HAHN AND ASSOCIATES, INC.
ENVIRONMENTAL CONSULTANTS

September 13, 2023
Mr. Wes Thomas
Oregon Department of Environmental Quality
Northwest Region, Portland Office
Portland Harbor Section
700 NE Multnomah Street, #600 HAI Project No. 2708
Portland, Oregon 97232 DEQ ECSI File No. 84

SUBJECT: Portland Liquefied Natural Gas (LNG) Compressor Equipment Foundation Needs, NW Natural Site, 7900 NW St. Helens Road, Portland, Oregon

Dear Mr. Thomas,

Hahn and Associates, Inc. (HAI) is transmitting a geotechnical evaluation report[1] documenting foundation needs for proposed new screw compressor and water / glycol cooler equipment (Compressor Equipment) at the Portland LNG facility, which operates at the Former Gasco Manufactured Gas Plant (MGP) Operable Unit (OU). NW Natural is providing this information to DEQ for information and concurrence in construction specifications design to mitigate impacts from contaminated media that may be encountered during the planned foundation preparation work once all required city permitting is complete.

As documented in the attached letter report, the proposed Compressor Equipment will be located in an approximate 35-foot by 50-foot area northeast of the LNG Control Building, with two separate pads (36 feet by 19 feet; and 20 feet by 15 feet) to be constructed within this footprint (see attached Figure S1.0, Foundation Plan). Because the proposed Compressor Equipment is considered essential to facility operations, the foundation design was prepared to be protective of seismically induced liquefaction-related displacements.

Based on soil conditions, environmental contamination, access limitations, vibration considerations, and structure type, the geotechnical evaluation concluded that a mat foundation on driven pipe piles is the most favorable support for the proposed Compressor Equipment.

The geotechnical evaluation identified a need for 15 steel piles with a minimum wall thickness of 0.83-inch, embedded a minimum of 5 feet into very dense gravels at the base of the alluvium, or to the surface of basalt. Based on geotechnical soil boring investigation work conducted in this area by GeoEngineers in 2017, and presented in the attached letter, necessary piling depths for these foundations are estimated to be between 49 feet and 55 feet below ground surface (bgs).

- Based on nearby geotechnical boring logs B-1-15, B-1-21, and B-3-17 (Figure 2 of attached letter report), the fill thickness in the area of the proposed foundation ranges from 12.5 feet to the west of the proposed foundation area to between 20 and 25 feet just east of the proposed foundation area.

Contaminant conditions at the site are well known. Site residuals mapping completed as part of Gasco OU RI/FS[2] interprets dense non-aqueous phase liquid (DNAPL) presence

[1] Cornforth Consultants, Inc. (2023). *Geotechnical Letter Report, Portland LNG Compressor Equipment Foundations, Portland, Oregon*. July 18, 2023.

[2] Anchor QEA, LLC. (2018). *Interim Feasibility Study*, Gasco OU, ECSI No. 84. November 21, 2018.

in fill soils near the footprint of the proposed foundation as likely being at residual saturation levels, although fill soils that are interpreted as having saturations levels typical of potentially mobile DNAPL are in the general vicinity (e.g., well MW-10-26). High concentrations of dissolved petroleum hydrocarbons are present in groundwater within the Fill WBZ at this portion of the site, while only trace concentrations have been detected in groundwater within the underlying Alluvium WBZ in this area.

The upper silt unit that underlies the Fill WBZ is estimated to range from 11 to 25 feet thick in the area surrounding the proposed Compressor Equipment foundation, based on logs from nearby borings. The upper silt unit serves as a low permeability semi-confining layer between the Fill WBZ and the underlying Alluvium WBZ, preventing the migration of DNAPL or dissolved phase contamination downward into the Alluvium WBZ at this portion of the site, although dissolved phase contamination and DNAPL have migrated into the Upper Alluvium WBZ at locations further down-gradient (east) of the proposed foundation location.

Contaminant exacerbation concerns related to piling construction through areas of shallow contamination may typically include: 1) vertical contaminant drag-down within or at the lead edge of the pile; 2) vertical migration along the exterior of the pile if an annular space were to be created; or 3) vertical migration along the interior of the pile if a breach of the pile wall or through an improperly constructed weld were to occur.

Based on a thorough understanding of site conditions, the piles are to be constructed and installed using means and methods that will mitigate the potential for contaminant transfer from the Fill WBZ to the underlying Alluvium WBZ. Measures that have been incorporated into the design to mitigate the potential for contaminant drag-down or conduit creation between the Fill WBZ and the underlying Alluvium WBZ are as follows:

- Increase the design specification pile wall thickness from 0.83 inch to 1.0 inch to mitigate against long term corrosion of the piling wall.
- Drive the piles with a closed end to prevent incorporation of shallow contamination into the piling orifice. In addition, to avoid carrying a plug of contaminated soil directly beneath the leading end of a closed pile, the pile end will be closed using a conical pile tip that does not extend past the outside piling wall. A conical pile tip will reduce/eliminate the volume potential of soil plug drag-down from the shallow contaminated zone (Fill) to the largely uncontaminated zone (Alluvium). See attached drawing S1.1 for specifications and a generalized piling profile.
- Fill the interior of the piles with a low permeability grout as an added precaution to protect against the breach of the piling wall due to corrosion or an improperly constructed weld.
- Use long enough lengths of pipe that will restrict the need to splice/weld pipe sections together to no more than one spliced section per pile.
- All welds will be ground flush with the exterior piling wall so that in no case would there be a protrusion beyond the smooth exterior piling surface, thereby preventing creation of an annular space around the outer edge of the piling.
- All weld joints will be inspected either by the fabrication shop or in the field to ensure each is continuous without any detectable defects. Inspections may include, but are not limited to, non-destructive methods such as ultrasound or radiographic methods sufficient to meet any City of Portland permit requirements.

As documented in a study published by The Environment Agency[3], solid cylindrical piles are effectively sealed with no vertical pathways created when driven through a low permeability confining layer with a thickness of two or more pile diameters, which for the Compressor Equipment Foundation (24-ich diameter piles) would equate to a minimum upper silt unit thickness of 4 feet. As described in adjacent borings, the upper silt in the proposed foundation area is estimated to range from 11 to 25 feet in thickness, which would be more than adequate to ensure effective sealing of a casing between WBZs.

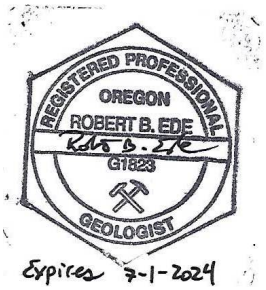
Based on an understanding of site geology and contaminant conditions, as well as similar pile construction methods successfully completed at the property in the past, the above mitigative measures will best ensure that pile installation does not exacerbate contaminant conditions at the site.

NW Natural would like to proceed with the planned foundation preparation work once all required city permitting is complete and requests DEQ concurrence to proceed with the mitigation measures described in this letter.

Should you have any questions, please contact the undersigned.

Sincerely,

Robert Ede



Rob Ede, R.G.
Principal

robe@hahnenv.com

Attachments: 1) Geotechnical Letter Report, 7/18/23
2) Foundation Plan Figure S.1.0, S.1.1

cc: Tim Murphy, NW Natural
Corey Raspone, NW Natural
Greg Landau, Cornforth Consultants, Inc.
Bob Wyatt, NW Natural
Patty Dost, Pearl Legal Group PC
Ryan Barth, Anchor QEA, L.L.C.
Jen Mott, Anchor QEA, L.L.C.
Tim Stone, Anchor QEA, L.L.C.
Halah Voges, Anchor QEA, L.L.C.
Chip Byrd, Sevenson Environmental Services, Inc.
Mike Crystal, Sevenson Environmental Services, Inc.

[3] Environment Agency, (2006). *Piling in Layered Ground: Risks to Groundwater and Archaeology*, Science Report SC020074/SR. October 2006.

ATTACHMENTS

Attachment 1

Geotechnical Letter Report, Cornforth Consultants, Inc.
July 18, 2023

July 18, 2023 3090

Tim Murphy, PE
NW Natural
250 SW Taylor Street
Portland, Oregon 97204

Geotechnical Letter Report
Portland LNG Compressor Equipment Foundations
Portland, Oregon

Dear Mr. Murphy,

Cornforth Consultants, Inc. (CCI) is pleased to submit this geotechnical engineering letter report for the proposed new screw compressor and water/glycol cooler equipment (Compressor Equipment) at the Portland Liquefied Natural Gas (LNG) facility in Portland, Oregon. The project area is located at the existing NW Natural LNG facility off Highway 30, in Portland, Oregon. Our services were performed in accordance with our Master Services Agreement with NW Natural dated July 25, 2022 and Purchase Order No. 4510002530.

Based on design drawings by Sandborn Head, the proposed improvements will be located in an approximately 40-foot by 60-foot area northeast of the Control Building. The compressor foundation pad measures approximately 36 feet by 19 feet while the pad for the heat exchangers measures approximately 20 feet by 15 feet. While the structural loads are relatively light, the equipment is considered essential to facility operations and NW Natural has requested the foundation system be designed to account for liquefaction and related effects.

The location of the facility is shown in the Vicinity Map, Figure 1. The project location is shown relative to surrounding features in the Site Plan, Figure 2.

BACKGROUND

Numerous geotechnical studies have been completed for the Portland LNG facility. These studies have identified the susceptibility of the site to liquefaction and associated lateral spreading. Potentially liquefiable soils at the site extend to approximately 50 to 55 feet below the ground surface (bgs) near the proposed compressor equipment. The average liquefaction-induced vertical settlement has been estimated to be on the order of 9 to 16 inches. Lateral ground displacement has been estimated on the order of 1 to 3 feet. Various deep foundation and ground improvement methods have been considered to support structures at the site, including driven piles, micropiles, augercast piles, deep soil mixing, mat foundations, and aggregate piers.

SURFACE AND SUBSURFACE CONDITIONS

Previous explorations completed by GeoEngineers in 2015, 2017, and 2021 nearby encountered a variable mantling of contaminated fill consisting of loose fine to medium sand with silt and very soft silt to depths of approximately 15 to 20 feet bgs over alluvium consisting of soft to medium stiff silt (occasionally stiff) and very loose to medium dense silty sand to a depth of approximately 50 to 55 feet bgs, over basalt bedrock. Boring B-1-21 encountered a 10-foot layer of very dense gravel with sand and silt between the loose to medium dense silty sand and Columbia River Basalt at a depth of 55 to 65 feet bgs. Boring B-3-17 did not encounter the gravel layer and encountered basalt at 49 feet bgs. Groundwater was encountered at approximately 17 feet bgs. Exploration locations near the proposed Compressor Equipment are shown in the Site Plan, Figure 2. Nearby boring logs are provided as an attachment.

GEOTECHNICAL DESIGN RECOMMENDATIONS

To mitigate for liquefaction-related displacements, we recommend the Compressor Equipment be supported on deep foundations. We recommend the deep foundation elements be designed for a maximum lateral displacement of 6 inches under seismic conditions.

Driven Pile Foundations

Based on soil conditions, environmental contamination, access limitations, vibration considerations, and proposed structure type, it is our opinion that a mat foundation supported on driven pipe piles is the most favorable foundation support option for the proposed Compressor Equipment.

Lateral Pile Capacity

The lateral loads on pile foundations resulting from lateral spread were evaluated using procedures presented in Caltrans (2012)[1]. Due to these high lateral loads, the lateral deflection under seismic conditions controls the pile design.

We utilized an iterative process to select a pile size that limited lateral displacement during the design seismic event to 6 inches or less. First, the lateral pressures on a given pile diameter were estimated using the procedures discussed above and those pressures were applied against the pile as a uniform horizontal pressure distributed over the non-liquefied upper "crust" to evaluate the lateral displacement. The piles were assumed to be embedded a minimum of 5 feet into the very dense gravel encountered below approximately 55 feet bgs or basalt encountered below approximately 49 feet bgs. We completed analyses for a single super pile under free-head conditions. Based on this analysis, a 24-inch diameter pipe pile with a 0.83-inch wall thickness will meet the lateral deflection criteria. We recommend the pile wall thickness be increased to 1-inch to account for potential corrosion of the steel due to groundwater and environmental contamination during the design life of the structure. Group reduction factors were estimated assuming a total of 9 piles installed in a 3 by 3 pile group for the compressor foundation. If an alternate layout is selected, we may need to perform additional analysis and update our recommendations.

[1] Caltrans. (2012). Guidelines on Foundation Loading and Deformation Due to Liquefaction Induced Lateral Spreading.

Axial Pile Capacity

The axial capacity for a 24-inch-diameter closed-end pipe pile is presented below and includes factors of safety of 2.0 for shaft friction and 3.0 for end bearing. We recommend the piles be embedded a minimum of 5 feet into the very dense gravel or basalt encountered below approximately 49 to 55 feet bgs. A reasonable contingency should be added to the pile lengths to account for construction considerations such as variable subsurface conditions. It is generally more cost effective to require the contractor to provide longer piles than weld, inspect and redrive piles that are too short to develop capacity. As discussed below, any welds should be ground flush to the pile face to minimize the potential to carry contaminated soil into the uncontaminated zone during pile installation.

Settlement of soils surrounding piles can induce frictional downdrag loads that essentially reduce the allowable pile capacity. This typically occurs if there are large fill embankments or if liquefaction-induced settlement occurs. Liquefaction will result in downdrag or negative skin friction from the top of the deep foundation to the base of the liquefiable layer. The downdrag load has been accounted for in the axial downward capacity presented below.

The structural engineer should verify that the piling is structurally capable of supporting the anticipated loads. The axial pile capacities are for single piles and do not include a group reduction factor. Group reduction factors are not required for piles with center-to-center spacing at least 3 times the pile diameter. Based on the anticipated design loads, the 24-inch-diameter piles will adequately support the estimated loads.

Table 1: Pile Capacity

Pile Diameter (inches)	Minimum Wall Thickness (inches)	Allowable Downward Capacity (kips)	Allowable Uplift Capacity (kips)
24	1	120	40

DESIGN AND CONSTRUCTION CONSIDERATIONS

Pile Installation

Piles may be vibrated or driven; however, all piles should be driven to their final tip elevation to verify the required capacities. We recommend using fixed leads and careful alignment and support of the piles during installation because the piles will tend to "run" in loose/soft soils or a sloping bedrock contact.

Our recommendations are based on using closed-end pipe piles. The piles should be equipped with a driving shoe to minimize damage to the pile tip during driving through underlying dense gravels and basalt. The pile driving shoe should be selected by the contractor and approved by the geotechnical engineer. To minimize the potential to carry contaminated soil into the uncontaminated zone, the driving shoe should not extend beyond the outside diameter of the pile. Any welds should be ground flush to the pile surface. Localized soil heave may occur adjacent to the pile during installation. The

contractor should be prepared to remove and properly dispose of contaminated soil adjacent to the piles following installation.

During pile driving, each pile should be driven continuously, with interruptions kept to a minimum. Piles should be driven with an impact hammer to establish the required penetration and terminal blow counts in the underlying very dense gravel and hard basalt. Driving criteria, including selection of hammer size and driving cushion, should be defined when the foundation design is completed. The Wave Equation Analysis of Pile Driving (WEAP) analysis should be used for establishing the criteria. We can provide driving criteria for the piles when the foundation design has been finalized and a driving system has been selected.

A continuous record of pile driving resistance (blows per foot) should be maintained by our representative for each pile during driving. If the pile cannot be driven to the required depth following an interruption, the pile may have to be extracted and re-driven, replaced and/or used with a reduced capacity. If piles reach refusal criteria before achieving the specified penetration, the adequacy of the pile should be determined by our representative who will advise whether to accept the pile at full capacity, at a reduced capacity, or reject the pile and require installation of substitute pile(s).

We do not recommend more than one splice per pipe pile. All splices must be capable of developing the full strength of the pile. No splices should be permitted within two-pile diameters of the depth at which maximum bending moment is developed. The maximum bending moment of the pile occurs at approximately 16 feet bgs and zero bending occurs at approximately 39 feet bgs. As discussed in the previous section of this report, it is generally more cost effective to require the contractor to provide longer piles than weld, inspect and redrive piles.

Pile Load Tests

Pile load testing is not required provided the piles are installed as recommended, since the anticipated axial load is significantly less than the axial capacity.

Vibration Considerations

We understand that significant vibrations are not permissible at the LNG tank periphery, but that surrounding structures are not vibration sensitive. Vibration monitoring should be completed during pile driving. The piles furthest from vibration sensitive structures should be installed first. If measured vibrations exceed the acceptable limit, alternate pile installation methods may be required, possibly including using a lower energy pile driving hammer, vibrating the piles before driving to final tip elevations, or other methods. We recommend the contractor provide a pile installation plan for review and approval by the geotechnical engineer.

In addition, a photographic survey of adjacent buildings should be considered to document pre-construction and post-construction conditions.

SEISMIC DESIGN PARAMETERS

Parameters provided in Table 2 are based on previous explorations performed adjacent to the proposed Compressor Equipment at the site. Based on the presence of liquefiable soils, Site Class F

was selected for preliminary seismic design. However, since the fundamental period of the proposed structure will be less than 0.5 seconds, exceptions documented in Section 20.3.1 of the 2016 *Minimum Design Loads for Buildings and Other Structures* (American Society of Civil Engineers [ASCE] 7-16) can be used to approximate recommended seismic design parameters for the project. In determining seismic design parameters with this exception, Site Class D was selected for the project, as allowed by ASCE 7-16 for structures with a period less than 0.5 seconds.

We recommend seismic design be performed using the procedure outlined in the 2021 International Building Code (IBC) and 2022 Oregon Structural Specialty Code (OSSC). Per American Society of Civil Engineers (ASCE) 7-16 Section 11.4.8, a ground motion hazard analysis or site-specific response analysis is required to determine the design ground motions for structures on Site Class D sites with S1 greater than or equal to 0.2g.

As discussed above, the site is classified as Site Class D with an S_1 value of 0.408g; therefore, the provision of 11.4.8 applies. The parameters listed in Table 2 below may be used to determine the design ground motions if Exception 2 of Section 11.4.8 of ASCE 7-16 is used. Using this exception, the seismic response coefficient (Cs) is determined by Equation (Eq.) (12.8-2) for values of $T \leq 1.5T_S$ and taken as equal to 1.5 times the value computed in accordance with either Eq. (12.8-3) for $T_L \geq T > 1.5T_S$ or Eq. (12.8-4) for $T > T_L$, where T represents the fundamental period of the structure and T_S=0.756 sec. If requested, we can complete a site-specific seismic response analysis which might provide somewhat reduced seismic demands from the parameters in Table 2 and the requirements for using Exception 2 of Section 11.4.8 in ASCE 7-16. The reduced values will likely not be significant enough to warrant the additional cost of further evaluation if designing to 2021 IBC.

Table 2: Mapped 2021 IBC Seismic Design Parameters

Parameter	Value[1,2,3]
Site Class	F
Mapped Spectral Response Acceleration at Short Period (S_S)	0.894 g
Mapped Spectral Response Acceleration at 1 Second Period (S_1)	0.408 g
Site Modified Peak Ground Acceleration (PGA_M)	0.484 g
Site Amplification Factor at 0.2 second period (F_a)	1.142
Site Amplification Factor at 1.0 second period (F_v)	1.892
Design Spectral Acceleration at 0.2 second period (S_{DS})	0.681 g
Design Spectral Acceleration at 1.0 second period (S_{D1})	0.515 g

Notes:

[1] In accordance with American Society of Civil Engineers (ASCE) 7-16, Site Class F soils vulnerable to potential failure or collapse under seismic loading, such as liquefiable soils, may be classified in accordance with Section 20.3, without regard for liquefaction, provided the structure under design has a fundamental period of vibration equal or less than 0.5 seconds.

[2] Parameters developed based on Latitude 45.578178° and Longitude -122.760778° using the ATC Hazards online tool.

[3] These values are only valid if the structural engineer utilizes Exception 2 of Section 11.4.8 (ASCE 7-16).

DESIGN REVIEW AND CONSTRUCTION SERVICES

Recommendations presented in this report are based on the assumptions and preliminary design information presented herein. Satisfactory foundation and earthwork performance depends to a large degree on the quality of construction. Sufficient monitoring of the contractor's activities is a key part of determining that the work is completed in accordance with the construction drawings and specifications. Subsurface conditions observed during construction should be compared with those assumed for design. Recognition of changed conditions often requires experience; therefore, qualified personnel should visit the site with sufficient frequency to detect whether subsurface conditions are significantly different from those anticipated.

LIMITATIONS

This report has been prepared for the exclusive use of NW Natural and their authorized agents and/or regulatory agencies for the Portland LNG Compressor Equipment project in Portland, Oregon. This report is not intended for use by others, and information contained herein is not applicable to other sites. No other party may rely on the product of our services unless we agree in advance and in writing to such reliance.

Within the limitations of scope, schedule, and budget, our services have been executed in accordance with the generally accepted geotechnical engineering practices in the area at the time this report was prepared. No warranty or other conditions, expressed or implied, should be understood.

CLOSING

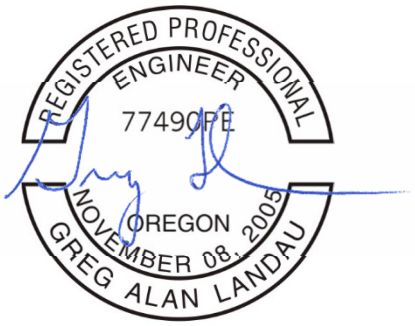
We appreciate the opportunity to assist NW Natural on this project. If you have questions, please call us at (503) 452-1100.

Sincerely,

CORNFORTH CONSULTANTS, INC.

Tygh Gianella, P.E.
Project Engineer

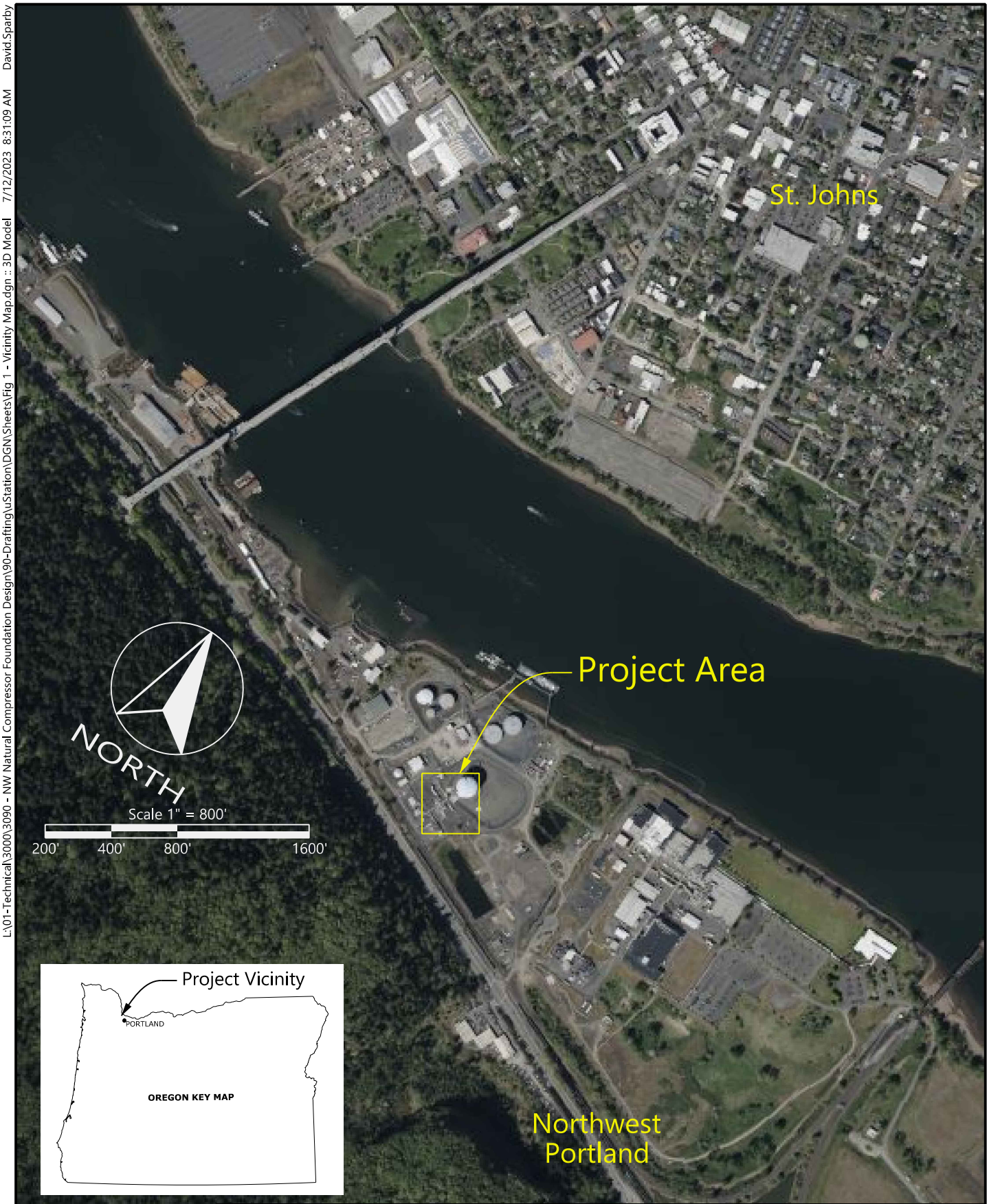
Greg A. Landau, P.E., G.E.
Senior Associate Engineer



EXPIRES: 12.31.2024

ATTACHMENTS:

Figure 1 – Vicinity Map
Figure 2 – Site Plan
Boring Logs



CORNFORTH CONSULTANTS

10250 S.W. Greenburg Road, Suite 111
Portland, Oregon 97223
Phone 503-452-1100 Fax 503-452-1528

Vicinity Map

NW Natural Compressor Foundation Design
Portland, Oregon

JUL 2023
PROJ. 3090
FIG. 1

CORNFORTH CONSULTANTS
10250 S.W. Greenburg Road, Suite 111
Portland, Oregon 97223
Phone 503-452-1100 Fax 503-452-1528

Site Plan

NW Natural Compressor Foundation Design
Portland, Oregon

JUL 2023
PROJ. 3090
FIG. 2

ATTACHMENT

Boring Logs Performed by Others

Drilled	Start 6/12/2015	End 6/12/2015	Total Depth (ft)	75	Logged By / Checked By	JL / GAL	Driller	Western States Drilling	Drilling Method	HSA
Surface Elevation (ft) Vertical Datum	Undetermined		Hammer Data	Auto 140 (lbs) / 30 (in) Drop			Drilling Equipment	CME-75		
Latitude Longitude			System Datum	Geographic			Groundwater Date Measured	Depth to Water (ft)	Elevation (ft)	

Notes: D&M values reduced by approximately 50% to correlate with SPT N-values

Elevation (feet) / Depth (feet)	FIELD DATA: Interval Recovered (in)	Blows/foot	Collected Sample: Sample Name / Testing	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
0						GM	Dark gray silty sandy gravel, angular basalt gravel to 2 inches (dense, moist) (fill)			
	16	26	1			SM	Black silty sand with gravel (medium dense, moist)			Slight sheen, strong petrochemical odor
5	14	7	2 MD				Grades to loose	9	81	No sheen to slight sheen
	16	4	3							
10	16	2	4 %F			SP	Dark gray to black poorly graded fine sand with trace silt (very loose, moist)			No sheen, faint petrochemical odor %F = 5
	16	3	5				Grades to wet			Heavy sheen, strong petrochemical odor
15	16	5	6			ML	Black silt with organics, trace fine sand (very loose to loose, wet)			Heavy sheen, strong organic odor
	16	6	7 MD			SP	Black to dark brown-black poorly graded fine sand (loose, wet)	30	88	
20	16	10	8				Grades to loose to medium dense			Brown thick tarry oil residiue, heavy sheen, strong odor
25	18	3	9 MD, AL			ML/CL	Gray silt to lean clay, trace fine sand, low plasticity (soft, moist) (alluvium)	30	89	(LL = 25, PL = 23, PI = 2) No sheen, no odor
30										

Note: See Figure A-1 for explanation of symbols.

Log of Boring B-1-15

GeoEngineers

Project: Proposed Communication Tower - Portland LNG Plant
Project Location: Portland, Oregon
Project Number: 6024-172-00

Figure A-5
Sheet 1 of 3

Elevation (feet)	Depth (feet)	FIELD DATA: Interval Recovered (in)	FIELD DATA: Blows/foot	FIELD DATA: Collected Sample / Sample Name Testing	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
	30	0 24		10 11 Consol, MD				Grades to very soft, trace small angular granules of sand			
		16	1	12					47	70	
	35	18	4	13				Grades to gray-green, trace to some wood fragments, low to moderate plasticity, medium stiff			
							CL	Gray-green lean clay, low to moderate plasticity, with trace brown mottling (medium stiff, moist)			
	40	18	5	14 MD, AL					35		(LL = 44, PL = 25, PI = 19)
	45	16	8	15 MD				Grades to brown, trace fine sand, medium stiff to stiff	37	83	
	50	14	10	16 %F			SM	4-inch thick brown silty fine sand interbed (loose to medium dense, wet)			%F = 75
							ML	Gray silt, trace fine sand, low plasticity (stiff, wet)			
	55	16	10	17			SM	Brown silty fine to medium sand (loose to medium dense, wet)			
	60	18	12	18				Grades to medium dense			
	65										

Note: See Figure A-1 for explanation of symbols.

Log of Boring B-1-15(continued)

GeoEngineers

Project: Proposed Communication Tower - Portland LNG Plant
Project Location: Portland, Oregon
Project Number: 6024-172-00

Figure A-5
Sheet 2 of 3

Elevation (feet)	Depth (feet)	FIELD DATA: Interval Recovered (in)	FIELD DATA: Blows/foot	FIELD DATA: Collected Sample / Sample Name Testing	FIELD DATA: Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
								Dark gray sandy gravel with silt, fine to medium sand (very dense, wet)			Drill action indicates gravel at 69 feet
70		18	84/11"	19			GP-GM				Very slow drilling, drilling actions suggests occasional cobbles
75		0	50/0"	20			BSLT	Basalt; angular basalt chips (Columbia River Basalt)			Basalt chip in shoe at 25 feet
								Boring completed at 75 feet Groundwater encountered at 12½ feet while drilling			

Note: See Figure A-1 for explanation of symbols.

Log of Boring B-1-15 (continued)

GeoEngineers

Project:	Proposed Communication Tower - Portland LNG Plant
Project Location:	Portland, Oregon
Project Number:	6024-172-00

Figure A-5
Sheet 3 of 3

Drilled: Start 8/3/2017 End 8/4/2017	Total Depth (ft): 60	Logged By: DMH Checked By: GAL	Driller: Cascade Drilling, LP	Drilling Method: Hollow-stem Auger/ Mud Rotary	
Surface Elevation (ft): 40.57 Vertical Datum: NAVD88		Hammer Data: Automatic 140 (lbs) / 30 (in) Drop		Drilling Equipment: CME-75	
Latitude: 45° 34' 42.942" Longitude: -122° 45' 40.5576"		System Datum: OR Degree Decimal Minutes WGS84 (feet)		Groundwater Date Measured:	Depth to Water (ft): Yes / Elevation (ft):

Notes: D&M N-values reduced by approximately 50% to roughly correlate with SPT N-values

Elevation (feet)	Depth (feet)	FIELD DATA: Interval Recovered (in)	Blows/foot	Collected Sample	Sample Name Testing	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content (%)	Fines Content (%)	REMARKS
40	0							GP	3 inches crushed aggregate			
								SP-SM	Brown fine to medium sand with silt (loose to medium dense, moist) (fill)			
		12	26		1 %F			SP	Gray-brown to black sand with gravel (medium dense, moist)		8	Heavy sheen and petrochemical-like odor
35	5	14	9		2 MD				Grades to loose	17		DD = 88 pcf
		12	7		3							Heavy sheen and odor
30	10	14	4		4 SA				Grades to very loose to loose		8	
		16	3		5				Grades to very loose			Heavy sheen and odor
								ML	Gray silt with organic matter (soft to medium stiff, moist)			
25	15	18	4		6 AL							AL (LL = 44; PI = 10)
20	20	16	3		7 MD,%F				Grades to soft	42	64	Heavy sheen and odor DD = 76 pcf
												Groundwater observed at 24 feet at time of exploration
15	25	14	7		8 AL							Heavy sheen and odor AL (non-plastic)
								SM	Gray silty fine sand (very loose to loose, moist to wet) (alluvium)			
10	30	16	3		9 %F			ML	Gray fine sandy silt (soft, moist to wet)		73	No sheen and no odor
	35											

Note: See Figure A-1 for explanation of symbols.
Coordinates Data Source: Horizontal approximated based on Aerial Imagery, Vertical approximated based on DEM

Date:10/6/17 Path:P:\6\6024210\GINT\602421000.GPJ DBLibrary/Library:GEOENGINEERS_DF_STD_US_JUNE_2017.GLB/GEI8_GEOTECH_STANDARD_%F

Log of Boring B-1-17

GeoEngineers

Project: NW Natural Portland LNG Liquification Facility
Project Location: Portland, Oregon
Project Number: 6024-210-00

Figure A-2
Sheet 1 of 2

Elevation (feet)	Depth (feet)	FIELD DATA: Interval Recovered (in)	FIELD DATA: Blows/foot	FIELD DATA: Collected Sample / Sample Name Testing	FIELD DATA: Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content (%)	Fines Content (%)	REMARKS
-5	35	16	9	10 MC				Grades to stiff	23		No sheen and no odor
-10	40	12	10	11 MD,%F					34	54	No sheen and no odor DD = 88 pcf
-15	45	0	7	12				No recovery, medium stiff			
	50	0	8	13				No recovery, medium stiff to stiff			
	55	10	18	14 MD,%F				Grades with trace sand, very stiff	34	96	No sheen and no odor DD = 85 pcf
	60		50/0"				BSLT	Basalt, angular basalt chips (very dense) (Columbia River Basalt)			

Date:10/6/17 Path:P:\6\6024210\GINT\602421000.GPJ DBLibrary/Library:GEOENGINEERS_DF_STD_US_JUNE_2017.GLB/GEI8_GEOTECH_STANDARD_%F

Log of Boring B-1-17 (continued)

GeoEngineers

Project: NW Natural Portland LNG Liquification Facility
Project Location: Portland, Oregon
Project Number: 6024-210-00

Figure A-2
Sheet 2 of 2

Drilled	Start 8/7/2017	End 8/8/2017	Total Depth (ft)	50	Logged By / Checked By	DMH / GAL	Driller	Cascade Drilling, LP	Drilling Method	Hollow-stem Auger/ Mud Rotary
Surface Elevation (ft) / Vertical Datum	39.77 NAVD88		Hammer Data	Automatic 140 (lbs) / 30 (in) Drop	Drilling Equipment	CME-75				
Latitude / Longitude	45° 34' 43.3596" -122° 45' 40.5612"		System Datum	OR Degree Decimal Minutes WGS84 (feet)	Groundwater Date Measured	Depth to Water (ft) Yes	Elevation (ft)			

Notes: D&M N-values reduced by approximately 50% to roughly correlate with SPT N-values

Elevation (feet)	Depth (feet)	FIELD DATA: Interval Recovered (in)	Blows/foot	Collected Sample	Sample Name Testing	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content (%)	Fines Content (%)	REMARKS
	0							GP	3 inches crushed aggregate			
								SP-SM	Brown fine to medium sand with silt (loose to medium dense, moist) (fill)			
		14	8		1 MC				Becomes black	18		Heavy sheen and petrochemical-like odor
35	5	12	5		2 MC					13		
		16	5		3 MD					18		Heavy sheen and odor DD = 85 pcf
30								SP	Brown fine to medium sand (loose, moist)			
	10	16	4		4 %F						1	
		16	3		5 MD,%F			ML	Gray silt with trace organic matter (soft, moist)	17	98	Heavy sheen and odor DD = 84 pcf
25	15	16	5		6 AL				Grades to medium stiff			AL (LL = 43; PI = 9)
20	20	16	5		7 MD					41		Heavy sheen and odor DD = 80 pcf
								SM	Black silty fine sand (loose, moist to wet)			Groundwater observed at 24 feet at time of exploration
15	25	14	6		8 SA						33	Heavy sheen and odor
10	30	16	4		9 %F				Grades to very loose to loose		42	Heavy sheen and odor
5	35											

Note: See Figure A-1 for explanation of symbols.
Coordinates Data Source: Horizontal approximated based on Aerial Imagery, Vertical approximated based on DEM

Date:10/6/17 Path:P:\6\6024210\GINT\602421000.GPJ DBLibrary/Library:GEOENGINEERS_DF_STD_US_JUNE_2017.GLB/GEI8_GEOTECH_STANDARD_%F

Log of Boring B-2-17

GeoEngineers

Project: NW Natural Portland LNG Liquification Facility
Project Location: Portland, Oregon
Project Number: 6024-210-00

Figure A-3
Sheet 1 of 2

Elevation (feet)	Depth (feet)	FIELD DATA: Interval Recovered (in)	FIELD DATA: Blows/foot	FIELD DATA: Collected Sample / Sample Name Testing	FIELD DATA: Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content (%)	Fines Content (%)	REMARKS
0	35	14	11	10 %F			ML	Brown fine sandy silt (stiff, moist to wet) (alluvium)		64	No sheen and no odor
	40	12	11	11 MD					35		No sheen and no odor Driller noted sheen in drilling mud; pumped out and replaced with clean mud DD = 89 pcf
-5	45	14	11	12 SA			SM	Brown silty fine sand (medium dense, moist to wet)		20	No sheen and no odor
							BSLT	Basalt, angular basalt chips (very dense) (Columbia River Basalt)			
-10	50		50/0"								

Log of Boring B-2-17 (continued)

GeoEngineers

Project: NW Natural Portland LNG Liquification Facility
Project Location: Portland, Oregon
Project Number: 6024-210-00

Figure A-3
Sheet 2 of 2

Drilled: Start 8/8/2017 End 8/9/2017	Total Depth (ft): 50.5	Logged By: DMH Checked By: GAL	Driller: Cascade Drilling, LP	Drilling Method: Hollow-stem Auger/ Mud Rotary	
Surface Elevation (ft): 44.4385 Vertical Datum: NAVD88		Hammer Data: Automatic 140 (lbs) / 30 (in) Drop		Drilling Equipment: CME-75	
Latitude: 45° 34' 41.3508" Longitude: -122° 45' 39.7044"		System Datum: OR Degree Decimal Minutes WGS84 (feet)		Groundwater Date Measured	Depth to Water (ft) / Elevation (ft)

Notes: D&M N-values reduced by approximately 50% to roughly correlate with SPT N-values

Elevation (feet)	Depth (feet)	FIELD DATA: Interval Recovered (in)	Blows/foot	Collected Sample	Sample Name Testing	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content (%)	Fines Content (%)	REMARKS
	0							GP	3 inches crushed aggregate			
								SP	Brown fine to medium sand with gravel (dense, moist) (fill)			
		8	40		1 SA				Becomes black		1	Slight sheen and petroleum-like odor
40								SP-SM	Brown fine to medium sand with silt (medium dense, moist) (fill)			
	5	12	14		2 %F						6	Moderate sheen and odor
		12	8		3 MD				Grades to loose	7		High sheen and odor DD = 86 pcf
35	10	16	4		4 SA						9	
								SM	Black silty fine sand (very loose to loose, moist)			
		16	2		5 MD,%F			ML	Black silt with trace sand and organic matter (soft to medium stiff, moist)	39	84	Heavy sheen and odor DD = 82 pcf
30	15	18	7		6 AL				Grades to gray with brown mottling, without sand or organic matter			Slight sheen and odor AL (LL = 45; PI = 10)
25	20	14	5		7 MD					40		Slight sheen and odor DD = 78 pcf
20	25	16	2		8 %F,AL				Grades to brown with trace sand, very soft and moist to wet		92	Slight sheen and no odor AL (LL = 36; PI = 5)
15	30	16	10		9 MD,%F			ML	Gray fine to medium sandy silt (stiff, moist) (alluvium)	34	66	No sheen and no odor DD = 86 pcf
10	35											

Note: See Figure A-1 for explanation of symbols.
Coordinates Data Source: Horizontal approximated based on Aerial Imagery, Vertical approximated based on DEM

Date:10/6/17 Path:P:\6\6024210\GINT\602421000.GPJ DBLibrary/Library:GEOENGINEERS_DF_STD_US_JUNE_2017.GLB/GEI8_GEOTECH_STANDARD_%F

Log of Boring B-3-17

GeoEngineers

Project: NW Natural Portland LNG Liquification Facility
Project Location: Portland, Oregon
Project Number: 6024-210-00

Figure A-4
Sheet 1 of 2

Elevation (feet)	Depth (feet)	FIELD DATA: Interval Recovered (in)	FIELD DATA: Blows/foot	FIELD DATA: Collected Sample / Sample Name Testing	FIELD DATA: Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content (%)	Fines Content (%)	REMARKS
	35	16	16	10 SA			SM	Gray fine to medium silty sand (medium dense, moist)		17	No sheen and no odor
	40	16	10	11 AL			ML	Gray with brown mottling silt (stiff, moist)			No sheen and no odor AL (non-plastic)
	45	0	14	12				No recovery			No sheen and no odor
	50	5	50/5"	13			BSLT	Basalt, angular basalt chips and gravel (very dense) (Columbia River Basalt)			

Date:10/6/17 Path:P:\6\6024210\GINT\602421000.GPJ DBLibrary/Library:GEOENGINEERS_DF_STD_US_JUNE_2017.GLB/GEI8_GEOTECH_STANDARD_%F

Log of Boring B-3-17 (continued)

GeoEngineers

Project: NW Natural Portland LNG Liquification Facility
Project Location: Portland, Oregon
Project Number: 6024-210-00

Figure A-4
Sheet 2 of 2

Drilled: Start 4/22/2021 End 4/23/2021	Total Depth (ft): 70	Logged By: JLL Checked By: BJH	Driller: Western States Soil Conservation, Inc.	Drilling Method: Hollow-stem Auger/Mud-Rotary	
Surface Elevation (ft): 39 Vertical Datum: NAVD88		Hammer Data: Autohammer 140 (lbs) / 30 (in) Drop		Drilling Equipment: CME-75 truck	
Latitude: 45.578425 Longitude: -122.760852		System Datum: Decimal Degrees WGS84		See "Remarks" section for groundwater observed	

Notes:

Elevation (feet)	Depth (feet)	FIELD DATA: Interval Recovered (in)	Blows/foot	Collected Sample	Sample Name Testing	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content (%)	Fines Content (%)	REMARKS
35	0						AC	4-inch-thick asphalt concrete pavement			
							GM	8-inch-thick aggregate base			
							SM	Black silty medium to coarse sand, occasional rounded to angular gravel (loose, moist) (fill)			Strong petroleum odor
							ML	Gray silt with fine sand, occasional gravel to cobble-sized basalt fragments, trace wood fragments and organic matter (very soft, moist)			
30	5	16	1		1						Strong odor
							SP-SM	Black poorly-graded fine sand with silt (loose, wet)			Groundwater observed at approximately 9 feet below ground surface during drilling
	10	14	8		2						
25											
	15										Heavy tar-like sheen at 17 feet Static water level at 17 feet
20											
	20	16	7		3		ML	Gray silt, low plasticity, micaceous, homogeneous (medium stiff, moist) (alluvium)			No odor
15											
	25										
10											
	30	16	8		4						No odor
							SM	Dark gray silty fine sand, micaceous (loose, wet)			
5											
	35										

Note: See Figure A-1 for explanation of symbols.
Coordinates Data Source: Horizontal approximated based on . Vertical approximated based on .

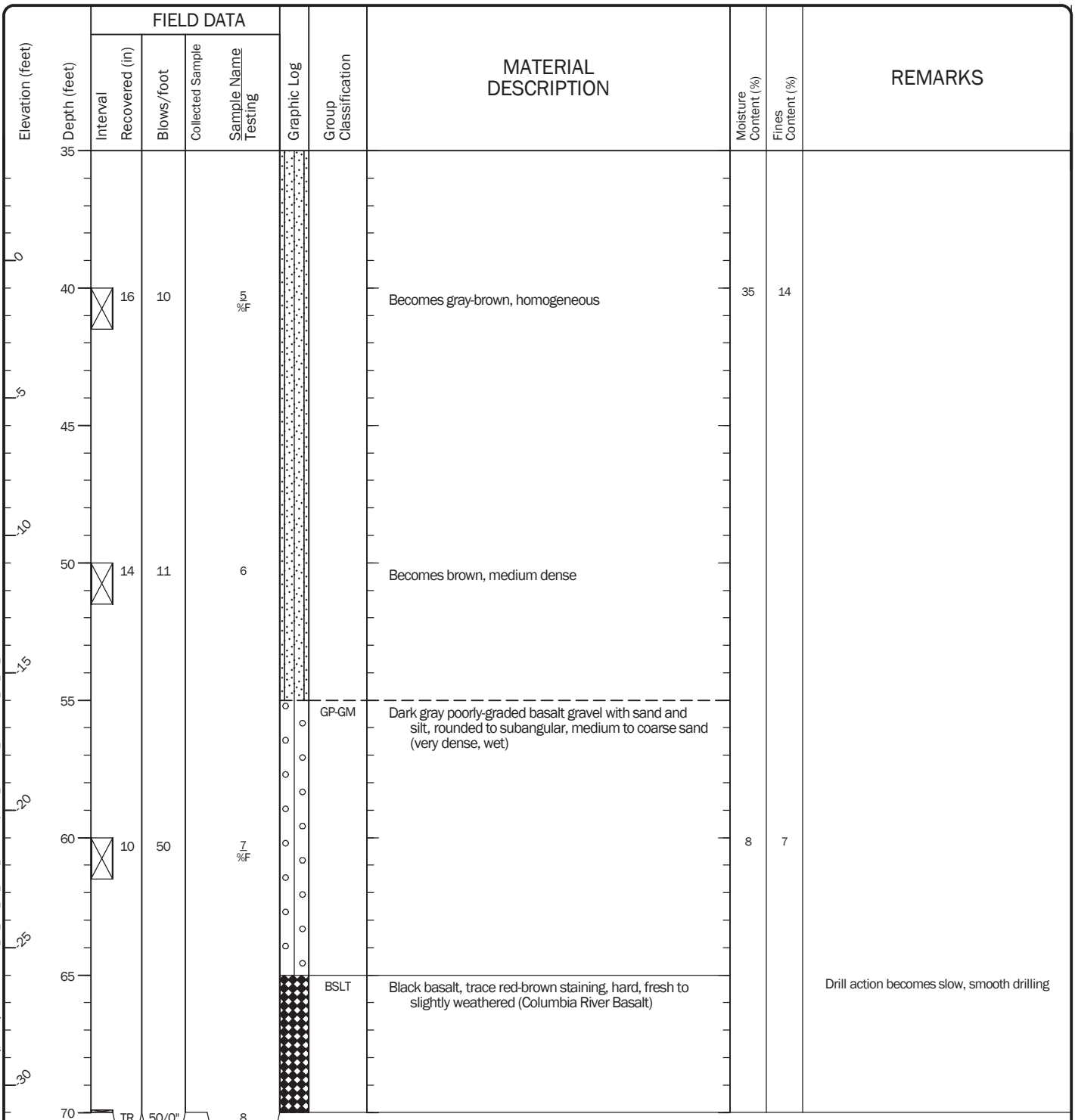
Date:6/16/21 Path:C:\USERS\CESTES\DOCUMENTS\SHAREPOINT DRAFTS\6024210O3.GPJ DBLibrary/Library:GEOENGINEERS_DF_STD_US_JUNE_2017.GLB/GEI8_GEOTECH_STANDARD_%F_NO_GW

Log of Boring B-1-21

GeoEngineers

Project: NW Natural Cold Box FEED - Portland LNG Facility
Project Location: Portland, Oregon
Project Number: 6024-210-03

Figure A-2
Sheet 1 of 2



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Log of Boring B-1-21 (continued)

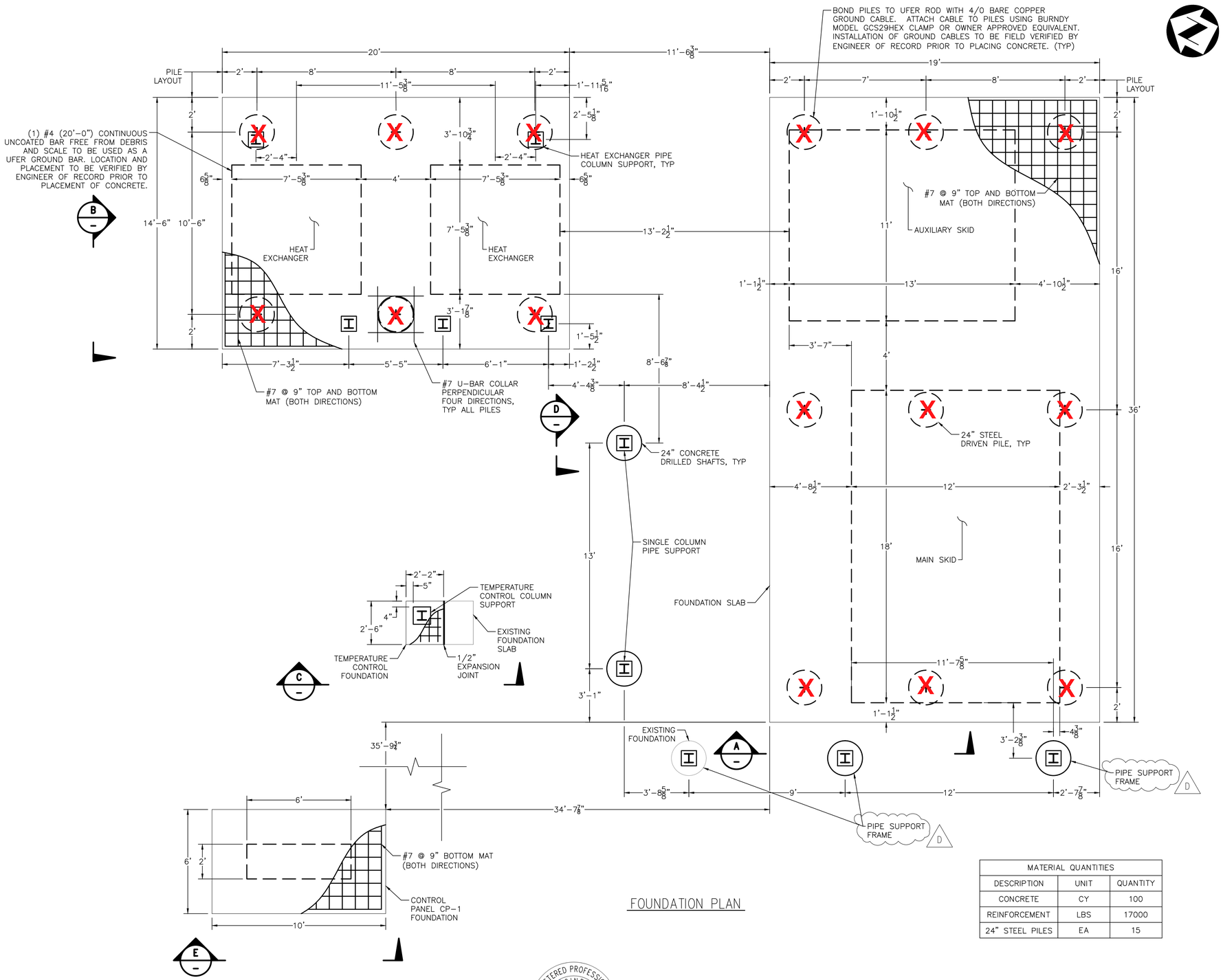
GeoEngineers

Project: NW Natural Cold Box FEED - Portland LNG Facility
Project Location: Portland, Oregon
Project Number: 6024-210-03

Figure A-2
Sheet 2 of 2

Attachment 2

Foundation Plan S1.0 and 1.1
Collins Engineers, Inc. dated July 26, 2023



FOUNDATION PLAN

MATERIAL QUANTITIES		
DESCRIPTION	UNIT	QUANTITY
CONCRETE	CY	100
REINFORCEMENT	LBS	17000
24" STEEL PILES	EA	15

REGISTERED PROFESSIONAL ENGINEER
T0188995
08/10/2023
OREGON
JAN. 10, 2023
ANTHONY J GARGARO
EXPIRES: JUN 30, 2025

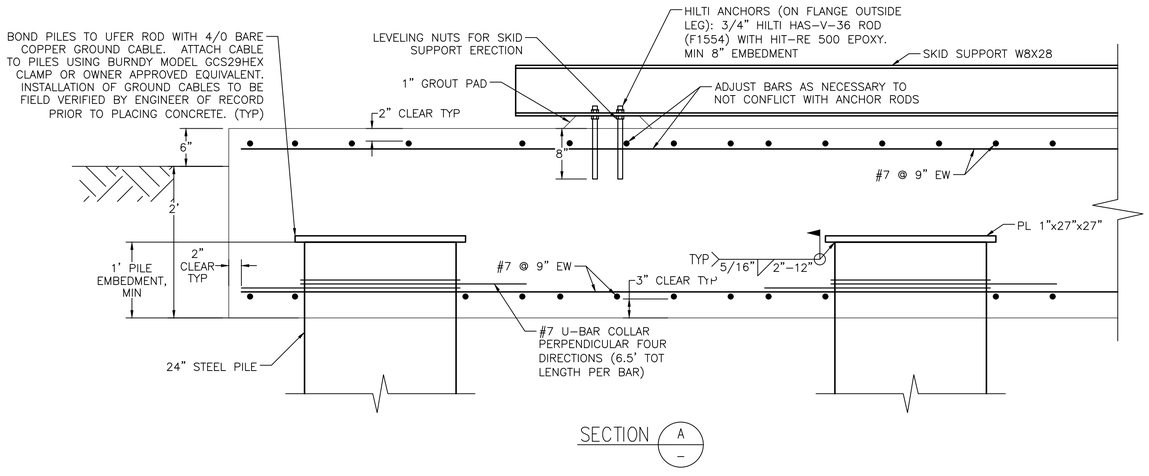
COLLINS ENGINEERS INC.
455 Sherman Street, Suite 160
Denver, Colorado 80203
voice: (303) 447-0090
fax: (303) 447-9141
web: collinsengr.com

ECO	DR.	APP.	REVISION	DATE
R-D	SCO	AJG	REVISED PER CLIENT COMMENTS	07/26/2023
R-C	SCO	AJG	100% PERMIT SET	06/19/2023
R-B	SCO	AJG	90% PERMIT SET	05/19/2023
R-A	SCO	AJG	ISSUED FOR CONSTRUCTION	04/28/2023

NW Natural
220 NW 2ND AVENUE
PORTLAND, OR 97209

PORTLAND BOG COMPRESSOR INSTALLATION
FOUNDATION PLAN
NW NATURAL LNG PLAN, PORTLAND, OREGON

DWG. NO. S1.0
SHEET 8 OF 11
SCALE NTS
DR. SCO
DATE 07/26/2023
PLAT NO.



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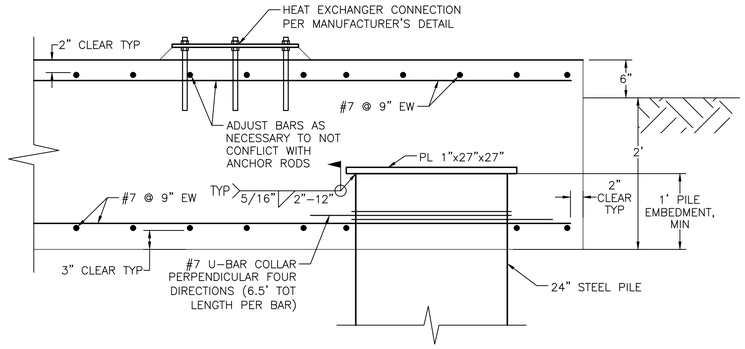

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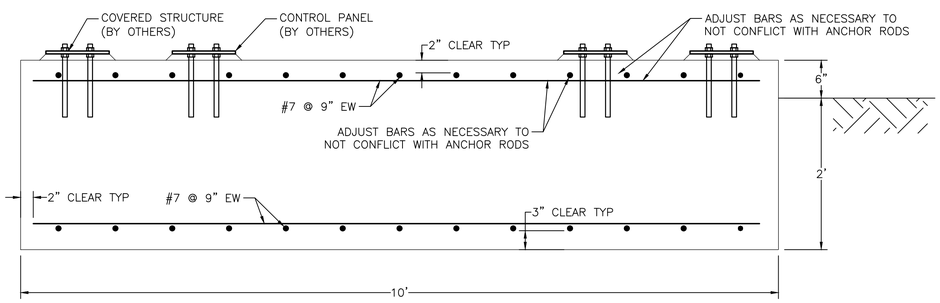

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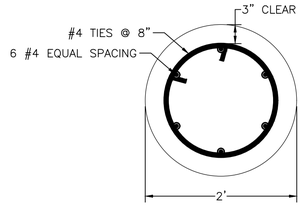

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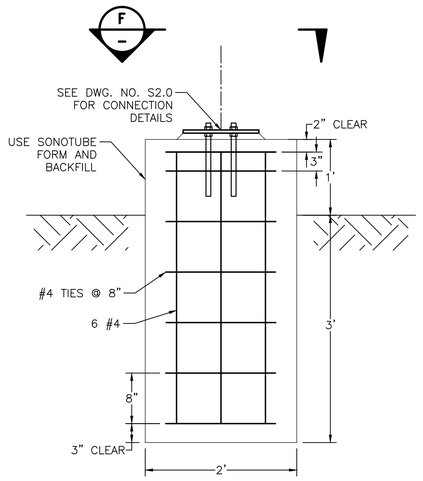

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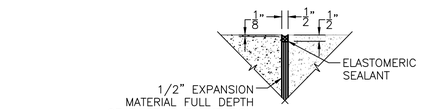
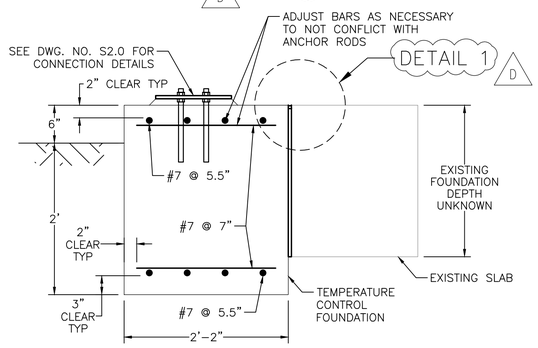


D DETAIL 1



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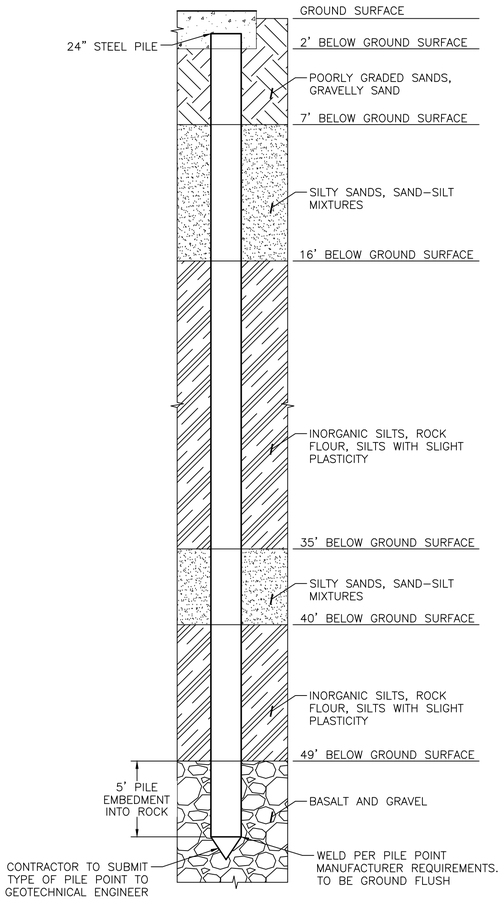
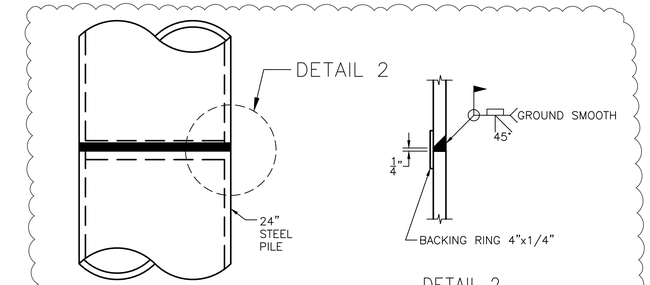


GENERALIZED SUBSURFACE PROFILE

SUBSURFACE CONDITION SHOWN IS APPROXIMATE AND FOR REFERENCE ONLY. SOURCE: OWNER'S SPECIFIED INDEPENDENT GEOTECHNICAL DESIGN AGENCY



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EXPIRES: JUN 30, 2025

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