Joint Water Commission

Seismic Hazard Mitigation Study

TECHNICAL MEMORANDUM NO. 1
SEISMIC HAZARD EVALUATION / GEOTECHNICAL REPORT

FINAL

October 2008

SHANNON & WILSON, INC.

carollo
Engineers...Working Wonders With Water™

4380 SOUTHWEST MACADAM AVENUE • SUITE 350 • PORTLAND, OREGON 97239-6406 • (503) 227-1885 • FAX (503) 227-1747

Joint Water Commission

SEISMIC HAZARD MITIGATION STUDY

TECHNICAL MEMORANDUM NO. 1
SEISMIC HAZARD EVALUATION / GEOTECHNICAL REPORT

TABLE OF CONTENTS

LIST OF APPENDICES

LIST OF TABLES

LIST OF FIGURES

SEISMIC HAZARD EVALUATION/ GEOTECHNICAL REPORT

1.0 INTRODUCTION

Shannon & Wilson has completed a geotechnical site-specific seismic hazard evaluation for the JWC (Fern Hill Road) Water Treatment Plant (WTP). The site specific evaluation was conducted in general accordance with the applicable portions of the 2006 International Building Code (IBC) and the 2007 Oregon Structural Specialty Code (OSSC). The evaluation includes:

- Review and compile existing geotechnical information,
- Characterize subsurface stratigraphy and soil properties based on the existing geotechnical information,
- Develop response spectra for ground motions with 2%, 10% and 50% probability of exceedance in 50 years,
- Evaluate the potential hazard posed by earthquake-induced geologic hazards including liquefaction and liquefaction-induced settlement,
- Provide geotechnical support and develop mitigation concepts.

The project site is located in Washington County, Oregon, approximately 2 miles south of the City of Forest Grove on Fern Hill Road. The JWC WTP is approximately 1,000 feet south of the Tualatin River (see Figure 1), about 30 feet above the river level. The initial phase of the JWC WTP was designed and constructed around 1974.

2.0 REVIEW OF EXISTING INFORMATION

The seismic evaluation provided in this report is based on existing subsurface information. Specifically, Shannon & Wilson collected and reviewed geotechnical information from the following documents.

Shannon & Wilson, Inc., 1974, Fern Hill WTP design report, prepared for the City of Hillsboro, Oregon, 1974.

"Geotechnical Investigation, Raw Water Intake Pipeline" by Shannon & Wilson, Inc., 1993, prepared for Ace Consultants, Beaverton, Oregon, 1993.

"Geotechnical and Seismic Investigation, Fern Hill Water Treatment Plant Expansion, Forest Grove, Oregon" by Cornforth Consultants, Inc., 1995, prepared for the Joint Water Commission.

"Seismic Liquefaction Evaluation, Fern Hill Water Treatment Plant Expansion, Forest Grove, Oregon" by Cornforth Consultants, Inc., 1995, prepared for Joint Water Commission.

"Geotechnical Data Report, Joint Water Commission's Fern Hill Reservoir No. 2 and Water Treatment Plant Near Term Improvements Projects" by CH2M Hill, Inc, 2005, prepared for the Joint Water Commission.

Borings drilled for the 1974 Shannon & Wilson (S&W) report and the two 1995 Cornforth reports were located in the immediate vicinity of the WTP. The boring locations are shown on Figure 2 and were used to develop the subsurface profiles on Figure 3. The logs of these borings are included in Appendix A. The results of previous laboratory tests performed on samples from these borings are provided in Appendix B.

The 1993 Shannon & Wilson report was prepared for design and construction of the pipeline between the raw water intake pump station on the Tualatin River and the WTP. The 2005 CH2M Hill report was prepared for the design and construction of a 20 million gallon (MG) reservoir on top of Fern Hill, a new transmission pipeline to the WTP, solids drying beds and overflow piping. The boring logs from these reports were used to characterize groundwater conditions in the general area, but were too distant to include subsurface profiles of the WTP and are not included with this report.

3.0 GEOLOGIC AND SEISMIC TERMINOLOGY

The following geologic and seismic terminologies are defined to expand readership:

Fossiliferous Sandstone – sandstone containing fossils.

Forearc Basin – a depression, often filled with sediment, between a volcanic arc and a subduction zone.

Quaternary – a geologic time period from about 2.6 million years ago until the present.

Response Spectra – a plot typically of either the spectral acceleration or the spectral velocity versus various natural periods (T's).

Subduction Zone – the area at the boundary between an oceanic and a continental plate where the oceanic plate descends under the continental plate.

Shallow Crustal Earthquake – an earthquake occurring on a fault within and near the surface of the earth's crust, not associated with a plate boundary.

Spectral Acceleration – the acceleration experienced by a structure during a seismic event.

Site Class – designation of a site from A through F, subsurface rock/soil properties.

Thrust Fault – a low-angle fault in which the upper block moves up and onto the underlying block in a zone of compression; a subduction zone is a large-scale thrust fault, or "mega-thrust".

4.0 GEOLOGIC AND SUBSURFACE CONDITIONS

4.1 Geology

Based on the mapping work performed by the Oregon Department of Geology and Mineral Industries (Schlicker and Deacon, 1967), the oldest materials in the area are Oligocene age marine sedimentary rocks, which rise to the ground surface along the southeast edge of the WTP site. The marine sediments consist of a deeply weathered zone about 35 to 45 feet thick consisting of medium to high plasticity silts and clays, which grade downward to fossiliferous sandstone. On the WTP site, fine-grained deposits of the late Pleistocene catastrophic Missoula Flood deposits overlie the marine sediments. The flood deposits consist of approximately 40 to 50 feet of fine-grained sand and non-plastic to low plasticity silt.

4.2 Subsurface Conditions

S&W's understanding of the subsurface conditions is based on the information included in the reviewed reports. A number of subsurface explorations have been completed at the WTP location. Data from the 1973 Shannon & Wilson exploration and the 1995 Cornforth Consultants exploration was incorporated into the seismic hazard evaluation. The location and designation for the exploratory borings are located on Figure 2, Site Plan. Additional explorations for this study were not performed. Based on the previous work, two geologic profiles across the site were developed. The location and length of the profiles are indicated on Figure 2, Site Plan. Geologic profiles were named A and B, and are presented on Figure 3. Groundwater elevations and soil units used in the geologic profile appear to be fairly consistent between the various reports.

Four soil units were identified for this evaluation. The soil units were grouped according to material type, density/consistency values and Atterberg limit values. The subsurface stratigraphy beneath the site is relatively uniform. The top 40 to 50 feet consists of loose silty sand and non-plastic to low plasticity, sandy silt. Below the silt and sand is a 35- to 45-foot thick zone of stiff to very stiff, interbedded, medium to high plasticity silt and clay. Below the interbedded silt and clay and at an elevation of approximately 100 feet, very dense sand and gravel was encountered. The deepest boring at the site, boring B-3, penetrated 19 feet of very dense sand and gravel and terminated in a weak, fossiliferous sandstone immediately below the sand and gravel.

4.2.1 Groundwater

Groundwater at the site is reported within a few feet of the ground surface. Groundwater measurements in piezometers installed for the plant construction and for the construction of the reservoir transmission pipeline indicate groundwater near the surface. Piezometer measurements for the plant construction indicated that groundwater varied between the ground surface and approximately 15 to 20 feet below ground surface (bgs). Piezometer measurements for the reservoir transmission pipeline design indicated groundwater

between 1 and 8 feet bgs. Anecdotal evidence of high ground water is also found in plant construction documentation, in which the contractor had groundwater control issues in excavations less than 10 feet deep. Based on this information, the groundwater level was assumed to be at the ground surface in the analyses.

5.0 EARTHQUAKE GROUND MOTIONS

The seismic evaluation of the WTP will be based on multiple ground motion hazard levels. This evaluation requires development of response spectra for ground motions with 2%, 10% and 50% probabilities of exceedance in 50 years. These probabilities of exceedance correspond to the return periods shown in Table 1.

Table 1 Probability of Exceedance and Corresponding Return Period
Seismic Hazard Mitigation Study
Joint Water Commission

Probability of Exceedance in 50 Years	Return Period (years)
2%	2,475 (~2,500)
10%	475 (~500)
50%	72 (~ 100)

Response spectra for these ground motion levels was developed using the code-based procedures in the IBC 2006 for Maximum Considered Earthquake (MCE) ground motions. Computation of spectra using this code is based on seismological inputs. The following provides a brief description of the seismogenic sources, seismological input, site soil response factors, and the resulting response spectra.

5.1 Seismogenic Sources

Within the present understanding of the regional tectonic framework and historical seismicity, three broad seismogenic sources have been identified:

- A mega-thrust source at in interface between the North American and Juan de Fuca plates in the Cascadia Subduction Zone (CSZ).
- A deep subcrustal zone (intra-slab) in the subducted Juan de Fuca Plate and Gorda plates in the CSZ.
- A shallow crustal zone within the forearc of North American Plate.

For the general area of the WTP, the seismogenic sources that contribute significantly to the ground motion hazard include both megathrust earthquakes on the CSZ (located about 85 miles west of the site) and shallow crustal earthquakes on nearby faults. The nearest mapped shallow crustal fault is the Gales Creek Fault Zone, located approximately 1.8 miles

WSW of the site. This zone consists of multiple northwest trending dextral strike-slip faults. The zone has been suggested to be inactive by researchers, but is classified by the U.S. Geological Survey (USGS) as potentially active with Quaternary movement (Personius, 2002a). The other two shallow crustal faults within a 10-mile radius of the site are the Beaverton Fault Zone and the Helvetia Fault. The Beaverton Fault Zone begins approximately 5.4 miles ESE of the site and strikes east-west; the Helvetia Fault is located about 9.5 miles ENE of the site. Similar to the Gales Creek Fault Zone, the USGS has classified these faults as potentially active with Quaternary movement (Personius, 2002b,c). Quaternary faults mapped within a 30-mile radius of the site are listed in Table 2.

Table 2 Quaternary Faults
Seismic Hazard Mitigation Study
Joint Water Commission

Fault Name	Distance To Fault (mi)	Direction to Fault
Gales Creek Fault Zone	1.8	WSW
Beaverton Fault Zone	5.4	ESE
Helvetia Fault	9.5	ENE
Newberg Fault	12.5	SSE
Oatfield Fault	14.8	ENE
Canby-Molalla Fault	15.5	ESE
Portland Hills Fault	16.2	NE
East Bank Fault	17.5	NE
Mount Angel Fault	25	SE
Grant Butte and Damascus-Tickle Creek Fault Zone	26	E
Tillamook Bay Fault Zone	26.3	WSW

As previously indicated, the seismic evaluation of the WTP is based on ground motions with 2%, 10% and 50% probabilities of exceedance in 50 years. The ground motion hazard at a given probability of exceedance is the sum of the hazard from the various seismogenic sources (the sum of the hazard is equal to 100% for a given probability of exceedance). Ground hazards for multiple seismogenic sources are computed using probabilistic seismic hazard analyses (PSHA). The USGS has performed PSHA and calculated ground motion hazard levels nationwide considering multiple seismogenic sources.

Table 3 shows the relative contribution of seismogenic sources to the ground motion hazard levels calculated from the USGS PSHA. As shown on this table, shallow crustal and CSZ megathrust earthquakes contribute the most to the seismic hazard at the WTP site for the probabilities of exceedance or return periods considered in the seismic evaluation. We note that the hazard contribution of a CSZ megathrust earthquake is only half of the shallow crustal source for the 72-year return period ground motions, while it is approximately equal in hazard contribution for the 475- and 2,475-year return period ground motions.

Table 3 Earthquake Hazard Contribution
Seismic Hazard Mitigation Study
Joint Water Commission

Return period, yr	Exceedance Probability	CSZ megathrust EQ % contribution to total hazard	CSZ intra-slab EQ % contribution to total hazard	Shallow Crustal EQ % contribution to total hazard
2,475	2 %	47 %	<1 %	53 %
475	10 %	52 %	4 %	44 %
72	50 %	26 %	17 %	57 %

Table 4 further illustrates the different properties or parameters for the earthquakes that contribute to the ground motion hazard levels. These earthquake parameters were used in evaluating the seismic hazards at the JWC WTP site. The magnitudes and distances of earthquakes were obtained from the USGS web site, Probabilistic Seismic Hazard Deaggregation, based upon the project site location (Longitude = -123.0970, and Latitude = 45.4877). Peak ground accelerations (PGA) shown on Table 4 were obtained from the 2002 USGS Seismic Hazard Maps (Frankel et al., 2002) and USGS Ground Motion Parameter Tool (Version 5.0.7) for the Pacific Northwest Region.

Table 4	Earthquake Characterization by Seismogenic Source Seismic Hazard Mitigation Study Joint Water Commission			
Exceedance Probability	**Bedrock PGA (g)**	**Seismogenic Source**	**Modal Distance from Site (km)**	**Modal Magnitude (M_w)**
2 %	0.371	Shallow Crustal	10	6
		CSZ Intra-slab	60	7.2
		CSZ Megathrust	72	8.6
10 %	0.188	Shallow Crustal	15	5.9
		CSZ Intra-slab	65	7.0
		CSZ Megathrust	76	8.6
50 %	0.053	Shallow Crustal	31	5.7
		CSZ Intra-slab	80	7.0
		CSZ Megathrust	100	8.3

5.2 S_S and S_1

The seismological inputs used to construct a response spectrum using the IBC 2006 procedure are short period spectral acceleration, S_S, and spectral acceleration at the 1-second period, S_1, shown on Figure 1615 in the code. As defined in the IBC 2006, S_S and S_1 are for a maximum considered earthquake that corresponds to ground motions with a 2% percent probability of exceedance in 50 years and determined from the USGS national PSHA. S_S and S_1 for other probabilities of exceedance or return periods are also published by the USGS. S_S and S_1 for ground motions with 2%, 10% and 50% probabilities of exceedance in 50 years from the USGS study in the vicinity of the site are summarized on Table 5.

Table 5	S_S and S_1 Seismic Hazard Mitigation Study Joint Water Commission		
Exceedance Probability	**Return period, yr**	**S_S (g's)**	**S_1 (g's)**
2 %	2475	0.887	0.370
10 %	475	0.442	0.167
50 %	72	0.114	0.034

5.3 Site Class

The site soil response factors are based on determination of the Site Class. Determination of the seismic Site Class was based on the procedure described in the OSSC for seismic site classification using standard penetration resistance values. Based on the subsurface explorations at the site, the engineering opinion is that the site is best classified as E.

The liquefaction hazard calculations, discussed in the following section of this report, indicate that some of the site soils are potentially liquefiable for the 2%- and 50%-probability-of-exceedance-in-50-year ground motions. Subsurface conditions with potentially liquefiable soils correspond to Site Class F. For F sites, the code requires a site-specific ground response evaluation for structures with periods greater than 0.5 seconds. For structures with periods less than 0.5 seconds, the code allows for seismic design based on a site class determined without regard to liquefaction.

Based upon initial discussions with the structural engineer, the fundamental periods of vibration of the structures are less than 0.5 seconds, since the buildings and facilities at the WTP are one or two story structures with concrete walls.

5.4 Response Spectra

The response spectra for ground motions with 2%, 10% and 50% probabilities of exceedance in 50 years and Site Class E are presented on Figure 4. Peak bedrock ground accelerations, S_S, and S_1 were determined using the USGS Earthquake Ground Motion Parameters software, version 5.0.7 (June 18, 2007). The Site Class E response spectra were constructed using the IBC 2006 procedure. It should be noted that the response spectra for a 2%-probability-of-exceedance-in-50-years ground motion presented in Figure 4 are for Maximum Considered Earthquake (MCE) ground motions and have not been scaled by 2/3 to generate "design" spectra, which is required in the IBC 2007.

6.0 EARTHQUAKE-INDUCED GEOLOGIC HAZARDS

Earthquake-induced geologic hazards that may affect a given site include landsliding, fault rupture, settlement, liquefaction and associated effects (loss of shear strength, bearing capacity failures, loss of lateral support, ground oscillation, lateral spreading, etc.), and flooding (i.e., seiche and tsunami). Liquefaction and related effects appear to pose the most likely and significant earthquake-induced geologic hazard at the site. The following sections of this report present an evaluation of the earthquake-induced geologic hazards, including liquefaction potential and associated effects.

6.1 Liquefaction Potential Analysis

Soils that are typically highly susceptible to liquefaction are loose, saturated cohesionless sandy, or silty soils. Soil particles in a loose soil will tend to arrange themselves in a more compact configuration (i.e., densify) when shaken with sufficient intensity. If there is water between the soils particles (i.e., the soil is saturated), the tendency of the soil to densify

decreases the pore space between the soil particles and increases the pore water pressure. Liquefaction results as pore water pressure in the soil approaches the effective confining stress, causing the soil to effectively loose most of its shear strength. The effects of liquefaction may include loss of bearing capacity for shallow foundations, reduction in lateral and vertical capacities of deep foundations, buoyant rise of buried structures, ground surface settlements, lateral spreading and embankment instability or slumping.

The most widely used method is an empirical procedure, termed "Seed's Simplified Procedure." This method was proposed by Seed and his colleagues (1971 and 1983) and updated by Youd et al. (2001) and is based on correlations between standard penetration resistance (SPT N-value), soil peak ground acceleration (PGA), and earthquake magnitude. Based upon the geologic profile presented in Figure 3, the subsurface soil conditions are relatively consistent across the WTP site. Therefore, we selected two borings, B-3 and B-8, to evaluate the liquefaction potential using the above procedure. The factors of safety against liquefaction for SPT N-values from borings B-3 and B-8 were calculated for each ground motion hazard level. The results of the analyses indicated similar conclusions for the liquefaction potential. Thus, the calculated factors of safety for Boring B-8 are presented in Figures 5 to 8, as illustrative purpose.

Because the calculated factor of safety is a function of earthquake magnitude, we considered magnitudes associated with both shallow crustal and CSZ mega-thrust events in the liquefaction analyses. For the 475- and 2,475-year ground motions, the calculated factors of safety against liquefaction for the saturated cohesionless soils in the top 40 to 50 feet (sand, silty sand, and non-plastic or low plasticity silt) were generally less than 1 regardless of whether a shallow crustal earthquake magnitude or CSZ megathrust earthquake magnitude was used in the analyses. For the 72-year return period ground motions, the factors of safety for a shallow crustal earthquake magnitude are generally greater than 1, but generally less than 1 for subduction zone megathrust earthquake magnitudes. It should be noted that for the 72-year return period most of the hazard is from shallow crustal sources (see Table 3); only 26 percent of the ground motion hazard is from the megathrust source.

The plastic silt and clay soils and very dense gravels below the silt and sand in the upper 40 to 50 feet (i.e., below an elevation of approximately 145 feet) all have cohesive properties or are sufficiently dense to preclude liquefaction.

6.2 Liquefaction-Induced Settlement

The potential range of liquefaction-induced settlement was estimated for borings B-3 and B-8 using the procedures by Tokimatsu and Seed (1987). Similar to the liquefaction potential factor-of-safety calculations, because of the relatively consistent subsurface conditions, the calculated settlements for the above two borings are in the same order of magnitude. Therefore, the range of the calculated settlements are representative for the entire WTP site. Further, based upon the analyses, significant settlements are estimated for both the 2,475- and 475-year earthquakes regardless of assumed magnitude. For the 72-

year return period ground motions, no liquefaction-induced ground settlement is estimated for shallow crustal earthquake magnitudes, while settlements are on the order of 7 to 9 inches estimated for CSZ megathrust magnitudes. The estimated settlements are shown on Table 6.

Table 6 Liquefaction Settlement
Seismic Hazard Mitigation Study
Joint Water Commission

Exceedance Probability	Magnitude Range of Settlements (in)
2% (2475 yr & M8.6)	13 – 15
10% (475 yr & M8.6)	12 – 14
50% (72 yr & M5.7)-crustal	No Liquefaction Induced Settlement
50% (72 yr & M8.3)-subduction	7 – 9

The settlements in Table 6 are total settlements. Differential settlements may be the same or nearly the same as the total settlements.

6.3 Lateral Spreading Hazard

Lateral spreading potential for the site was evaluated, using the procedures described by Youd, Hansen and Bartlett, 2002. We evaluated the hazard for ground deformation between the WTP and the Tualatin River. As described by Youd et al., liquefaction-induced lateral spreading resulting in ground deformations occur on slopes underlain by loose sands and shallow ground water with as little as 0.3% ground slope. If liquefaction occurs, intact soils on top of liquefied soils may move as blocks down slope under the force of gravity. In order to perform the lateral spreading analysis, the following site and geologic conditions have been assumed based on review of available information.

- The northwest corner of the plant is approximately 1,000 feet from the river.
- The ground slopes down from the plant to the river at a slope of approximately 3.5 percent (assume a continuous slope from the WTP to the river).
- We estimate that the there may be a continuous 20-foot thick layer of liquefiable soil between the WTP and the river.
- The lateral spread potential was evaluated for the three earthquake ground motion levels.

Similar to the liquefaction potential factor-of-safety calculations, the settlement calculations are a function of the earthquake magnitude. Based on the "best estimate" subsurface model and the above assumptions, ground deformation is calculated to occur with all three ground motion levels and CSZ earthquake magnitudes, but essentially no movement is calculated

to occur with the shallow crustal earthquake magnitudes. Table 7 presents the results from the lateral spreading evaluation.

Table 7 Lateral Spreading Evaluation Seismic Hazard Mitigation Study Joint Water Commission

Exceedance Probability	Potential Range of Ground Deformations [Towards River] (in)
2% (2475 yr & M8.6)	6 - 8
2% (2475 yr & M6.0)	< 0.5
10% (475 yr & M8.6)	4 - 6
50% (72 yr & M8.3)-subduction	< 0.5

The results of the lateral spreading hazard evaluation represent a "best estimate" with the limited available subsurface information between the WTP and the river. A more reliable estimate of liquefaction hazard could be made if subsurface explorations are performed to explore the actual subsurface conditions between the WTP and the river.

6.4 Liquefaction-Related Reduced Foundation Capacities

The effects of liquefaction on the foundation capacities of specific structures or of uplift forces on buried structures have not been analyzed. We believe that reduction in foundation capacities, both lateral and vertical, and uplift forces, particularly for 475- and 2,475-year return period ground motions will likely be significant. However, due to the estimated significant liquefaction-induced settlement, our opinion is that the seismic performance of the buildings and structures founded on the liquefiable soils will be controlled by the liquefaction-induced settlements instead of seismic bearing capacities.

6.5 Other Earthquake-Induced Geologic Hazards

The risk posed by other earthquake-induced geologic hazards to the WTP is considered to be relatively low. A brief discussion of other earthquake-induced geologic hazards is provided in this section of the report.

The risk posed by landsliding is considered relatively low. This opinion is based on the flat topography at the site and the large distance to significant slopes (e.g., river edge or Fern Hill). The potential for fault rupture is also relatively low. The nearest mapped fault is the Gales Creek Fault Zone, located approximately 1.8 miles WSW of the site. This zone consists of multiple northwest trending dextral strike-slip faults. While this fault is considered potentially active by the USGS, the potential for fault rupture at the site is relatively low because of the distance and orientation between the site and the fault.

The potential for flooding due to seismic waves (tsunami or seiches) is also relatively low as the site is located several tens of miles inland from the coast and any potential tsunami wave, and there are no significant adjacent closed water bodies in which a free-standing oscillating wave (seiche) could develop and affect the site.

6.6 Recommended Site-Specific Seismic Hazard Evaluations

The seismic hazard evaluation performed for this study is a simplified code-based seismic hazard evaluation. A complete site-specific evaluation was not performed based on the project scope requirements for a conceptual-level seismic evaluation of the JWC WTP. A site-specific seismic hazard evaluation for this site should include field explorations, laboratory testing, and numerical modeling analyses, such as Shake or D-MOD2000 analysis. These evaluations may reduce the estimated magnitudes of the seismic parameters, such as spectral accelerations, which in turn may reduce the risk associated with liquefaction and its induced settlements, as well as lateral spreading. Therefore, performing a site-specific seismic hazard evaluation is recommended during the next phase of the project, or prior to design of any seismic upgrades and/or expansion of the plant.

7.0 LIMITATIONS

The observations, analyses, conclusions, and recommendations contained in this report are based upon site conditions as they presently exist, and further assume that the borings are representative of subsurface conditions throughout the site, i.e., the subsurface conditions everywhere are not significantly different from those disclosed by the field explorations.

If, during construction or future explorations, subsurface conditions different from those encountered in the field explorations are observed, JWC staff should advise S&W at once so that these conditions can be reviewed and the recommendations can be reconsidered where necessary. If there is a substantial lapse of time since the submission of this report or if conditions have changed due to natural causes or construction operations at or adjacent to the site, it is recommended that this report be reviewed to determine the applicability of these conclusions and recommendations, considering the changed conditions and the elapsed time.

This report is prepared for the exclusive use of the Joint Water Commission and Carollo Engineers. It should be made available to prospective contractors for information on factual data only, and not as a warranty of subsurface conditions described in this report. Shannon & Wilson has prepared the attached, "Important Information About Your Geotechnical Engineering Report," to assist you and others in understanding the use and limitations of our reports. This attachment is presented in Appendix C of this report.

Please note that the scope of 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 or around the JWC WTP site.

SHANNON & WILSON, INC.

Derrick Hayes
Engineering Staff

Risheng Piao, PE
Project Manager/Associate

DRH :WJP:RPP/drh

8.0 REFERENCES

2006 International Building Code, January 2006, International Code Council, Inc, Section 1615

2007 Oregon Structural Specialty Code, January 2007, International Code Council, Inc, Section 1613, pp 407-414.

CH2M Hill, Inc, "Geotechnical Data Report, Joint Water Commission's Fern Hill Reservoir No. 2 and Water Treatment Plant Near Term Improvements Projects", Prepared for Joint Water Commission, 2005.

Cornforth Consultants, Inc., "Geotechnical and Seismic Investigation, Fern Hill Water Treatment Plant Expansion, Forest Grove, Oregon" Prepared for Joint Water Commission, 1995.

Cornforth Consultants, Inc., "Seismic Liquefaction Evaluation, Fern Hill Water Treatment Plant Expansion, Forest Grove, Oregon" Prepared for Joint Water Commission, 1995.

Frankel, A., Petersen, M., Mueller, C., Haller, K., Wheeler, R., Leyendecker, E., Wesson, R., Harmsen, S., Cramer, C., Perkins, D., and Rukstales, K., 2002, Documentation for the 2002 update of the national seismic hazard maps: U.S. Geological Survey Open-File Report 02-420, 39 p

Fujitani Hilts and Associates, "Geotechnical Investigation, Raw Water Intake Pipeline, Forest Grove, Oregon" prepared for Ace Consultants, Inc, 1993.

Kramer, Steven L. (1995), "Geotechnical Earthquake Engineering," pp 487-496.

Oregon Department of Geology and Mineral Industries, Geologic map of the Tualatin Valley 1967, Schlicker and Deacon.

Oregon Department of Forestry, Oregon Latitude Longitude Locator, accessed 12, October 2007, from ODF GIS website: http://salemgis.odf.state.or.us/scripts/esrimap.dll?name=locate&cmd=start

Personius, S.F., compiler, 2002a, Fault number 718, Gales Creek fault zone, in Quaternary fault and fold database of the United States: U.S. Geological Survey website, http://earthquakes.usgs.gov/regional/qfaults, accessed 12/04/2007 02:17 PM.

Personius, S.F., compiler, 2002b, Fault number 714, Helvetia fault, in Quaternary fault and fold database of the United States: U.S. Geological Survey website, http://earthquakes.usgs.gov/regional/qfaults, accessed 12/04/2007 02:21 PM.

Personius, S.F., compiler, 2002c, Fault number 715, Beaverton fault zone, in Quaternary fault and fold database of the United States: U.S. Geological Survey website, http://earthquakes.usgs.gov/regional/qfaults, accessed 12/04/2007 02:22 PM.

Seed, H.B., and Idriss, I.M., 1971, Simplified procedure for evaluating soil liquefaction potential in Journal of the Soil Mechanics and Foundations Division, New York, American Society of Civil Engineers, vol. 97, no. SM9, p. 1249-1273.

Seed, H.B., Idriss, I., and Arango, I., 1983, Evaluation of liquefaction potential using field performance data: Journal of Geotechnical Engineering, New York, American Society of Civil Engineers, vol. 109, no. 3, p. 458-482.

Seed, R.B. and Harder, L.F., Jr. (1990), "SPT-Based Analysis of Cyclic Pore Pressure Generation and Undrained Residual Strength," H.B. Seed Memorial Symposium, J.M. Duncan, Editor, Tech Publishers Ltd., Vancouver, Canada, Vol. 2, pp. 351-376.

Shannon & Wilson, Inc., Fern Hill WTP design report, prepared for the City of Hillsboro, Oregon, 1974.

Tokimatsu, K. and Seed, H.B., (1987), "Evaluation of Settlements in Sands Due to Earthquake Shaking", JGED, ASCE, Vol. 113, No. 8, pp. 861-878.

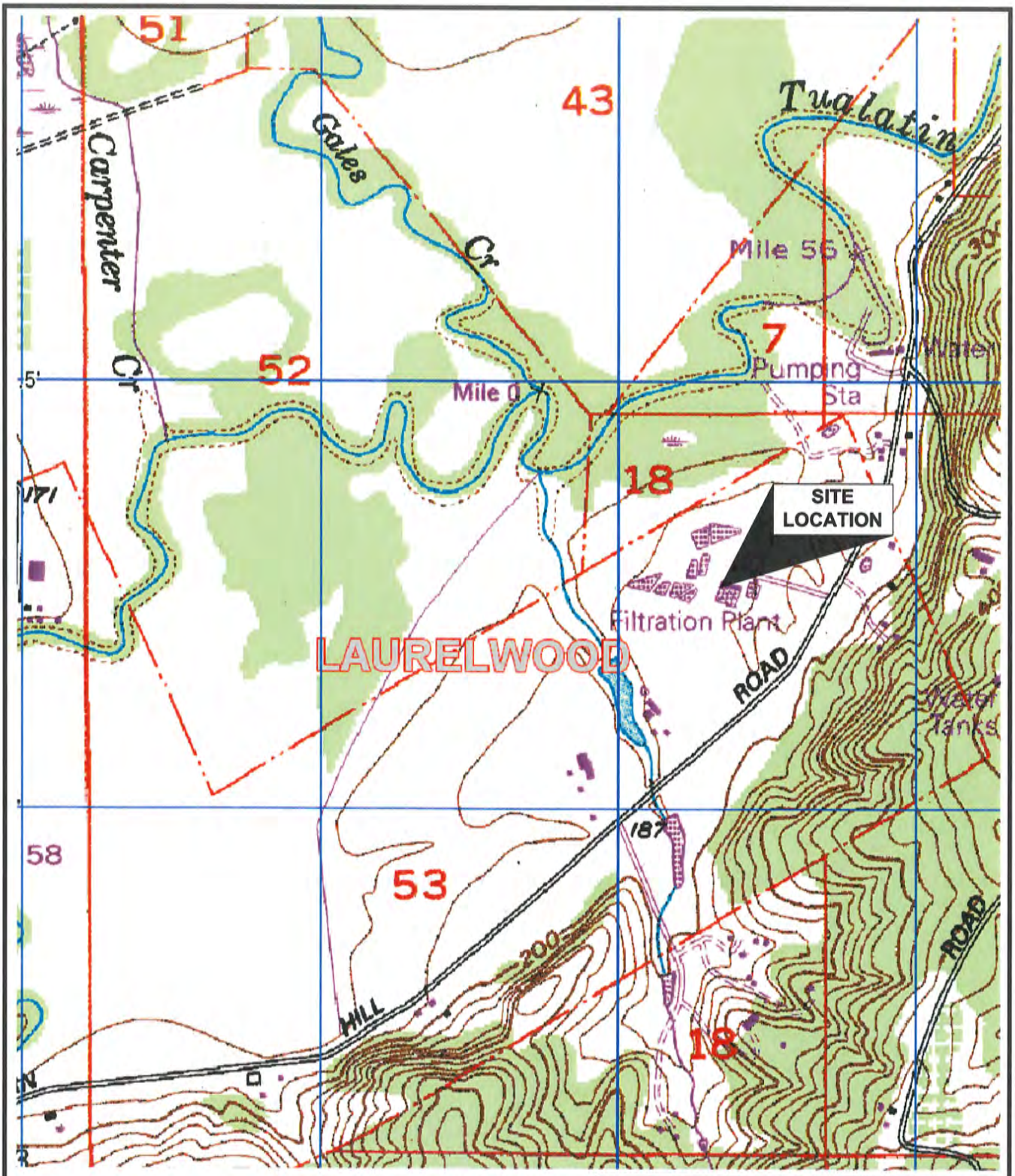
United States Geological Survey, 2002, Interactive deaggregation, accessed 22, October 2007, from USGS Custom Mapping and Analysis Tools Website: http://earthquake.usgs.gov/research/hazmaps/interactive/index.php

United States Geological Survey, 2006, Quaternary fault and fold database for the United States, Accessed 25 October 2007, from USGS web site: http//earthquakes.usgs.gov/regional/qfaults/.

United States Geological Survey Earthquake Ground Motion Tool, version 5.0.7, June 18, 2007.

Youd, L.T., I. M. Idriss, Ronald D. Andrus, Ignacio Arango, Gonzalo Castro, John T. Christian, Richardo Dobry, W. D. Liam Finn, Leslie F. Harder Jr., Mary Ellen Hynes, Kenji Ishihara, Joseph P. Koester, Sam S. C. Liao, William F. Marcuson III, Geoffrey R. Martin, James K. Mitchell, Yoshiharu Moriwaki, Maurice S. Power, Peter K. Robertson, Raymond B. Seed, and Kenneth H. Stokoe II, 2001, Liquefaction resistance of soils: Summary report from the 1996 NCEER and 1998 NCEER/NSF workshops on Evaluation of Liquefaction Resistance of Soils *in* Journal of Geotechnical and Environmental Engineering, New York, American Society of Civil Engineers, vol. 127, no. 10, p. 817-833, October..

Youd, L.T., Hansen, C. M., and Bartlett, S.F., 2002, Revised MLR equations for prediction of lateral spread displacement, Journal of Geotechnical and Geoenvironmental Engineering, American Society of Civil Engineers, vol. 128, no. 12, December, p. 1007-1017.



0 1250 2500

Scale in Feet

N

From 1961 Laurelwood, Oregon
USGS 7.5 Minute Topographic Quadrangle Map.

Joint Water Commission
Fern Hill Road WTP Seismic Evaluation
Forest Grove, Oregon

VICINITY MAP

December 2007 24-1-03459-001

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. 1

N

B-1 Shannon & Wilson Borings, 1973

CC-1 Cornforth Consultants Borings, 1995

A A' Location and Name of Geologic Profile

0 200 400

Scale in Feet

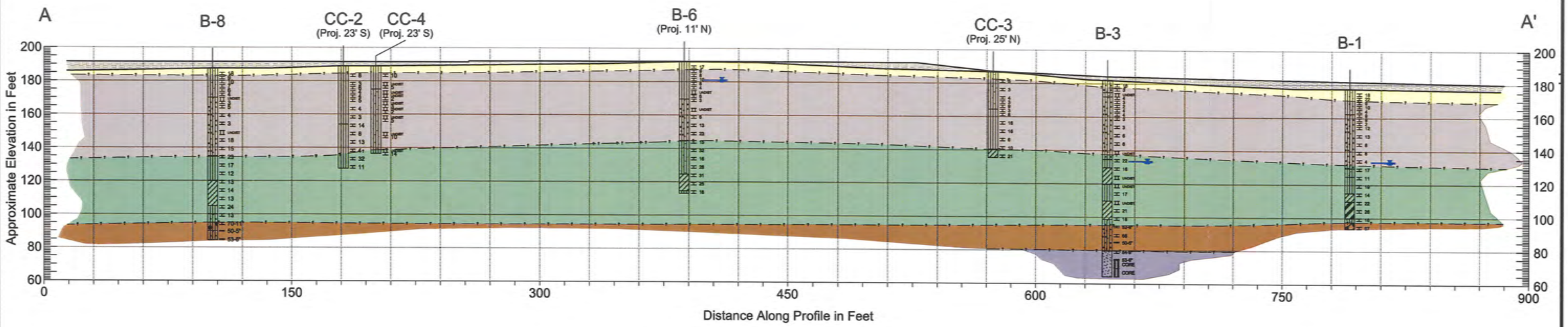
Joint Water Comission
Fern Hill Road WTP Seismic Evaluation
Forest Grove, Oregon

LOCATION OF PREVIOUS EXPLORATIONS

December 2007 24-1-03459-001

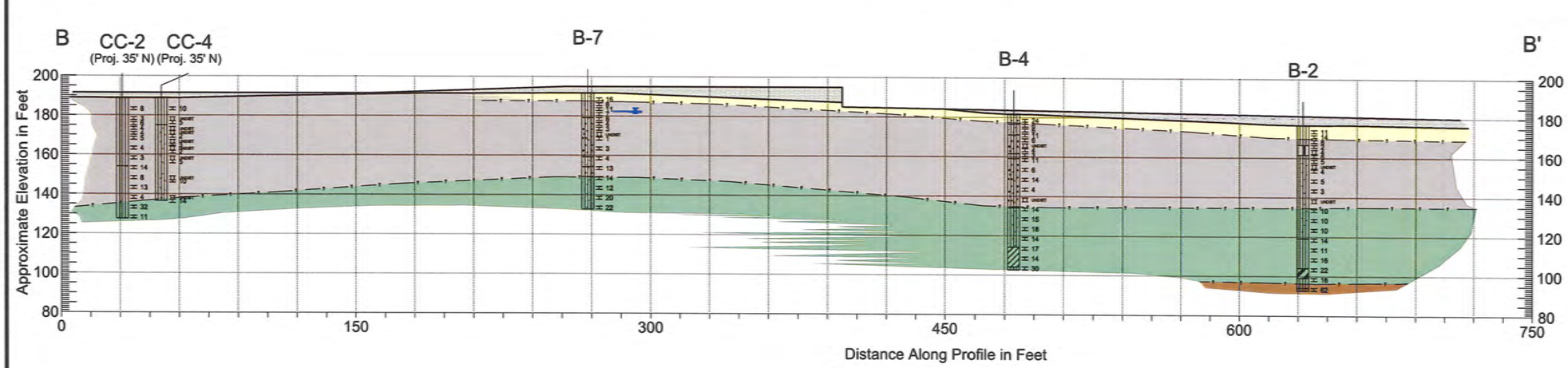
SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. 2



GEOLOGIC PROFILE A-A'

H&V Scale: 1" = 60 ft



GEOLOGIC PROFILE B-B'

H&V Scale: 1" = 60 ft

EXPLANATION

- Site Fill - Undifferentiated
- Medium dense silty SAND to sandy SILT.
- Loose silty SAND to medium stiff sandy SILT; non to low plasticity [**Potentially Liquefiable**].
- Stiff to very stiff, interbedded SILT and CLAY; medium to high plasticity.
- Very dense SAND and GRAVEL.
- Low strength SANDSTONE
- Split spoon sampler (SPT) and field blow counts (Nvalue)
- Thin walled sampler

Joint Water Commission
Fern Hill Road WTP Seismic Evaluation
Forest Grove, Oregon

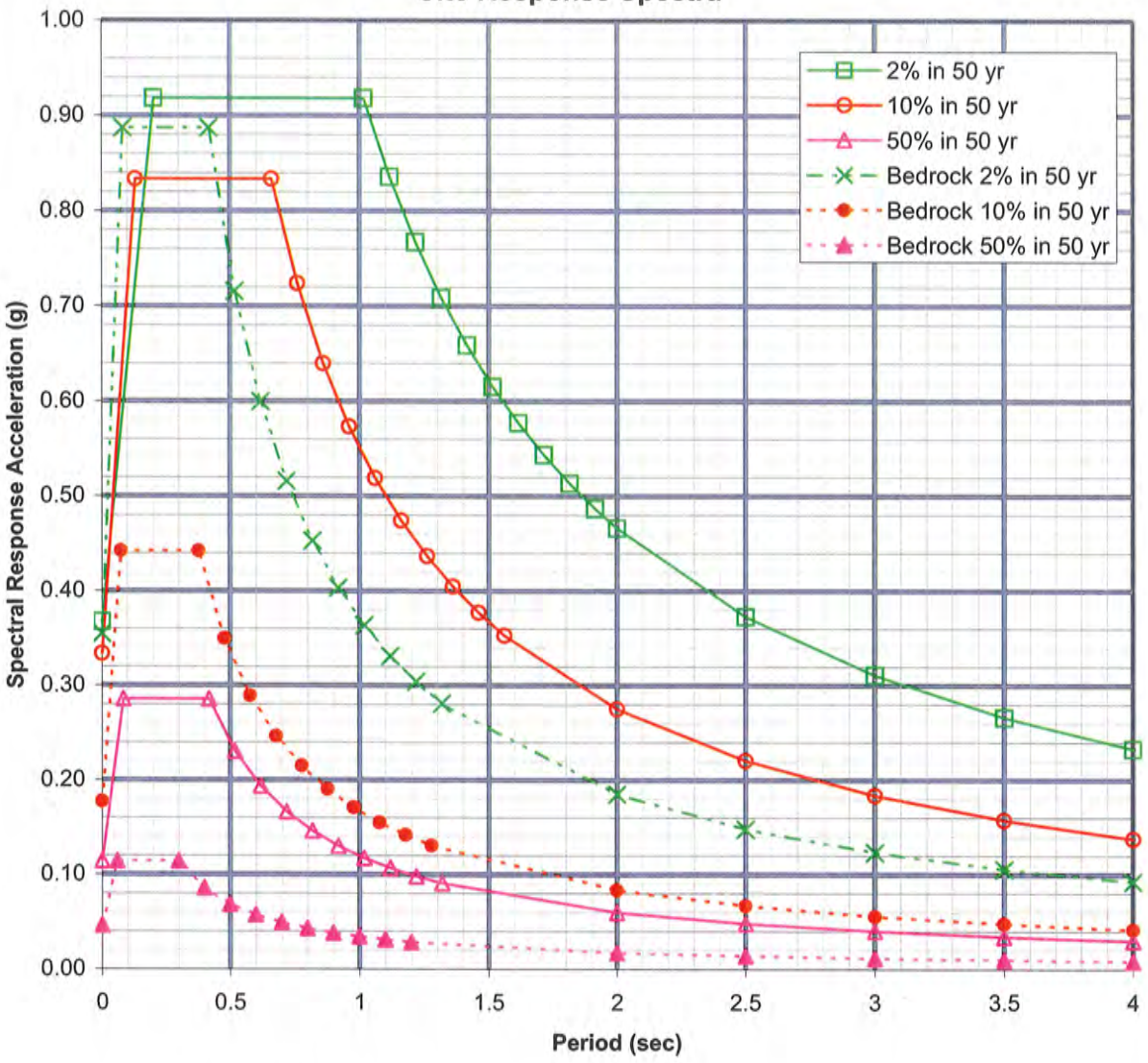
GEOLOGIC PROFILE

December 2007 24-1-03459-001

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. 3

Site Response Spectra



Seismic Design Parameters

Site Classification	E - ground surface		
Return Period, yr	2475	475	72
PGA, g	0.367	0.333	0.114
F_a	1.04	1.89	2.50
F_v	2.52	3.30	3.50
S_{MS}	0.92	0.83	0.29
S_{M1}	0.93	0.55	0.12

Site Classification	B - Bedrock		
Return Period, yr	2475	475	72
PGA, g	0.371	0.188	0.053
S_S	0.887	0.442	0.114
S_1	0.370	0.167	0.034
F_a	1.000	1.000	1.000
F_v	1.000	1.000	1.000

Joint Water Commission
Fern Hill Road WTP Seismic Evaluation
Forest Grove, Oregon

CODE BASED RESPONSE SPECTRA

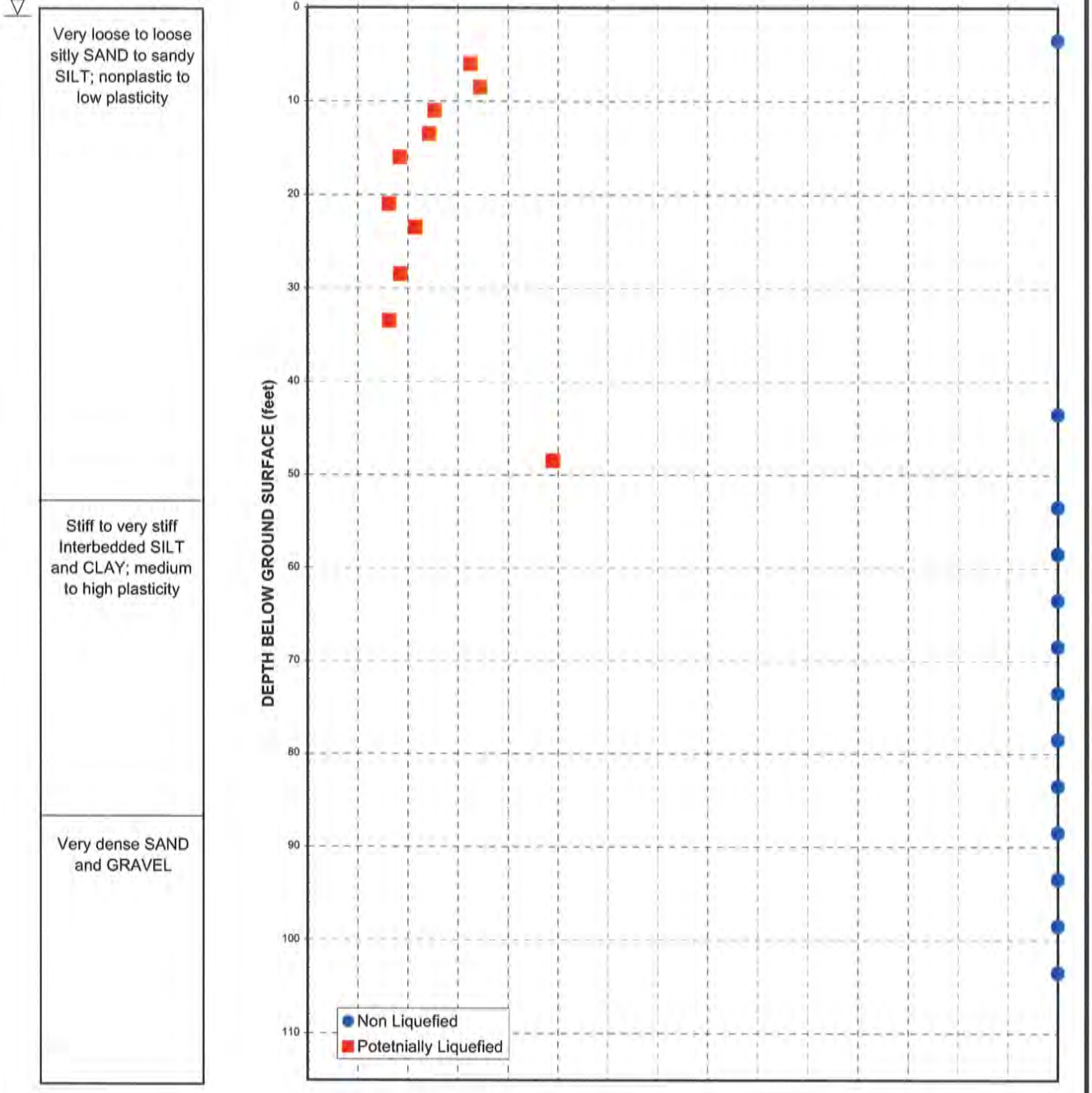
December 2007 24-1-03459-001

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. 4

SUBSURFACE PROFILE

(Based on Boring B-8)



NOTES:

1. *Reference:* Youd, T.L. and Idriss, I.M., 2001, Liquefaction Resistance of Soils: Summary Report from the 1996 NCEER and 1998 NCEER/ NSF Workshops on Evaluation of Liquefaction Resistance of Soils.
2. The analysis was performed for an earthquake with a magnitude of 8.6 and a peak ground acceleration of 0.367g.
3. The liquefaction resistance of a soil is dependent on its density and fines content. The fines content was estimated based on selected grain-size analyses and soil description.

Joint Water Commission
Fern Hill Road WTP Seismic Evaluation
Forest Grove, Oregon

RESULTS OF LIQUEFACTION ANALYSES
BORING B-8: Mw= 8.6: Return= 2475

November 2007 24-1-3459-001

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. 5

SUBSURFACE PROFILE

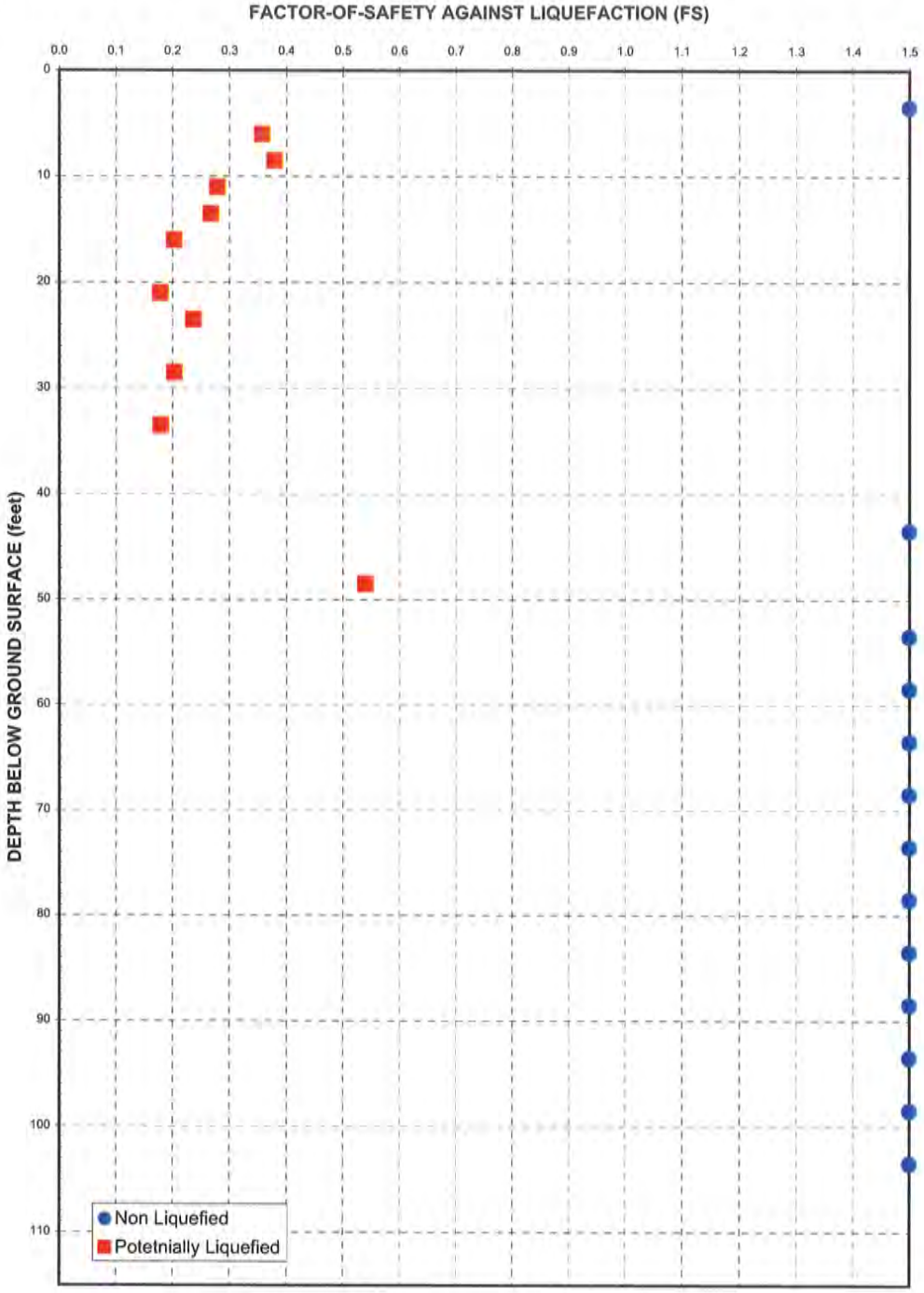
(Based on Boring B-8)

▽

Very loose to loose sitly SAND to sandy SILT; nonplastic to low plasticity

Stiff to very stiff Interbedded SILT and CLAY; medium to high plasticity

Very dense SAND and GRAVEL



NOTES:

1. *Reference:* Youd, T.L. and Idriss, I.M., 2001, Liquefaction Resistance of Soils: Summary Report from the 1996 NCEER and 1998 NCEER/ NSF Workshops on Evaluation of Liquefaction Resistance of Soils.
2. The analysis was performed for an earthquake with a magnitude of 8.6 and a peak ground acceleration of 0.333g.
3. The liquefaction resistance of a soil is dependent on its density and fines content. The fines content was estimated based on selected grain-size analyses and soil description.

Joint Water Commission
Fern Hill Road WTP Seismic Evaluation
Forest Grove, Oregon

RESULTS OF LIQUEFACTION ANALYSES
BORING B-8: Mw= 8.6: Return= 475

December 2007 24-1-3459-001

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. 6

SUBSURFACE PROFILE

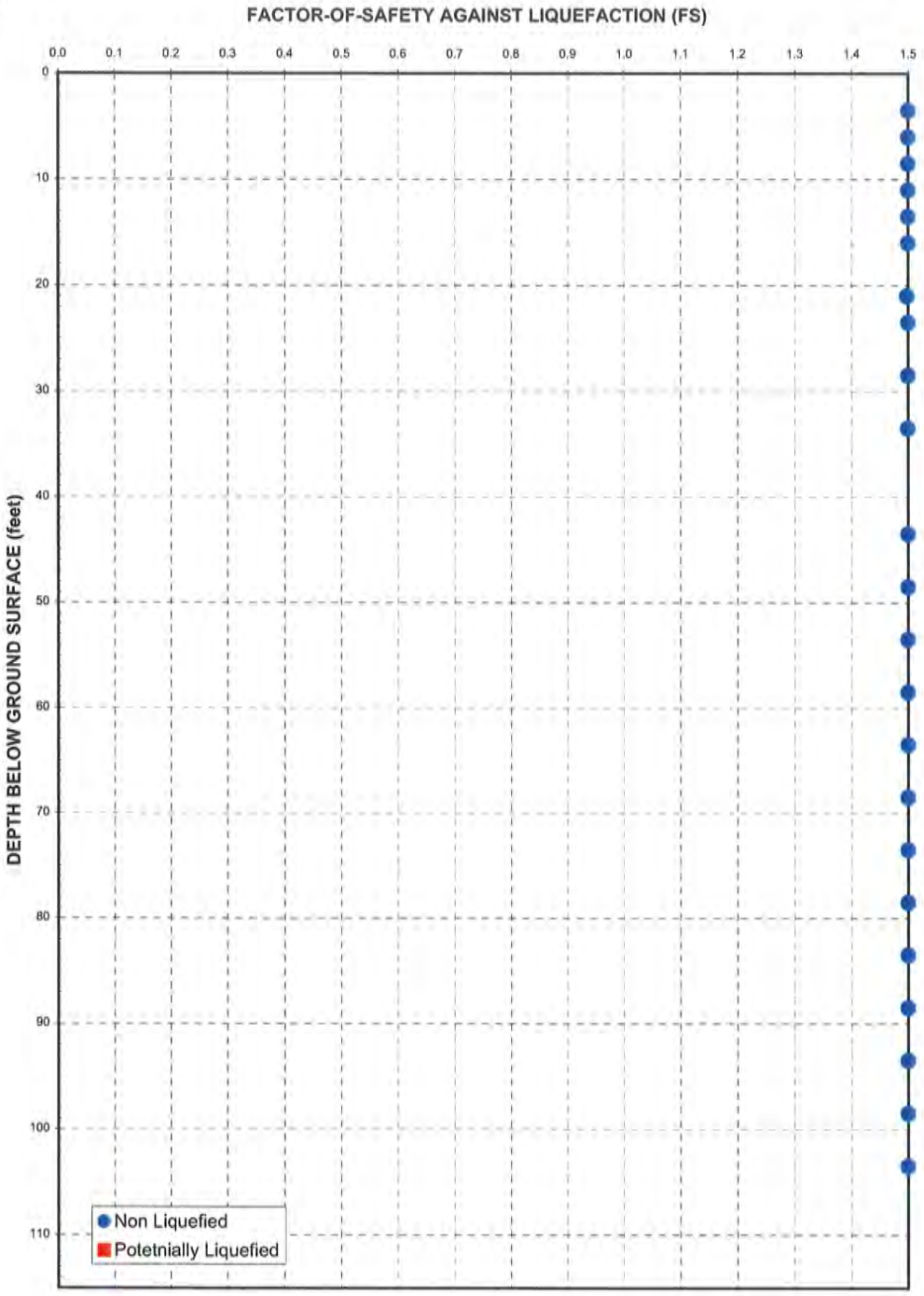
(Based on Boring B-8)

▽

Very loose to loose sitly SAND to sandy SILT; nonplastic to low plasticity

Stiff to very stiff Interbedded SILT and CLAY; medium to high plasticity

Very dense SAND and GRAVEL



NOTES:

1. *Reference:* Youd, T.L. and Idriss, I.M., 2001, Liquefaction Resistance of Soils: Summary Report from the 1996 NCEER and 1998 NCEER/ NSF Workshops on Evaluation of Liquefaction Resistance of Soils.
2. The analysis was performed for an earthquake with a magnitude of 5.7 and a peak ground acceleration of 0.114g.
3. The liquefaction resistance of a soil is dependent on its density and fines content. The fines content was estimated based on selected grain-size analyses and soil description.

Joint Water Commission
Fern Hill Road WTP Seismic Evaluation
Forest Grove, Oregon

RESULTS OF LIQUEFACTION ANALYSES
BORING B-8: Mw= 5.7: Return= 72

December 2007 24-1-3459-001

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. 7

SUBSURFACE PROFILE

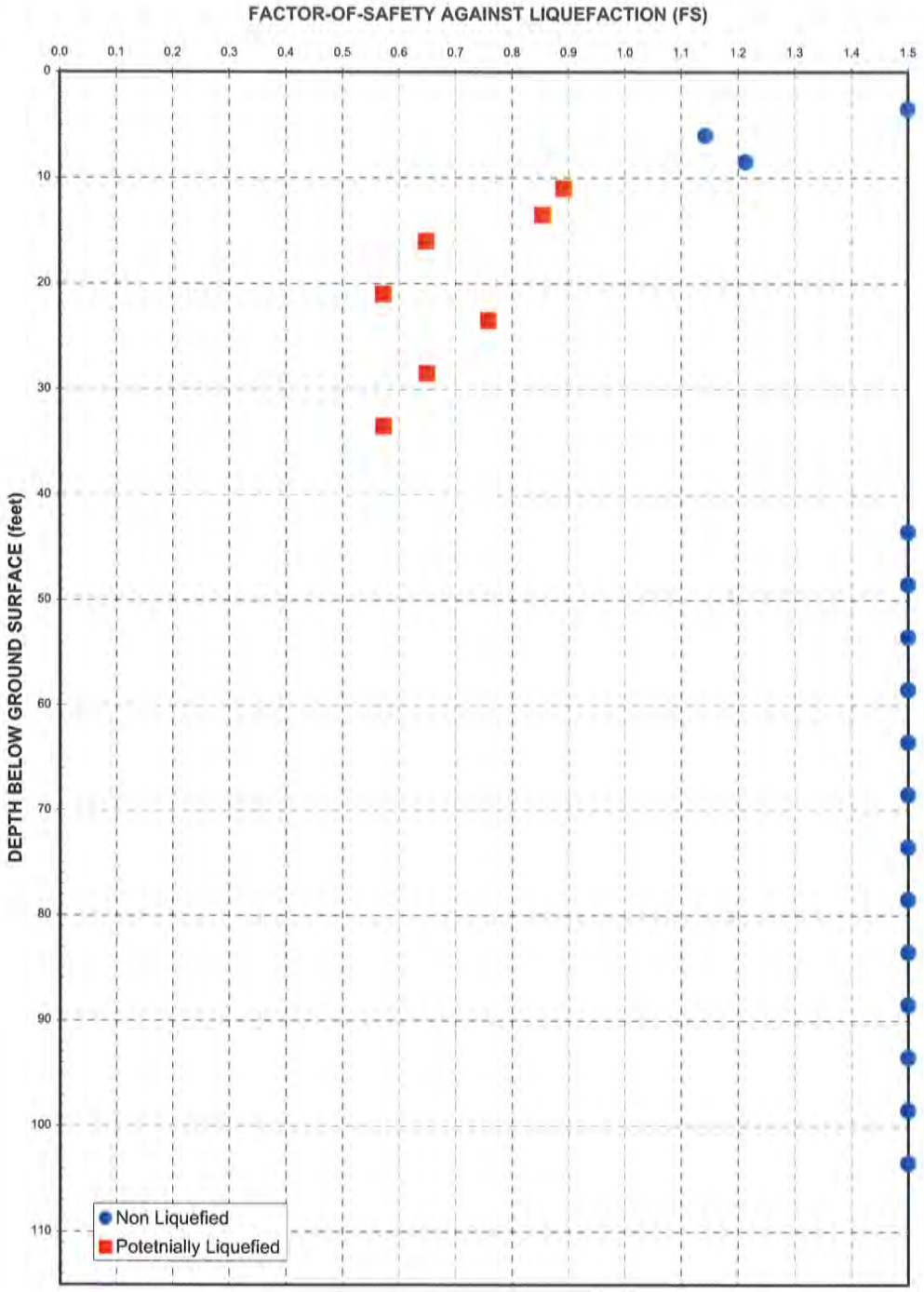
(Based on Boring B-8)

▽

Very loose to loose sitly SAND to sandy SILT; nonplastic to low plasticity

Stiff to very stiff Interbedded SILT and CLAY; medium to high plasticity

Very dense SAND and GRAVEL



NOTES:

1. *Reference:* Youd, T.L. and Idriss, I.M., 2001, Liquefaction Resistance of Soils: Summary Report from the 1996 NCEER and 1998 NCEER/ NSF Workshops on Evaluation of Liquefaction Resistance of Soils.
2. The analysis was performed for an earthquake with a magnitude of 8.3 and a peak ground acceleration of 0.114g.
3. The liquefaction resistance of a soil is dependent on its density and fines content. The fines content was estimated based on selected grain-size analyses and soil description.

Joint Water Commission
Fern Hill Road WTP Seismic Evaluation
Forest Grove, Oregon

RESULTS OF LIQUEFACTION ANALYSES
BORING B-8: Mw= 8.3: Return= 72

December 2007 24-1-3459-001

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. 8

Appendix A

BORING LOGS

APPENDIX A
PREVIOUS FIELD EXPLORATION

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

S&W CLASSIFICATION OF SOIL CONSTITUENTS

- MAJOR constituents compose more than 50 percent, by weight, of the soil. Major consituents are capitalized (i.e., SAND).
- Modifying (secondary) constituents compose 30 to 45 percent of the soil (i.e. sandy, silty, etc).
- Minor constituents compose 12 to 50 percent of the soil and precede the major constituents (i.e., silty SAND). Minor constituents preceded by "slightly" compose 5 to 12 percent of the soil (i.e., slightly silty SAND).
- Trace constituents compose 5 percent of the soil (i.e., slightly silty SAND, trace of gravel).
- Dual symbols apply to coarse grained soils with 10 percent fines.

MOISTURE CONTENT DEFINITIONS

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

ABBREVIATIONS

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

GRAIN SIZE DEFINITION

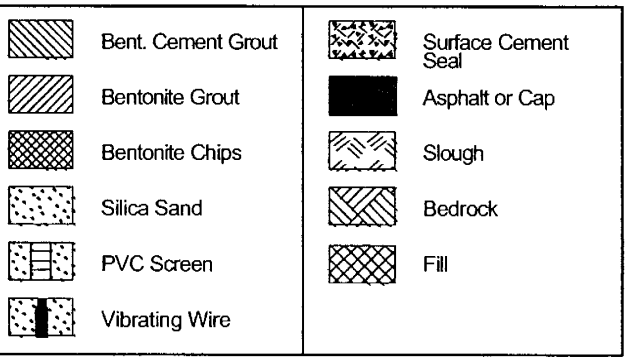
DESCRIPTION	SIEVE NUMBER AND/OR SIZE
FINES	< #200 (0.08 mm)
SAND*	
- Fine	#200 to #40 (0.08 to 0.4 mm)
- Medium	#40 to #10 (0.4 to 2 mm)
- Coarse	#10 to #4 (2 to 5 mm)
GRAVEL*	
- Fine	#4 to 3/4 inch (5 to 19 mm)
- Coarse	3/4 to 3 inches (19 to 76 mm)
COBBLES	3 to 12 inches (76 to 305 mm)
BOULDERS	> 12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

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

RELATIVE DENSITY / CONSISTENCY

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

WELL AND OTHER SYMBOLS



Joint Water Commission
Fern Hill Road WTP Seismic Evaluation
Forest Grove, Oregon

SOIL CLASSIFICATION AND LOG KEY

24-1-3459-001

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG.
Sheet 1 of 2

BORING CLASS1 1973 SW LOGS.GPJ SWNEW.GDT 12/5/07

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

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

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

NOTES

1. Dual symbols *(symbols separated by a hyphen, i.e., SP-SM, slightly silty fine SAND)* are used for soils with between 5% and 10% fines or when the liquid limit and plasticity index values plot in the CL-ML area of the plasticity chart.

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

Joint Water Commission
Fern Hill Road WTP Seismic Evaluation
Forest Grove, Oregon

SOIL CLASSIFICATION AND LOG KEY

24-1-3459-001

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG.
Sheet 2 of 2

BORING CLASS2 1973 SW LOGS.GPJ SWNEW.GDT 12/5/07

Total Depth:	84 ft.	Northing:	~ 16 ft.	Drilling Method:	N/A	Hole Diam.:	N/A in.
Top Elevation:	~ 177.5 ft.	Easting:	~ 118 ft.	Drilling Company:	Soil Sampling	Rod Type:	N/A
Vert. Datum:	N/A	Station:	~	Drill Rig Equipment:	N/A	Hammer Type:	N/A
Horiz. Datum:	N/A	Offset:	~	Other Comments:	Drilled in 1973		

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 transition may be gradual.

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

PENETRATION RESISTANCE (blows/foot)

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

Very stiff light brown sandy SILT; fine sand. (ML)

Grades to gray; dry to moist.

Grades to stiff; moist.

Grades to scattered organics; wet.

Grades to soft to medium stiff.

15.0

Loose dark gray silty SAND; fine sand; scattered organics; wet. (SM)

Grades to very loose; scattered large organic debris.

Grades to medium dense.

No organics encountered.

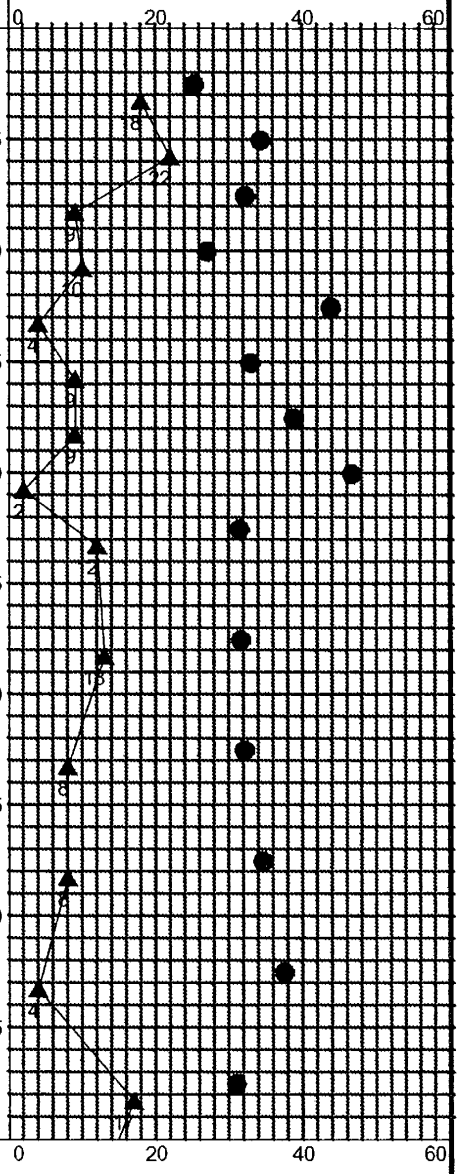
Grades to loose.

Grades to very loose to loose.

47.5

Stiff dark gray sandy SILT; fine sand; moist. (ML)

CONTINUED NEXT SHEET



LEGEND

* Sample Not Recovered

Standard Penetration Test

Ground Water Level

Plastic Limit — Liquid Limit

Natural Water Content

NOTES

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

Joint Water Commission
Fern Hill Road WTP Seismic Evaluation
Forest Grove, Oregon

LOG OF BORING B-1

24-1-3459-001

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. A2
Sheet 1 of 2

MASTER LOG E 1973 SW LOGS.GPJ SHAN WIL.GDT 12/5/07 Log: Rev: Typ: DRH

Total Depth:	84 ft.	Northing:	~ 16 ft.	Drilling Method:	N/A	Hole Diam.:	N/A in.
Top Elevation:	~ 177.5 ft.	Easting:	~ 118 ft.	Drilling Company:	Soil Sampling	Rod Type:	N/A
Vert. Datum:	N/A	Station:	~	Drill Rig Equipment:	N/A	Hammer Type:	N/A
Horiz. Datum:	N/A	Offset:	~	Other Comments:	Drilled in 1973		

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 transition may be gradual.

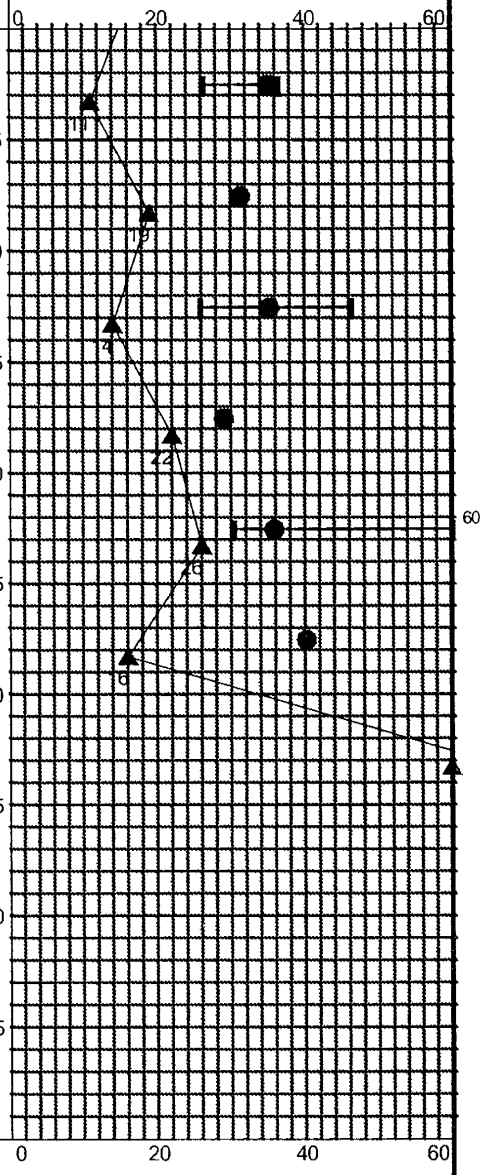
Depth, ft.	Soil Description
52.5	Stiff dark gray SILT; low to medium plasticity; wet. (ML)
	grades to very stiff.
62.5	Stiff dark gray sandy silty CLAY; medium to high plasticity; fine sand; moist to wet. (CL)
67.5	Very stiff dark gray silty CLAY. (CH)
	Very stiff dark gray silty CLAY with gravel; high plasticity; fine subrounded gravel; moist. (CH)
77.5	Very stiff dark gray sandy SILT; fine to medium sand; moist. (ML)
80.0	Hard dark gray silty clayey GRAVEL; fine subrounded to subangular gravel; moist. (GM)
84.0	

Symbol | Samples | Ground Water Depth, ft.

S-15 S-16 S-17 S-18 S-19 S-20 S-21

PENETRATION RESISTANCE (blows/foot)

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



LEGEND

* Sample Not Recovered

Standard Penetration Test

Ground Water Level

Plastic Limit — Liquid Limit

Natural Water Content

NOTES

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

Joint Water Commission
Fern Hill Road WTP Seismic Evaluation
Forest Grove, Oregon

LOG OF BORING B-1

24-1-3459-001

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. A2
Sheet 2 of 2

MASTER LOG E 1973.SW LOGS.GPJ SHAN WIL.GDT 12/5/07 Log: Rev: Typ: DRH

Total Depth:	84 ft.	Northing:	~ 34 ft.	Drilling Method:	N/A	Hole Diam.:	N/A in.
Top Elevation:	~ 176.7 ft.	Easting:	~ 119 ft.	Drilling Company:	Soil Sampling	Rod Type:	N/A
Vert. Datum:	N/A	Station:	~	Drill Rig Equipment:	N/A	Hammer Type:	N/A
Horiz. Datum:	N/A	Offset:	~	Other Comments:	Drilled in 1973		

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 transition may be gradual.

Stiff light brown mottled SILT with sand. (ML)

Grades to sandy SILT. (ML)

Medium stiff to stiff gray sandy SILT. (ML)

10.0

Very soft to soft gray sandy clayey SILT. (MH)

15.0

Medium stiff gray sandy SILT. (ML)

Grades to scattered organics. (ML)

Grades to soft to medium stiff. (ML)

grades to no organics encountered

Grades to stiff; fine sand; wet.

Grades to moist to wet.

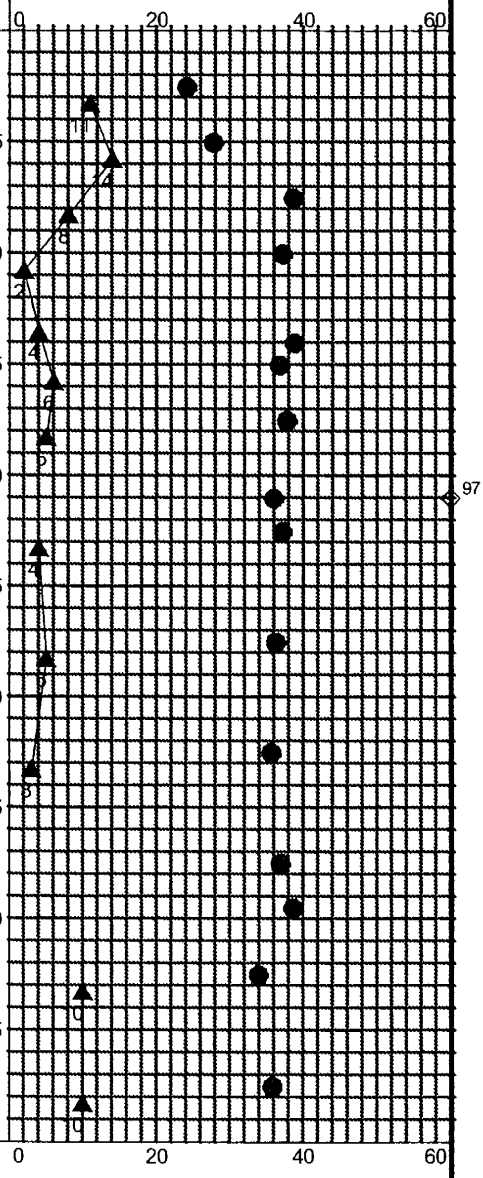
CONTINUED NEXT SHEET

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

S-1 S-2 S-3 S-4 S-5 S-6 S-7 S-8 S-9 S-10 S-11 S-12 S-13 S-14

PENETRATION RESISTANCE (blows/foot)

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



LEGEND

* Sample Not Recovered

Standard Penetration Test

3" O.D. Shelby Tube

◇ % Fines (<0.075mm)

● % Water Content

Plastic Limit ⊢●⊣ Liquid Limit

Natural Water Content

NOTES

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

Joint Water Commission
Fern Hill Road WTP Seismic Evaluation
Forest Grove, Oregon

LOG OF BORING B-2

24-1-3459-001

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. A3
Sheet 1 of 2

MASTER LOG E 1973 SW LOGS.GPJ SHAN WIL.GDT 12/5/07 Log: Rev: Typ: DRH

Total Depth:	84 ft.	Northing:	~ 34 ft.	Drilling Method:	N/A	Hole Diam.:	N/A in.
Top Elevation:	~ 176.7 ft.	Easting:	~ 119 ft.	Drilling Company:	Soil Sampling	Rod Type:	N/A
Vert. Datum:	N/A	Station:	~	Drill Rig Equipment:	N/A	Hammer Type:	N/A
Horiz. Datum:	N/A	Offset:	~	Other Comments:	Drilled in 1973		

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 transition may be gradual.

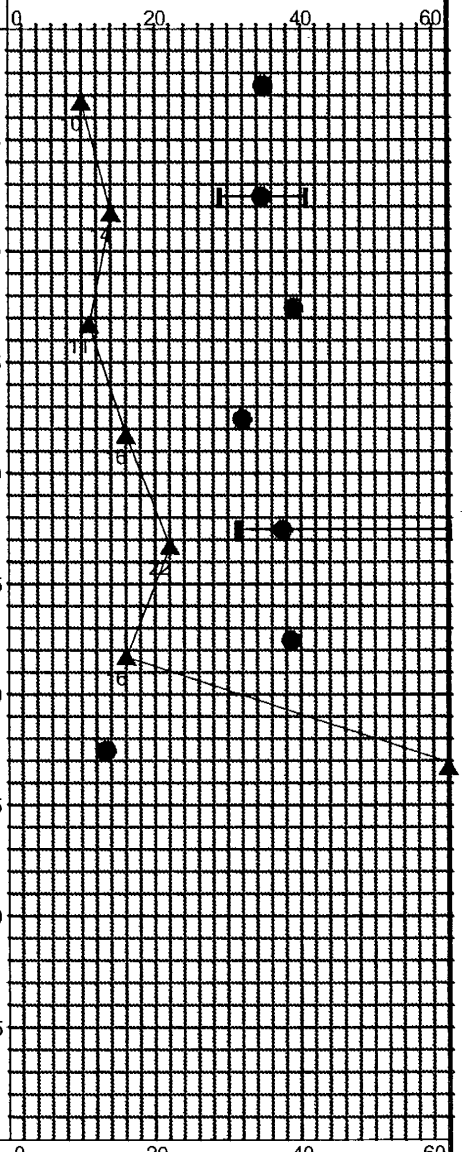
Depth, ft.	Soil Description
	Grades to sandy silt with scattered organics.
57.5	Stiff dark gray SILT; medium plasticity; moist. (ML)
	Grades to very stiff.
72.5	Very stiff dark gray CLAY; very high plasticity; moist. (CH)
77.5	Very stiff dark gray with olive mottled sandy SILT; fine sand; moist. (ML)
82.5	Hard dark blue gray gravelly clayey SILT; fine to coarse, subangular to subround gravel; moist. (ML)
84.0	

Symbol | Samples: S-15, S-16, S-17, S-18, S-19, S-20, S-21

Ground Water Depth, ft.

PENETRATION RESISTANCE (blows/foot)

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



LEGEND

* Sample Not Recovered

Standard Penetration Test

3" O.D. Shelby Tube

◇ % Fines (<0.075mm)

● % Water Content

Plastic Limit ⊢●⊣ Liquid Limit

Natural Water Content

NOTES

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

Joint Water Commission
Fern Hill Road WTP Seismic Evaluation
Forest Grove, Oregon

LOG OF BORING B-2

24-1-3459-001

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. A3
Sheet 2 of 2

MASTER LOG E 1973 SW LOGS.GPJ SHAN WIL.GDT 12/5/07 Log: Rev: Typ: DRH

Total Depth:	118 ft.	Northing:	~ 16 ft.	Drilling Method:	N/A	Hole Diam.:	N/A in.
Top Elevation:	~ 182.3 ft.	Easting:	~ 133 ft.	Drilling Company:	Soil Sampling	Rod Type:	N/A
Vert. Datum:	N/A	Station:	~	Drill Rig Equipment:	N/A	Hammer Type:	N/A
Horiz. Datum:	N/A	Offset:	~	Other Comments:	Drilled in 1973		

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 transition may be gradual.

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

Medium dense light brown silty SAND; fine sand; dry. (SM)

Grades to very loose.

7.5

Soft to medium stiff gray sandy SILT. (ML)

10.0

Very loose to loose dark gray silty SAND; fine sand; wet. (SM)

Grades to very loose.

Grades to very loose to loose.

Grades to loose.

47.5

Stiff dark gray SILT; moist to wet. (ML)

CONTINUED NEXT SHEET

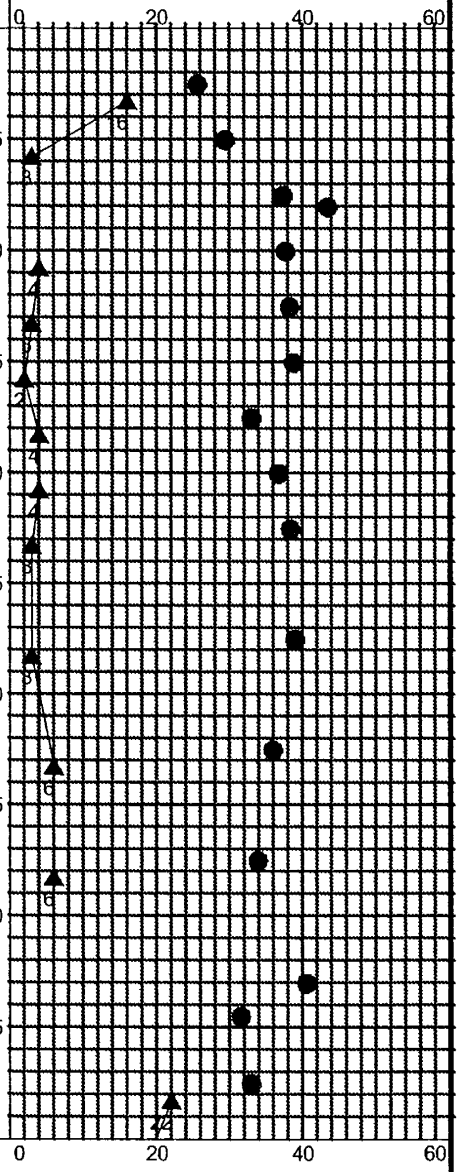
Samples: S-1, S-2, S-3, S-4, S-5, S-6, S-7, S-8, S-9, S-10, S-11, S-12, S-13, S-14

Ground Water: During Drilling

PENETRATION RESISTANCE (blows/foot)

▲ Hammer Wt. & Drop: *lbs / inches*

140 lbs / 30 inches



LEGEND

* Sample Not Recovered

Standard Penetration Test

3" O.D. Shelby Tube

Rock Core

Ground Water Level

◇ % Fines (<0.075mm)

● % Water Content

Plastic Limit ⊢●⊣ Liquid Limit

Natural Water Content

NOTES

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

Joint Water Commission
Fern Hill Road WTP Seismic Evaluation
Forest Grove, Oregon

LOG OF BORING B-3

24-1-3459-001

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. A4
Sheet 1 of 3

MASTER LOG E 1973 SW LOGS.GPJ SHAN WIL.GDT 12/5/07 Log: Rev: Typ: DRH

Total Depth:	118 ft.	Northing:	~ 16 ft.	Drilling Method:	N/A	Hole Diam.:	N/A in.
Top Elevation:	~ 182.3 ft.	Easting:	~ 133 ft.	Drilling Company:	Soil Sampling	Rod Type:	N/A
Vert. Datum:	N/A	Station:	~	Drill Rig Equipment:	N/A	Hammer Type:	N/A
Horiz. Datum:	N/A	Offset:	~	Other Comments:	Drilled in 1973		

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 transition may be gradual.

Depth, ft.	Soil Description
52.5	Very stiff dark gray silty CLAY with sand; high plasticity; fine sand; moist to wet. (CL)
62.5	Very stiff dark gray SILT; medium plasticity; moist to wet. (ML)
72.5	Very stiff dark gray silty CLAY with sand; medium to high plasticity; fine sand; moist to wet. (CL) Grades to dark gray mottled; moist.
83.5	Medium dense gray silty SAND; fine to medium sand. (SM) Very dense dark gray silty sandy GRAVEL; fine to coarse sand; fine to coarse, subangular to subround gravel. (GM) Very dense dark gray silty SAND; fine to medium sand; moist to wet. (SM)

Symbol | Samples | Ground Water

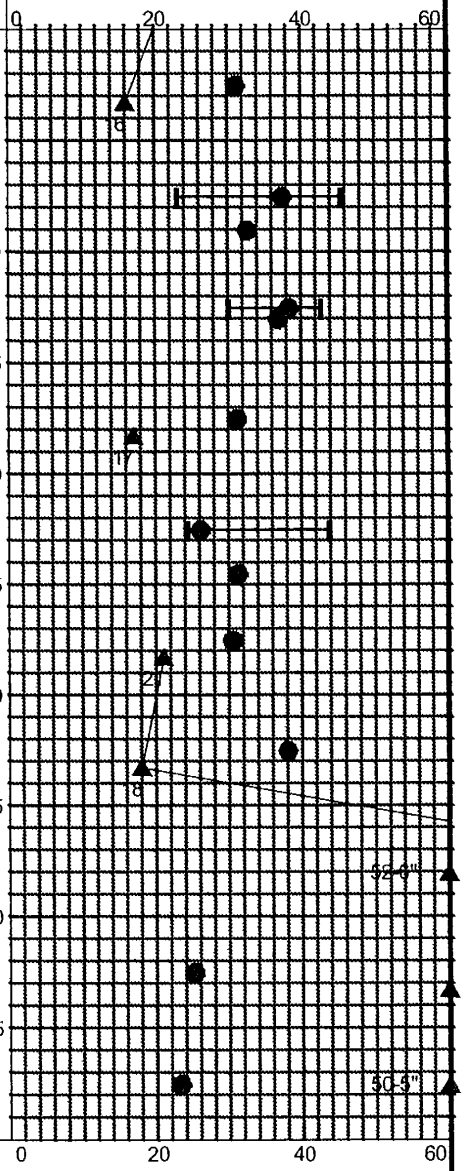
S-15 S-16 S-17 S-18 S-19 S-20 S-21 S-22 S-24 S-25

CONTINUED NEXT SHEET

PENETRATION RESISTANCE (blows/foot)

▲ Hammer Wt. & Drop: *lbs / inches*

140 lbs / 30 inches



LEGEND

* Sample Not Recovered
Standard Penetration Test
3" O.D. Shelby Tube
Rock Core
Ground Water Level

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

NOTES

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

Joint Water Commission
Fern Hill Road WTP Seismic Evaluation
Forest Grove, Oregon

LOG OF BORING B-3

24-1-3459-001

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. A4
Sheet 2 of 3

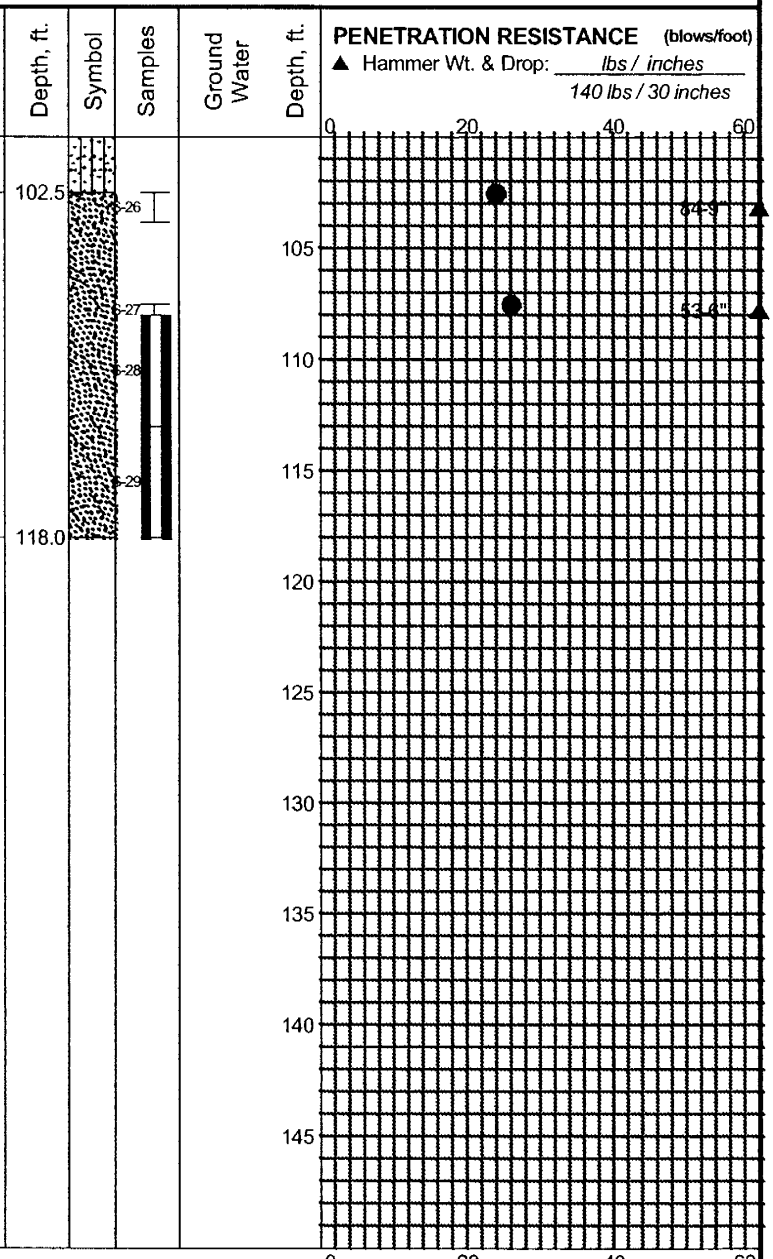
MASTER LOG E 1973 SW LOGS.GPJ SHAN WIL.GDT 12/5/07 Log: Rev: Typ: DRH

Total Depth:	118 ft.	Northing:	~ 16 ft.	Drilling Method:	N/A	Hole Diam.:	N/A in.
Top Elevation:	~ 182.3 ft.	Easting:	~ 133 ft.	Drilling Company:	Soil Sampling	Rod Type:	N/A
Vert. Datum:	N/A	Station:	~	Drill Rig Equipment:	N/A	Hammer Type:	N/A
Horiz. Datum:	N/A	Offset:	~	Other Comments:	Drilled in 1973		

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 transition may be gradual.

SANDSTONE, fine to medium grained, fossiliferous; slight horizontal bedding.



LEGEND

* Sample Not Recovered
Standard Penetration Test
3" O.D. Shelby Tube
Rock Core
Ground Water Level

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

NOTES

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

Joint Water Commission
Fern Hill Road WTP Seismic Evaluation
Forest Grove, Oregon

LOG OF BORING B-3

24-1-3459-001

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. A4
Sheet 3 of 3

MASTER LOG E 1973 SW LOGS.GPJ SHAN WIL.GDT 12/5/07 Log: Rev: Typ: DRH

Total Depth:	79 ft.	Northing:	~ 33 ft.	Drilling Method:	N/A	Hole Diam.:	N/A in.
Top Elevation:	~ 181.7 ft.	Easting:	~ 134 ft.	Drilling Company:	Soil Sampling	Rod Type:	N/A
Vert. Datum:	N/A	Station:	~	Drill Rig Equipment:	N/A	Hammer Type:	N/A
Horiz. Datum:	N/A	Offset:	~	Other Comments:	Drilled in 1973		

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 transition may be gradual.

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

PENETRATION RESISTANCE (blows/foot)

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

0 20 40 60

Medium dense light brown silty SAND; fine sand; scattered organics; dry. (SM)

5.0

Medium stiff light brown sandy SILT; fine sand; dry. (ML)

Stiff dark gray sandy SILT; fine sand; moist. (ML)

10.5

Loose dark gray SAND with silt; fine sand; wet. (SM)

Grades to very loose.

20.0

Soft dark gray sandy SILT; fine sand; moist to wet. (ML)

22.5

Medium dense silty SAND; fine sand; wet. (SM)

Grades to loose.

Grades to medium dense; moist to wet.

Grades to very loose; wet.

47.5

Stiff dark gray sandy SILT; fine sand; wet. (ML)

CONTINUED NEXT SHEET

S-1 S-2 S-3 S-4 S-5 S-6 S-7 S-8 S-9 S-10 S-11 S-12 S-13 S-14

During Drilling ▽

0 5 10 15 20 25 30 35 40 45

24 6 6 11 6 4 3 7 6 4 4 4

0 20 40 60

◇ % Fines (<0.075mm)

● % Water Content

Plastic Limit ⊢●⊣ Liquid Limit

Natural Water Content

LEGEND

* Sample Not Recovered

I Standard Penetration Test

II 3" O.D. Shelby Tube

▽ Ground Water Level

NOTES

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

Joint Water Commission
Fern Hill Road WTP Seismic Evaluation
Forest Grove, Oregon

LOG OF BORING B-4

24-1-3459-001

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. A5
Sheet 1 of 2

MASTER LOG E 1973 SW LOGS.GPJ SHAN WIL.GDT 12/5/07 Log: Rev: Typ: DRH

Total Depth:	79 ft.	Northing:	~ 33 ft.	Drilling Method:	N/A	Hole Diam.:	N/A in.
Top Elevation:	~ 181.7 ft.	Easting:	~ 134 ft.	Drilling Company:	Soil Sampling	Rod Type:	N/A
Vert. Datum:	N/A	Station:	~	Drill Rig Equipment:	N/A	Hammer Type:	N/A
Horiz. Datum:	N/A	Offset:	~	Other Comments:	Drilled in 1973		

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 transition may be gradual.

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

PENETRATION RESISTANCE (blows/foot)

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

Grades to moist to wet.

Grades to sandy SILT with clay; moist. (ML)

67.5

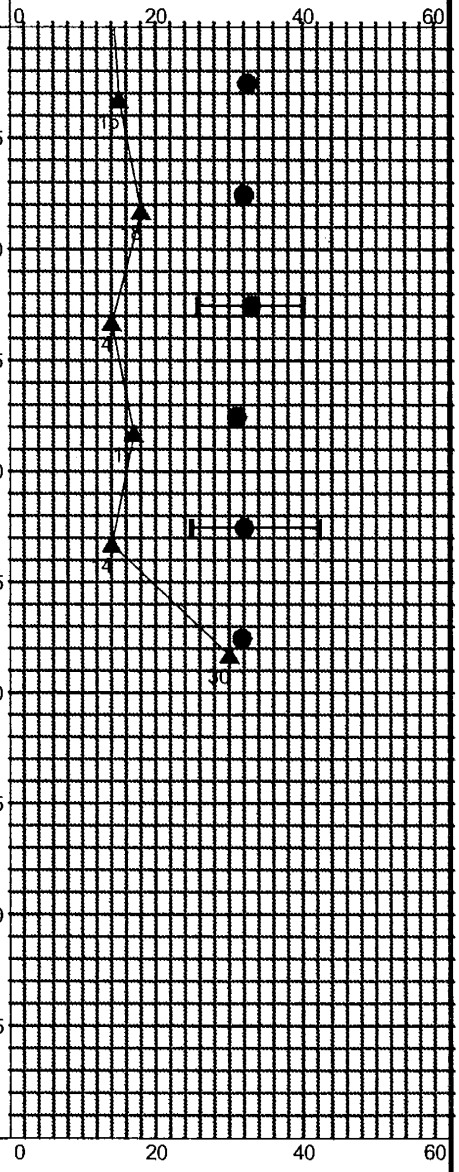
Very stiff dark gray silty CLAY; moist. (CL)

77.5

Hard dark gray sandy SILT; fine sand; moist. (ML)

79.0

S-15 S-16 S-17 S-18 S-19 S-20



LEGEND

* Sample Not Recovered

Standard Penetration Test

3" O.D. Shelby Tube

Ground Water Level

◇ % Fines (<0.075mm)

● % Water Content

Plastic Limit ⊢●⊣ Liquid Limit

Natural Water Content

NOTES

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

Joint Water Commission
Fern Hill Road WTP Seismic Evaluation
Forest Grove, Oregon

LOG OF BORING B-4

24-1-3459-001

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. A5
Sheet 2 of 2

MASTER LOG E 1973 SW LOGS.GPJ SHAN WIL.GDT 12/5/07 Log: Rev: Typ: DRH

Total Depth:	60 ft.	Northing:	~ 58 ft.	Drilling Method:	N/A	Hole Diam.:	N/A in.
Top Elevation:	~ 178 ft.	Easting:	~ 134 ft.	Drilling Company:	Soil Sampling	Rod Type:	N/A
Vert. Datum:	N/A	Station:	~	Drill Rig Equipment:	N/A	Hammer Type:	N/A
Horiz. Datum:	N/A	Offset:	~	Other Comments:	Drilled in 1973		

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 transition may be gradual.

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

PENETRATION RESISTANCE (blows/foot)

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

Medium dense light brown mottled brown silty SAND; fine sand; dry. (SM)

Grades to dark gray stratified with 1" to 2" layers of silt

Very loose to loose dark gray SAND with silt; fine sand; wet. (SM)

Grades to silty SAND. (SM)

Grades to loose; scattered organic material

Grades to no organics encountered.

32.5

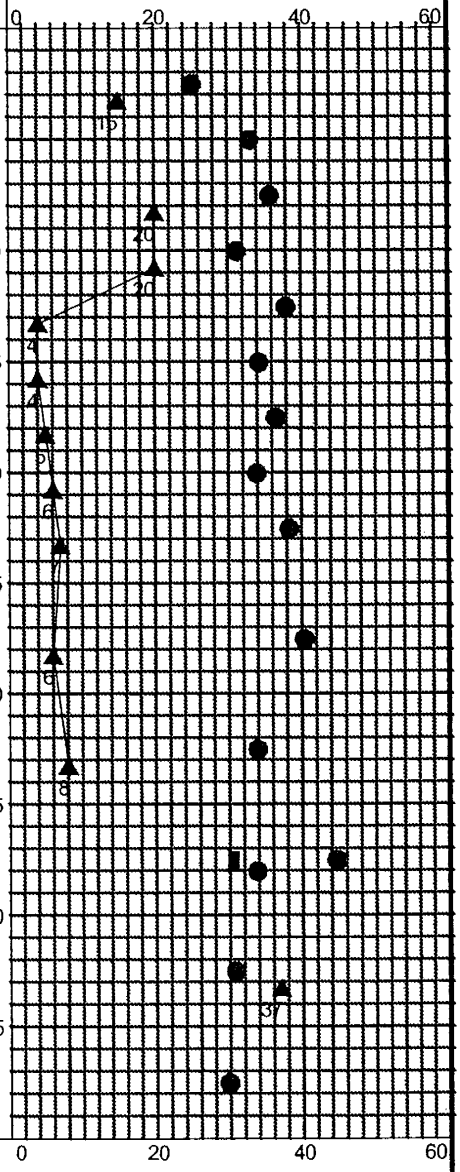
Medium stiff to stiff dark gray sandy SILT; non-plastic; fine sand; scattered organics. (ML)

Grades to very stiff; moist.

47.5

Very stiff dark gray sandy silty CLAY; medium to high plasticity; fine sand; [illegible] (CL)

S-1 S-2 S-3 S-4 S-5 S-6 S-7 S-8 S-9 S-10 S-11 S-12 S-13 S-14



LEGEND

* Sample Not Recovered

I Standard Penetration Test

II 3" O.D. Shelby Tube

Plastic Limit ⊢●⊣ Liquid Limit

Natural Water Content

NOTES

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

Joint Water Commission
Fern Hill Road WTP Seismic Evaluation
Forest Grove, Oregon

LOG OF BORING B-5

24-1-3459-001

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. A6
Sheet 1 of 2

MASTER LOG E 1973 SW LOGS.GPJ SHAN WIL.GDT 12/5/07 Log: Rev: Typ: DRH

Total Depth:	60 ft.	Northing:	~ 58 ft.	Drilling Method:	N/A	Hole Diam.:	N/A in.
Top Elevation:	~ 178 ft.	Easting:	~ 134 ft.	Drilling Company:	Soil Sampling	Rod Type:	N/A
Vert. Datum:	N/A	Station:	~	Drill Rig Equipment:	N/A	Hammer Type:	N/A
Horiz. Datum:	N/A	Offset:	~	Other Comments:	Drilled in 1973		

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 transition may be gradual.

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

PENETRATION RESISTANCE (blows/foot)

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

Depth, ft.	Soil Description	Sample
57.5	Dark gray SILT; low plasticity. (ML)	S-15
60.0		S-16

0 20 40 60

55 60 65 70 75 80 85 90 95

0 20 40 60

LEGEND

* Sample Not Recovered

Standard Penetration Test

3" O.D. Shelby Tube

Plastic Limit ⊢●⊣ Liquid Limit

Natural Water Content

NOTES

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

Joint Water Commission
Fern Hill Road WTP Seismic Evaluation
Forest Grove, Oregon

LOG OF BORING B-5

24-1-3459-001

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. A6
Sheet 2 of 2

MASTER LOG E 1973 SW LOGS.GPJ SHAN WIL.GDT 12/5/07 Log: Rev: Typ: DRH

Total Depth:	77 ft.	Northing:	~ 12 ft.	Drilling Method:	N/A	Hole Diam.:	N/A in.
Top Elevation:	~ 192.1 ft.	Easting:	~ 159 ft.	Drilling Company:	Soil Sampling	Rod Type:	N/A
Vert. Datum:	N/A	Station:	~	Drill Rig Equipment:	N/A	Hammer Type:	N/A
Horiz. Datum:	N/A	Offset:	~	Other Comments:	Drilled in 1973		

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 transition may be gradual.

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

PENETRATION RESISTANCE (blows/foot)

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

Very dense light brown sandy SILT; fine sand; scattered organics; dry. (ML)

S-1

Grades to stiff

S-2

Grades to medium stiff; no organics encountered; moist.

S-3

Grades to stiff.

S-4

Grades to wet.

S-5

Grades to soft to medium stiff.

S-6

S-7

Grades to medium stiff.

S-8

22.5

Very loose brown silty SAND; fine sand; wet. (SM)

S-9

S-10

Grades to loose

S-11

S-12

Grades to dark gray

S-13

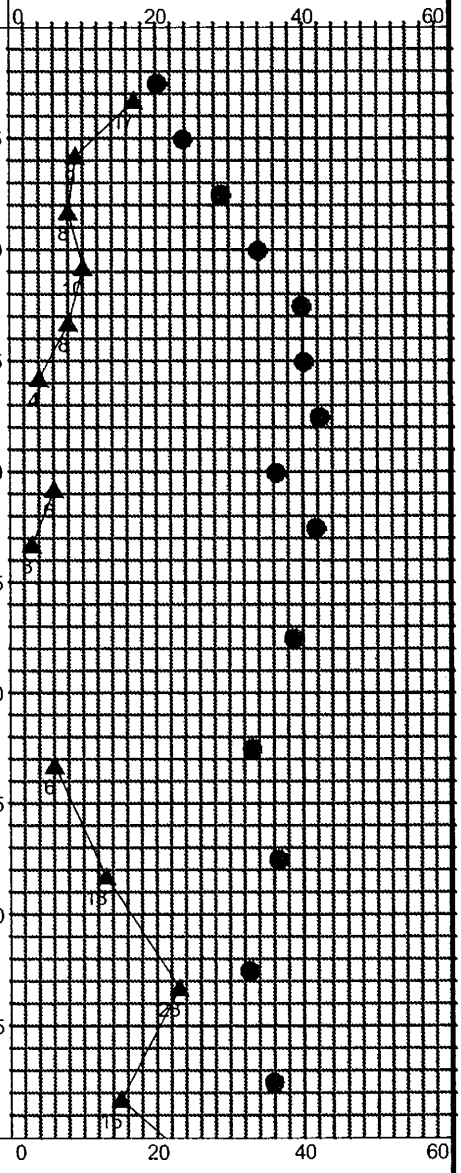
47.5

Stiff to very stiff dark gray sandy SILT; fine sand; moist. (ML)

S-14

CONTINUED NEXT SHEET

During Drilling ▽



LEGEND

* Sample Not Recovered

Standard Penetration Test

3" O.D. Shelby Tube

▽ Ground Water Level

Plastic Limit ⊢●⊣ Liquid Limit

Natural Water Content

Joint Water Commission
Fern Hill Road WTP Seismic Evaluation
Forest Grove, Oregon

LOG OF BORING B-6

24-1-3459-001

NOTES

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

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

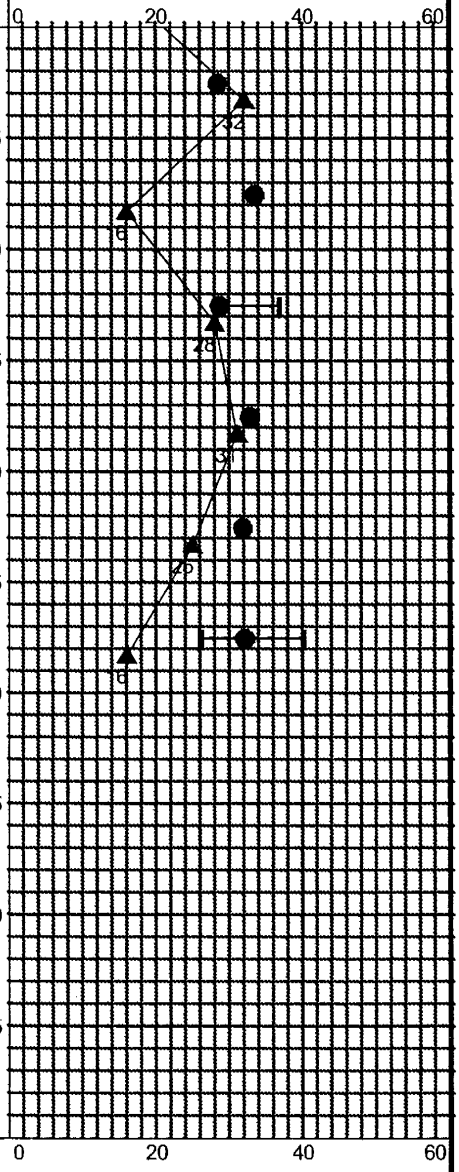
FIG. A7
Sheet 1 of 2

MASTER LOG_E 1973 SW LOGS.GPJ SHAN WIL.GDT 12/5/07 Log: Rev: Typ: DRH

Total Depth:	77 ft.	Northing:	~ 12 ft.	Drilling Method:	N/A	Hole Diam.:	N/A in.
Top Elevation:	~ 192.1 ft.	Easting:	~ 159 ft.	Drilling Company:	Soil Sampling	Rod Type:	N/A
Vert. Datum:	N/A	Station:	~	Drill Rig Equipment:	N/A	Hammer Type:	N/A
Horiz. Datum:	N/A	Offset:	~	Other Comments:	Drilled in 1973		

SOIL DESCRIPTION	Depth, ft.	Symbol	Samples	Ground Water Depth, ft.
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 transition may be gradual.				
Grades to hard.			S-15	
Grades to very stiff.			S-16	
Grades to SILT; low plasticity; moist. (ML)			S-17	
Hard dark gray silty CLAY; moist. (CL)	67.5		S-18	
			S-19	
Very stiff dark gray SILT; low plasticity; moist. (ML)	77.5 79.0		S-20	

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



LEGEND

* Sample Not Recovered
Standard Penetration Test
3" O.D. Shelby Tube
Ground Water Level

Plastic Limit — Liquid Limit
Natural Water Content

NOTES

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

Joint Water Commission
Fern Hill Road WTP Seismic Evaluation
Forest Grove, Oregon

LOG OF BORING B-6

24-1-3459-001

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. A7
Sheet 2 of 2

MASTER_LOG_E_1973 SW LOGS.GPJ SHAN_WIL.GDT 12/5/07 Log: Rev: Typ: DRH

Total Depth:	59 ft.	Northing:	~ 33 ft.	Drilling Method:	N/A	Hole Diam.:	N/A in.
Top Elevation:	~ 191.7 ft.	Easting:	~ 156 ft.	Drilling Company:	Soil Sampling	Rod Type:	N/A
Vert. Datum:	N/A	Station:	~	Drill Rig Equipment:	N/A	Hammer Type:	N/A
Horiz. Datum:	N/A	Offset:	~	Other Comments:	Drilled in 1973		

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 transition may be gradual.

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

PENETRATION RESISTANCE (blows/foot)

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

Very stiff brown sandy SILT; fine sand; dry. (ML)

Grades to medium stiff.

Grades to stiff.

Grades to medium stiff; moist.

12.5

Loose brown silty SAND; fine sand; moist. (SM)

Grades to very loose to loose; wet.

Grades to very loose.

32.5

Soft to medium stiff brown sandy SILT; fine sand; wet. (ML)

37.5

Medium dense dark gray silty SAND; fine sand; wet. (SM)

42.5

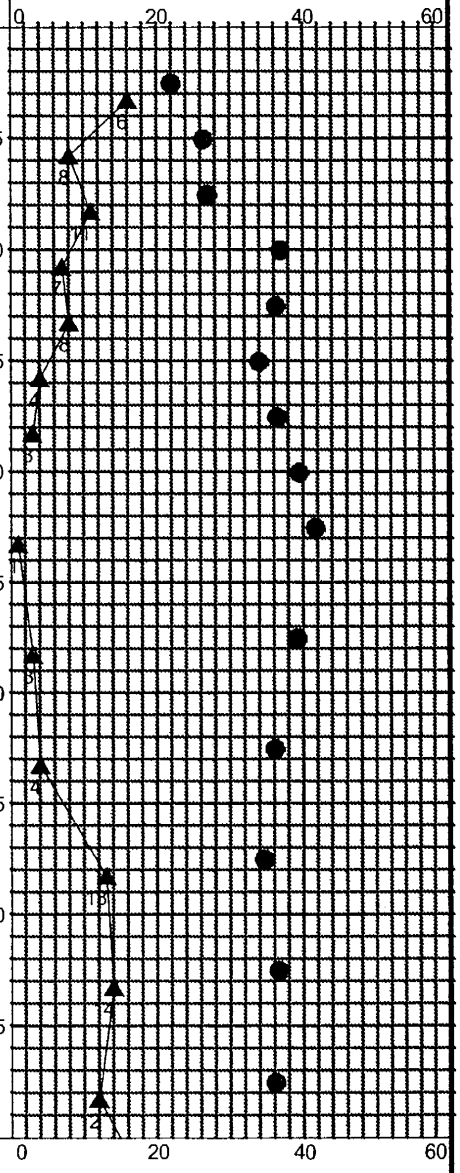
Stiff dark gray sandy SILT; fine sand; moist. (ML)

Grades to wet.

CONTINUED NEXT SHEET

S-1 S-2 S-3 S-4 S-5 S-6 S-7 S-8 S-9 S-10 S-11 S-12 S-13 S-14

During Drilling



LEGEND

* Sample Not Recovered

Standard Penetration Test

3" O.D. Shelby Tube

▽ Ground Water Level

Plastic Limit ⊢●⊣ Liquid Limit

Natural Water Content

NOTES

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

Joint Water Commission
Fern Hill Road WTP Seismic Evaluation
Forest Grove, Oregon

LOG OF BORING B-7

24-1-3459-001

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. A8
Sheet 1 of 2

MASTER LOG E 1973 SW LOGS.GPJ SHAN WIL.GDT 12/5/07 Log: Rev: Typ: DRH

Total Depth:	59 ft.	Northing:	~ 33 ft.	Drilling Method:	N/A	Hole Diam.:	N/A in.
Top Elevation:	~ 191.7 ft.	Easting:	~ 156 ft.	Drilling Company:	Soil Sampling	Rod Type:	N/A
Vert. Datum:	N/A	Station:	~	Drill Rig Equipment:	N/A	Hammer Type:	N/A
Horiz. Datum:	N/A	Offset:	~	Other Comments:	Drilled in 1973		

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 transition may be gradual.

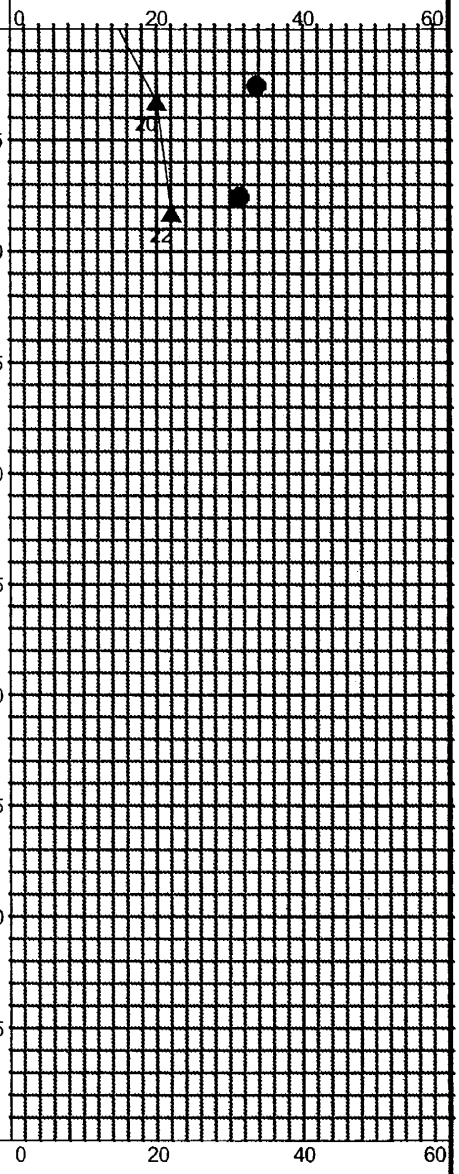
Grades to very stiff.

59.0

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

PENETRATION RESISTANCE (blows/foot)

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



LEGEND

* Sample Not Recovered

Standard Penetration Test

3" O.D. Shelby Tube

Ground Water Level

Plastic Limit — Liquid Limit

Natural Water Content

NOTES

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

Joint Water Commission
Fern Hill Road WTP Seismic Evaluation
Forest Grove, Oregon

LOG OF BORING B-7

24-1-3459-001

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. A8
Sheet 2 of 2

MASTER LOG E 1973 SW LOGS.GPJ SHAN WIL.GDT 12/5/07 Log: Rev: Typ: DRH

Total Depth:	103 ft.	Northing:	~ 15 ft.	Drilling Method:	N/A	Hole Diam.:	N/A in.
Top Elevation:	~ 187.4 ft.	Easting:	~ 188 ft.	Drilling Company:	Soil Sampling	Rod Type:	N/A
Vert. Datum:	N/A	Station:	~	Drill Rig Equipment:	N/A	Hammer Type:	N/A
Horiz. Datum:	N/A	Offset:	~	Other Comments:	Drilled in 1973		

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 transition may be gradual.

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

PENETRATION RESISTANCE (blows/foot)

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

Very stiff brown sandy SILT; fine sand; dry. (ML)

Grades to stiff.

Grades to medium stiff.

Grades to wet.

Grades to soft to medium stiff.

17.5

Loose brown silty SAND; fine sand; wet. (SM)

Grades to very loose

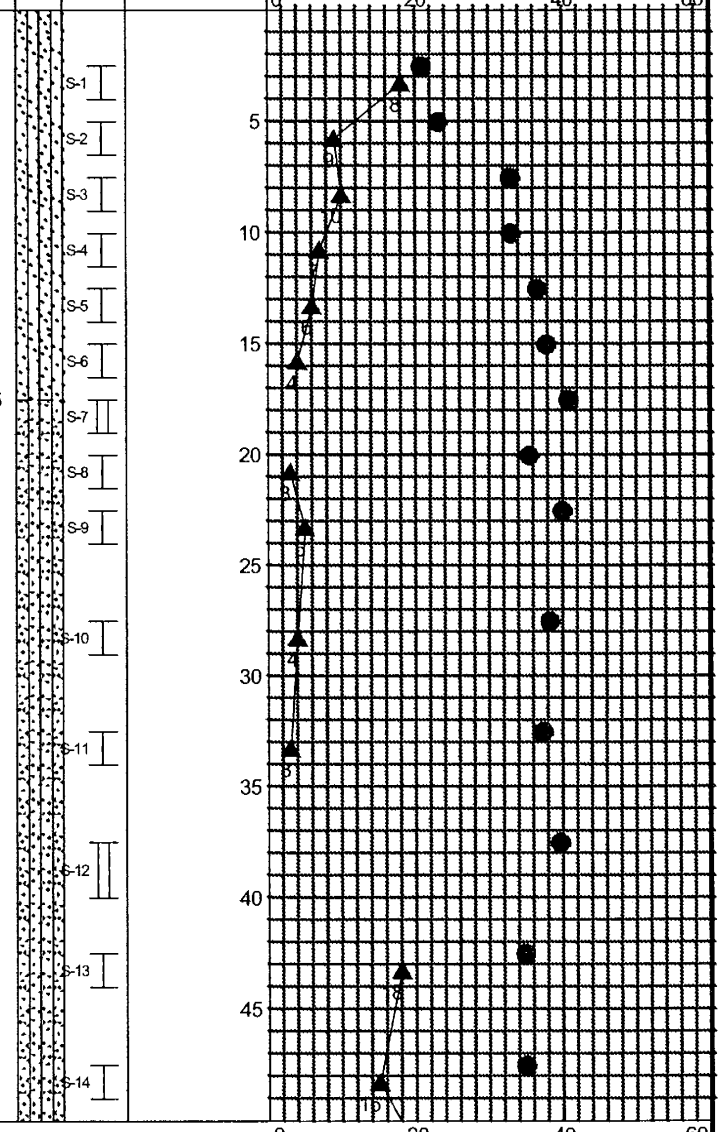
Grades to loose

Grades to very loose.

Grades to dark gray.

Grades to medium dense.

CONTINUED NEXT SHEET



LEGEND

* Sample Not Recovered

I Standard Penetration Test

II 3" O.D. Shelby Tube

Plastic Limit ⊢●⊣ Liquid Limit

Natural Water Content

NOTES

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

Joint Water Commission
Fern Hill Road WTP Seismic Evaluation
Forest Grove, Oregon

LOG OF BORING B-8

24-1-3459-001

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. A9
Sheet 1 of 3

MASTER LOG E 1973 SW LOGS.GPJ SHAN WIL.GDT 12/5/07 Log: Rev: Typ: DRH

Total Depth:	103 ft.	Northing:	~ 15 ft.	Drilling Method:	N/A	Hole Diam.:	N/A in.
Top Elevation:	~ 187.4 ft.	Easting:	~ 188 ft.	Drilling Company:	Soil Sampling	Rod Type:	N/A
Vert. Datum:	N/A	Station:	~	Drill Rig Equipment:	N/A	Hammer Type:	N/A
Horiz. Datum:	N/A	Offset:	~	Other Comments:	Drilled in 1973		

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 transition may be gradual.

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

PENETRATION RESISTANCE (blows/foot)

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

Depth, ft.	Description
52.5	Very stiff dark gray sandy SILT; fine sand; moist. (ML)
	Medium plasticity
	Grades to stiff.
67.5	Stiff dark gray silty CLAY; high plasticity; moist (CL)
82.5	Very stiff Sandy SILT with clay; moist. (ML)
87.5	Medium dense dark gray silty SAND; fine to medium; sand; thinly bedded; scattered organics; moist. (SM)
92.5	Very dense dark gray silty GRAVEL with trace sand; fine to medium sand; fine gravel; moist. (gm)
97.5	Very dense dark gray silty SAND; fine to medium sand; thinly bedded; wet. (SM)

S-15, S-16, S-17, S-18, S-19, S-20, S-21, S-22, S-23, S-24

25, 1, 2, 18, 4, 18, 4, 18, 70-1", 50-5"

0 20 40 60

55 60 65 70 75 80 85 90 95

0 20 40 60

CONTINUED NEXT SHEET

LEGEND

* Sample Not Recovered

Standard Penetration Test

3" O.D. Shelby Tube

Plastic Limit — Liquid Limit

Natural Water Content

NOTES

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

Joint Water Commission
Fern Hill Road WTP Seismic Evaluation
Forest Grove, Oregon

LOG OF BORING B-8

24-1-3459-001

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. A9
Sheet 2 of 3

MASTER LOG E 1973 SW LOGS.GPJ SHAN WIL.GDT 12/5/07 Log: Rev: Typ: DRH

Total Depth:	103 ft.	Northing:	~ 15 ft.	Drilling Method:	N/A	Hole Diam.:	N/A in.
Top Elevation:	~ 187.4 ft.	Easting:	~ 188 ft.	Drilling Company:	Soil Sampling	Rod Type:	N/A
Vert. Datum:	N/A	Station:	~	Drill Rig Equipment:	N/A	Hammer Type:	N/A
Horiz. Datum:	N/A	Offset:	~	Other Comments:	Drilled in 1973		

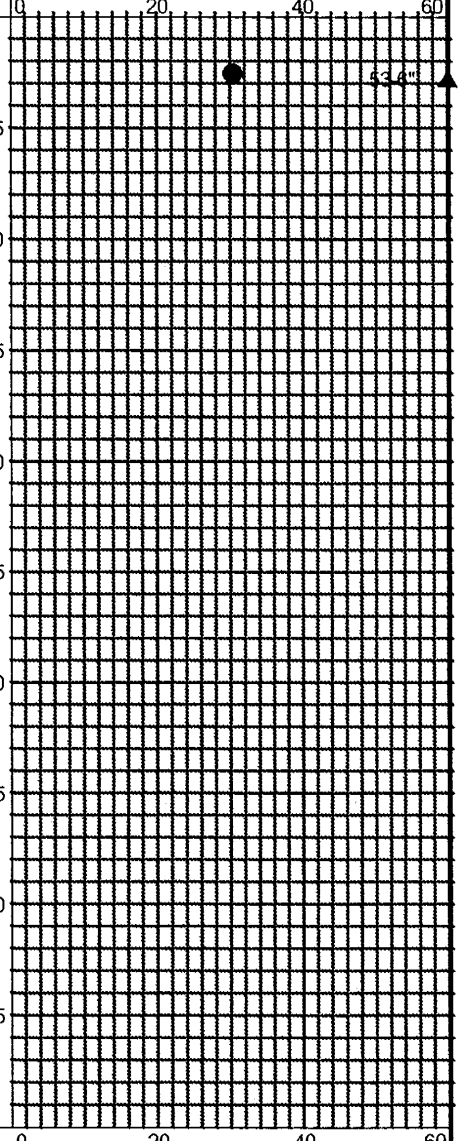
SOIL DESCRIPTION

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 transition may be gradual.

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

PENETRATION RESISTANCE (blows/foot)

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



LEGEND

* Sample Not Recovered

I Standard Penetration Test

II 3" O.D. Shelby Tube

Plastic Limit ⊢●⊣ Liquid Limit

Natural Water Content

NOTES

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

Joint Water Commission
Fern Hill Road WTP Seismic Evaluation
Forest Grove, Oregon

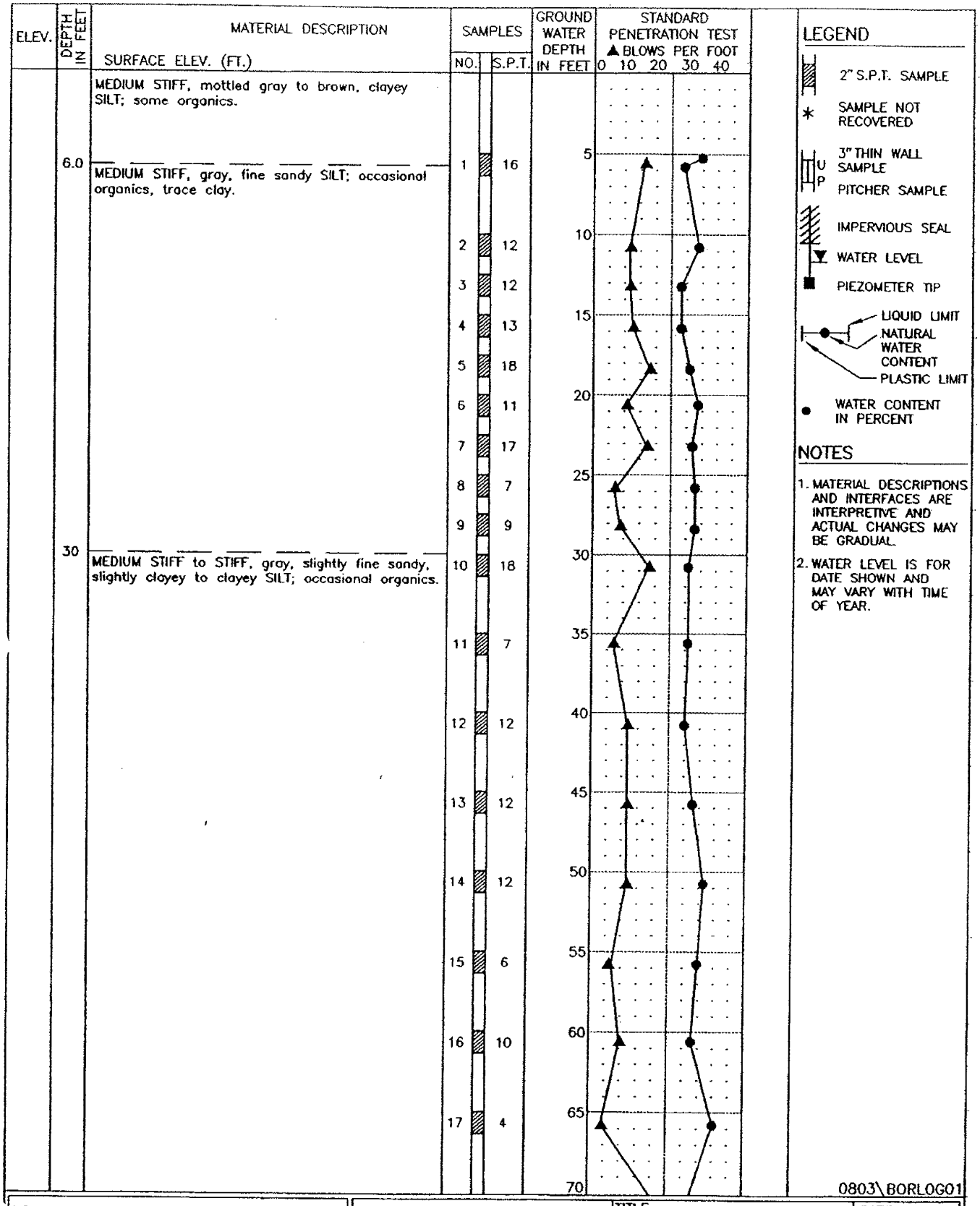
LOG OF BORING B-8

24-1-3459-001

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. A9
Sheet 3 of 3

MASTER_LOG_E_1973 SW LOGS.GPJ SHAN_WIL.GDT 12/5/07 Log: Rev: Typ: DRH



DRILLER Geo-Tech Explorations
DATE START 1/23/95 FINISH 1/23/95
DRILLING TECHNIQUE Mud Rotary

Comforth Consultants, Inc.
10250 S.W. Greenburg Rd.
Portland, OR 97223

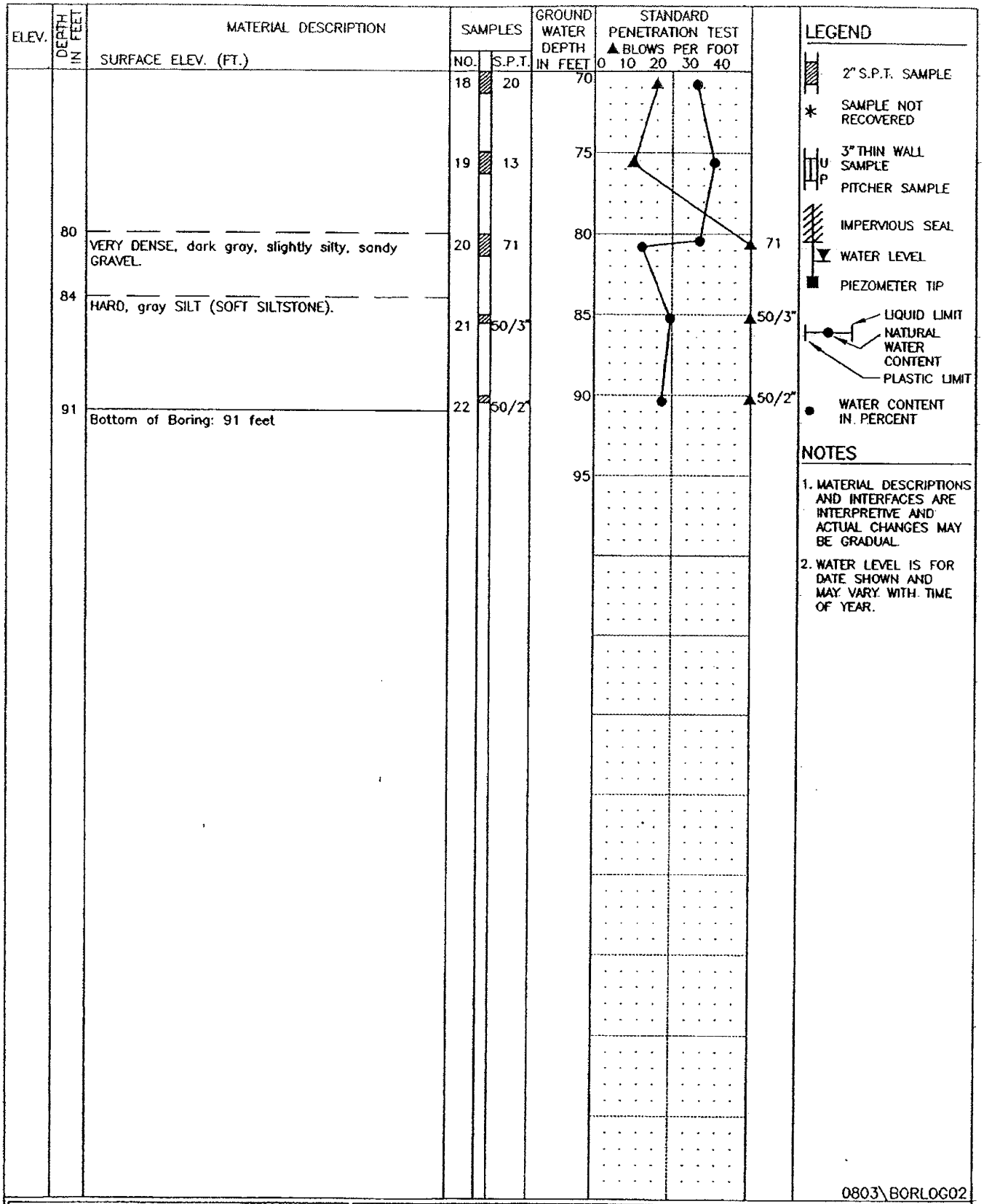
TITLE
SUMMARY BORING LOG
CC-1

JOB FERN HILL W.T.P. EXPANSION
FOREST GROVE, OREGON

DATE
APR 1995

JOB NO.
0803

FIG. 2



0803\BORLOG02

DRILLER Geo-Tech Explorations
DATE START 1/23/95 FINISH 1/23/95
DRILLING TECHNIQUE Mud Rotary

Comforth Consultants, Inc.
10250 S.W. Greenburg Rd.
Portland, OR 97223

TITLE
SUMMARY BORING LOG
CC-1 (cont.)

JOB FERN HILL W.T.P. EXPANSION
FOREST GROVE, OREGON

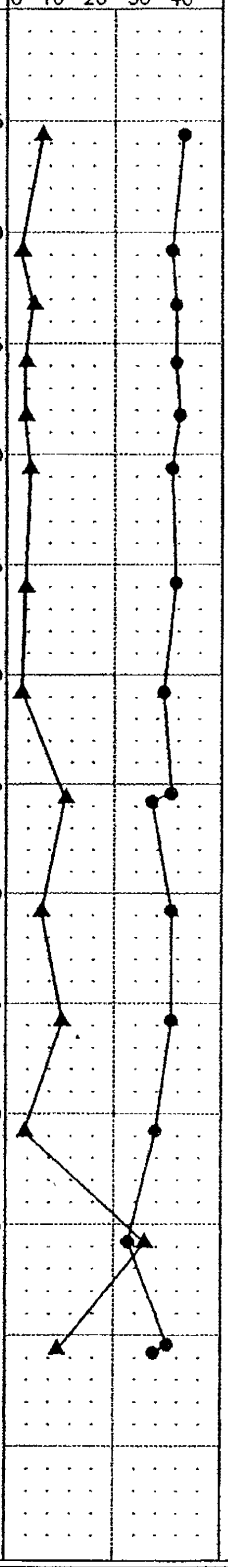
DATE
APR 1995

JOB NO.
0803

FIG. 2

ELEV.	DEPTH IN FEET	MATERIAL DESCRIPTION SURFACE ELEV. (FT.)	SAMPLES NO.	SAMPLES S.P.T.	GROUND WATER DEPTH IN FEET
		VERY SOFT to SOFT, mottled orange-brown, slightly fine sandy SILT; trace clay.	1	8	
			2	3	
		...becomes gray-brown.	3	6	
			4	4	
			5	4	
			6	5	
			7	4	
			8	3	
	35	SOFT to STIFF, gray, slightly clayey, fine sandy, clayey SILT; interbedded with thin layers of LOOSE to MEDIUM DENSE, fine sandy SILT.	9	14	
			10	8	
			11	13	
			12	4	
			13	32	
			14	11	
	61.5	Bottom of Boring: 61.5 feet			

STANDARD PENETRATION TEST
▲ BLOWS PER FOOT
0 10 20 30 40



LEGEND

- 2" S.P.T. SAMPLE
- SAMPLE NOT RECOVERED
- U P 3" THIN WALL SAMPLE
- PITCHER SAMPLE
- IMPERVIOUS SEAL
- WATER LEVEL
- PIEZOMETER TIP
- LIQUID LIMIT
- NATURAL WATER CONTENT
- PLASTIC LIMIT
- WATER CONTENT IN PERCENT

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. WATER LEVEL IS FOR DATE SHOWN AND MAY VARY WITH TIME OF YEAR.

0803\BORLOG03

DRILLER Geo-Tech Explorations
DATE START 1/24/95 FINISH 1/24/95
DRILLING TECHNIQUE Mud Rotary

Cornforth Consultants, Inc.
10250 S.W. Greenburg Rd.
Portland, OR 97223

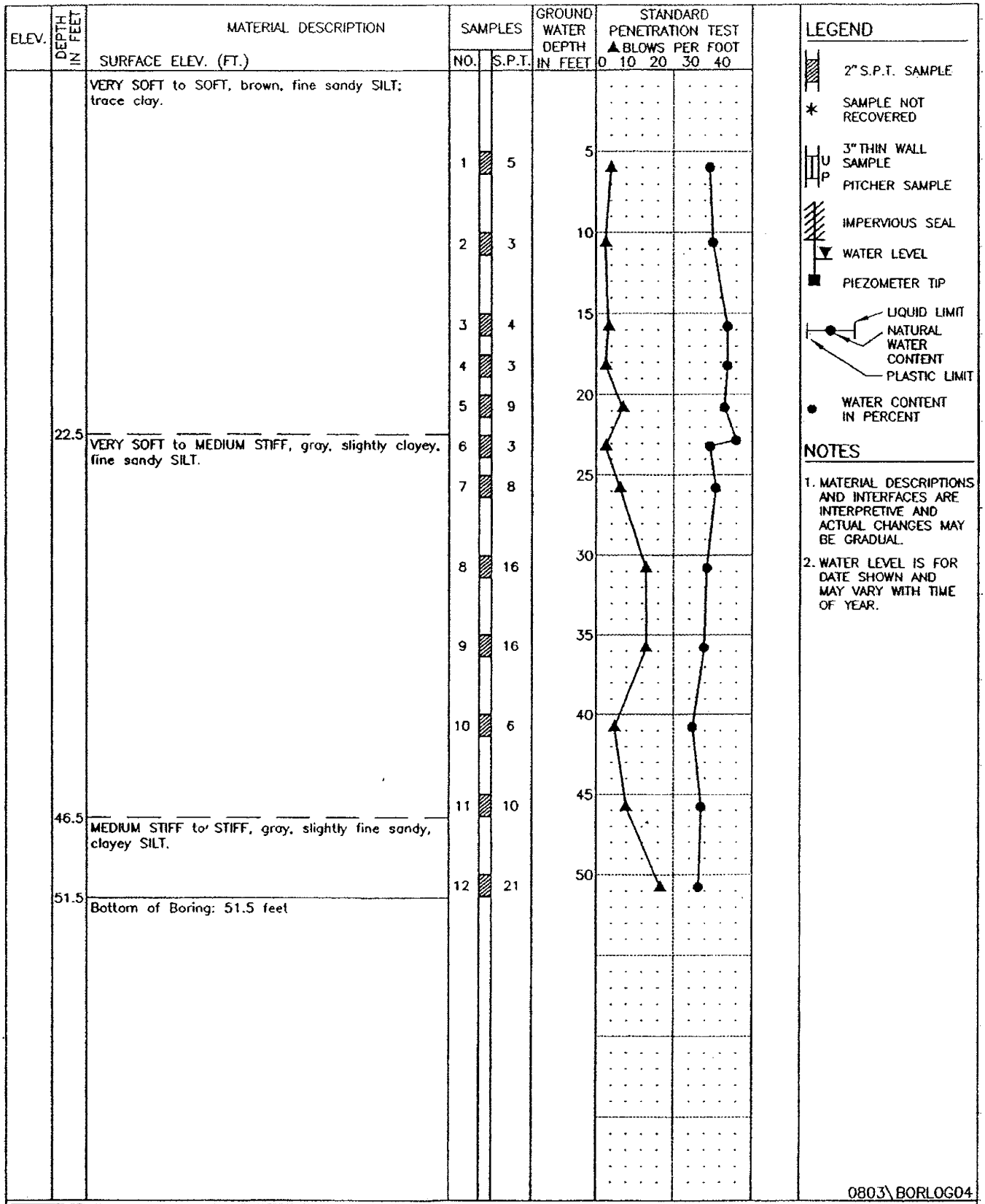
TITLE
SUMMARY BORING LOG
CC-2

JOB FERN HILL W.T.P. EXPANSION
FOREST GROVE, OREGON

DATE
APR 1995

JOB NO.
0803

FIG. 3



0803\BORLOG04

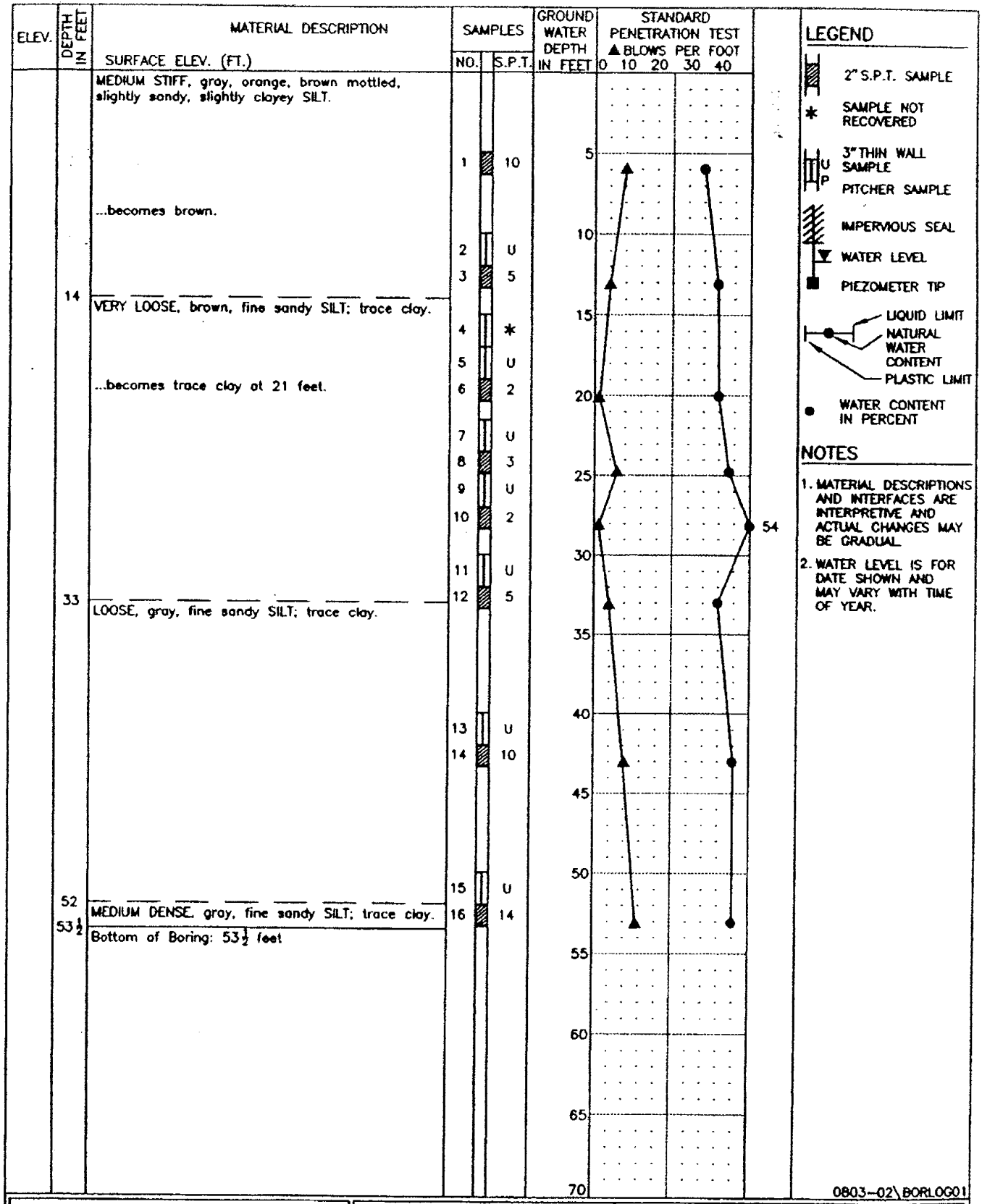
DRILLER Geo-Tech Explorations
DATE START 1/24/95 FINISH 1/24/95
DRILLING TECHNIQUE Mud Rotary

Cornforth Consultants, Inc.
10250 S.W. Greenburg Rd.
Portland, OR 97223

TITLE: SUMMARY BORING LOG CC-3

JOB: FERN HILL W.T.P. EXPANSION
FOREST GROVE, OREGON

DATE: APR 1995
JOB NO. 0803
FIG. 4



DRILLER Geo-Tech Explorations
DATE START 3/6/95 FINISH 3/6/95
DRILLING TECHNIQUE Mud Rotary
4⅞ tricone

Cornforth Consultants, Inc.
10250 S.W. Greenburg Rd.
Portland, OR 97223

TITLE
SUMMARY BORING LOG
CC-4

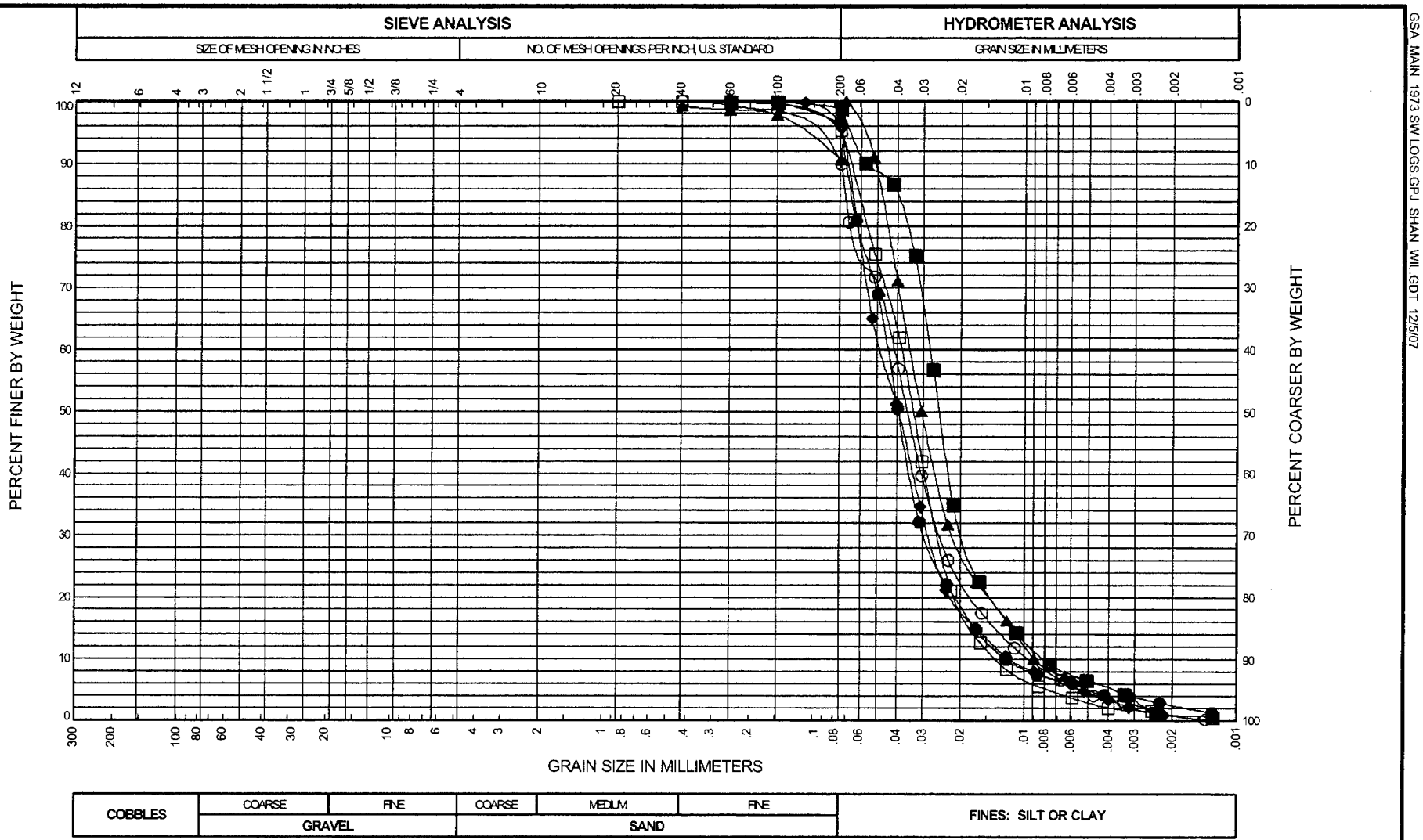
JOB LIQUEFACTION EVALUATION
FERN HILL W.T.P. EXPANSION

DATE MAY 1995
JOB NO. 0803-2
FIG. 2

Appendix B

LAB DATA

APPENDIX B
PREVIOUS LABORATORY TESTING



BORING AND SAMPLE NO.	DEPTH (feet)	U.S.C.S. SYMBOL	SAMPLE DESCRIPTION	FINES %	NAT. W.C. %	LL %	PL %	PI %
● B-2, S-S-8	21.0		Gray sandy SILT	96.6	35.9			
■ B-2, S-S-12	37.5		Gray sandy SILT		36.9			
▲ B-3, S-S-6	15.0				38.7			
◆ B-3, S-S-9	22.5				38.3			
○ B-3, S-S-10	27.5				39.0			
□ B-4, S-S-12	37.5				33.2			

Joint Water Commission
Fern Hill Road WTP Seismic Evaluation
Forest Grove, Oregon

GRAIN SIZE DISTRIBUTION

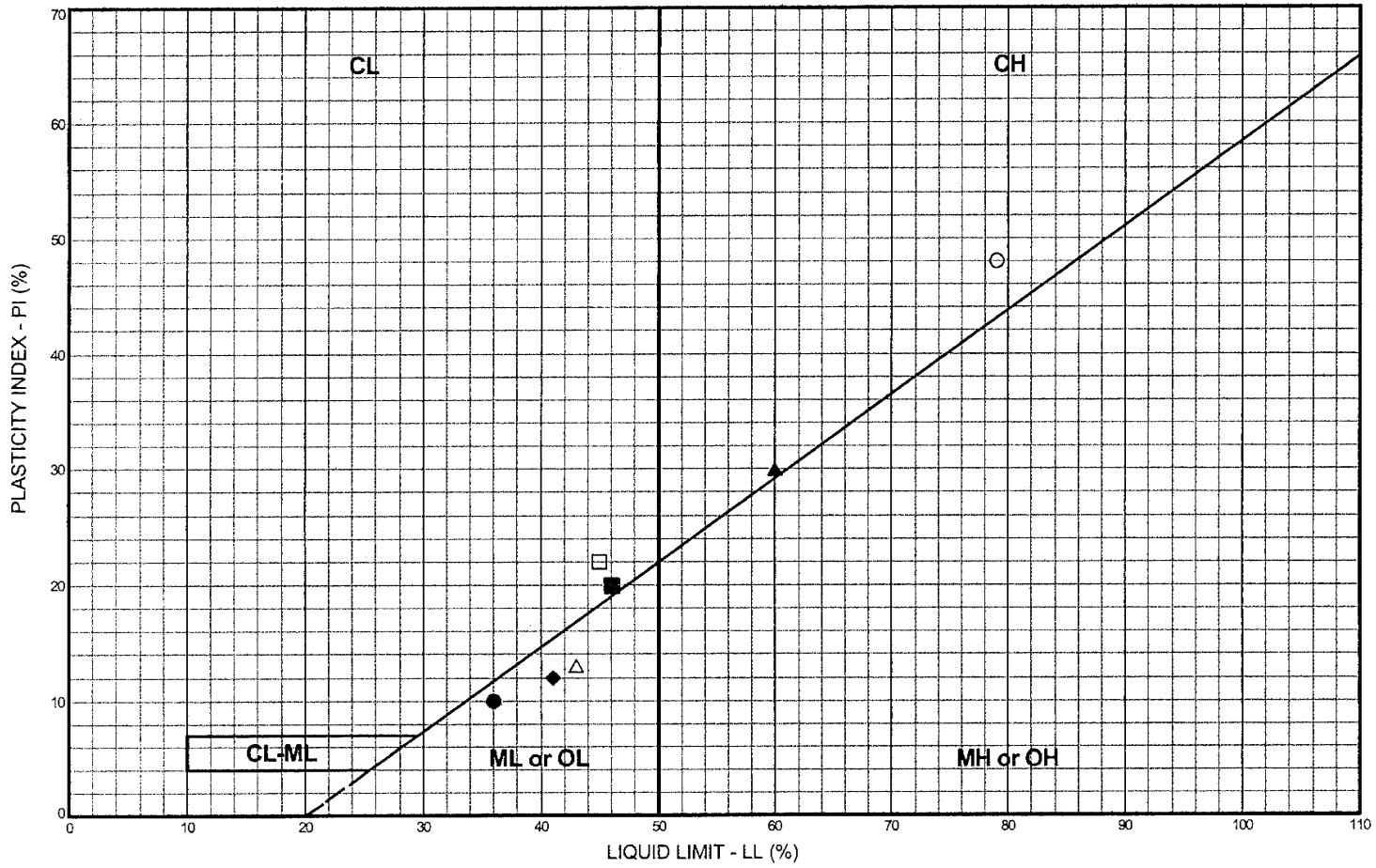
24-1-3459-001

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B1

FIG. B1

GSA MAIN 1973 SW LOGS.GPJ SHAN WIL.GDT 12/5/07



LEGEND

CL: Low plasticity inorganic clays; sandy and silty clays

CH: High plasticity inorganic clays

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

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

CL-ML: Silty clays and clayey silts

BORING AND SAMPLE NO.	DEPTH (feet)	U.S.C.S. SYMBOL	SOIL CLASSIFICATION	LL %	PL %	PI %	NAT. W.C. %	PASS. #200, %
● B-1, S-15	52.5	ML		36	26	10	35.0	
■ B-1, S-17	62.5	CL		46	26	20	35.2	
▲ B-1, S-19	72.5	CH		60	30	30	35.8	
◆ B-2, S-16	57.5	ML		41	29	12	34.5	
○ B-2, S-19	72.5	CH		79	31	48	37.4	
□ B-3, S-16	57.5	CL		45	23	22	37.4	
△ B-3, S-17	62.5	ML	Gray silty CLAY	43	30	13	38.3	

Joint Water Commission
Fern Hill Road WTP Seismic Evaluation
Forest Grove, Oregon

PLASTICITY CHART

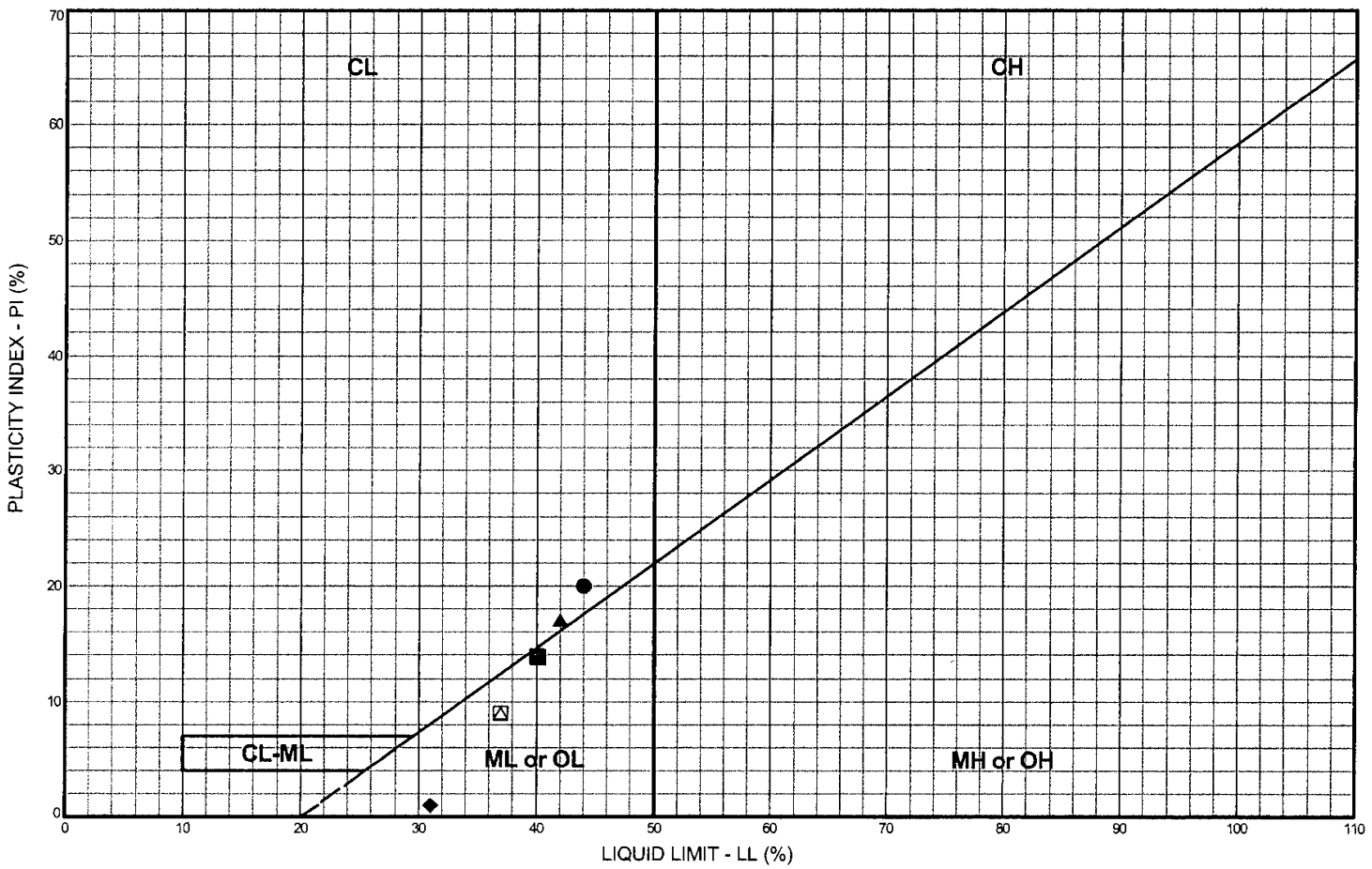
24-1-3459-001

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B2
Sheet 1 of 4

FIG. B2

ATT MAIN 1973 SW LOGS.GPJ SHAN_WIL.GDT 12/5/07



LEGEND

CL: Low plasticity inorganic clays; sandy and silty clays

CH: High plasticity inorganic clays

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

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

CL-ML: Silty clays and clayey silts

BORING AND SAMPLE NO.	DEPTH (feet)	U.S.C.S. SYMBOL	SOIL CLASSIFICATION	LL %	PL %	PI %	NAT. W.C. %	PASS. #200, %
● B-3, S-19	72.5	CL	Gray clayey SILT	44	24	20	26.1	
■ B-4, S-17	62.5	ML		40	26	14	33.0	
▲ B-4, S-19	72.5	CL		42	25	17	32.0	
◆ B-5, S-12	37.5	ML	Gray sandy SILT	31	30	1	44.6	
○ B-5, S-15	52.5	CL	Gray sandy SILT	44	24	20	38.5	
□ B-5, S-16	57.5	ML	Gray clayey SILT	37	28	9	36.5	
△ B-6, S-17	62.5	ML		37	28	9	28.7	

Joint Water Commission
Fern Hill Road WTP Seismic Evaluation
Forest Grove, Oregon

PLASTICITY CHART

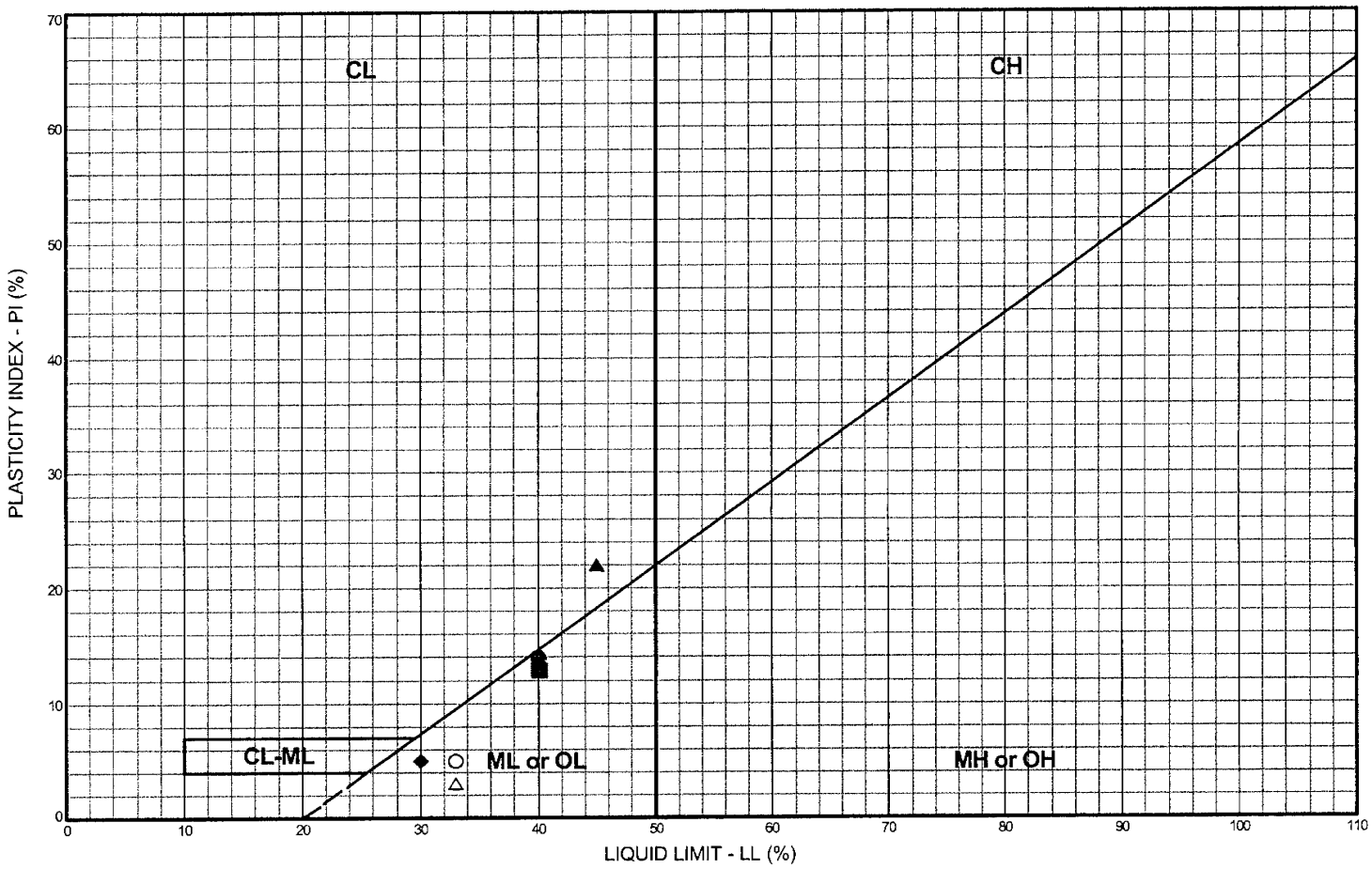
24-1-3459-001

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B2
Sheet 2 of 4

FIG. B2

ATT_MAIN_1973 SW LOGS.GPJ SHAN_WIL.GDT 12/5/07



LEGEND

CL: Low plasticity inorganic clays; sandy and silty clays

CH: High plasticity inorganic clays

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

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

CL-ML: Silty clays and clayey silts

BORING AND SAMPLE NO.	DEPTH (feet)	U.S.C.S. SYMBOL	SOIL CLASSIFICATION	LL %	PL %	PI %	NAT. W.C. %	PASS. #200, %
● B-6, S-20	77.5	ML		40	26	14	32.1	
■ B-8, S-16	57.5	ML		40	27	13	32.6	
▲ B-8, S-20	77.5	CL		45	23	22	34.1	
◆ CC-4, S-7	22.0			30	25	5		
○ CC-4, S-7	22.5			33	28	5		
CC-4, S-7	23.0			31	31	NP		
△ CC-4, S-9	26.0			33	30	3		

Joint Water Commission
Fern Hill Road WTP Seismic Evaluation
Forest Grove, Oregon

PLASTICITY CHART

24-1-3459-001

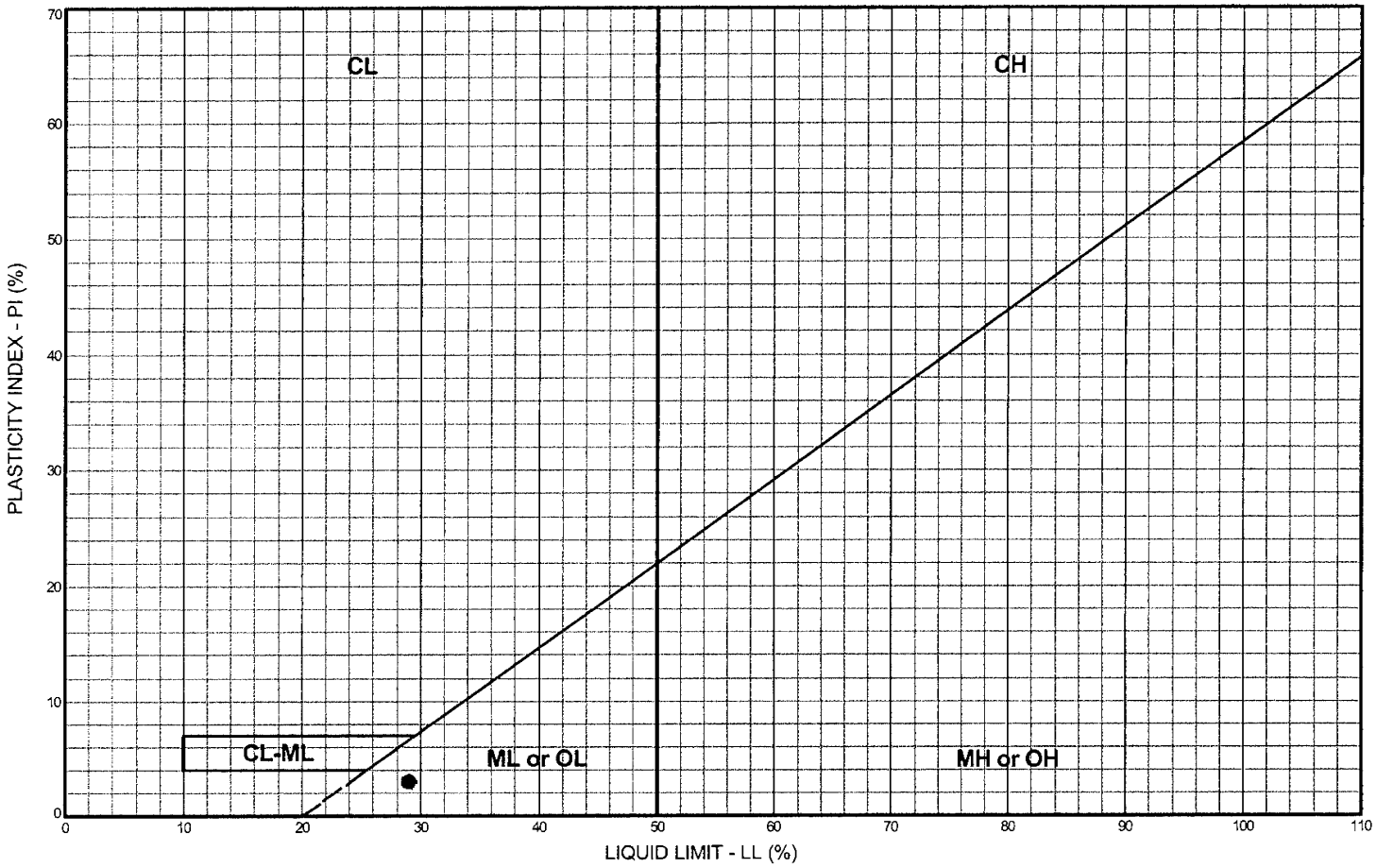
SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B2
Sheet 3 of 4

FIG. B2

Joint Water Commission

ATT_MAIN_1973 SW LOGS.GPJ SHAN_WIL.GDT 12/5/07



LEGEND

CL: Low plasticity inorganic clays; sandy and silty clays

CH: High plasticity inorganic clays

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

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

CL-ML: Silty clays and clayey silts

BORING AND SAMPLE NO.	DEPTH (feet)	U.S.C.S. SYMBOL	SOIL CLASSIFICATION	LL %	PL %	PI %	NAT. W.C. %	PASS. #200, %
● CC-4, S-11	31.0			29	26	3		

Joint Water Commission
Fern Hill Road WTP Seismic Evaluation
Forest Grove, Oregon

PLASTICITY CHART

24-1-3459-001

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B2
Sheet 4 of 4

FIG. B2

ATT MAIN 1973 SW LOGS.GPJ SHAN WIL.GDT 12/5/07

Appendix C

IMPORTANT INFORMATION ABOUT YOUR GEOTECHNICAL REPORT

APPENDIX C
IMPORTANT INFORMATION ABOUT YOUR GEOTECHNICAL REPORT

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

Attachment to and part of Joint Water Commission
Fern Hill Road WTP Seismic Evaluation
Date: December, 2007
To: Todd Perimon, P.E.
Carollo Engineers

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