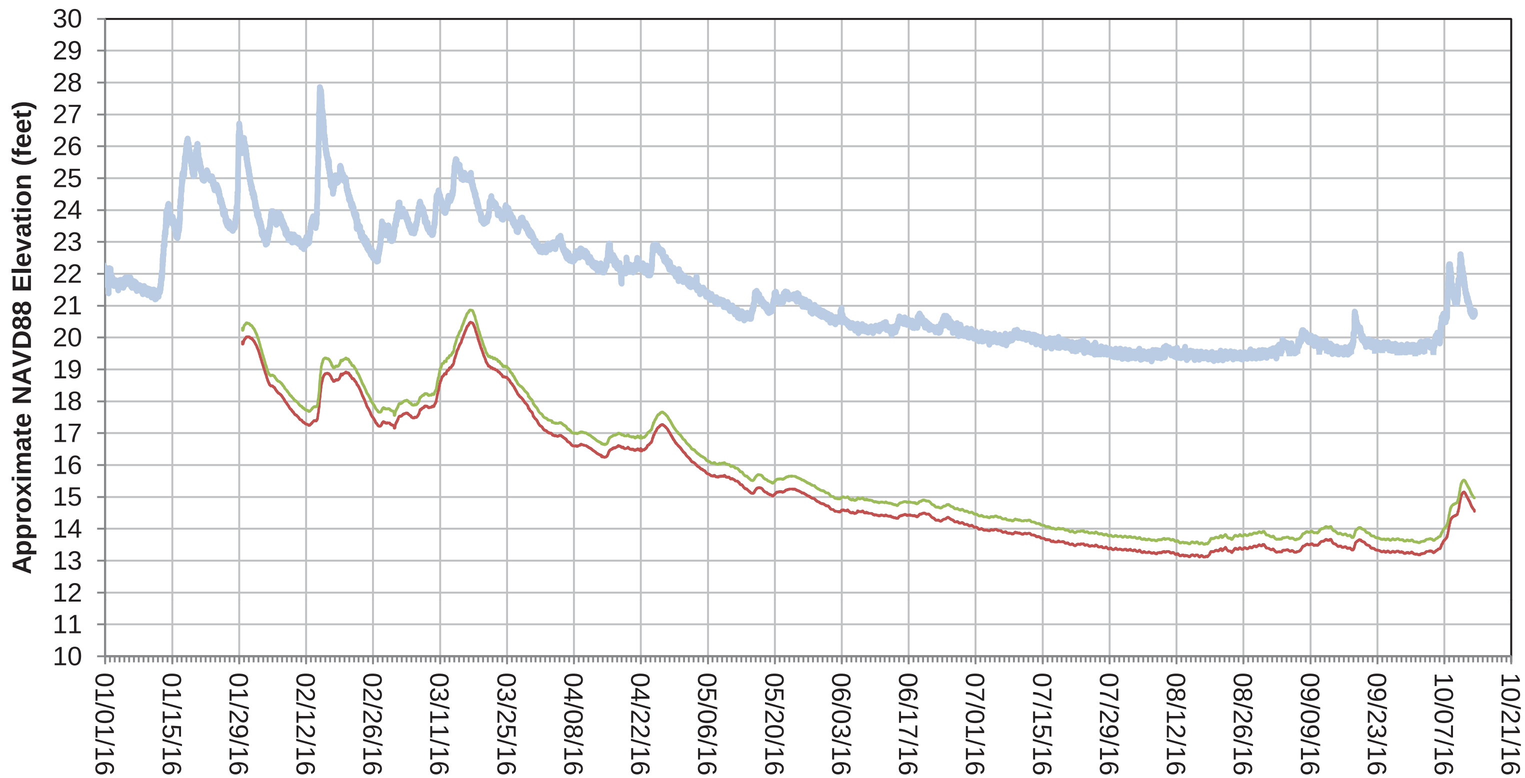
FIG. 2

Filename: T:\Projects\24-1\3996_Tri-City WPCP Solids Handling Impr\Avmxd\SitePlan.mxd Date: 4/12/2016 Login: aah




Note: Data last collected October 13, 2016

SH-1 (assumed NAVD88 ground surface elevation = 49.0 feet)

SH-2 (assumed NAVD88 ground surface elevation = 49.0 feet)

Clackamas River Gauge (0.8 miles upstream)

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## GROUNDWATER LEVEL DATA

October 2016 24-1-03996-002

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**FIG. 3**

FIG. 3

# APPENDIX A

# FIELD EXPLORATIONS

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## FIGURES

# APPENDIX A

# FIELD EXPLORATIONS

## A.1 GENERAL

Shannon &Wilson, Inc., explored subsurface conditions at the project site with two geotechnical borings, designated SH-1 and SH-2. Borehole locations were measured in the field relative to existing site features using a tape-measure. Approximate locations of the explorations are shown on the Site and Exploration Plan, Figure 2. This appendix describes the techniques used to advance and sample the borings and presents logs and photographs of the materials encountered.

## A.2 SONIC DRILLING AND SAMPLING

The geotechnical borings were drilled between January 27 and January 28, 2016, using a track-mounted Boart Longyear Mini-Sonic drill rig provided and operated by Cascade Drilling, L.P. (Cascade), of Clackamas, Oregon. The borings were advanced to depths of 70 feet below the existing ground surface using sonic drilling techniques. A Shannon & Wilson geologist was present during the explorations to locate the borings, observe the drilling, collect soil and rock core samples, and log the materials encountered.

Sonic drilling combines high frequency vibrations, downward pressure, and relatively slow rotations to advance through and sample soil and rock. Typically, a core barrel is advanced first. Then, to maintain borehole integrity, a larger-diameter outer casing is advanced over the core barrel. If the borehole will reliably remain open, the outer casing is not required. Hardened steel casing shoe-type bits are attached to the bottom of both the core barrel and the outer drill casing. The bits have several carbide buttons around the tips and outer edges that cut through the soil and rock as the drill string is vibrated and rotated. Drilling can be completed without the use of drill fluids, but water is commonly used to flush material from the annular space between the core barrel and outer casing, while the outer casing is driven.

To retrieve core sample, the core barrel is withdrawn from the hole and the sample is extruded into tubular plastic bags using vibration. During this exploration program, the boreholes were advanced in five-foot intervals while continuously core sampling. The bags of approximately 4-inch diameter core were placed into wooden boxes. A Shannon & Wilson geologist labeled the boxes, cut open the plastic bags, collected sealed jar samples at selected depths, and recorded a preliminary log of the materials encountered. Pieces of intact Sandy River Mudstone were carefully wrapped in plastic to retain native moisture and integrity for unconfined compressive strength testing. The wooden core boxes were loaded onto pallets and transported to the lower level of the Screenings Building at the Tri-City Water Resource Recovery Facility for further evaluation, photographing (discussed below), and long-term storage.

## A.3 OBSERVATION WELL INSTALLATIONS

Observation wells were installed in both boring SH-1 and boring SH2 to allow ongoing groundwater level measurements. The wells were each installed to depths of approximately 50 feet below the existing ground surface using 2-inch diameter schedule 40 polyvinyl chloride (PVC) pipe. Portions of the hole below approximately 50 feet were backfilled with bentonite chips. The bottom 20 feet of the pipes (approximately) were machine slotted to allow groundwater to enter. The annuli around the screened sections were backfilled with sand filter packs. Above the screened section, the annuli around the solid PVC pipes were backfilled with additional bentonite chips. The wells are protected at the surface with flush-mount monuments set in concrete. Well construction details and measured water levels are shown on the Logs of Borings in this appendix.

On January 29, 2016, after the observation wells were installed, we developed them by running a surge block up and down the screened sections and purging numerous well-volumes of water. This improves the consistency of the communication between the wells and the aquifer. After well development, we installed a fully encapsulated groundwater level datalogger (Solinst Levelogger®) in each well. The dataloggers were programmed to record groundwater level measurements at 1-hour intervals. Data obtained from the dataloggers are presented in Figure 3 of the main text.

## A.4 MATERIAL DESCRIPTIONS

Soil samples were described and identified visually in the field in general accordance with ASTM D2488, Standard Practice for Description and Identification of Soils (Visual-Manual Procedure). The specific terminology used is defined in the Soil Description and Log Key, Figure A1. Consistency, color, relative moisture, degree of plasticity, peculiar odors, and other distinguishing characteristics of the samples were noted. The samples were re-examined at the Tri-City Water pollution Control Plant facility after drilling, and the field descriptions and identifications were modified where necessary.

## A.5 BORING LOGS AND CORE PHOTOGRAPHS

Summary logs of borings are presented in Figures A2 and A3. Material descriptions and interfaces on the logs are interpretive, and actual changes may be gradual. The left-hand portion of the boring logs gives our description, identification, and geotechnical unit designation for the materials encountered in the boring. The right-hand portion of the boring logs shows a graphic log, sample locations and designations, and a graphical representation sample recovery, moisture content, and fines content. Photographs of the continuous sonic core samples are presented in Figures A4 and A5. Some sonic core runs recovered less than 100 percent of the depth interval sampled. This may occur in loose material or when a cobble becomes lodged in the cutting shoe, preventing material from entering the core barrel. In sonic core runs where less than 100 percent sample recovery was achieved, some empty spaces or gaps are apparent in the core box photographs.

Shannon & Wilson, Inc. (S&W), uses a soil identification system modified from the Unified Soil Classification System (USCS). Elements of the USCS and other definitions are provided on this and the following pages. Soil descriptions are based on visual-manual procedures (ASTM D2488) and laboratory testing procedures (ASTM D2487), if performed.

## S&W INORGANIC SOIL CONSTITUENT DEFINITIONS

| CONSTITUENT[2] | FINE-GRAINED SOILS (50% or more fines)[1] | COARSE-GRAINED SOILS (less than 50% fines)[1] |
|---|---|---|
| **Major** | ***Silt, Lean Clay, Elastic Silt,*** or ***Fat Clay***[3] | ***Sand*** or ***Gravel***[4] |
| **Modifying (Secondary)** Precedes major constituent | 30% or more coarse-grained: ***Sandy*** or ***Gravelly***[4] | More than 12% fine-grained: ***Silty*** or ***Clayey***[3] |
| **Minor** Follows major constituent | 15% to 30% coarse-grained: ***with Sand*** or ***with Gravel***[4] | 5% to 12% fine-grained: ***with Silt*** or ***with Clay***[3] |
| | 30% or more total coarse-grained *and* lesser coarse-grained constituent is 15% or more: ***with Sand*** or ***with Gravel***[5] | 15% or more of a second coarse-grained constituent: ***with Sand*** or ***with Gravel***[5] |

[1]All percentages are by weight of total specimen passing a 3-inch sieve.
[2]The order of terms is: *Modifying Major with Minor*.
[3]Determined based on behavior.
[4]Determined based on which constituent comprises a larger percentage.
[5]Whichever is the lesser constituent.

## MOISTURE CONTENT TERMS

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

## STANDARD PENETRATION TEST (SPT) SPECIFICATIONS

| | |
|---|---|
| Hammer: | 140 pounds with a 30-inch free fall. Rope on 6- to 10-inch-diam. cathead 2-1/4 rope turns, > 100 rpm |
| Sampler: | 10 to 30 inches long<br>Shoe I.D. = 1.375 inches<br>Barrel I.D. = 1.5 inches<br>Barrel O.D. = 2 inches |
| N-Value: | Sum blow counts for second and third 6-inch increments.<br>Refusal: 50 blows for 6 inches or less; 10 blows for 0 inches. |

*NOTE: Penetration resistances (N-values) shown on boring logs are as recorded in the field and have not been corrected for hammer efficiency, overburden, or other factors.*

## PARTICLE SIZE DEFINITIONS

| DESCRIPTION | SIEVE NUMBER AND/OR APPROXIMATE SIZE |
|---|---|
| FINES | < #200 (0.075 mm = 0.003 in.) |
| SAND | |
| Fine | #200 to #40 (0.075 to 0.4 mm; 0.003 to 0.02 in.) |
| Medium | #40 to #10 (0.4 to 2 mm; 0.02 to 0.08 in.) |
| Coarse | #10 to #4 (2 to 4.75 mm; 0.08 to 0.187 in.) |
| GRAVEL | |
| Fine | #4 to 3/4 in. (4.75 to 19 mm; 0.187 to 0.75 in.) |
| Coarse | 3/4 to 3 in. (19 to 76 mm) |
| COBBLES | 3 to 12 in. (76 to 305 mm) |
| BOULDERS | > 12 in. (305 mm) |

## RELATIVE DENSITY / CONSISTENCY

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

## WELL AND BACKFILL SYMBOLS

| | |
|---|---|
| Bentonite Cement Grout | Surface Cement Seal |
| Bentonite Grout | Asphalt or Cap |
| Bentonite Chips | Slough |
| Silica Sand | Inclinometer or Non-perforated Casing |
| Gravel | Vibrating Wire Piezometer |
| Perforated or Screened Casing | |

## PERCENTAGES TERMS[1, 2]

| | |
|---|---|
| Trace | < 5% |
| Few | 5 to 10% |
| Little | 15 to 25% |
| Some | 30 to 45% |
| Mostly | 50 to 100% |

[1]Gravel, sand, and fines estimated by mass. Other constituents, such as organics, cobbles, and boulders, estimated by volume.

[2]Reprinted, with permission, from ASTM D2488 - 09a Standard Practice for Description and Identification of Soils (Visual-Manual Procedure), copyright ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428. A copy of the complete standard may be obtained from ASTM International, www.astm.org.

Tri-City WRRF Solids Handling Improvement
Clackamas County, Oregon

# SOIL DESCRIPTION AND LOG KEY

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**FIG. A1**
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# UNIFIED SOIL CLASSIFICATION SYSTEM (USCS)
## (Modified From USACE Tech Memo 3-357, ASTM D2487, and ASTM D2488)

| MAJOR DIVISIONS | | | GROUP/GRAPHIC SYMBOL | TYPICAL IDENTIFICATIONS |
|---|---|---|---|---|
| COARSE-GRAINED SOILS *(more than 50% retained on No. 200 sieve)* | Gravels *(more than 50% of coarse fraction retained on No. 4 sieve)* | Gravel *(less than 5% fines)* | GW | Well-Graded Gravel; Well-Graded Gravel with Sand |
| | | | GP | Poorly Graded Gravel; Poorly Graded Gravel with Sand |
| | | Silty or Clayey Gravel *(more than 12% fines)* | GM | Silty Gravel; Silty Gravel with Sand |
| | | | GC | Clayey Gravel; Clayey Gravel with Sand |
| | Sands *(50% or more of coarse fraction passes the No. 4 sieve)* | Sand *(less than 5% fines)* | SW | Well-Graded Sand; Well-Graded Sand with Gravel |
| | | | SP | Poorly Graded Sand; Poorly Graded Sand with Gravel |
| | | Silty or Clayey Sand *(more than 12% fines)* | SM | Silty Sand; Silty Sand with Gravel |
| | | | SC | Clayey Sand; Clayey Sand with Gravel |
| FINE-GRAINED SOILS *(50% or more passes the No. 200 sieve)* | Silts and Clays *(liquid limit less than 50)* | Inorganic | ML | Silt; Silt with Sand or Gravel; Sandy or Gravelly Silt |
| | | | CL | Lean Clay; Lean Clay with Sand or Gravel; Sandy or Gravelly Lean Clay |
| | | Organic | OL | Organic Silt or Clay; Organic Silt or Clay with Sand or Gravel; Sandy or Gravelly Organic Silt or Clay |
| | Silts and Clays *(liquid limit 50 or more)* | Inorganic | MH | Elastic Silt; Elastic Silt with Sand or Gravel; Sandy or Gravelly Elastic Silt |
| | | | CH | Fat Clay; Fat Clay with Sand or Gravel; Sandy or Gravelly Fat Clay |
| | | Organic | OH | Organic Silt or Clay; Organic Silt or Clay with Sand or Gravel; Sandy or Gravelly Organic Silt or Clay |
| HIGHLY-ORGANIC SOILS | Primarily organic matter, dark in color, and organic odor | | PT | Peat or other highly organic soils (see ASTM D4427) |

| | | | |
|---|---|---|---|
| FILL | Placed by humans, both engineered and nonengineered. May include various soil materials and debris. | | The Fill graphic symbol is combined with the soil graphic that best represents the observed material |

NOTE: No. 4 size = 4.75 mm = 0.187 in.; No. 200 size = 0.075 mm = 0.003 in.

NOTES

1. Dual symbols *(symbols separated by a hyphen, i.e., SP-SM, Sand with Silt)* 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, Lean Clay to Silt; SP-SM/SM, Sand with Silt to Silty Sand)* indicate that the soil properties are close to the defining boundary between two groups.

3. The soil graphics above represent the various USCS identifications (i.e., *GP*, *SM*, etc.) and may be augmented with additional symbology to represent differences within USCS designations. *Sandy Silt (ML)*, for example, may be accompanied by the *ML* soil graphic with sand grains added.

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Clackamas County, Oregon

**SOIL DESCRIPTION AND LOG KEY**

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**FIG. A1**
Sheet 2 of 3

## GRADATION TERMS

| | |
|---|---|
| Poorly Graded | Narrow range of grain sizes present or, within the range of grain sizes present, one or more sizes are missing (Gap Graded). Meets criteria in ASTM D2487, if tested. |
| Well-Graded | Full range and even distribution of grain sizes present. Meets criteria in ASTM D2487, if tested. |

## CEMENTATION TERMS[1]

| | |
|---|---|
| Weak | Crumbles or breaks with handling or slight finger pressure |
| Moderate | Crumbles or breaks with considerable finger pressure |
| Strong | Will not crumble or break with finger pressure |

## PLASTICITY[2]

| DESCRIPTION | VISUAL-MANUAL CRITERIA | APPROX. PLASITICTY INDEX RANGE |
|---|---|---|
| Nonplastic | A 1/8-in. thread cannot be rolled at any water content. | < 4% |
| Low | A thread can barely be rolled and a lump cannot be formed when drier than the plastic limit. | 4 to 10% |
| Medium | A thread is easy to roll and not much time is required to reach the plastic limit. The thread cannot be rerolled after reaching the plastic limit. A lump crumbles when drier than the plastic limit. | 10 to 20% |
| High | It take considerable time rolling and kneading to reach the plastic limit. A thread can be rerolled several times after reaching the plastic limit. A lump can be formed without crumbling when drier than the plastic limit. | > 20% |

## ADDITIONAL TERMS

| | |
|---|---|
| Mottled | Irregular patches of different colors. |
| Bioturbated | Soil disturbance or mixing by plants or animals. |
| Diamict | Nonsorted sediment; sand and gravel in silt and/or clay matrix. |
| Cuttings | Material brought to surface by drilling. |
| Slough | Material that caved from sides of borehole. |
| Sheared | Disturbed texture, mix of strengths. |

## PARTICLE ANGULARITY AND SHAPE TERMS[1]

| | |
|---|---|
| Angular | Sharp edges and unpolished planar surfaces. |
| Subangular | Similar to angular, but with rounded edges. |
| Subrounded | Nearly planar sides with well-rounded edges. |
| Rounded | Smoothly curved sides with no edges. |
| Flat | Width/thickness ratio > 3. |
| Elongated | Length/width ratio > 3. |

[1]Reprinted, with permission, from ASTM D2488 - 09a Standard Practice for Description and Identification of Soils (Visual-Manual Procedure), copyright ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428. A copy of the complete standard may be obtained from ASTM International, www.astm.org.

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## ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| ATD | At Time of Drilling |
| approx. | Approximate/Approximately |
| Diam. | Diameter |
| Elev. | Elevation |
| ft. | Feet |
| FeO | Iron Oxide |
| gal. | Gallons |
| Horiz. | Horizontal |
| HSA | Hollow Stem Auger |
| I.D. | Inside Diameter |
| in. | Inches |
| lbs. | Pounds |
| MgO | Magnesium Oxide |
| mm | Millimeter |
| MnO | Manganese Oxide |
| NA | Not Applicable or Not Available |
| NP | Nonplastic |
| O.D. | Outside Diameter |
| OW | Observation Well |
| pcf | Pounds per Cubic Foot |
| PID | Photo-Ionization Detector |
| PMT | Pressuremeter Test |
| ppm | Parts per Million |
| psi | Pounds per Square Inch |
| PVC | Polyvinyl Chloride |
| rpm | Rotations per Minute |
| SPT | Standard Penetration Test |
| USCS | Unified Soil Classification System |
| $q_u$ | Unconfined Compressive Strength |
| VWP | Vibrating Wire Piezometer |
| Vert. | Vertical |
| WOH | Weight of Hammer |
| WOR | Weight of Rods |
| Wt. | Weight |

## STRUCTURE TERMS[1]

| | |
|---|---|
| Interbedded | Alternating layers of varying material or color with layers at least 1/4-inch thick; singular: bed. |
| Laminated | Alternating layers of varying material or color with layers less than 1/4-inch thick; singular: lamination. |
| Fissured | Breaks along definite planes or fractures with little resistance. |
| Slickensided | Fracture planes appear polished or glossy; sometimes striated. |
| Blocky | Cohesive soil that can be broken down into small angular lumps that resist further breakdown. |
| Lensed | Inclusion of small pockets of different soils, such as small lenses of sand scattered through a mass of clay. |
| Homogeneous | Same color and appearance throughout. |

Tri-City WRRF Solids Handling Improvement
Clackamas County, Oregon

# SOIL DESCRIPTION AND LOG KEY

April 2016 24-1-03996-002

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**FIG. A1**
Sheet 3 of 3

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Total Depth: | 70 ft. | Northing: | ~ | Drilling Method: | *Rotosonic* | Hole Diam.: | 6 in. |
| Top Elevation: | ~ 49 ft. | Easting: | ~ | Drilling Company: | *Cascade Drilling* | Rod Type: | ~ |
| Vert. Datum: | | Station: | ~ | Drill Rig Equipment: | *BL Minisonic* | Hammer Type: | N/A |
| Horiz. Datum: | | Offset: | ~ | Other Comments: | | | |

**SOIL DESCRIPTION**

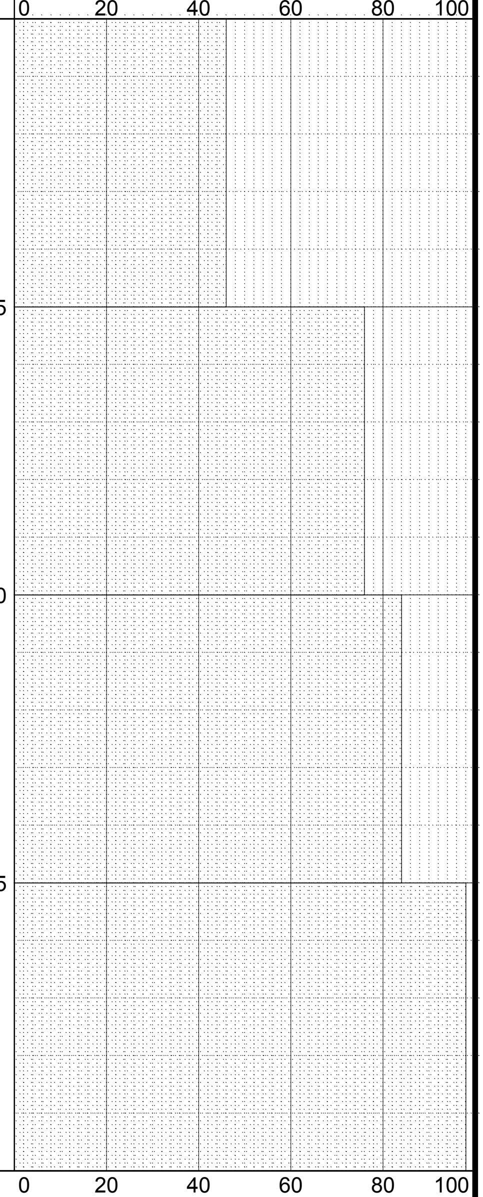
*Refer to the report text for a proper understanding of the subsurface materials and drilling methods. The stratification lines indicated below represent the approximate boundaries between soil types, and the transitions may be gradual.*

| Soil Description | Elev. Depth (ft.) | Samples | Depth, ft. |
|---|---|---|---|
| Soft to medium stiff, brown, *Lean Clay to Lean Clay with Sand (CL)*; moist; fine sand; medium plasticity; trace organics in upper 1 ft; micaceous. **FILL** | | R-1, S-1 | 5 |
| Soft to medium stiff, brown, *Silt with Sand to Sandy Silt (ML)*; moist; fine sand; nonplastic to low plasticity; micaceous. **FINE-GRAINED ALLUVIUM** | *42.0* 7.0 | R-2, S-2, R-3, S-3, R-4 | 10, 15 |
| Loose, brown, *Silty Sand (SM)*; moist; fine to medium sand; nonplastic fines. | *30.0* 19.0 | S-4 | |

**PENETRATION RESISTANCE, N** (blows/ft.)

▲ Hammer Wt. & Drop: *lbs / inches*

*140 lbs / 30 inches*




CONTINUED NEXT SHEET

LEGEND

- Soil Core - Sonic
- Jar Sample
- Grab Sample
- Groundwater Level on Date Shown

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

NOTES

1. Refer to KEY for explanation of symbols, codes, abbreviations, and definitions.
2. Groundwater level, if indicated above, is for the date specified and may vary.
3. Group symbol is based on visual-manual identification and selected lab testing.
4. The hole location and elevation should be considered approximate.

Tri-City WRRF Solids Handling Improvement
Clackamas County, Oregon

**LOG OF BORING SH-1**

April 2016 24-1-03996-002

**SHANNON & WILSON, INC.**
Geotechnical and Environmental Consultants

**FIG. A2**
Sheet 1 of 4

REV 3

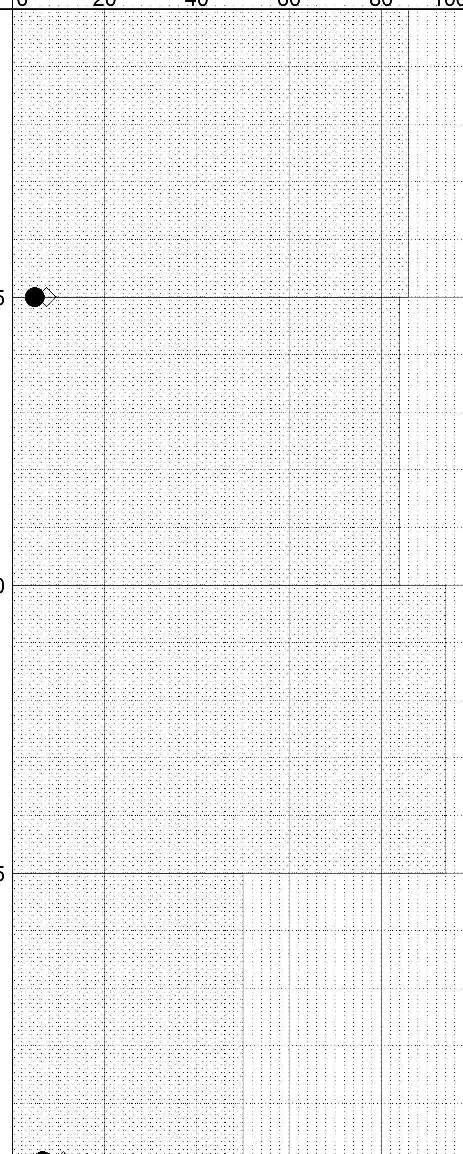
| | | | | | |
|---|---|---|---|---|---|
| Total Depth: | 70 ft. | Northing: | ~ | Drilling Method: | Rotosonic |
| Top Elevation: | ~ 49 ft. | Easting: | ~ | Drilling Company: | Cascade Drilling |
| Vert. Datum: | | Station: | ~ | Drill Rig Equipment: | BL Minisonic |
| Horiz. Datum: | | Offset: | ~ | Other Comments: | |

Hole Diam.: 6 in.
Rod Type: ~
Hammer Type: N/A

| SOIL DESCRIPTION | Elev. Depth (ft.) | Symbol | Samples | Ground Water | Depth, ft. |
|---|---|---|---|---|---|
| Continued: Loose, brown, *Silty Sand (SM)*; moist; fine to medium sand; nonplastic fines. **SAND ALLUVIUM** | 28.0 / 21.0 | | | | |
| Medium dense to very dense, gray and brown, *Poorly Graded Gravel with Silt and Sand, with Cobbles (GP-GM)*; moist; few cobbles; fine to coarse, subrounded to rounded gravel; fine to coarse sand; nonplastic fines. **GRAVEL ALLUVIUM** | | | R-5, R-6 | | 25 |
| Brown, *Lean Clay (CL)*; moist; trace fine to coarse, subrounded to rounded gravel; trace fine sand; medium plasticity. | 19.0 / 30.0 | | S-5 | | 30 |
| Medium dense to very dense, gray and brown, *Poorly Graded Gravel with Silt and Sand, with Cobbles (GP-GM)*; moist; few cobbles; fine to coarse, subrounded to subangular gravel; fine to coarse sand; nonplastic fines. 2 ft thick layer of *Silty/Clayey Gravel with Sand (GM/GC)* at 35 ft. *Cobbles stuck in bit likely caused poor recovery in R-8* | 18.0 / 31.0 | | R-7, R-8 | 3/1/2016 | 35 |
| | 9.0 | | | | |

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

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




CONTINUED NEXT SHEET

LEGEND

- Soil Core - Sonic
- Jar Sample
- Grab Sample
- Groundwater Level on Date Shown

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

NOTES

1. Refer to KEY for explanation of symbols, codes, abbreviations, and definitions.
2. Groundwater level, if indicated above, is for the date specified and may vary.
3. Group symbol is based on visual-manual identification and selected lab testing.
4. The hole location and elevation should be considered approximate.

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Clackamas County, Oregon

## LOG OF BORING SH-1

April 2016 24-1-03996-002

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**FIG. A2**
Sheet 2 of 4

*REV 3*

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Total Depth: | 70 ft. | Northing: | ~ | Drilling Method: | Rotosonic | Hole Diam.: | 6 in. |
| Top Elevation: | ~ 49 ft. | Easting: | ~ | Drilling Company: | Cascade Drilling | Rod Type: | ~ |
| Vert. Datum: | | Station: | ~ | Drill Rig Equipment: | BL Minisonic | Hammer Type: | N/A |
| Horiz. Datum: | | Offset: | ~ | Other Comments: | | | |

**SOIL DESCRIPTION**

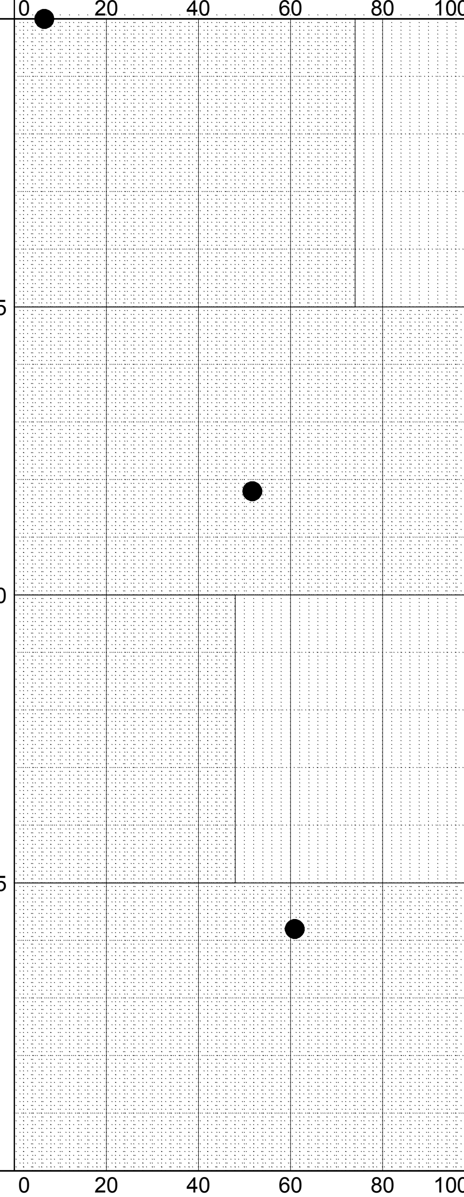
*Refer to the report text for a proper understanding of the subsurface materials and drilling methods. The stratification lines indicated below represent the approximate boundaries between soil types, and the transitions may be gradual.*

| SOIL DESCRIPTION | Elev. Depth (ft.) | Samples | Depth, ft. |
|---|---|---|---|
| Medium dense to very dense, gray and brown, *Poorly Graded Gravel with Silt and Sand, with Cobbles (GP-GM)*; moist; few to little cobbles; fine to coarse, subrounded to subangular gravel; mostly medium to coarse sand; trace nonplastic fines. **GRAVEL ALLUVIUM** | 40.0 | R-9 | |
| Stiff to very stiff, red and blue-gray, *Lean Clay to Fat Clay (CL/CH)*; moist; medium to high plasticity. **SANDY RIVER MUDSTONE** *48.2-49.5 ft: UCS = 50 psi Dry Density = 72 pcf* Basaltic cobble (fresh, R4-R5) encountered at 54 ft. | 4.3 / 44.7 | S-6, R-10, R-11 | 45, 50 |
| Stiff to hard, blue-gray and brown, *Lean Clay to Lean Clay with Sand (CL)*; moist; fine sand; medium to high plasticity; contains zones of relict vesicular basalt texture and relict mudstone texture. *55.8-57.2 ft: UCS = 71 psi Dry Density = 65 pcf* | -6.0 / 55.0 | R-12 | 55 |

**PENETRATION RESISTANCE, N** (blows/ft.)

▲ Hammer Wt. & Drop: *lbs / inches*

*140 lbs / 30 inches*




CONTINUED NEXT SHEET

LEGEND

- Soil Core - Sonic
- Jar Sample
- Grab Sample
- Groundwater Level on Date Shown

Recovery (%)

◇ % Fines (<0.075mm)

● % Water Content

Plastic Limit |———| Liquid Limit

NOTES

1. Refer to KEY for explanation of symbols, codes, abbreviations, and definitions.
2. Groundwater level, if indicated above, is for the date specified and may vary.
3. Group symbol is based on visual-manual identification and selected lab testing.
4. The hole location and elevation should be considered approximate.

Tri-City WRRF Solids Handling Improvement
Clackamas County, Oregon

**LOG OF BORING SH-1**

April 2016 24-1-03996-002

**SHANNON & WILSON, INC.**
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**FIG. A2**
Sheet 3 of 4

REV 3

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Total Depth: | 70 ft. | Northing: | ~ | Drilling Method: | Rotosonic | Hole Diam.: | 6 in. |
| Top Elevation: | ~ 49 ft. | Easting: | ~ | Drilling Company: | Cascade Drilling | Rod Type: | ~ |
| Vert. Datum: | | Station: | ~ | Drill Rig Equipment: | BL Minisonic | Hammer Type: | N/A |
| Horiz. Datum: | | Offset: | ~ | Other Comments: | | | |

**SOIL DESCRIPTION**

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

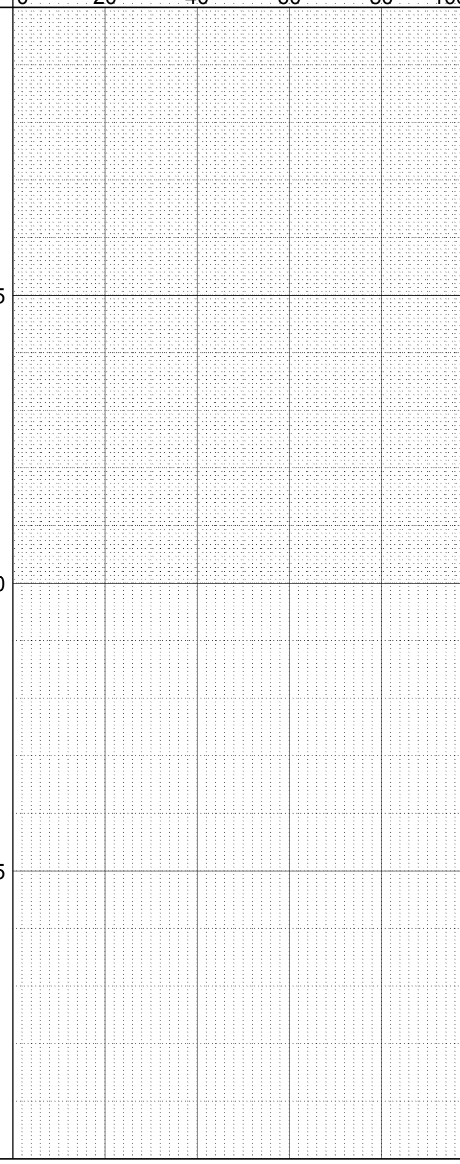
| SOIL DESCRIPTION | Elev. Depth (ft.) | Samples | Depth, ft. |
|---|---|---|---|
| Continued: Stiff to hard, blue-gray and brown, *Lean Clay to Lean Clay with Sand (CL)*; moist; fine sand; medium to high plasticity; contains zones of relict vesicular basalt texture and relict mudstone texture. **SANDY RIVER MUDSTONE** | | S-7, R-13 | 65 |
| Stiff to hard, blue-gray, *Lean Clay to Lean Clay with Sand (CL)*; moist; fine sand; medium to high plasticity; micaceous. | -18.0 / 67.0 | R-14, S-8 | 70 |
| Completed: January 28, 2016 | -21.0 / 70.0 | | 75 |

**PENETRATION RESISTANCE, N** (blows/ft.)

▲ Hammer Wt. & Drop: lbs / inches

*140 lbs / 30 inches*

0 20 40 60 80 100



LEGEND

- Soil Core - Sonic
- Jar Sample
- Grab Sample
- Groundwater Level on Date Shown

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

NOTES

1. Refer to KEY for explanation of symbols, codes, abbreviations, and definitions.
2. Groundwater level, if indicated above, is for the date specified and may vary.
3. Group symbol is based on visual-manual identification and selected lab testing.
4. The hole location and elevation should be considered approximate.

Tri-City WRRF Solids Handling Improvement
Clackamas County, Oregon

## LOG OF BORING SH-1

April 2016 24-1-03996-002

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**FIG. A2**
Sheet 4 of 4

REV 3

MASTER_LOG_E 24-1-03996-001.GPJ SW2013LIBRARYPDX.GLB SHANWIL_PDX.GDT 4/12/16 Log: AAJH Rev: AAJH Typ: AAJH

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Total Depth: | 70 ft. | Northing: | ~ | Drilling Method: | Rotosonic | Hole Diam.: | 6 in. |
| Top Elevation: | ~ 49 ft. | Easting: | ~ | Drilling Company: | Cascade Drilling | Rod Type: | ~ |
| Vert. Datum: | | Station: | ~ | Drill Rig Equipment: | BL Minisonic | Hammer Type: | N/A |
| Horiz. Datum: | | Offset: | ~ | Other Comments: | | | |

**SOIL DESCRIPTION**

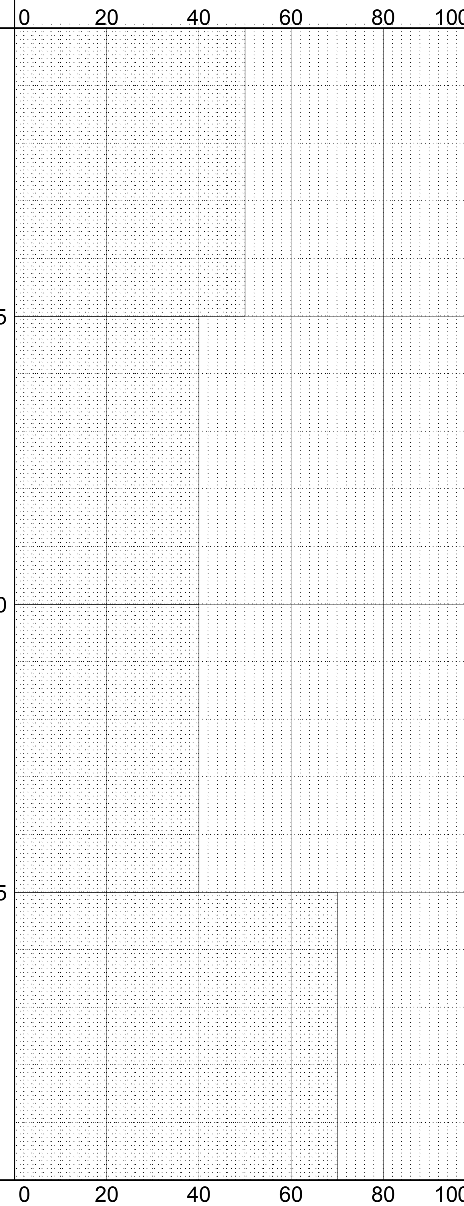
*Refer to the report text for a proper understanding of the subsurface materials and drilling methods. The stratification lines indicated below represent the approximate boundaries between soil types, and the transitions may be gradual.*

| SOIL DESCRIPTION | Elev. / Depth (ft.) | Samples |
|---|---|---|
| Asphalt/Concrete | 48.8 / 0.2 | |
| Aggregate Base | 48.1 / 0.9 | |
| Soft to medium stiff, brown, *Silt with Sand to Sandy Silt (ML)*; moist to wet; fine to medium sand; low plasticity; trace rootlets and organics; few pockets of *Silty Sand (SM)*. **FILL** | 46.0 / 3.0 | S-1, R-1 |
| Soft to medium stiff, brown, *Silt with Sand to Sandy Silt (ML)*; moist; fine sand; nonplastic to low plasticity; stratified with few interbeds of *Silty Sand (SM)*; micaceous. **FINE-GRAINED ALLUVIUM** | 32.0 / 17.0 | S-2, R-2, S-3, R-3 |
| Loose, gray-brown, *Silty Sand (SM)*; moist; fine to medium sand; nonplastic fines; micaceous. **SAND ALLUVIUM** | 31.5 / 17.5 | S-4, R-4 |
| Medium dense to very dense, *Silty Gravel with Sand and Cobbles (GM)*; little cobbles. | 29.0 | |

Symbol | Ground Water | Depth, ft. (5, 10, 15)

**PENETRATION RESISTANCE, N** (blows/ft.)

▲ Hammer Wt. & Drop: lbs / inches




CONTINUED NEXT SHEET

LEGEND

- Soil Core - Sonic
- Jar Sample
- Grab Sample
- Groundwater Level on Date Shown

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

NOTES

1. Refer to KEY for explanation of symbols, codes, abbreviations, and definitions.
2. Groundwater level, if indicated above, is for the date specified and may vary.
3. Group symbol is based on visual-manual identification and selected lab testing.
4. The hole location and elevation should be considered approximate.

Tri-City WRRF Solids Handling Improvement
Clackamas County, Oregon

## LOG OF BORING SH-2

April 2016 24-1-03996-002

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**FIG. A3**
Sheet 1 of 4

REV 3

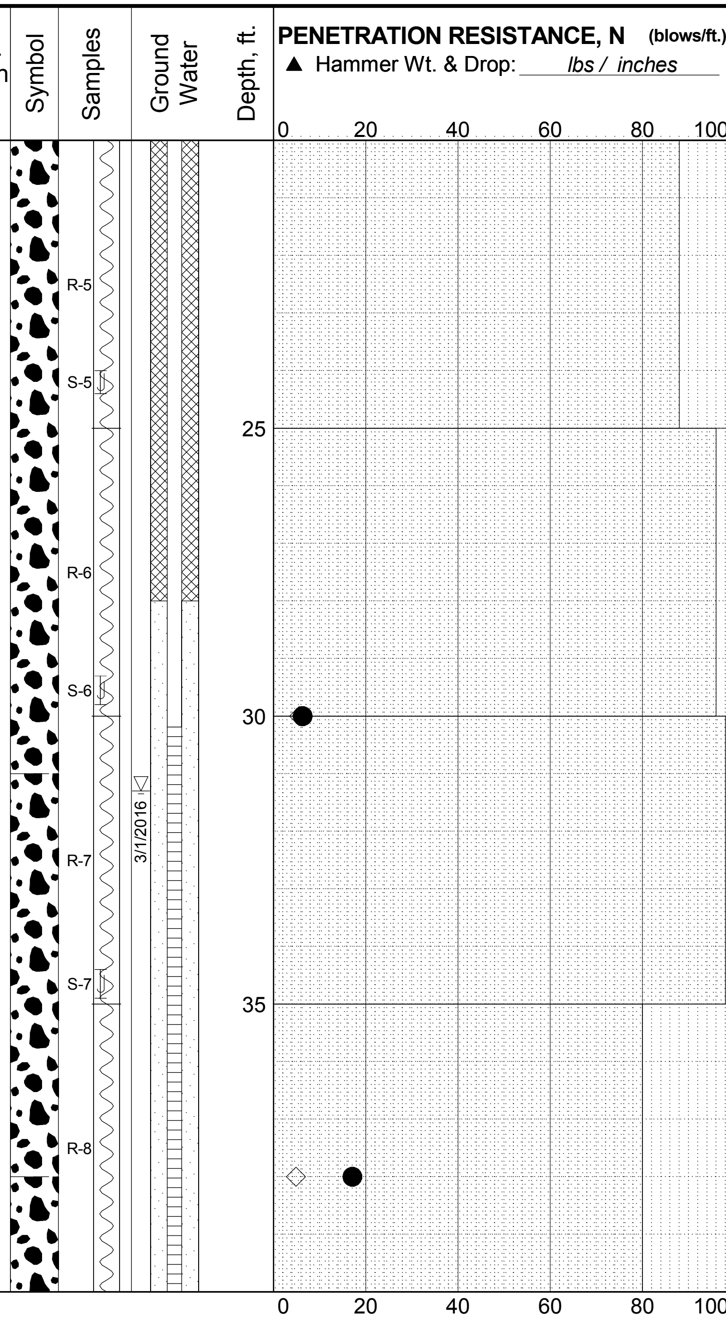
| | | | | | |
|---|---|---|---|---|---|
| Total Depth: | 70 ft. | Northing: | ~ | Drilling Method: | Rotosonic |
| Top Elevation: | ~ 49 ft. | Easting: | ~ | Drilling Company: | Cascade Drilling |
| Vert. Datum: | | Station: | ~ | Drill Rig Equipment: | BL Minisonic |
| Horiz. Datum: | | Offset: | ~ | Other Comments: | |

Hole Diam.: 6 in.
Rod Type: ~
Hammer Type: N/A

**SOIL DESCRIPTION**

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

| Soil Description | Elev. Depth (ft.) |
|---|---|
| Medium dense to very dense, gray and brown, *Poorly Graded Gravel with Silt and Sand, with Cobbles (GP-GM)*; moist; few to little rounded cobbles; fine to coarse, subrounded to rounded gravel; fine to coarse sand; nonplastic fines. **GRAVEL ALLUVIUM** | 20.0 |
| Medium dense to very dense, gray and brown, *Poorly Graded Gravel with Silt and Sand, with Cobbles (GP-GM)*; wet; few to little rounded cobbles; fine to coarse, subrounded to rounded gravel; mostly medium to coarse sand; nonplastic fines; trace to few interbeds of *Silty Gravel with Sand (GM)*. Cobbly zone from 37.5 feet to 39 feet. | 18.0 / 31.0 |
| Medium dense to very dense, gray and brown, *Well-Graded Gravel with Sand, with Cobbles (GW)*; little to some cobbles. | 11.0 / 38.0 |




CONTINUED NEXT SHEET

LEGEND

- Soil Core - Sonic
- Jar Sample
- Grab Sample
- Groundwater Level on Date Shown

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

NOTES

1. Refer to KEY for explanation of symbols, codes, abbreviations, and definitions.
2. Groundwater level, if indicated above, is for the date specified and may vary.
3. Group symbol is based on visual-manual identification and selected lab testing.
4. The hole location and elevation should be considered approximate.

Tri-City WRRF Solids Handling Improvement
Clackamas County, Oregon

## LOG OF BORING SH-2

April 2016 24-1-03996-002

**SHANNON & WILSON, INC.**
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**FIG. A3**
Sheet 2 of 4

REV 3

| | | | | | |
|---|---|---|---|---|---|
| Total Depth: 70 ft. | Northing: ~ | Drilling Method: | Rotosonic | Hole Diam.: | 6 in. |
| Top Elevation: ~ 49 ft. | Easting: ~ | Drilling Company: | Cascade Drilling | Rod Type: | ~ |
| Vert. Datum: | Station: ~ | Drill Rig Equipment: | BL Minisonic | Hammer Type: | N/A |
| Horiz. Datum: | Offset: ~ | Other Comments: | | | |

**SOIL DESCRIPTION**

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

Elev. Depth (ft.) | Symbol | Samples | Ground Water | Depth, ft.

**PENETRATION RESISTANCE, N** (blows/ft.)
▲ Hammer Wt. & Drop: lbs / inches

0 20 40 60 80 100

Medium dense to very dense, gray and orange-brown to brown, *Well-Graded Gravel with Sand, with Cobbles (GW)*; wet; little to some subrounded to rounded cobbles; fine to coarse, subrounded to rounded gravel; mostly medium to coarse sand; nonplastic fines.

**GRAVEL ALLUVIUM**

R-9

4.0
45.0

45

Soft, gray, *Lean Clay (CL)*; wet; trace fine sand; medium plasticity; some highly weathered to decomposed gravel and cobbles from 48.5 to 49.2 feet.

**FINE-GRAINED ALLUVIUM**

S-8
R-10

-0.7
49.7

50

Stiff to very stiff, brown to yellow-brown, orange brown, and gray, *Fat Clay with Sand (CH)*; moist to wet; fine to coarse sand; medium to high plasticity; relict rock texture; secondary yellow and orange-brown mineralization; relict vesicular basalt texture from 52.5 to 54.5 feet.

**SANDY RIVER MUDSTONE**

S-9
R-11

-6.0
55.0

55

Stiff to hard, brown to yellow to orange-brown to gray, *Lean Clay with Sand (CL) to Elastic Silt with Sand (MH)*; moist; fine to medium sand; medium to high plasticity; zones of relict vesicular basalt texture.

R-12
S-10

CONTINUED NEXT SHEET

0 20 40 60 80 100

LEGEND

- Soil Core - Sonic
- Jar Sample
- Grab Sample
- Groundwater Level on Date Shown

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

NOTES

1. Refer to KEY for explanation of symbols, codes, abbreviations, and definitions.
2. Groundwater level, if indicated above, is for the date specified and may vary.
3. Group symbol is based on visual-manual identification and selected lab testing.
4. The hole location and elevation should be considered approximate.

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**LOG OF BORING SH-2**

April 2016 24-1-03996-002

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**FIG. A3**


REV 3

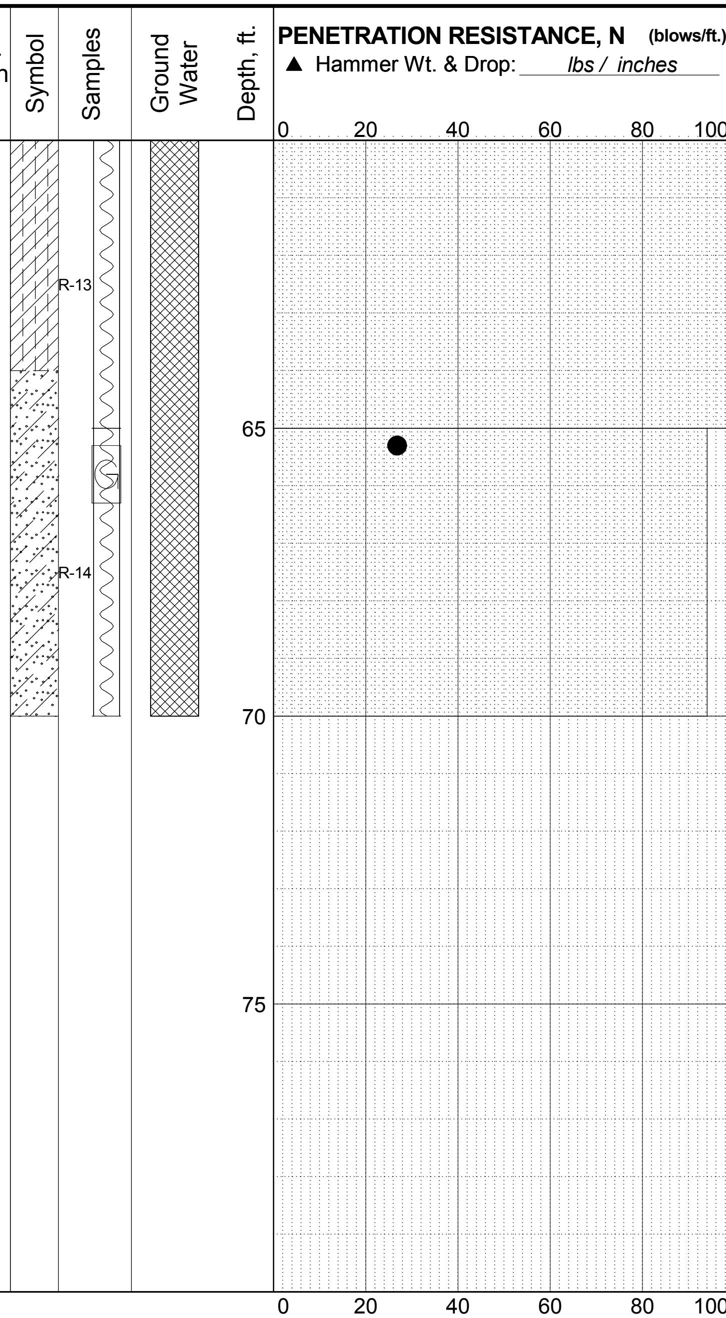
MASTER_LOG_E 24-1-03996-001.GPJ SW2013LIBRARYPDX.GLB SHANWIL_PDX.GDT 4/12/16
Log: CKS Rev: AAJH Typ: SCS

Total Depth: 70 ft.
Top Elevation: ~ 49 ft.
Vert. Datum:
Horiz. Datum:
Northing: ~
Easting: ~
Station: ~
Offset: ~
Drilling Method: Rotosonic
Drilling Company: Cascade Drilling
Drill Rig Equipment: BL Minisonic
Other Comments:
Hole Diam.: 6 in.
Rod Type: ~
Hammer Type: N/A

**SOIL DESCRIPTION**

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

| Soil Description | Elev. Depth (ft.) |
|---|---|
| Continued: Stiff to hard, brown to yellow to orange-brown to gray, *Lean Clay with Sand (CL) to Elastic Silt with Sand (MH)*; moist; fine to medium sand; medium to high plasticity; zones of relict vesicular basalt texture. **SANDY RIVER MUDSTONE** | -15.0<br>64.0 |
| Stiff to hard, gray, *Clayey Sand (SC) to Sandy Lean Clay (CL)*; moist; fine to medium sand; medium to high plasticity; relict sandstone structure; slight iron-oxide staining. *65.3-66.3 ft: UCS = 29 psi* *Dry Density = 94 pcf* | -21.0<br>70.0 |
| Completed: January 27, 2016 | |




Recovery (%)
◇ % Fines (<0.075mm)
● % Water Content
Plastic Limit ⊢—⊣ Liquid Limit

LEGEND

Soil Core - Sonic
Jar Sample
Grab Sample
Groundwater Level on Date Shown

NOTES

1. Refer to KEY for explanation of symbols, codes, abbreviations, and definitions.
2. Groundwater level, if indicated above, is for the date specified and may vary.
3. Group symbol is based on visual-manual identification and selected lab testing.
4. The hole location and elevation should be considered approximate.

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## LOG OF BORING SH-2

April 2016 24-1-03996-002

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**FIG. A3**
Sheet 4 of 4

DEPTH
(feet)

0 to 5

5 to 10

10 to 15

15 to 20

Tri-City WRRF Solids Handling Improvement
Clackamas County, Oregon

**BORING SH-1**
**SONIC CORE PHOTOGRAPHS**

April 2016 24-1-03996-002

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**FIG. A4**
(Sheet 1 of 4)

**FIG. A4**
(Sheet 1 of 4)

DEPTH (feet)

20 to 25

25 to 30

30 to 35

35 to 40

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Clackamas County, Oregon

**BORING SH-1**
**SONIC CORE PHOTOGRAPHS**

April 2016 24-1-03996-002

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**FIG. A4**
(Sheet 2 of 4)

**FIG. A4**
(Sheet 2 of 4)

DEPTH
(feet)

40 to 45

45 to 50

50 to 55

55 to 60

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Clackamas County, Oregon

**BORING SH-1**
**SONIC CORE PHOTOGRAPHS**

April 2016 24-1-03996-002

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**FIG. A4**
(Sheet 3 of 4)

**FIG. A4**
(Sheet 3 of 4)

DEPTH
(feet)

60 to 65

65 to 70

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Clackamas County, Oregon

**BORING SH-1**
**SONIC CORE PHOTOGRAPHS**

April 2016 24-1-03996-002

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**FIG. A4**
(Sheet 4 of 4)

**FIG. A4**
(Sheet 4 of 4)

DEPTH
(feet)

0 to 5

5 to 10

10 to 15

15 to 20

Tri-City WRRF Solids Handling Improvement
Clackamas County, Oregon

**BORING SH-2**
**SONIC CORE PHOTOGRAPHS**

April 2016 24-1-03996-002

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**FIG. A5**
(Sheet 1 of 4)

**FIG. A5**
(Sheet 1 of 4)

DEPTH
(feet)

20 to 25

25 to 30

30 to 35

35 to 40

Tri-City WRRF Solids Handling Improvement
Clackamas County, Oregon

**BORING SH-2**
**SONIC CORE PHOTOGRAPHS**

April 2016 24-1-03996-002

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**FIG. A5**
(Sheet 2 of 4)

**FIG. A5**
(Sheet 2 of 4)

DEPTH
(feet)

40 to 45

45 to 50

50 to 55

55 to 60

FIG. A5
(Sheet 3 of 4)

Tri-City WRRF Solids Handling Improvement
Clackamas County, Oregon

**BORING SH-2**
**SONIC CORE PHOTOGRAPHS**

April 2016 24-1-03996-002

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**FIG. A5**
(Sheet 3 of 4)

DEPTH
(feet)

60 to 65

65 to 70


Tri-City WRRF Solids Handling Improvement
Clackamas County, Oregon

**BORING SH-2**
**SONIC CORE PHOTOGRAPHS**

April 2016 24-1-03996-002

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**FIG. A5**
(Sheet 4 of 4)

**FIG. A5**
(Sheet 4 of 4)

# APPENDIX B

# LABORATORY TEST RESULTS

## TABLE OF CONTENTS



## FIGURES



## ATTACHMENTS

# APPENDIX B

# LABORATORY TEST RESULTS

## B.1 GENERAL

The soil samples obtained during the field explorations were described and identified in the field in general accordance with the Standard Practice for Description and Identification of Soils (Visual-Manual Procedure), ASTM D2488. The specific terminology used is presented in Appendix A, Figure A1. The samples were reviewed at the Tri-City Water pollution Control Plant after drilling. The physical characteristics of the samples were noted, and the field descriptions and identifications were modified where necessary in accordance with terminology presented in Appendix A, Figure A1. After core photographs were taken, representative samples were selected for various laboratory tests. We refined our visual-manual soil descriptions and identifications based on the results of the laboratory tests, using elements of the Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System), ASTM D2487. The refined descriptions and identifications were then incorporated into the Logs of Borings, presented in Appendix A. Note that ASTM D2487 was not followed in full because it requires that a suite of tests be performed to fully classify a single sample.

The soil testing program included moisture content tests, unit weight determinations, particle-size analyses, and unconfined compressive strength testing. Particle-size analyses and associated moisture content tests were performed by Shannon & Wilson, Inc. Unconfined compressive strength testing, and associated unit weight and moisture content tests, were performed by FEI Testing & Inspection, Inc. (FEI), of Corvallis, Oregon. All test procedures were performed in accordance with applicable ASTM International (ASTM) standards. General testing procedures are summarized in the following paragraphs.

## B.2 SOIL TESTING

### B.2.1 Moisture (Natural Water) Content

Natural moisture content analyses were performed, in accordance with ASTM D2216, on samples that were selected for particle-size analyses and unconfined compressive strength testing. The natural moisture content is a measure of the amount of moisture in the soil at the time the explorations are performed, and is defined as the ratio of water weight to dry soil weight, expressed as a percentage. The results of all moisture content analyses are presented graphically on the Logs of Borings in Appendix A. Results of moisture content analyses performed by Shannon & Wilson as part of the particle-size analyses are also shown on Figure B1, Grain Size Distribution. Results of moisture content analyses performed by FEI as part of the unconfined compressive strength tests are also shown in the FEI Testing Results attached to this appendix.

### B.2.2 Unit Weight Determinations

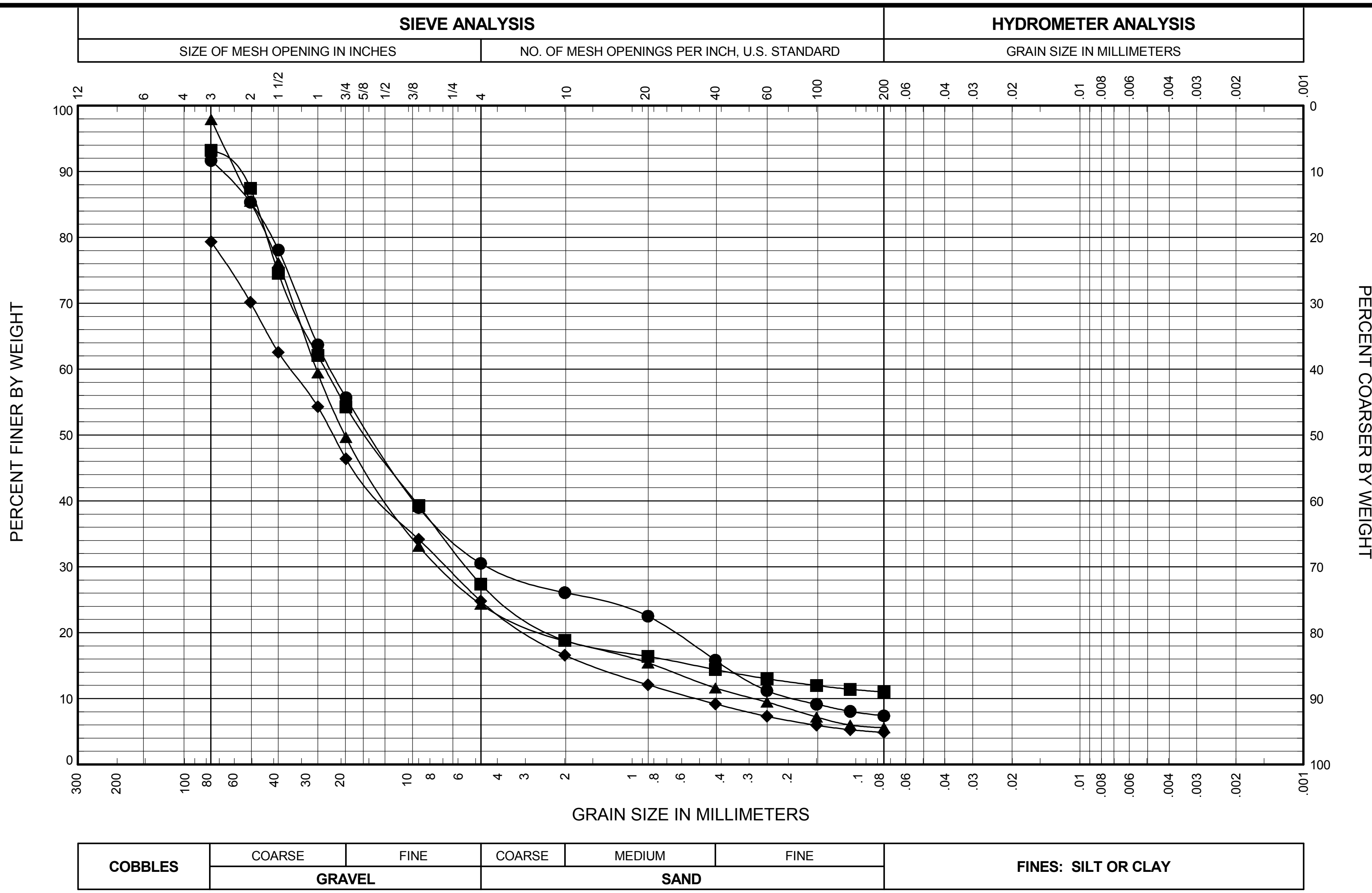
Some unit weights were determined during the course of FEI's unconfined compressive strength testing. The results of all unit weight determinations are presented on the Logs of Borings in Appendix A and in the FEI Testing Results attached to this appendix.

### B.2.3 Particle-Size Analysis

Particle-size analyses were conducted on select samples in accordance with ASTM D6913. A wet sieve analysis was performed to determine a percentage (by weight) of the sample passing the No. 200 (0.075 mm) sieve. The material retained on the No. 200 sieve was shaken through a series of sieves to determine the distribution of the plus No. 200 fraction. The results of all particle-size analyses are plotted on Figure B1, Grain Size Distribution, and the amount of material passing the No. 200 sieve for each tested sample is indicated on the Logs of Borings in Appendix A.

### B.2.4 Compressive Strength Testing

Selected sonic core samples of the Sandy River Mudstone were tested using ASTM D7012 (Method C), the Compressive Strength of Intact Rock Core Specimens. The test consists of placing a rock core specimen between two bearing plates and applying and measuring an axial load increasing at a constant rate until failure. During the application of increasing axial load, strain of the core sample is continuously measured with a dial indicator placed between the two bearing blocks, measuring the decreasing length of the rock core. The highest load achieved, and the length of the rock core at failure, are recorded. Measurements made during the test are used to calculate the uniaxial compressive strength, $C_o$, in psi. Results of the unconfined compressive strength tests are presented on the Logs of Borings in Appendix A and in the FEI Testing Results attached to this appendix.




| BORING AND SAMPLE NO. | DEPTH (feet) | GROUP SYMBOL[2] | GROUP NAME[2] | GRAVEL % | SAND % | FINES % | NAT. W.C. % | DRY DENSITY PCF |
|---|---|---|---|---|---|---|---|---|
| ● SH-1, R-6 | 25.0 | *GP-GM* | *Poorly Graded Gravel with Silt and Sand, with Cobbles* | 61 | 23 | 7 | 5 | |
| ■ SH-1, R-9 | 40.0 | *GP-GM* | *Poorly Graded Gravel with Silt and Sand, with Cobbles* | 66 | 16 | 11 | 7 | |
| ▲ SH-2, R-7 | 30.0 | *GP-GM* | *Poorly Graded Gravel with Silt and Sand, with Cobbles* | 74 | 19 | 6 | 6 | |
| ◆ SH-2, R-8/R-9 | 38.0 | *GW* | *Well-Graded Gravel with Sand, with Cobbles* | 55 | 20 | 5 | 17 | |

Tri-City WRRF Solids Handling Improvement
Clackamas County, Oregon

# GRAIN SIZE DISTRIBUTION

April 2016 24-1-03996-002

**SHANNON & WILSON, INC.**
Geotechnical and Environmental Consultants

**FIG. B1**

NOTES:
1) Sieve analyses were performed in general accordance with ASTM D6913, sieve with hydrometer analyses were performed in general accordance with ASTM D422, and amount finer than #200 sieve analyses were performed in general accordance with ASTM D1140 unless otherwise noted in the report.
2) Group Name and Group Symbol are in accordance with ASTM D2488 and are refined in accordance with ASTM D2487 where appropriate laboratory tests are performed.

GSA MAIN 24-1-03996-001.GPJ SHAN WIL.GDT 4/12/16

**FEI**
TESTING & INSPECTION, INC.
Geotechnical & Construction Services

# LETTER OF TRANSMITTAL

*Date:* February 16, 2016

*Project No.:* 2166028-900
*Report No.:* C-34645

*Re:* Tri-City Solids WWTP

*To:* Shannon & Wilson, Inc.
3990 Collins Way, Suite 100
Lake Oswego, OR 97035

*Attn:*

*Enclosed are:*

- ☐ Report
- ☐ Copy of Letter
- ☐ Other
- ☐ Drawings
- ☐ Specifications
- ☑ Test Results (4 Pages Total Incl. Cover)

*These are transmitted as checked below:*

- ☑ For your use
- ☑ As requested
- ☐ For your review/approval
- ☐ For your files

*Remarks:* Requested laboratory testing results attached. Please call if you have any questions.

*Copy to:*

*Signature:*

Rachel Rucker
Rachel Rucker
President



750 NW Cornell Avenue · Corvallis, Oregon 97330 · phone (541) 757-4698 · fax (541) 757-2991
29540 B Airport Road · Eugene, Oregon 97402 · phone (541) 684-3849 · fax (541) 684-3851
62979 NE Plateau Drive, Suite 3 · Bend, Oregon 97701 · phone (541) 382-4844 · fax (541) 382-4846

FEI Testing & Inspection, Inc.
Project Name: Tri-City Solids WWTP
Client Project #24-1-03996-002
FEI Project # 2166028-600

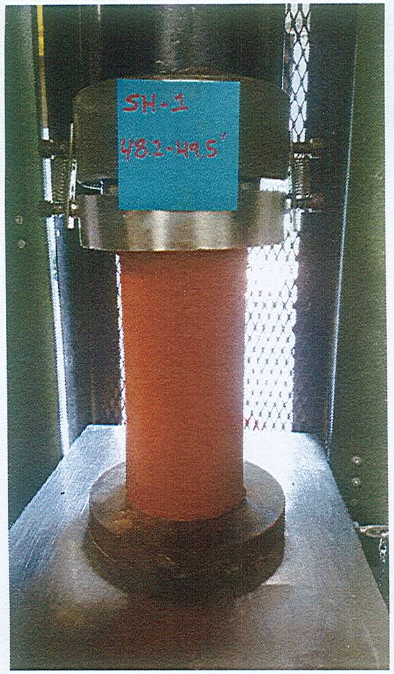
## Table 1. Unconfined Compression (ASTM D 7012)

| Sample Number* | Sample Depth (ft) | Length (in) | Diameter (in) | Corrected Area ($in^2$) | Water Content (percent) | Load (lbs) | Compressive Strength (psi) |
|---|---|---|---|---|---|---|---|
| SH-1 | 48.2-49.5 | 8.90 | 4.18 | 13.72 | 51.7 | 690 | 50 |
| SH-1 | 55.8-57.2 | 8.45 | 4.18 | 13.72 | 60.9 | 980 | 71 |
| SH-2 | 65.3-66.3 | 9.26 | 4.16 | 13.59 | 26.8 | 400 | 29 |

## Table 2. Unit Weight

| Sample Number* | Sample Depth (feet) | Wet Density (pcf) | Dry Density (pcf) |
|---|---|---|---|
| SH-1 | 48.2-49.5 | 109.3 | 72.0 |
| SH-1 | 55.8-57.2 | 104.5 | 64.9 |
| SH-2 | 65.3-66.3 | 119.0 | 93.8 |

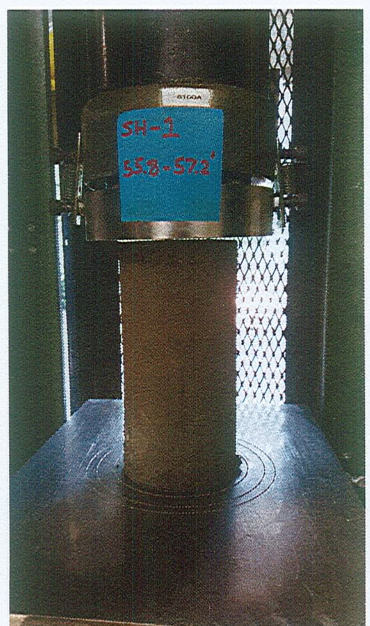
*FEI Sample No. 5964



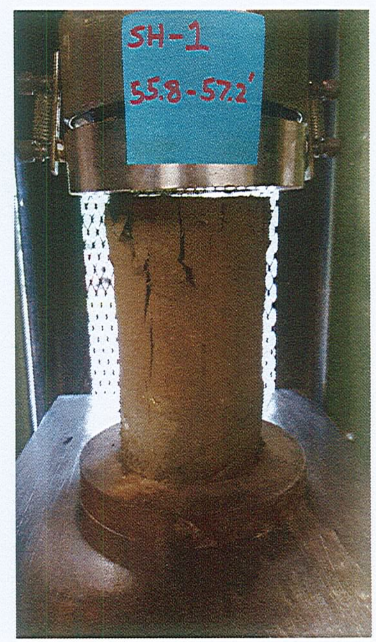

48.2 – 49.5 (before)


48.2 – 49.5 (after)

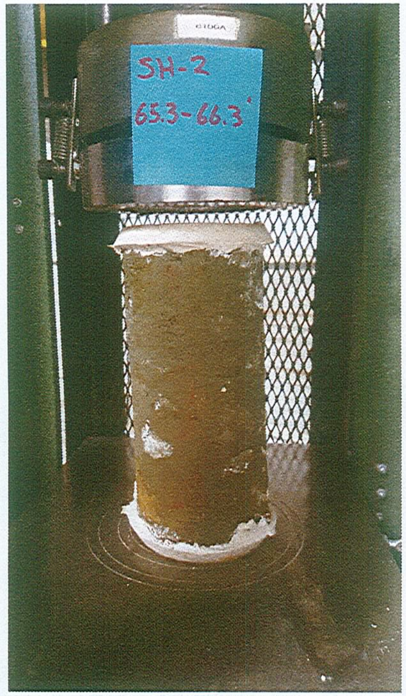

48.2 – 49.5 (internal)




55.8 – 57.2 (before)




55.8 – 57.2 (after)




65.3 – 66.3 (before)


65.3 – 66.3 (after)

# APPENDIX C

# 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