Appendix E

SESIMIC RESPONSE AND GEOLOGIC HAZARDS ASSESSMENT

Northwest Geotech, Inc.
9120 SW Pioneer Court, Suite B, Wilsonville, Oregon 97070 | ph: 503.682.1880 fax: 503.682.2753 | www.nwgeotech.com

TECHNICAL MEMORANDUM

To: Dave Price / Carollo Engineers

From: Alan P. Bean / Northwest Geotech, Inc.

Date: June 25, 2021

Subject: Seismic Response and Geologic Hazards Assessment of the Wilsonville WWTP Campus

Project: Wilsonville WWTP Plan 2020

Project No. 3553.1.1

15951PE
July 21, 1992
ALAN P. BEAN

Expiration Date: 12/31/2021

Purpose and Scope

The purpose of this memorandum is to provide Geotechnical opinions and recommendations based on past and present site investigations and engineering analysis performed for this study. Our scope of work was primarily developed based on the 2013 Oregon State Seismic Resiliency Plan's goal of achieving operational public lifeline infrastructure and services following the Cascadia Subduction Zone (CSZ) full rupture event. Our scope included developing CSZ site specific spectra for structures, and assessing geotechnical/geologic hazards and risks that may influence master planning. In order to facilitate spectra development three geophysical survey lines were performed across the site to acquire Vs30 shear wave velocity profiles. Our assessment and studies were limited to the WWTP campus and excluded assessment of the 700 foot long outlet pipe and river bank, presumably because failure of the outlet pipe south of the campus in a seismic event would not necessarily result in plant inoperability.

Site Overview and Conditions

The plant site is a former gravel pit located approximately 600 feet from the Willamette River as indicated on the Vicinity Map, Figure 1. We understand that the pit mining operation was primarily used to construct the adjacent Willamette River bridge approach embankments in 1953 and removed a portion of the Missoula Flood Deposit formation that consisted of sandy gravel with numerous cobbles and scattered boulders. Major plant construction and expansion occurred in the mid-70s, mid-90s and again in 2012, and improvements continue to be constructed as recent as 2020.

It is estimated that the pit mining removed approximately 55 vertical feet of soils based on the northern slope that peaks at approximately elevation 145 feet, and borings performed around the perimeter that indicated a pit base at elevation 91 feet in the north to 85 feet in the south portions of the campus. The gravel and pavement surfacing present throughout the campus ranges from elevation 113 feet in the north to 107 feet in the south. It is important to note however, that we are not aware of any prior borings available near the interior portions of the pit, and therefore the maximum depth of the pit has not been confirmed. Locations of borings performed by others in 2009 used to supplement geophysical surveys and our assessment are shown on the Site Plan in Figure 2, along with the locations of the three geophysical survey lines and plant facility structure nomenclature. Land adjacent to the pit on the west side slopes north to south from 160 feet down to 135 feet. Land to the east of the site is currently being used as a soil spoils stockpile site operated by ODOT, and stockpile heights relative to the surrounding grades increase from north to south. Average river elevations are on the order of 60 feet, and can rise to 68 to 70 feet during extreme flood events.

Prior Exploration Summary

Based on prior borings included in Appendix A and reviewed test pit summaries and photos, the site backfill varies, but can generally be described as loose to medium dense granular soils with cobbles and boulders. Swarms of boulder and cobble spoils were encountered in previous test pits and facility construction excavations, and we understand a majority of these oversized spoil areas are on the southern edge of the campus, but should be expected to be present at any location campus wide. Prior explorations indicated that the water table is likely at the elevation of the base of the pit backfill. Native soils below the pit backfill consist of the Missoula Flood Deposits (MFD) which are composed of medium dense sandy gravel with cobles and boulders and may include isolated thin lenses of silty sand and sandy silt. Beneath the MFD deposits, the Troutdale Formation is present and are composed of a wide variety of stratified over-consolidated, hard clay and cohesive silts with inter-beds of weathered sands and gravels; typically the more granular beds are cemented at depth to some extent, and course gravel with a clay matrix is also characteristic of the formation. Prior explorations penetrated a few feet into the Troutdale formation and indicated primarily very stiff to hard fine grained (clay) sequences.

Geophysical Survey

The geophysical survey consisted of three lines performed at the locations indicated in Figure 2. The survey utilized Micro-tremor Array Measurements (MAM) to determine the change in shear wave velocity with depth such that average shear wave velocity profiles (Vs30) could be developed in the vicinity of each structure. The survey also included Multichannel Analysis of Surface Waves (MASW) data collection and processing. A more detailed description and summary of results of the geophysical work performed for this assessment is provided in Appendix B. Separately, the geophysical consultant provided shear wave profiles at a spacing of every 10 feet (roughly 80 profiles), such that average structure specific Vs30 profiles could be developed by NGI.

Site Specific Spectra

Table 1 provides the results of the structure specific CSZ spectra development process. The first two columns in Table 1 identify the individual structures and year of construction provided to us. Columns 3 through 6 identify the estimated fill thickness from the ground surface and below structure foundations. The remainder of the columns in Table 1 provide the basis and results of the calculated Vs30 values developed for each structure.

Review of the information indicates that Vs30 profiles vary between 400 and 600 m/s. As a result NGI developed spectra that envelopes the structure specific values which is presented in Figure 3 as spectra for 400, 500 and 600 m/s. We suggest utilizing the lower bound spectra (400 or 500) for Vs30 structure specific values in Table 1. The Vs30 spectra for 600 m/s provides the basis for interpolation in the event intermediate spectra ordinates are desired. The points or spectral ordinates utilized in the Figure 2 spectra plots are provided for convenience in Table 2. The spectra were developed based on the web based tool that calculates the deterministic acceleration response spectra of a full rupture CSZ (Cascadia Subduction Zone) earthquake for any site in Oregon. The tool uses the methods and assumptions adopted by USGS in considering CSZ when generating the 2014 seismic hazard maps.

For comparison, probabilistic USGS spectra such as the BSE-1E and BSE-2E can be determined using the site coordinates and Site Class C input at the site hosted by the Structural Engineers Association of California https://seismicmaps.org. In Oregon little is known about the local crustal fault activity, location, and recurrence periods of the identified faults due to the lack of recorded earthquake history. Accordingly, USGS has generally defaulted to assuming a random or "grid" of potential faults present every 5 kilometers. This tends to dominate the ground and spectra developed, and while it provides a uniform basis for performing building facility ASCE 41-17 evaluations, State experts and legislators have emphasized the need to focus on infrastructure resiliency studies and improvements for the more predictable CSZ mega-thrust source/event. As a comparison, the CSZ mega-thrust events have been shown to have an average return period of 550 years for a magnitude M_w=8 to 9 event. The last event was in 1700 AD, and experts predict a 35% chance of a mega-thrust event occurring in the next 50 years. For comparison, return periods for significant (M_w=6.0) events related to individual crustal faults in Northwest Oregon are unknown and known faults have been assigned very slow creep rates indicative of recurrence periods of 3,000 to 12,000 years.

Geologic Hazards Assessment and Reconnaissance Observations

Based on review of the 2009 borings and core photos, and our prior local experience with exploring this course grained sequence of the MFD formation, it is our opinion that liquefaction risk is low in these native soils present below the pit backfill. Pit backfill soils have not been shown to be saturated, as the prior groundwater measurements indicate the groundwater levels are likely consistent with the base of the pit.

Previously, as part of the 2012 improvements, the northern steeper slopes were evaluated and regraded to lessen the risk of raveling or shallow debris slides. Our reconnaissance of site slopes did not identify any obvious areas of concern. We reviewed the ODOT spoil site conditions east/upslope of the campus and found that ODOT site managers were making an effort to maintain a top of slope offset estimated at 25 to 30 feet wide while also incorporating an erosion containment berm as indicated in Figure 3, ODOT Spoils Observations. The approximately 25 feet high southern portion of the spoil berm also appears to be separated sufficiently from the plant campus by a shallow swale and lower gradient pit slope such that slumping of the spoil should be largely captured by the shallow swale. Nonetheless, while not perceived to be a present risk, continued spoiling over time will increase the risk of a heavy rainfall instability event impacting the campus.

We expended considerable effort developing and applying a variety of published methods to assess the potential risk of seismic induced settlement of the granular pit backfill, that we perceive as having been placed with very little compactive effort. To form a conclusion and frame or envelope the risk, we evaluated two potential conditions based on the 2009 borings. One, an existing relative density profile of the fill equivalent to a standard penetration test result of 10 blows per foot and a second assuming a profile of 20 blows per foot. The results of the study are summarized in Table 3, and estimated settlement of about 0.6 inches for a loose fill profile and generally negligible settlement for a medium dense deposit. The empirical analysis method was originally developed for natural loose sand or somewhat uniform deposits. The pit backfill is not a uniform natural deposit, and thus the results may under-estimate the hazard. For evaluation purposes we recommend assuming 1 inch of seismic settlement for every 15 feet of fill anticipated to be present beneath the site. Differential settlement may be assumed to be 1 inch in 30 lateral feet.

Sink holes had been reported in the past at the south end of the plant near the access road. This is also the location where boulders where reportedly spoiled and confirmed in prior test pits. Boulder swarms were also reportedly discovered during excavations for below grade facilities and we understand that voids observed between boulders as large as 4 to 6 feet in diameter were filled by tremie pouring cement slurry beneath some of the structures where observed. We consider the potential for soil piping and sinkhole development beneath structures and pipelines as a primary site hazard. Soil piping needs water supply or other fluids in order to move soils vertically or horizontally, and as a result, the control of surface water or any leakage is paramount to reducing this hazard as discussed in the following section.

Fill thicknesses beneath structures indicated in Table 1 may be used to quantify seismic dry settlement and soil piping hazards discussed herein.

Summary Recommendations for Master Planning

1. In our opinion, the primary geotechnical hazard at the site is differential settlement due to soil piping resulting in sinkholes and loss of portions of structure support. The hazard is most prevalent for the structures on Table 1 that include more than a few feet of pit backfill below the foundations; the greater the depth of the fill the greater the hazard. Soil piping is a process that occurs typically in unsaturated soils when a water (storm or leaking facilities) source is present and percolating into the ground. While a majority of the site has been paved, and stormwater collected, there may be significant portions of the site where infiltration is occurring adjacent to structures or beneath pipelines. Thus incorporating a stormwater evaluation and control process into the master plan program is recommended and should include paving right up to structure exterior walls. All stormwater, including that sheeting down the site slopes, should be captured and metered or released off site. A further step would include low viscosity cement pressure grouting beneath key structures that have significant thicknesses of fill beneath them, or foundation types more susceptible to differential settlement and loss of support.

2. Available information appears to indicate the pit excavations may have terminated once groundwater was encountered, resulting in the hypothesis that the pit has/had a rather flat base grading from elevation 91 feet in the north to 85 feet in the south. We recommend confirming this with up to three interior borings. Based on these results, it may be recommended that significant structures located on thicker fill sequences be grouted to mitigate both dry seismic induced settlement and potential sinkhole development induced loss of support. In addition, if not already in place, retrofitting pipeline entrances and exits to and from structures with a flexible section or joint is a common tool to significantly reduce risk of pipeline failure due to differential ground movement (fill settlement or sink holes).

3. We also recommend performing a periodic drone topographic survey of the eastern slope and ODOT spoil area as necessary to monitor for spoil pile growth and potential encroachment.

Attachments: Figure 1 – Vicinity Map
Figure 2 – Site Plan
Figure 3 – Generalized Site Specific Spectra, CSZ
Figure 4 – ODOT Spoils Observations

Table 1 – Structure Specific Vs30 Determination Summary
Table 2 – CSZ Generated Response Spectra Ordinates
Table 3 – Estimated Settlement CSZ, Full Rupture

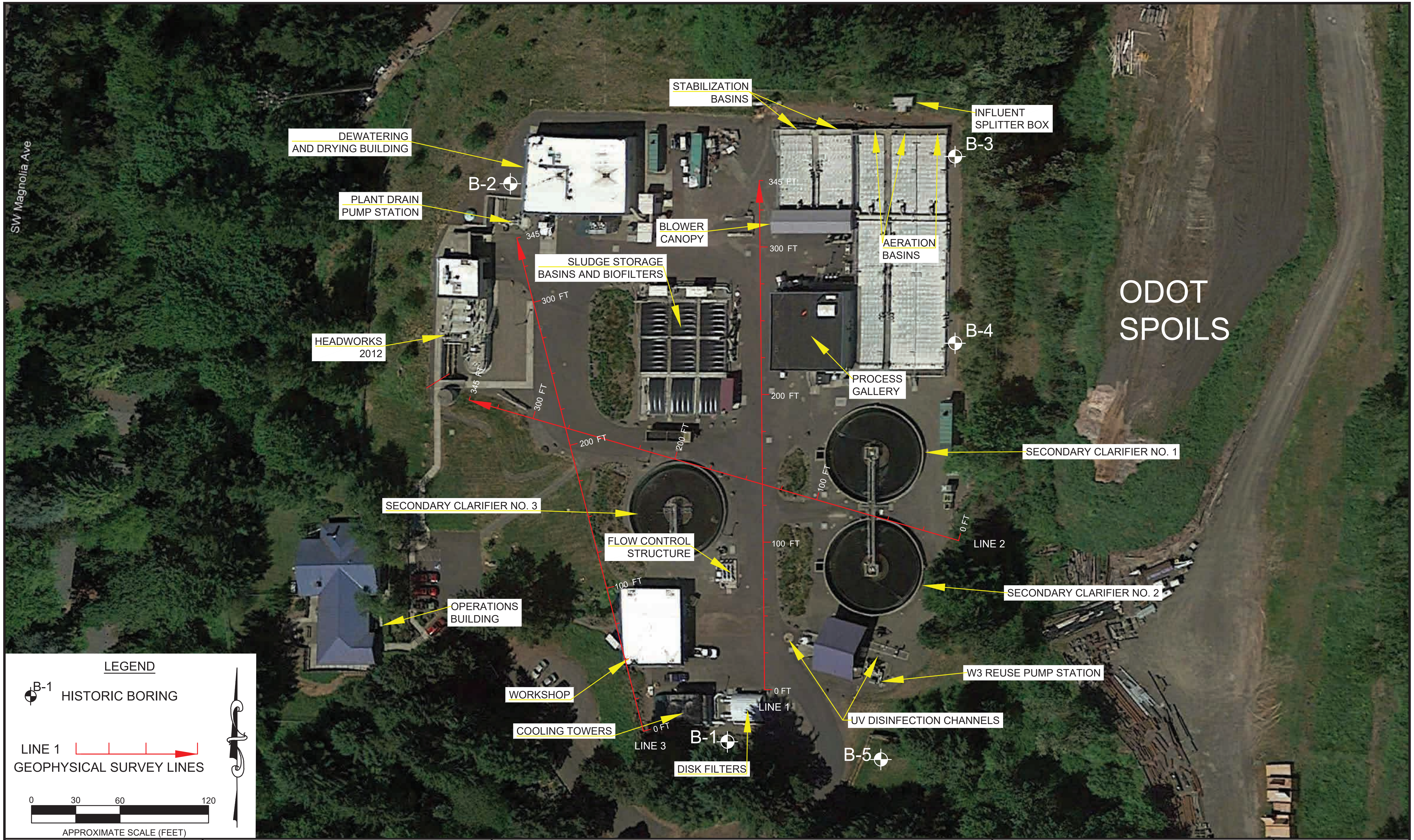
Appendix A – Site Topography and 2009 Bore Logs B1 through B-5
Appendix B – AG&E Geophysical Survey Report

COPY

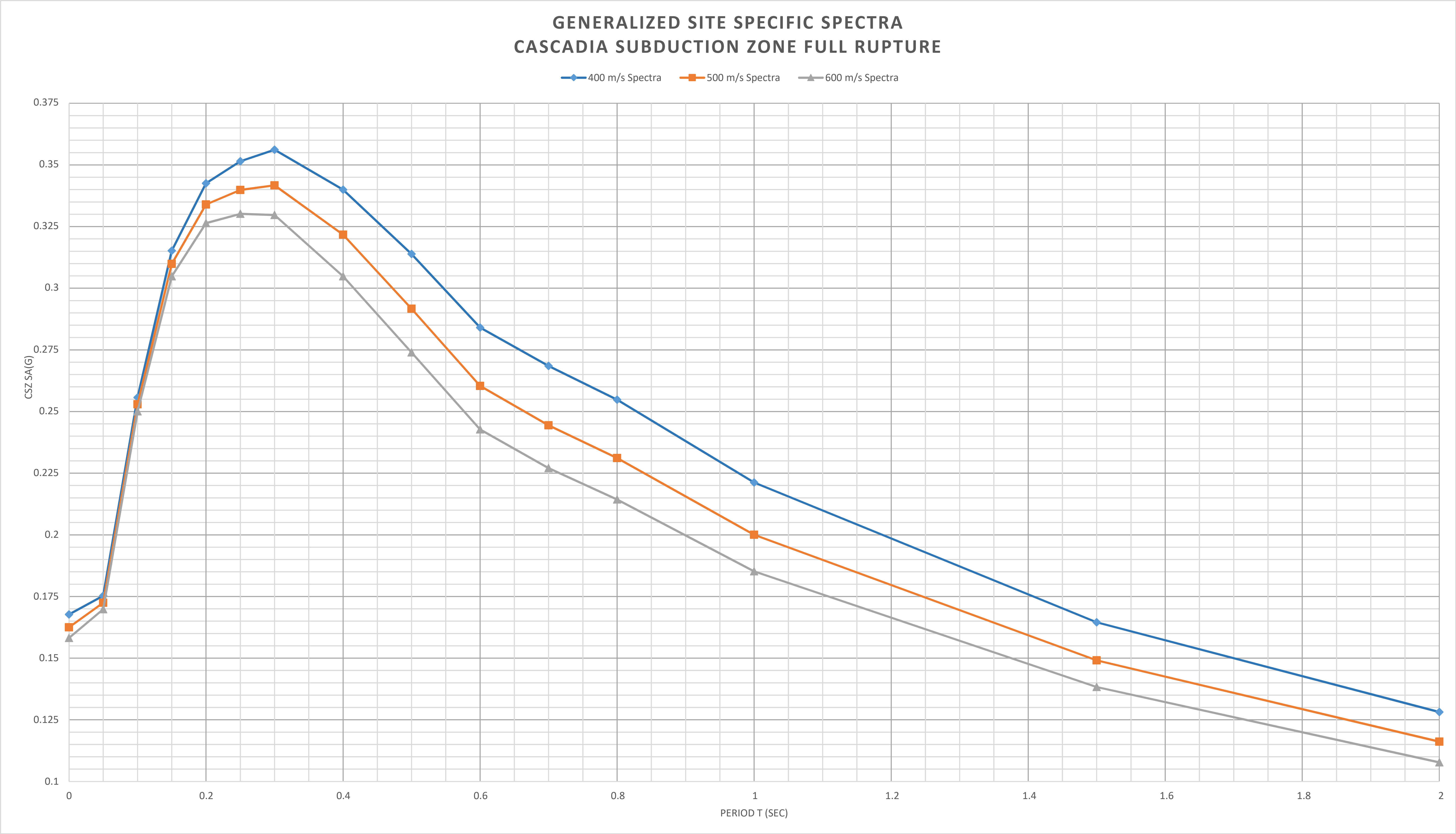
VICINITY MAP

PROJECT NO. 3553.1.1	WILSONVILLE WASTE WATER TREATMENT PLANT WILSONVILLE, OREGON	FIGURE NO. 1

Northwest Geotech, Inc.



PROJECT NO. 3553.1.1	SITE MAP	WILSONVILLE WASTE WATER TREATMENT PLANT WILSONVILLE, OREGON	Northwest Geotech, Inc.	FIGURE NO. 2



GENERALIZED SITE SPECIFIC SPECTRA
CASCADIA SUBDUCTION ZONE FULL RUPTURE

Northwest Geotech, Inc.

Figure No. 3

PROJECT NO. 3553.1.1

ODOT SPOILS OBSERVATIONS

WILSONVILLE WASTE WATER TREATMENT PLANT
WILSONVILLE, OREGON

Northwest Geotech, Inc.

FIGURE NO. 4

Table 1: Wilsonville Waste Water Treatment Plant - Structure Specific Vs30 Determination Summary

Facility Name	Year Built	Estimated Fill Thickness (ft)	Est. Fill Thickness Below Foundation (ft)	Basement Foundation EL (ft)	Ground Surface EL (ft)	Line #, Station and Depths Used for Ground Surface Vs30 Determination	Depths Used for Basement Footing Vs30 Determination (ft)	Surface Vs30 (m/s)	Basement Vs30 (m/s)
W3 Reuse Pump Station	1993	24	6	90.3	108.0	Line 1, Station 45, 0 to -100 ft	-20 to -120	436	478
UV Disinfection Channels	1993	24	8	92.0	108.0	Line 1, Station 45, 0 to -100 ft	-15 to -115	436	468
Disk Filters	2012	32	31	108.0	109.0	Line 1, Station 45, 0 to -100 ft	N/A	436	N/A
Cooling Towers	2012	32	31	108.0	109.0	Line 1, Station 45, 0 to -100 ft	N/A	436	N/A
Workshop	1979	23	21	106.5	108.5	Line 1, Station 45, 0 to -100 ft	N/A	436	N/A
Flow Control Structure	2012	23	8	92.7	107.5	Line 1, Station 75, 0 to -100 ft	-15 to -115	443	473
Sludge Storage Basins and Biofilters	1979	24	12	98.9	110.6	Avg. of Line 1, Station 225, and Line 2, Station 210, 0 to -100 ft	-15 to -115	468	482
Dewatering and Drying Building	2012	24	23	112.8	114.0	Avg of Line 1 and Line 2, Both Station 300, 0 to -100 ft	N/A	469	N/A
Plant Drain Pump Station	2012	24	0	89.3	114.0	Avg of Line 1 and Line 2, Both Station 300, 0 to -100 ft	-20 to -120	469	480
Secondary Clarifier No. 1	1993	21	5	92.0	108.5	Avg of Line 1, Station's 225 and 160, 0 to -100 ft	-15 to -115	470	491
Secondary Clarifier No. 2	1993	20	4	92.0	108.5	Avg of Line 1, Station's 225 and 160, 0 to -100 ft	-15 to -115	470	491
Secondary Clarifier No. 3	2012	20	4	92.0	108.5	Avg of Line 1, Station's 225 and 160, 0 to -100 ft	-15 to -115	470	491
Process Gallery	1993	28	13	95.0	110.5	Avg of Line 1, Station's 210 and 270, 0 to -100 ft	-15 to -115	494	510
Aeration Basins	1993/2012	20	1	93.8	112.7	Avg of Line 1, Stations 300 and 210, 0 to -100 ft	-15 to -115	498	513
Headworks 2012	2012	22	20	112.2	114.0	Avg of Line 1, Station's 195 and 300, 0 to -100 ft	N/A	498	N/A
Blower Canopy	2012	25	23	109.1	110.7	Avg of Line 2, Stations 100 and 150, 0 to -100 ft	N/A	499	N/A
Influent Splitter Box	2012	26	19	103.0	110.5	Line 1, Station 300, 0 to -100 ft	-15 to -115	532	541
Stabilization Basins	2012	25	11	97.5	111.3	Line 1, Station 300, 0 to -100 ft	-15 to -115	532	541
Operations Building	1993	0	0	123.0	125.0	Line 1, Station 100, ave. of CFD and Troutdale Fm Expanded to 100 ft	N/A	413	N/A

Note: Structure and surface elevations utitlized are based on 2012 site plan dwgs (NAVD 88). See 2012 drawings sheet 00-G-0021 notes for more information.

Table 2: CSZ Generalized Response Spectra Ordinates

Latitude 45.295155 degrees Longitude -122.771810 degrees

Vs30 = 400 m/s		Vs30 = 500 m/s		Vs30 = 600 m/s	
Period T(sec)	**CSZ Sa(g)**	**Period T (sec)**	**CSZ Sa (g)**	**Period T (sec)**	**CSZ Sa (g)**
0	0.168	0	0.163	0	0.158
0.05	0.175	0.05	0.172	0.05	0.170
0.1	0.256	0.1	0.253	0.1	0.250
0.15	0.315	0.15	0.310	0.15	0.305
0.2	0.343	0.2	0.334	0.2	0.326
0.25	0.352	0.25	0.340	0.25	0.330
0.3	0.356	0.3	0.342	0.3	0.330
0.4	0.340	0.4	0.322	0.4	0.305
0.5	0.314	0.5	0.292	0.5	0.274
0.6	0.284	0.6	0.260	0.6	0.243
0.7	0.269	0.7	0.244	0.7	0.227
0.8	0.255	0.8	0.231	0.8	0.214
1	0.221	1	0.200	1	0.185
1.5	0.165	1.5	0.149	1.5	0.138
2	0.128	2	0.116	2	0.108
2.5	0.104	2.5	0.094	2.5	0.087
3	0.085	3	0.077	3	0.071

Table 3: Estimated Settlement CSZ, Full Rupture

Estimated Settlement CSZ Full Rupture for SPT = 10

Layer Number	Elevation (ft)	Range (ft)	Settlement (in)	Cumulative from base of fill (in)
1	110	105	0.03	0.57
2	105	100	0.11	0.53
3	100	95	0.13	0.42
4	95	90	0.15	0.30
5	90	85	0.15	0.15
		Total	0.57	

Estimated Settlement CSZ Full Rupture for SPT = 20

Layer Number	Elevation (ft)	Range (ft)	Settlement (in)	Cumulative from base of fill (in)
1	110	105	0.01	0.13
2	105	100	0.02	0.12
3	100	95	0.03	0.10
4	95	90	0.03	0.07
5	90	85	0.04	0.04
		Total	0.13	

Reference:

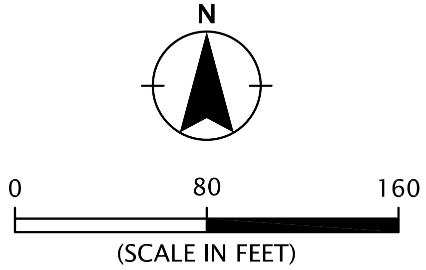
FHWA-NHI-11-032: LRFD SEISMIC ANALYSIS AND DESIGN OF TRANSPORTATION GEOTECHNICAL FEATURES AND STRUCTURAL FOUNDATIONS, NHI COURSE NO. 130094 REFERENCE MANUAL, GEOTECHNICAL ENGINEERING CIRCULAR NO. 3. Rev. 1, 2011.

$(Note\colon\ G_{max} = K_2(1000)(\sigma'_m)^{\frac{1}{2}})$

APPENDIX A

LEGEND:

B-1 ●	BORING
TP-A ▣	TEST PIT (CH2MHILL, 1995)
TP-1 ▣	TEST PIT (CH2MHILL, 1979)
— - — -	PROPERTY BOUNDARY
A ↑ ↑ A'	CROSS SECTION



SITE PLAN BASED ON DRAWING PROVIDED BY
BROWN CALDWELL, APRIL 16, 2009

GEODESIGN INC
15575 SW Sequoia Parkway - Suite 100
Portland OR 97224
Off 503.968.8787 Fax 503.968.3068

BROWNCALD-44-01

AUGUST 2009

SITE PLAN WITH SECTION LINES

WILSONVILLE SEWAGE TREATMENT PLANT
WILSONVILLE, OR

FIGURE 3

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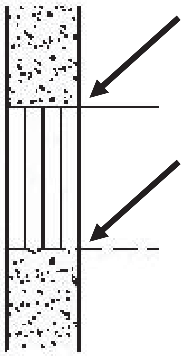
SYMBOL	SAMPLING DESCRIPTION
◨	Location of sample obtained in general accordance with ASTM D 1586 Standard Penetration Test with recovery
◧	Location of sample obtained using thin-wall Shelby tube or Geoprobe® sampler in general accordance with ASTM D 1587 with recovery
▥	Location of sample obtained using Dames & Moore sampler and 300-pound hammer or pushed with recovery
▤	Location of sample obtained using Dames & Moore or 3-inch-O.D. split-spoon sampler and 140-pound hammer or pushed with recovery
⊠	Location of grab sample
▮	Rock coring interval
▽	Water level during drilling
▼	Water level taken on date shown

Graphic Log of Soil and Rock Types



Observed contact between soil or rock units (at depth indicated)

Inferred contact between soil or rock units (at approximate depths indicated)

GEOTECHNICAL TESTING EXPLANATIONS

ATT	Atterberg Limits	P	Pushed Sample
CBR	California Bearing Ratio	PP	Pocket Penetrometer
CON	Consolidation	P200	Percent Passing U.S. Standard No. 200 Sieve
DD	Dry Density	RES	Resilient Modulus
DS	Direct Shear	SIEV	Sieve Gradation
HYD	Hydrometer Gradation	TOR	Torvane
MC	Moisture Content	UC	Unconfined Compressive Strength
MD	Moisture-Density Relationship	VS	Vane Shear
OC	Organic Content	kPa	Kilopascal

ENVIRONMENTAL TESTING EXPLANATIONS

CA	Sample Submitted for Chemical Analysis	ND	Not Detected
P	Pushed Sample	NS	No Visible Sheen
PID	Photoionization Detector Headspace Analysis	SS	Slight Sheen
ppm	Parts per Million	MS	Moderate Sheen
		HS	Heavy Sheen

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15575 SW Sequoia Parkway - Suite 100
Portland OR 97224
Off 503.968.8787 Fax 503.968.3068

EXPLORATION KEY

TABLE A-1

RELATIVE DENSITY - COARSE-GRAINED SOILS

Relative Density	Standard Penetration Resistance	Dames & Moore Sampler (140-pound hammer)	Dames & Moore Sampler (300-pound hammer)
Very Loose	0 – 4	0 - 11	0 - 4
Loose	4 – 10	11 - 26	4 - 10
Medium Dense	10 – 30	26 - 74	10 - 30
Dense	30 – 50	74 - 120	30 - 47
Very Dense	More than 50	More than 120	More than 47

CONSISTENCY - FINE-GRAINED SOILS

Consistency	Standard Penetration Resistance	Dames & Moore Sampler (140-pound hammer)	Dames & Moore Sampler (300-pound hammer)	Unconfined Compressive Strength (tsf)
Very Soft	Less than 2	Less than 3	Less than 2	Less than 0.25
Soft	2 - 4	3 – 6	2 - 5	0.25 - 0.50
Medium Stiff	4 - 8	6 – 12	5 - 9	0.50 - 1.0
Stiff	8 - 15	12 – 25	9 - 19	1.0 - 2.0
Very Stiff	15 - 30	25 – 65	19 – 31	2.0 - 4.0
Hard	More than 30	More than 65	More than 31	More than 4.0

PRIMARY SOIL DIVISIONS			GROUP SYMBOL	GROUP NAME
COARSE-GRAINED SOILS (more than 50% retained on No. 200 sieve)	GRAVEL (more than 50% of coarse fraction retained on No. 4 sieve)	CLEAN GRAVELS (< 5% fines)	GW or GP	GRAVEL
		GRAVEL WITH FINES (≥ 5% and ≤ 12% fines)	GW-GM or GP-GM	GRAVEL with silt
			GW-GC or GP-GC	GRAVEL with clay
		GRAVELS WITH FINES (> 12% fines)	GM	silty GRAVEL
			GC	clayey GRAVEL
			GC-GM	silty, clayey GRAVEL
	SAND (50% or more of coarse fraction passing No. 4 sieve)	CLEAN SANDS (<5% fines)	SW or SP	SAND
		SANDS WITH FINES (≥ 5% and ≤ 12% fines)	SW-SM or SP-SM	SAND with silt
			SW-SC or SP-SC	SAND with clay
		SANDS WITH FINES (> 12% fines)	SM	silty SAND
			SC	clayey SAND
			SC-SM	silty, clayey SAND
FINE-GRAINED SOILS (50% or more passing No. 200 sieve)	SILT AND CLAY	Liquid limit less than 50	ML	SILT
			CL	CLAY
			CL-ML	silty CLAY
			OL	ORGANIC SILT or ORGANIC CLAY
		Liquid limit 50 or greater	MH	SILT
			CH	CLAY
			OH	ORGANIC SILT or ORGANIC CLAY
HIGHLY ORGANIC SOILS			PT	PEAT

MOISTURE CLASSIFICATION

Term	Field Test
dry	very low moisture, dry to touch
moist	damp, without visible moisture
wet	visible free water, usually saturated

ADDITIONAL CONSTITUENTS

Secondary granular components or other materials such as organics, man-made debris, etc.					
Percent	Silt and Clay In:		Percent	Sand and Gravel In:	
	Fine-Grained Soils	Coarse-Grained Soils		Fine-Grained Soils	Coarse-Grained Soils
< 5	trace	trace	< 5	trace	trace
5 – 12	minor	with	5 – 15	minor	minor
> 12	some	silty/clayey	15 – 30	with	with
			> 30	sandy/gravelly	sandy/gravelly

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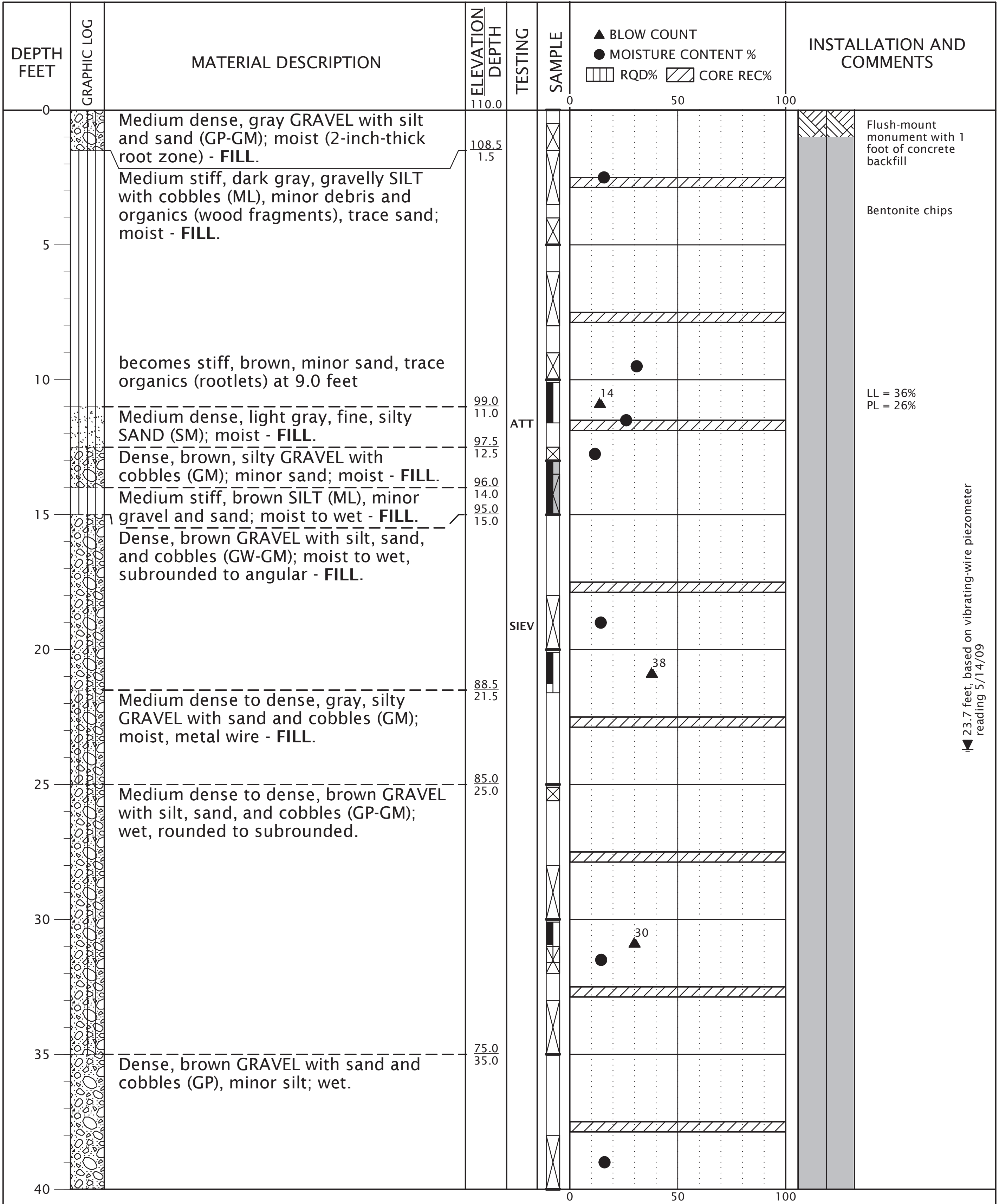
Portland OR 97224
Off 503.968.8787 Fax 503.968.3068

SOIL CLASSIFICATION SYSTEM

TABLE A-2

COPY



DEPTH FEET	MATERIAL DESCRIPTION	ELEVATION DEPTH	TESTING	INSTALLATION AND COMMENTS
0	Medium dense, gray GRAVEL with silt and sand (GP-GM); moist (2-inch-thick root zone) - **FILL**.	110.0		Flush-mount monument with 1 foot of concrete backfill
	Medium stiff, dark gray, gravelly SILT with cobbles (ML), minor debris and organics (wood fragments), trace sand; moist - **FILL**.	108.5 1.5		Bentonite chips
	becomes stiff, brown, minor sand, trace organics (rootlets) at 9.0 feet			
	Medium dense, light gray, fine, silty SAND (SM); moist - **FILL**.	99.0 11.0	ATT	LL = 36% PL = 26%
	Dense, brown, silty GRAVEL with cobbles (GM); minor sand; moist - **FILL**.	97.5 12.5		
	Medium stiff, brown SILT (ML), minor gravel and sand; moist to wet - **FILL**.	96.0 14.0		
15	Dense, brown GRAVEL with silt, sand, and cobbles (GW-GM); moist to wet, subrounded to angular - **FILL**.	95.0 15.0	SIEV	
	Medium dense to dense, gray, silty GRAVEL with sand and cobbles (GM); moist, metal wire - **FILL**.	88.5 21.5		
25	Medium dense to dense, brown GRAVEL with silt, sand, and cobbles (GP-GM); wet, rounded to subrounded.	85.0 25.0		
35	Dense, brown GRAVEL with sand and cobbles (GP), minor silt; wet.	75.0 35.0		
40				

DRILLED BY: Boart Longyear

LOGGED BY: JGH

COMPLETED: 05/12/09

BORING METHOD: sonic drilling (see report text)

BORING BIT DIAMETER: 4 7/8-inch

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15575 SW Sequoia Parkway - Suite 100
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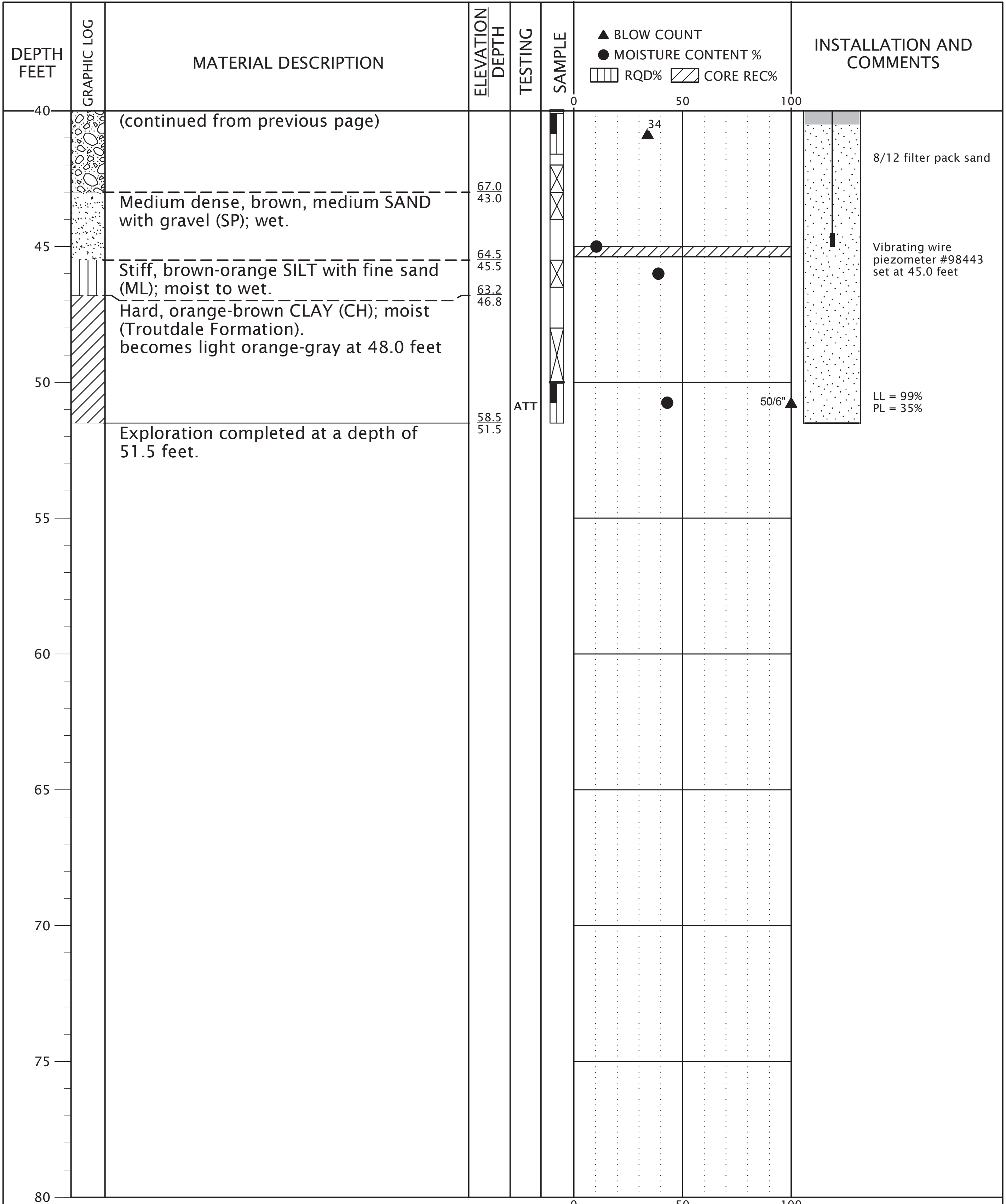
BROWNCALD-44-01

AUGUST 2009

BORING B-1

WILSONVILLE SEWAGE TREATMENT PLANT
WILSONVILLE, OR

FIGURE A-1



(continued from previous page)

Medium dense, brown, medium SAND with gravel (SP); wet.

Stiff, brown-orange SILT with fine sand (ML); moist to wet.

Hard, orange-brown CLAY (CH); moist (Troutdale Formation).
becomes light orange-gray at 48.0 feet

Exploration completed at a depth of 51.5 feet.

Vibrating wire piezometer #98443 set at 45.0 feet

LL = 99%
PL = 35%

DRILLED BY: Boart Longyear

LOGGED BY: JGH

COMPLETED: 05/12/09

BORING METHOD: sonic drilling (see report text)

BORING BIT DIAMETER: 4 7/8-inch

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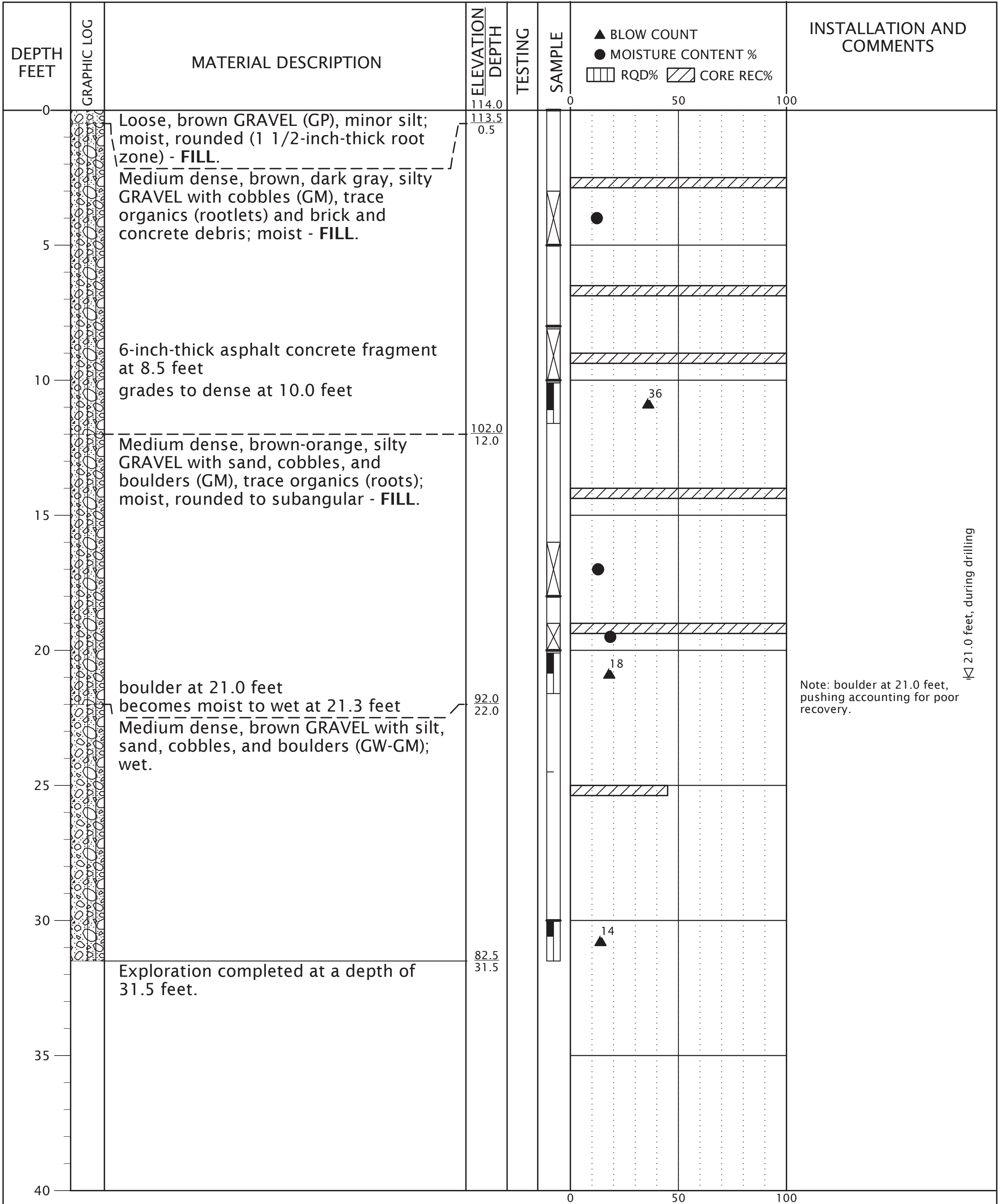
BORING B-1
(continued)

WILSONVILLE SEWAGE TREATMENT PLANT
WILSONVILLE, OR

FIGURE A-1



DEPTH FEET	MATERIAL DESCRIPTION	ELEVATION DEPTH
0		114.0
	Loose, brown GRAVEL (GP), minor silt; moist, rounded (1 1/2-inch-thick root zone) - **FILL**.	113.5 0.5
	Medium dense, brown, dark gray, silty GRAVEL with cobbles (GM), trace organics (rootlets) and brick and concrete debris; moist - **FILL**. 6-inch-thick asphalt concrete fragment at 8.5 feet grades to dense at 10.0 feet	102.0 12.0
	Medium dense, brown-orange, silty GRAVEL with sand, cobbles, and boulders (GM), trace organics (roots); moist, rounded to subangular - **FILL**. boulder at 21.0 feet becomes moist to wet at 21.3 feet	92.0 22.0
	Medium dense, brown GRAVEL with silt, sand, cobbles, and boulders (GW-GM); wet.	82.5 31.5
	Exploration completed at a depth of 31.5 feet.	

INSTALLATION AND COMMENTS

Note: boulder at 21.0 feet, pushing accounting for poor recovery.

DRILLED BY: Boart Longyear

LOGGED BY: JGH

COMPLETED: 05/12/09

BORING METHOD: sonic drilling (see report text)

BORING BIT DIAMETER: 4 7/8-inch

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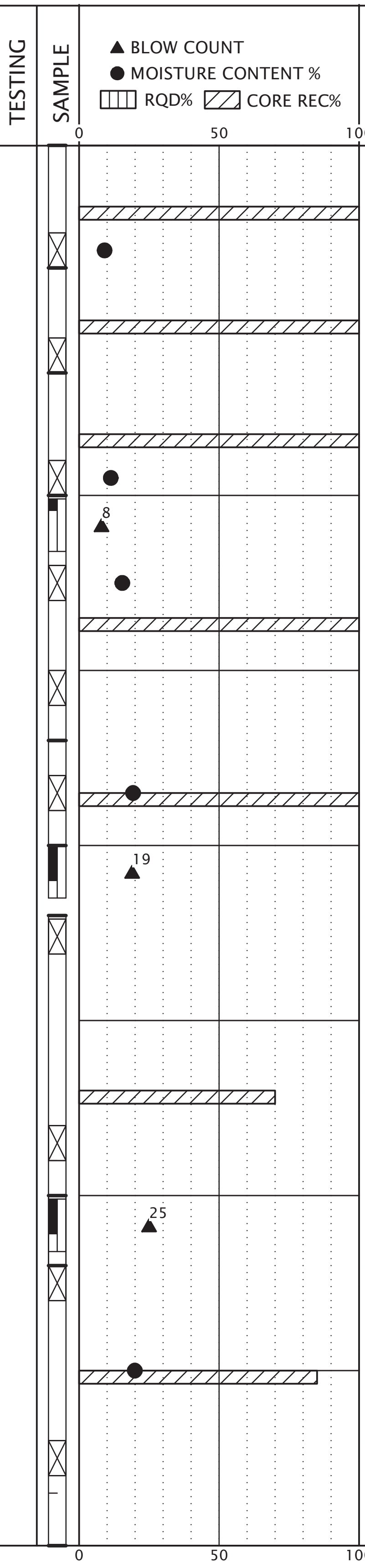
BORING B-2

WILSONVILLE SEWAGE TREATMENT PLANT
WILSONVILLE, OR

FIGURE A-2

DEPTH FEET	MATERIAL DESCRIPTION	ELEVATION DEPTH	INSTALLATION AND COMMENTS
0		112.0	
0–1.0	Stiff, brown SILT with gravel and sand (ML); moist (1 1/2-inch-thick root zone) - **FILL**.	111.0 1.0	
1.0–14.0	Medium dense, brown-gray, silty GRAVEL with sand, cobbles, and boulders (GM); moist, subrounded to angular - **FILL**. trace organics (rootlets) at 7.5 feet becomes loose at 10.0 feet	98.0 14.0	
14.0–21.0	Medium dense, brown-gray GRAVEL with silt, sand, cobbles, and boulders (GW-GM); moist to wet, rounded to angular - **FILL**. becomes wet at 20.0 feet	91.0 21.0	⊻ 20.0 feet, during drilling
21.0–27.0	Medium dense, brown GRAVEL with silt, sand, and cobbles (GW-GM); wet, subrounded. 12-inch-diameter boulder at 26.0 feet	85.0 27.0	
27.0–40	Medium dense, brown GRAVEL with sand, cobbles, and boulder (GW), minor silt; wet, rounded to subrounded.		



DRILLED BY: Boart Longyear

LOGGED BY: JGH

COMPLETED: 05/13/09

BORING METHOD: sonic drilling (see report text)

BORING BIT DIAMETER: 4 7/8-inch

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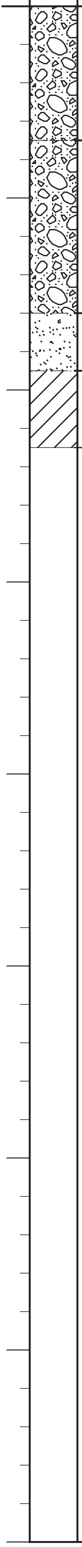
BORING B-3

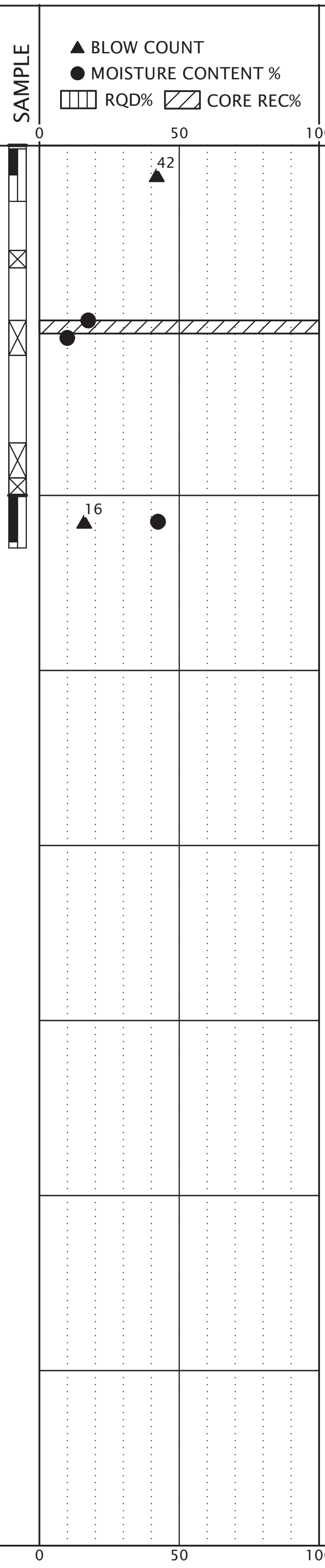
WILSONVILLE SEWAGE TREATMENT PLANT
WILSONVILLE, OR

FIGURE A-3

COPY

DEPTH FEET	MATERIAL DESCRIPTION	ELEVATION / DEPTH
40	grades to dense at 40.0 feet	
	with 6-inch-thick silty sand lens at 43.0 feet	68.5 43.5
45	Medium dense, brown GRAVEL with sand and silt (GP-GW); wet.	64.0 48.0
	Medium dense, gray, medium SAND with gravel (SP); wet.	62.5 49.5
50	Very stiff, light gray-orange CLAY (CH); moist (Troutdale Formation).	60.5 51.5
	Exploration completed at a depth of 51.5 feet.	
55		
60		
65		
70		
75		
80		





INSTALLATION AND COMMENTS

DRILLED BY: Boart Longyear
LOGGED BY: JGH
COMPLETED: 05/13/09

BORING METHOD: sonic drilling (see report text)
BORING BIT DIAMETER: 4 7/8-inch

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BORING B-3
(continued)

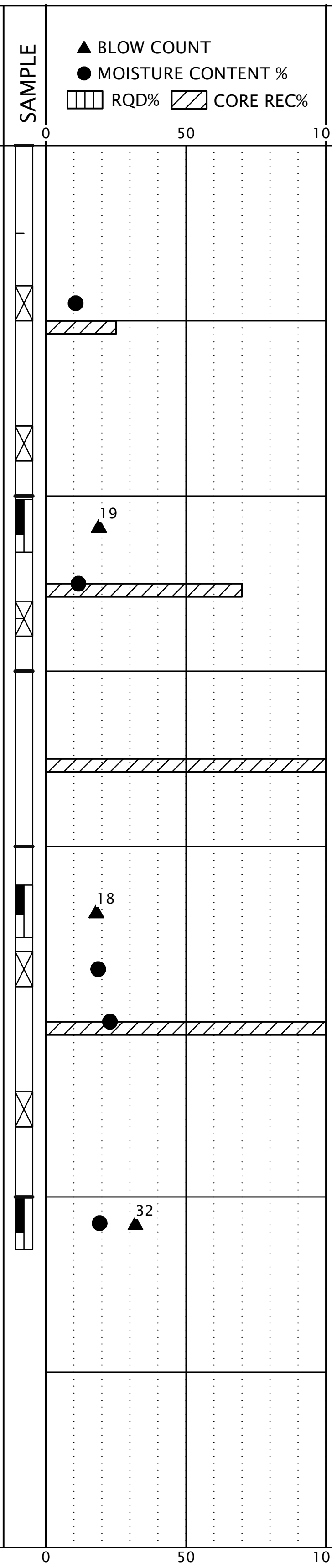
WILSONVILLE SEWAGE TREATMENT PLANT
WILSONVILLE, OR

FIGURE A-3

BORING LOG BROWNCALD-44-01-B1_5.GPJ GEODESIGN.GDT PRINT DATE: 8/26/09:KT

COPY

DEPTH FEET	MATERIAL DESCRIPTION	ELEVATION DEPTH	TESTING
0		112.0	
	SAWDUST (3 inches).	111.7 0.3	
	Medium stiff, gray SILT with sand, gravel, and cobbles (ML); moist - **FILL**.	110.0 2.0	
5	Medium dense, gray, silty GRAVEL with sand, cobbles, and boulders (GM), trace debris (wire); moist, subrounded to subangular gravel - **FILL**.		
10	grades to brown-gray with boulders at 10.0 feet		
15	24-inch diameter boulder at 15.0 feet		
	becomes moist to wet at 17.0 feet		
20		91.0 21.0	
	Medium dense, brown GRAVEL with silt, sand, cobbles, and boulders (GP-GM); wet.		SIEV
25			
30	grades to dense at 30.0 feet	80.5 31.5	
	Exploration completed at a depth of 31.5 feet.		
35			
40			



INSTALLATION AND COMMENTS

DRILLED BY: Boart Longyear

LOGGED BY: JGH

COMPLETED: 05/13/09

BORING METHOD: sonic drilling (see report text)

BORING BIT DIAMETER: 4 7/8-inch

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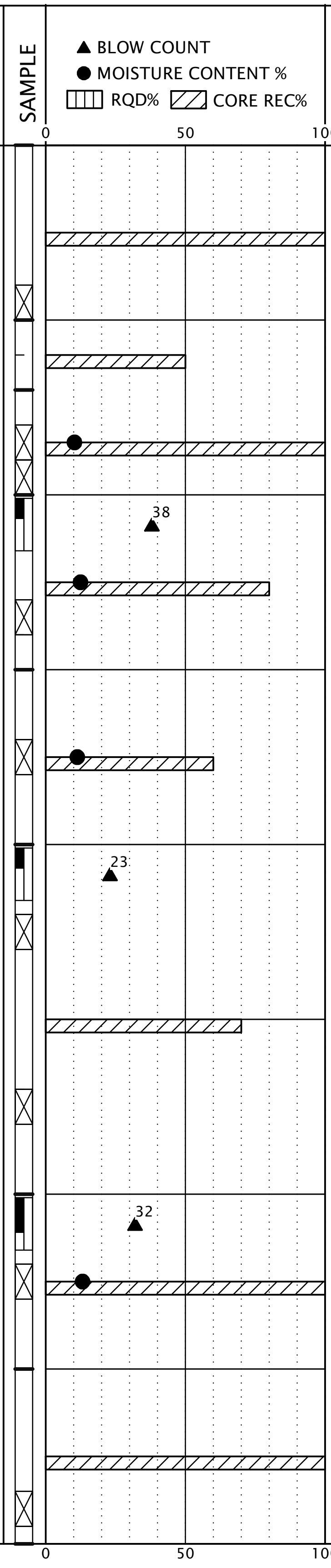
BORING B-4

WILSONVILLE SEWAGE TREATMENT PLANT
WILSONVILLE, OR

FIGURE A-4

BORING LOG BROWNCALD-44-01-B1_5.GPJ GEODESIGN.GDT PRINT DATE: 8/26/09:KT

DEPTH FEET	MATERIAL DESCRIPTION	ELEVATION / DEPTH	TESTING
0	Medium dense, brown, silty GRAVEL with sand and cobbles (GM); moist, rounded to angular (1-inch-thick root zone) - **FILL**.	123.0	
	with boulders at 6.0 feet		
	becomes moist to wet at 8.0 feet		
	becomes moist at 9.0 feet		
	Loose to medium dense, brown GRAVEL with silt, sand, and cobbles (GP-GM); wet, rounded - **FILL**.	110.5 12.5	
	Medium dense, brown, silty GRAVEL with sand, cobbles, and boulders (GM); moist, subrounded to angular - **FILL**.	109.0 14.0	
	Medium dense, brown-gray, silty GRAVEL with sand and cobbles (GM); moist to wet, subrounded to angular - **FILL**.	107.0 16.0	
	grades to dense and rounded to angular at 30.0 feet		
	Dense, brown GRAVEL with sand and cobbles (GP), minor silt; wet, subrounded)	85.0 38.0	
40			



INSTALLATION AND COMMENTS

DRILLED BY: Boart Longyear

LOGGED BY: JGH

COMPLETED: 05/14/09

BORING METHOD: sonic drilling (see report text)

BORING BIT DIAMETER: 4 7/8-inch

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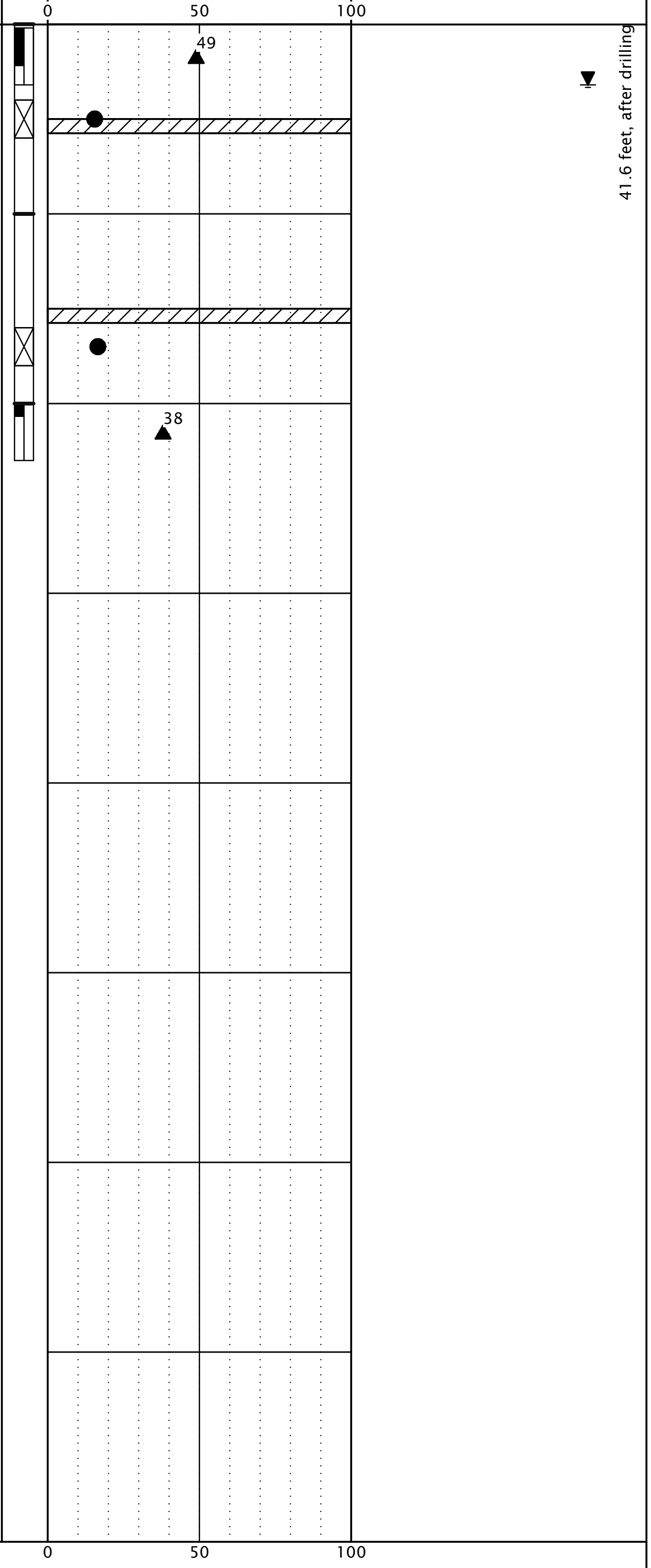
BORING B-5

WILSONVILLE SEWAGE TREATMENT PLANT
WILSONVILLE, OR

FIGURE A-5

DEPTH FEET	GRAPHIC LOG	MATERIAL DESCRIPTION	ELEVATION DEPTH	TESTING	SAMPLE	▲ BLOW COUNT ● MOISTURE CONTENT % ▥ RQD% ▨ CORE REC%	INSTALLATION AND COMMENTS
40		Dense, brown GRAVEL with silt, sand, and cobbles (GP-GM); wet to moist.	83.0 40.0				
45							
50							
		Exploration completed at a depth of 51.5 feet.	71.5 51.5				
55							
60							
65							
70							
75							
80							



DRILLED BY: Boart Longyear

LOGGED BY: JGH

COMPLETED: 05/14/09

BORING METHOD: sonic drilling (see report text)

BORING BIT DIAMETER: 4 7/8-inch

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BORING B-5
(continued)

WILSONVILLE SEWAGE TREATMENT PLANT
WILSONVILLE, OR

FIGURE A-5

APPENDIX B

AG&E Geophysics, Engineering, Geology, & Instrumentation

Subject:

Geophysical Survey
Wilsonville Wastewater Treatment Plant
Wilsonville, Oregon

Prepared For:

Alan P. Bean, G.E.
Northwest Geotech, Inc.
9120 SW Pioneer Court, Suite B
Wilsonville, Oregon 97070

Date Submitted:

July 10, 2020

By:

Everett C. Tabor, RPG # 1064
President, Applied Geoscience and Engineering, Inc.

AG&E Geophysics, Engineering, Geology, & Instrumentation

Alan P. Bean, G.E.
Northwest Geotech, Inc.
9120 SW Pioneer Court, Suite B
Wilsonville, Oregon 97070

NWGEO-01-R-WWWTP

Subject: Geophysical Survey, Wilsonville Wastewater Treatment Plant
Wilsonville, Oregon

Dear Mr. Bean,

In accordance with your request we are pleased to submit this report of geophysical services performed at the subject site to Northwest Geotech, Inc. This report outlines our project understanding, methods, scope of services, and our findings. The site is located 10350 Arrowhead Creek Lane in Wilsonville, Oregon (see Figure 1, Site Vicinity Map).

Respectfully submitted,

Everett Tabor

Everett C. Tabor, RPG, PE, CEG
President, Applied Geoscience
and Engineering, Inc.
etabor@ageoe.com
949-558-1489
www.ageoe.com

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Appendices

INTRODUCTION AND PROJECT DESCRIPTION

The geophysical survey was performed across the majority of the facility area at the Wilsonville Wastewater Treatment Plant in Wilsonville (WWWTP), Oregon (See Figure 1, Site Vicinity Map). It is our understanding the WWWTP was constructed across an old gravel pit with about 20 to 30 feet of uncontrolled fill over roughly 40 to 50 feet of catastrophic flood deposits underlain by Troutdale Formation. We understand the facility may be reconfigured and/or expanded to accommodate higher volume treatment capabilities.

The objectives of the geophysical survey program were to provide data for seismic site-specific spectra analysis and to use additional shear wave seismic methods to interpret if subsurface variations differ across the site to an approximate maximum target depth of 100 feet.

SCOPE OF SERVICES

The following scope of services performed for this project are summarized below:

- Review available background data such as historic photos, and previous subject reporting.
- Coordination with Northwest Geotech, Inc. for scheduling.
- Mobilization to and from site.
- Perform geophysical survey consisting of seismic data acquisition for Micro-Tremor Array Measurements (MAM) and active source S-wave Multichannel Analysis of Surface Waves (MASW) within the subject site boundaries.
- Process seismic data to produce 1-Dimensional soundings and 2-Dimensional profiles to allow for detailed data evaluation.
- Generate technical report with descriptive figures detailing equipment, methods, data results, and interpretations.

GENERAL SITE CONDITIONS

The site is an active wastewater treatment plant with numerous above and below-ground structures. Where there are no structures, most of the site surface consisted of asphalt pavement with some areas of gravel, water features, and grass. The area of our study was generally flat with only gentle changes in relief.

At the time of our field work the weather was predominantly clear and approximately 80 to 85 degrees. There were no apparent indications of recent rain, such as ponded water, or observable wet soil conditions.

GEOPHYSICAL METHODS, INSTRUMENTATION, AND DATA COLLECTION

Micro-tremor Array Measurements (MAM)

On June 22, 2020, we performed a seismic survey at the subject site. The objective of the first stage of the geophysical study was to evaluate the subsurface shear wave velocity using passive surface wave techniques. The seismic method used, Micro-tremor Array Measurements (MAM) and consisted of three linear profiles of seismic data collection. (see Figure 2, Seismic Survey Locations). Shear wave velocity data are directly related to soil stiffness and may be used to evaluate subsurface properties. This method provides a shear wave velocity sounding to a depth of approximately 100 feet, or greater, below the ground surface (bgs) and V_s100 for seismic site classification.

The seismic data was collected using a 24-channel Geometrics Geode, exploration seismograph with 24 vertical component, 4.5 Hertz geophones. Geophones were spaced every 15 feet for total profile lengths of 345 feet. For each of the three MAM lines, approximately thirty records were collected, with a record length of 30 seconds (s) and 2 millisecond (ms) sample interval. The data were evaluated in the field for quality and saved in SEG2 format.

The collected data were processed using the Seisimager/SW-Pro™ Version 3.3, Geometrics, Inc., suite of programs. Data records were imported and analyzed to determine the estimated maximum and minimum shear wave velocities and to create an initial 1-D subsurface model. A shear wave velocity inversion was performed by a non-linear Genetic Algorithm (GA) method to calculate the Average Shear-wave Velocities (AVS) to a depth of 100 feet (V_s100) below ground surface (bgs). The MAM seismic model results for Lines L-1 through L-3 are provided in Figures 3 through 5.

Multichannel Analysis of Surface Waves (MASW)

Multichannel Analysis of Surface Waves (MASW) uses the dispersive relationship of surface waves to characterize the shear wave velocity structure along a profile beneath the seismic line. At each line location where MAM measurements were performed, active source MASW records were also recorded.

The MASW data were collected along the same arrays used to acquire passive data and using the same 24-channel Geometrics Geode and associated components as the MAM data. A 10-pound hammer and plastic plate were used as the seismic wave active source for this survey. A total of nine shots were collected at each line, including two off-end shots outside the limits of the geophone array. A record length of 2 seconds was chosen in attempt to acquire data to the full depth of the associated MAM records, or to an excess of 100 feet bgs.

The collected data were processed using the Seisimager/SW-Pro™ Version 3.3, Geometrics, Inc., suite of programs. Data were imported into Pickwin v. 5.2.1.3 to calculate phase velocity curves. The phase velocity data were then imported into WaveEq 4.0.1.0 to determine the estimated maximum and minimum shear wave velocities and to create an initial subsurface model. A shear wave velocity inversion was performed by a non-linear Genetic Algorithm (GA) method. GeoPlot 10.0.1.4 was used to create contoured, profile views of the processed shear wave data The MASW seismic profile results for Lines L-1 through L-3 are provided in Appendix A-1 through A-3, respectively.

GEOPHYSICAL DATA RESULTS AND INTERPRETATIONS.

In general, depth of reliable data in the MAM 1-D soundings data ranged from approximately 5 feet near the surface to a depth of over 100 feet. With a minor exception on the plotted MAM L-3, all subsurface shear wave velocities are in excess of 1,000 feet/second (ft./sec.). Maximum velocities in the MAM plots ranged from about 1,450 ft./sec. to over 1,700 ft./sec. and all the soundings show a final sharp increase at roughly 90 feet bgs.

Processed MASW data were in general agreement with the results of the MAM plotted data; however, one cannot compare 1 and 2-Dimensional data sets with any exact agreement unless the subsurface has no variations. Line 1 (Appendix A-1) has a relatively thin layer of a higher velocity zone (blue) of roughly

1900 ft. /sec. This is discontinuous and does show up on the associated MAM. Line 2 (Appendix A-2) also shows a zone with the same high velocity, that is thicker, yet is only on the eastern part of the line before it pinches out. This area, as noted below, was reportedly at/near the location of active mechanical structures and equipment in the subsurface. It is probable this equipment caused noise at the eastern end of this line. Line 3 (Appendix A-3) shows the most consistency across the profile and is also the most distant from structures and reported subsurface structures.

CONCLUSIONS

The objectives of the geophysical survey program were to provide data for seismic site-specific spectra analysis and to use additional shear wave seismic methods to interpret if subsurface variations differ across the site. Based on the results of our background review, field observations and geophysical data collection, we conclude that:

- MAM data showed fairly consistent velocities from roughly 0 to 30 feet bgs and from roughly 65 to 100 feet bgs. Variations between the soundings were found to be less between Lines 1 and 3, with Line 2 showing a nearly consistent velocity from 35 to 75 feet bgs.
- Interpreted geophysical data do not suggest the presence of widespread very low velocity (soft) layers within the subsurface to the limits of our study depth.
- MASW profiles all show a relatively lower velocity fill with near surface variations. This is more consistent and pronounced in Lines 1 and 3 (Appendix A-1 and A-3).
- MASW profiles all show a velocity increase with depth immediately under the fill, however, as described below, a subsequent decrease is generally shown below this layer within the target depth of 100 feet bgs.
- As compared to Lines 1 and 3, Line 2 (A-2) Shows a roughly 2,000 feet/second higher velocity across the shallow area assumed to be fill. This zone changes from East to West to better agree with the other Lines. The Eastern side of the data may have been affected by active subsurface facility components that could not be shut off during data collection.
- From a range of depth from roughly 75 feet bgs, Lines 2 and 3 show a marked velocity decrease, however, on Line 1, this decrease occurs at roughly 60 feet bgs and is not distinct in the southern one-fourth of the Line.
- Based on attempts at plotting deeper profiles and examining the 'XYZ' data, this decreased velocity area was observed to continue to roughly 130 feet bgs where velocity levels are noted to increase to approximately 2,500 ft./sec. These plots and data were generated to confirm data integrity and will be delivered separate from this report.
- Processed MAM data and MASW data were reliable and within acceptable limits of calculated error.

LIMITATIONS

The field evaluation and analyses presented in this geophysical report have been conducted in general accordance with current practice and the standard of care exercised by consultants performing similar investigations. No warranty, expressed or implied, is made regarding the conclusions, interpretations, and opinions presented in this report. There is no evaluation detailed enough to reveal every subsurface condition. Variations may exist and conditions not observed, or described in this report, may be encountered during further site investigations. Uncertainties relative to subsurface conditions can be reduced through additional subsurface exploration. Additional subsurface evaluation will be performed upon request.

Conclusions, recommendations, and opinions are based on an analysis of the observed site conditions and data collected on site. If conditions different from those described in this report are encountered, our office should be notified, and additional recommendations may be provided upon request. Conditions of a site could change with time as a result of natural processes or the activities of mankind at the subject site. Please also note that this evaluation was limited to the assessment of select geophysical aspects of the project and did not include evaluation of environmental concerns or the presence of hazardous materials.

This report is intended exclusively for use by Northwest Geotech, Inc. Any use or reuse of the findings, conclusions, and/or recommendations of this report by parties other than Northwest Geotech, Inc. is undertaken at said parties' sole risk.

REFERENCES

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Geometrics, 2016, Seisimager/SW-Pro™, Windows Software for Analysis of Surface Waves, Copyright 2016.

Choon B. Park¤, Richard D. Miller¤, and Jianghai Xia, Multichannel Analysis of Surface Waves, GEOPHYSICS, VOL. 64, NO. 3 (MAY-JUNE 1999); P. 800–808, 7 FIGS.

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Figure 1: Site Vicinity Map

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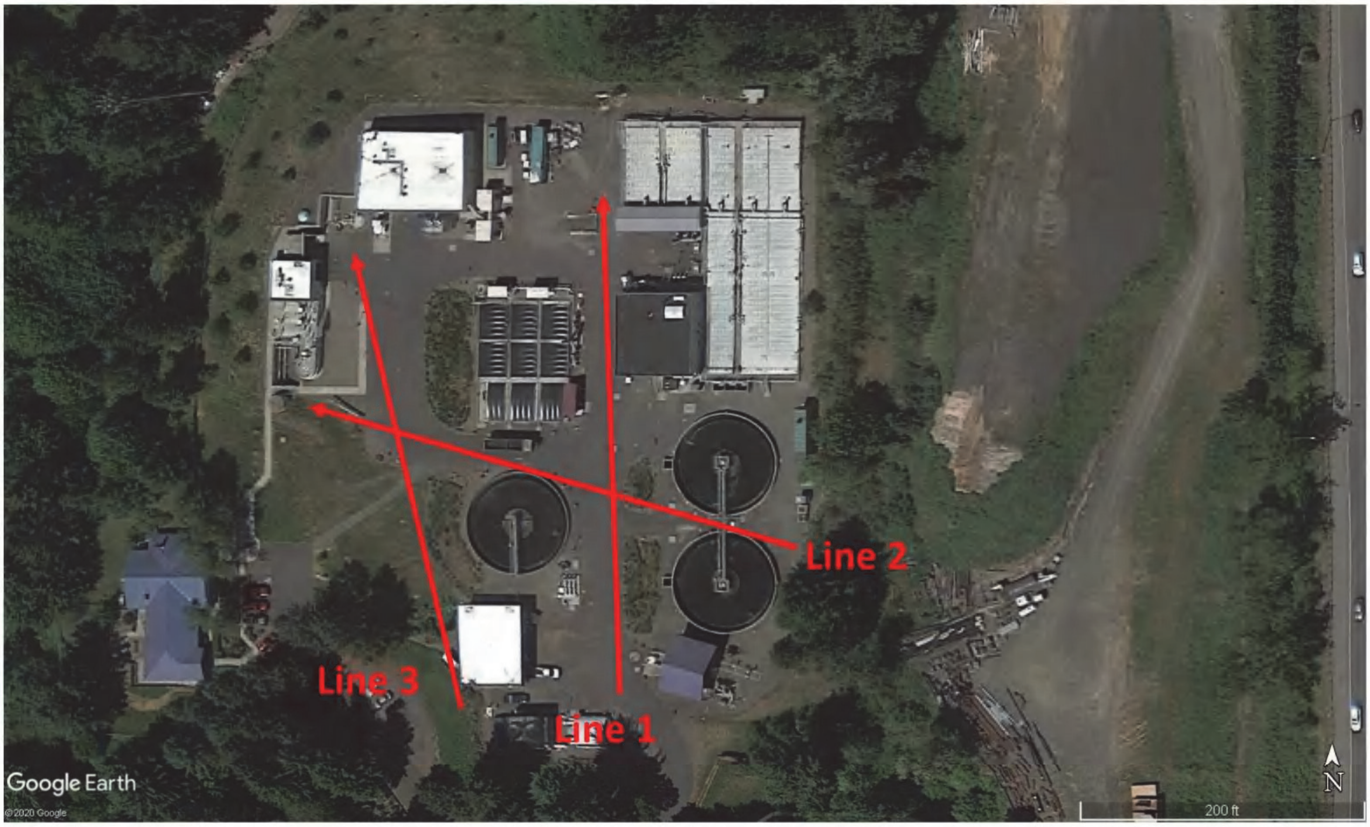
City of Wilsonville Wastewater
Treatment Plant
Wilsonville, Oregon

Figure 2: MASW/MAM Line Locations



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Wilsonville, Oregon

Figure 3: Vs100' Model- Line 1

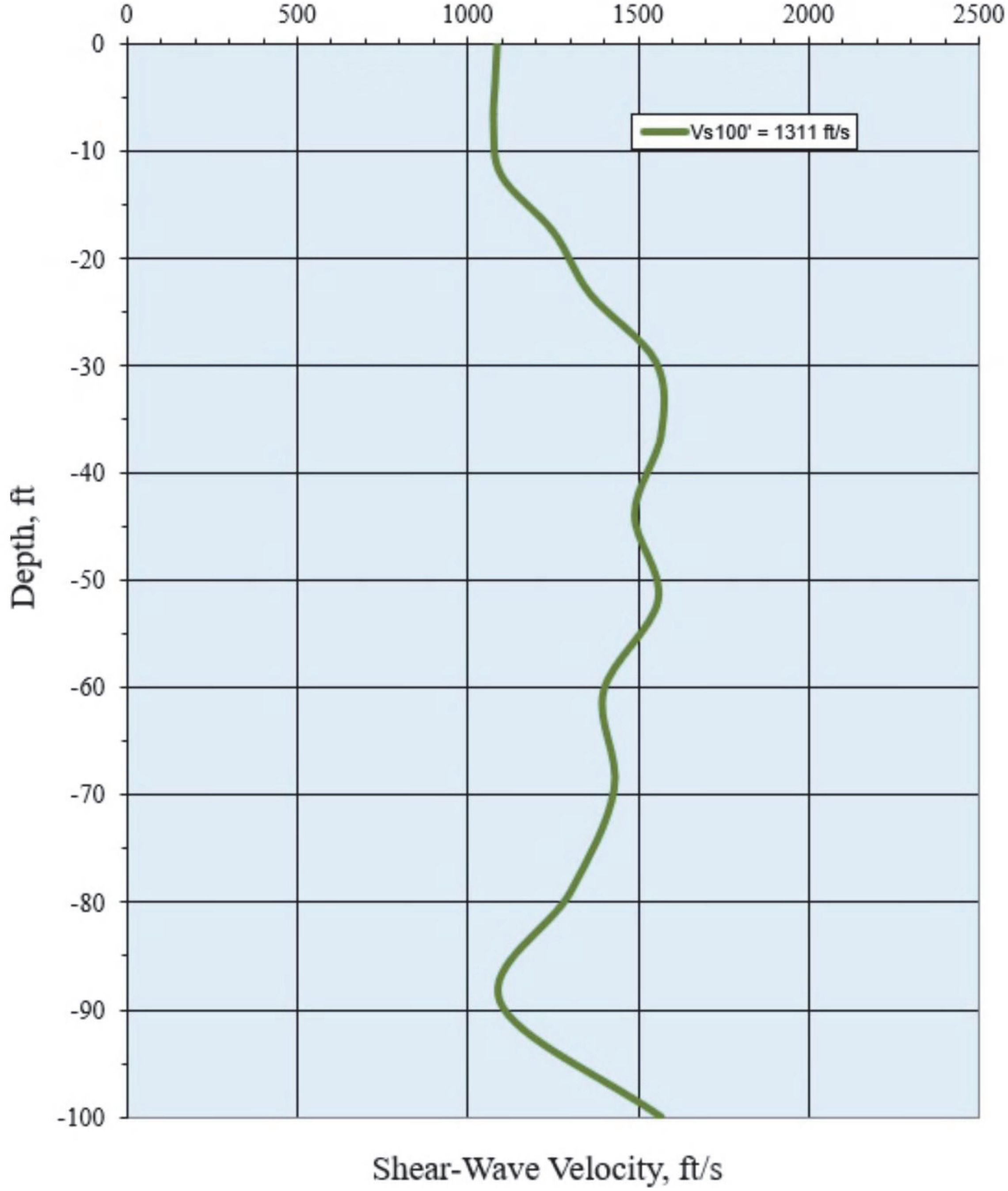

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Figure 4: Vs100' Model- Line 2

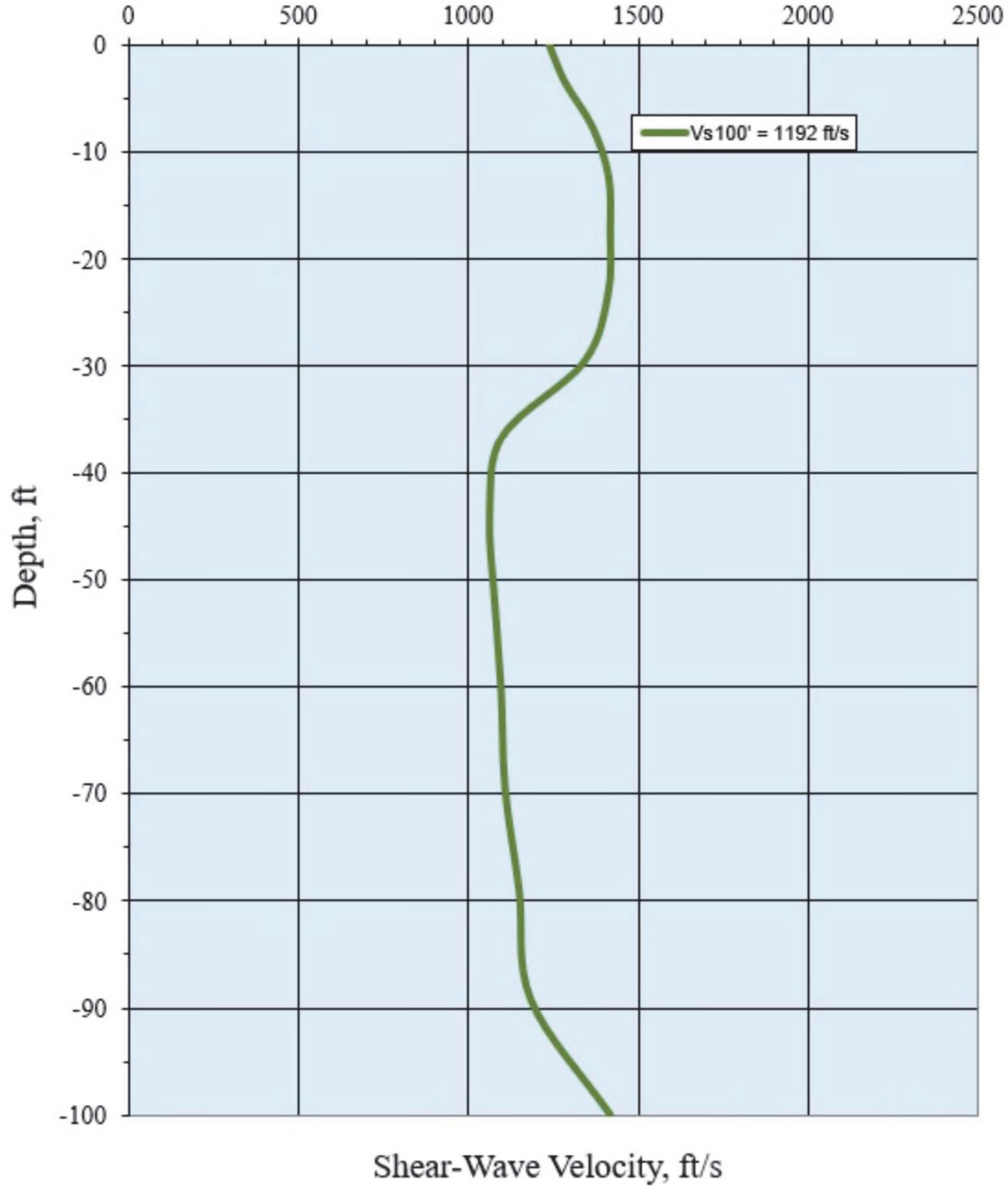

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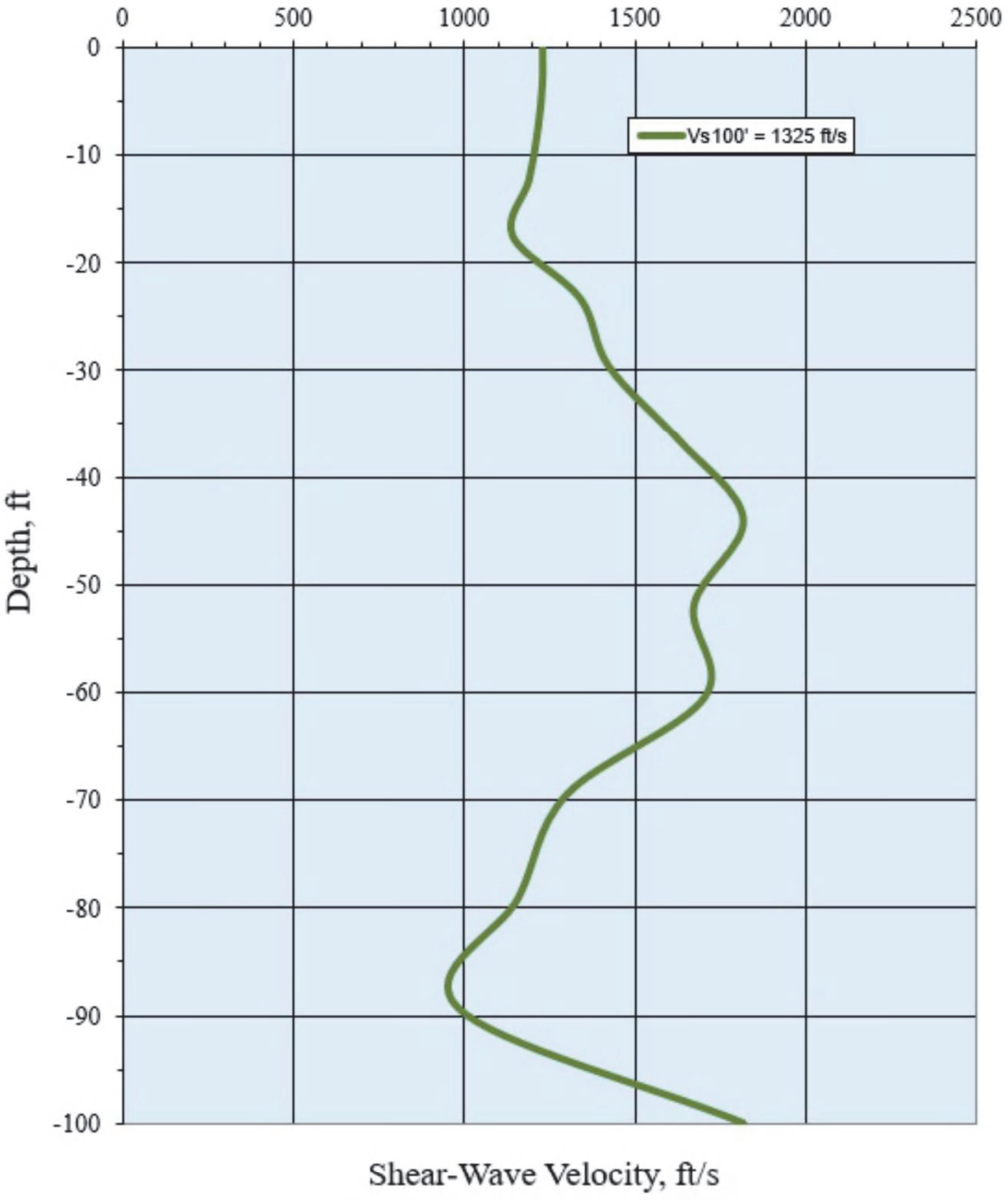
Figure 5: Vs100' Model- Line 3



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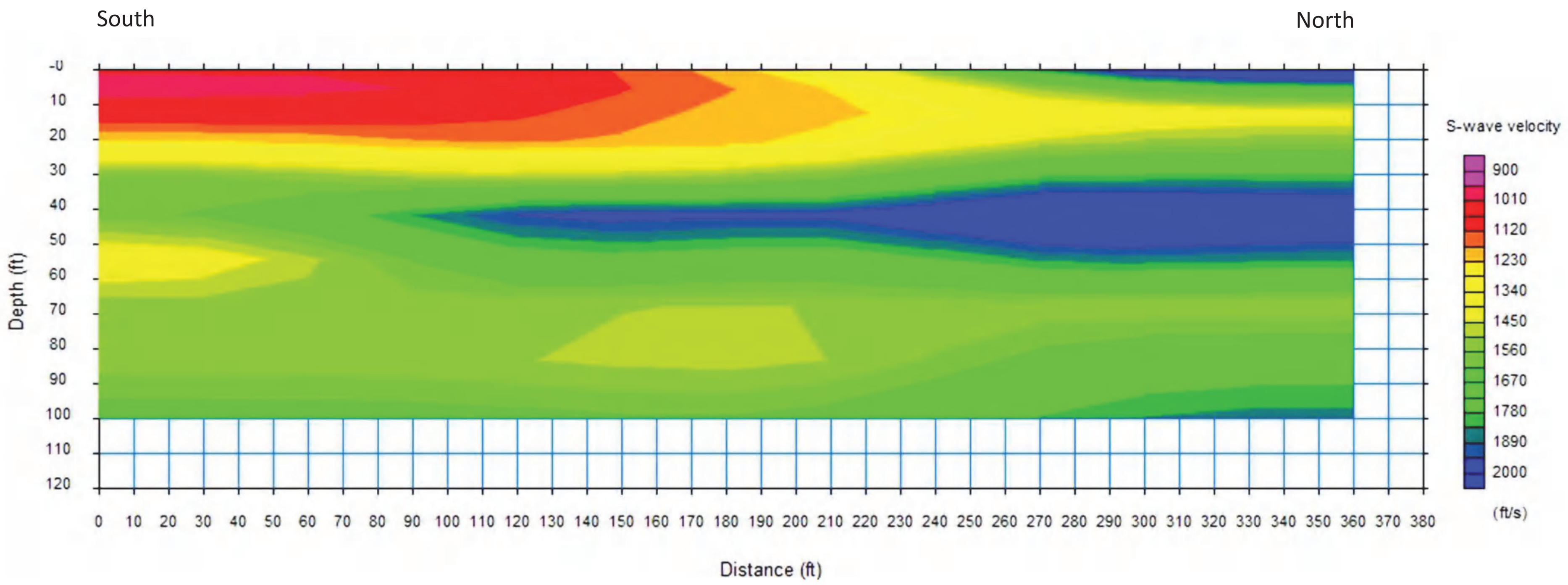
City of Wilsonville Wastewater
Treatment Plant
Wilsonville, Oregon

Appendix A:

Profiles of Multichannel Analysis of Surface Waves (MASW)



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A-1

S-Wave Profile for L-1

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Treatment Plant
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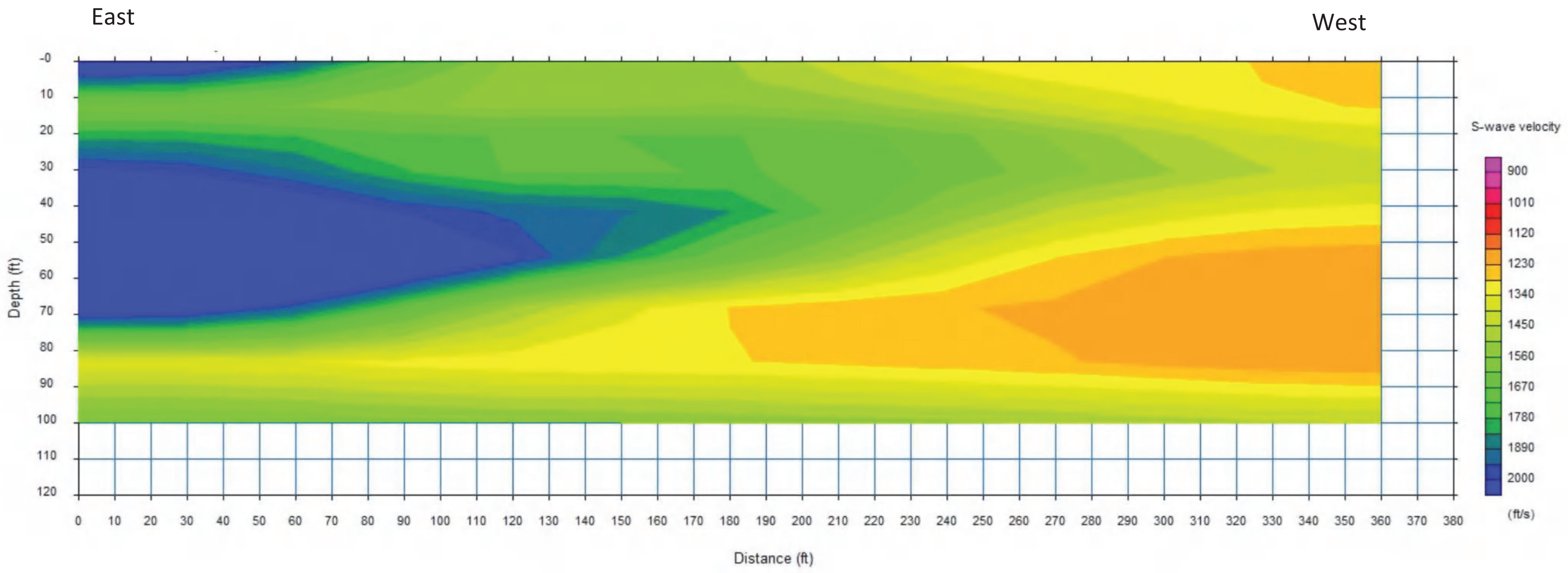

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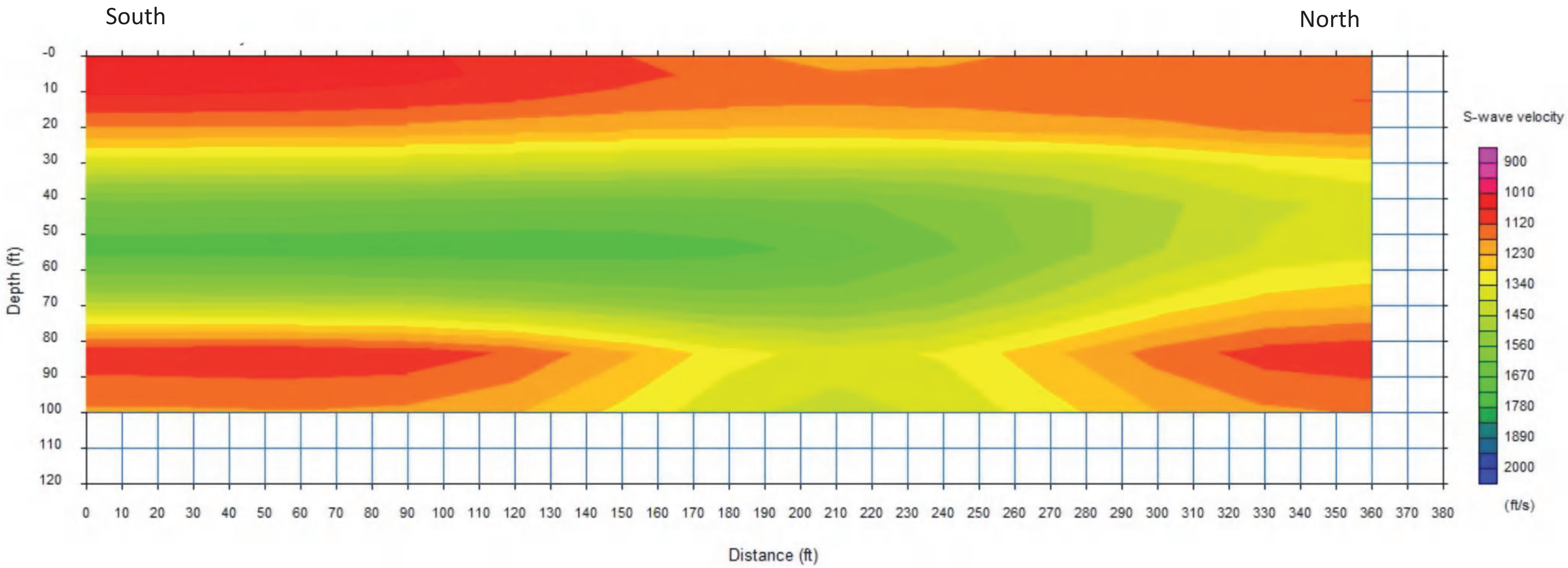
A-2

S-Wave Profile for L-2

City of Wilsonville Wastewater Treatment Plant

Wilsonville, Oregon



A-3

S-Wave Profile for L-3
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