Braun Intertec Corporation
1160 Mustang Drive, Ste. 300
Dallas, TX 75261
Send USPS mail to P.O. Box 1685
Grapevine, TX 76099

Phone: 903.581.8080
Web: braunintertec.com

February 14, 2023 Project B2208058

Mr. Brent Shimanek
TranSystems Corporation
2400 Pershing Road, Suite 400
Kansas City, MO 64108

Re: Geotechnical Letter
Trinity Lakes Station – Parking Lot and Bus Turnaround
Hurst, Texas

Dear Mr. Shimanek:

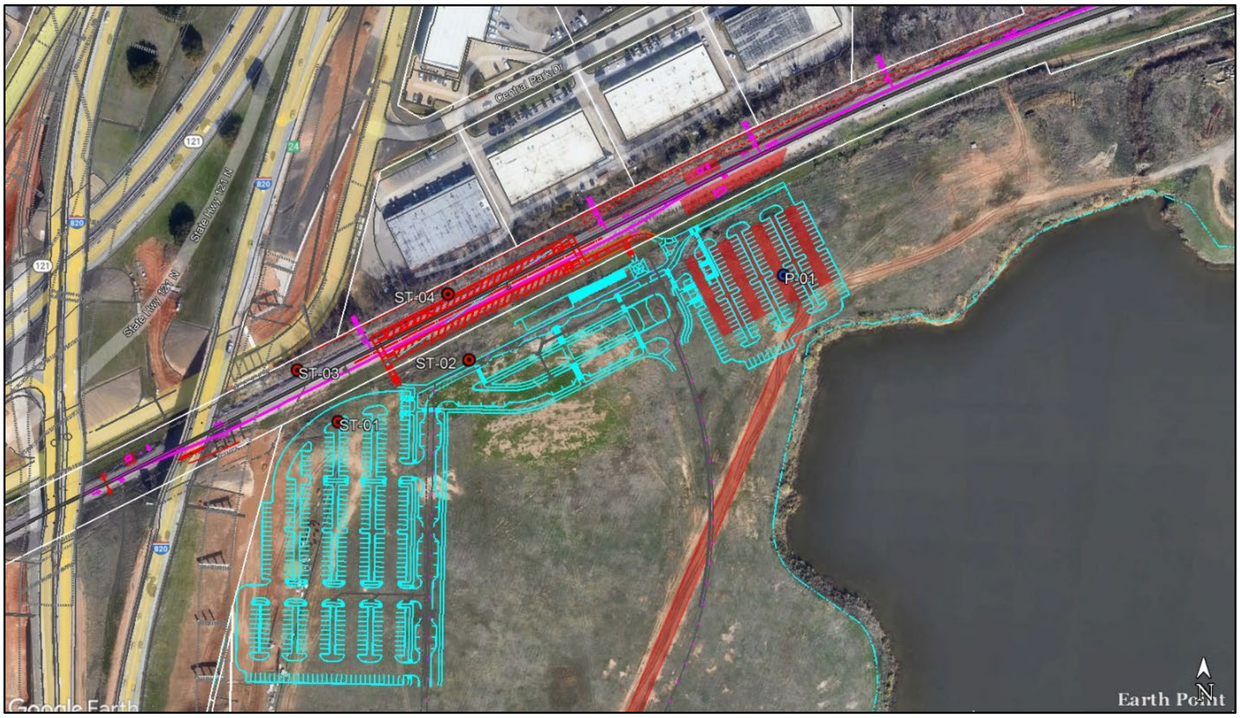
We are pleased to present this Geotechnical Letter summarizing the parking lot and bus turnaround pavement recommendations based on our soil boring completed on January 25, 2023.

A. Project Description

This Geotechnical Letter addresses the design and construction of the proposed parking lot and bus turnaround at Trinity Lakes Station for Trinity Metro. Our recommendations were based upon the completion of soil boring P-01, the corresponding lab testing, and our previously completed Geotechnical Evaluation Report B2009472 addressing the Trinity Railway Express (TRE) submitted to Mr. Chad Gartner with TranSystems dated April 22, 2021.

A preliminary site plan with the location of our soil borings is illustrated in Figure 1 below. Please note that the soil borings completed in Geotechnical Evaluation Report B2009472 were also overlayed in the figure and utilized for the purposes of the recommended pavement and flatwork recommendations.

Figure 1. Preliminary Site Plan and Boring Layout



Preliminary site plan provided by TranSystems with boring overlay.

B. Subsurface Conditions and Laboratory Test Results

The following findings are based on the result of our soil boring, denoted P-01, completed on January 25, 2023. The corresponding Log of Boring Sheet is attached to this letter.

- We observed predominately clayey sand fill from the surface to about six feet below existing grade. Please note that the depth of fill probably varies across the site and may extend deeper than six feet which was the maximum exploration depth of boring P-01.

- Groundwater was not observed during drilling or immediately after the withdrawal of the hand auger. Based on the absence of groundwater during drilling, it appears that groundwater is located below the depths explored.

- An Atterberg limits test, several moisture content tests, and a percent passing the No. 200 sieve test were performed on selected soil sample(s) from boring P-01. The individual test results can also be found on the Log of Boring for P-01. The in-situ moisture content of the soils ranged from approximately 13 to 16 percent. The observed moisture contents indicated the soils were generally in a dry condition.

- The observed liquid limit of the selected soil sample was 37 with a corresponding plasticity index of 22, indicating the presence of soils with low plasticity. High soil plasticity is generally associated with a high potential for active clay soils to shrink and swell in response to changes in the soil moisture content.

In addition to the index testing illustrated above, one soluble sulfate test was conducted in general accordance with TEX-145-E. Sulfates are a naturally occurring component of soils in Texas. Sulfates commonly occur in veins and seams and can be difficult to identify during a geotechnical exploration. Site grading can cause veins of sulfate-rich soils to become distributed across the site, and sites with fill can be unpredictable with respect to sulfate distribution in both plan location and depth. Sulfates are known to react with calcium-based stabilizing agents, including lime and cement, and form a mineral called ettringite. During ettringite formation, the resulting crystals can swell to approximately 2 to 2½ times their original volume creating sulfated-induced heave. Sulfate concentrations greater than 3,000 parts per million (ppm) are considered to pose a significant risk of damage. The results of the sulfate tests are outlined in Table 1 below.

Table 1. Soluble Sulfate Test Results

Boring ID	Depth (ft)	Sulfate Level (ppm)
P-01	0-2	3,760

The soluble sulfate test results of the near-surface soils suggest a high sulfate level, as outlined by The Texas Department of Transportation Guidelines for Treatment of Sulfate-Rich Soils and Bases. Based on ACI 318, these results indicate an exposure class of S2. Both hydrated lime and Portland cement contain calcium products and are likely to react with the sulfates present at this site and with Portland cement concrete pavements and flatwork. Most of the flexible base available in the DFW area are mined from limestone sources and are also calcium-based. We recommend that a combination of lime- and cement-treatment of the in-situ clayey sand and the addition of significant amounts of water to accelerate the reaction prior to final grading and compaction. The utilization of flexible base beneath Portland cement concrete pavements and flatwork is not recommended and should not be placed against an untreated subgrade at this site due to the potential sulfate reaction and the rapid transport of water beneath the paving. Below we have included a copy of ACI 318 Table 19.3.2.1 that outlines the requirements of concrete in contact with soils based on exposure class.

Table 2. Concrete Mix Design Requirements (ACI 318 Table 19.3.2.1)

Exposure Class	Maximum water/cement ratio	Minimum f'_c, psi	Cementitious Material Types	Calcium Chloride Admixture Suffix*
S1	0.50	4,000	Type II	MS
S2	0.45	4,500	Type V	HS

Exposure Class	Maximum water/cement ratio	Minimum f'_c, psi	Cementitious Material Types	Calcium Chloride Admixture Suffix*
S3	0.45	4,500	Type V plus pozzolan or slag cement**	Not permitted

* This classification is based on the exposure class.

**The amount of the specific source of the pozzolan or slag cement to be used shall be at least the amount that has been determined by service record to improve sulfate resistance when used in concrete containing Type V cement. Alternatively, the amount of the specific source of the pozzolan or slag cement to be used shall be at least the amount tested in accordance with ASTM C1012 and meeting the criteria in [ACI 318] 26.4.2.2(c)

Type 5 Portland cement is not produced in the DFW area; we understand that it is common practice to substitute Type II cement plus pozzolan or slag cement in lieu of Type V cement. We recommend that additional sulfate testing be completed in the field prior to the construction of lime and cement treatment of the in-situ soils. Depending on the results of the sulfate testing, our recommendations utilizing lime and/or cement treatment as an option beneath pavements may change.

C. Pavements

C.1. Pavement Considerations

The general pavement design information presented in this report is based on subsurface conditions inferred by the borings performed at this site, the Portland Cement Association, the American Association of State Highway and Transportation Officials (AASHTO), the Texas Department of Transportation (TxDOT), the Federal Highway Administration (FHWA), and experience in the area.

C.1.a. Pavement Potential Vertical Movements

Common project budgetary constraints limit subgrade preparation below pavement areas, and it is atypical to limit potential vertical movements to one inch or less for parking and drive areas. However, if desired, additional subgrade preparations can be provided beneath pavements to reduce vertical movement to an acceptable, or desired, level.

C.1.b. Traffic Loading and Frequency

Traffic data was not available at the time of our study. However, we have assumed that the vehicular parking that is currently planned will be constructed as either light or medium-duty pavement. We have assumed traffic loading of approximately 40,000 Equivalent (18-kip) Single Axle Loads (ESALs) and 1,000,000 for a 30-year design life for light-duty and heavy-duty pavements respectively.

The following assumptions were used in our analysis:

1. Design life of 30 years for all rigid pavements
2. Bus traffic is 5% of traffic (heavy duty areas) and none (light duty areas)
3. Traffic growth is 3%
4. A k-value of 150 pci for lime/cement/fly-ash treated subgrades at least 6 inches in thickness and 110 pci for untreated clay subgrade
5. Reliability of 90 percent for rigid pavements
6. Initial serviceability, p_o of 4.2 for rigid pavements
7. Terminal serviceability, p_t of 2.0 for rigid pavement types
8. Drainage coefficient of 1.0 (good drainage)
9. Load transfer of 3.8

C.1.c. Design Sections

Based on our experience with similar soils anticipated at the pavement subgrade elevation, we recommend pavement design be based on an assumed CBR value of 5 for treated soils. The contractor may need to perform some removal of unsuitable or less-suitable soils to achieve this value. Table 3 provides recommended pavement sections, based on the soil support, and assumed traffic loads.

Table 3. Recommended Pavement Sections*

	Pavement Type	
Use	**Light Duty Areas (100,000 18-kip ESALs)**	**Heavy Duty & Dumpster Pad Areas (1,000,000 18-kip ESALs)**
Minimum concrete thickness (inches)	5 inches	8 inches
Lime and Cement treated subgrade (inches)	6 inches	8 inches
Total thickness (inches)	11 inches	16 inches

*All materials should meet the TXDOT Standard Specifications for Highway Construction. Proof roll pavement areas following Section C.2.i. before compacting subgrade

We have also included a recommended pavement criteria correlating the depth of concrete and allowable ESAL's. <u>Please note that these correlations provided in Table 4 below are used assuming that the subgrade beneath the pavement consists of at least 6 and 8 inches of lime- and cement-treated in-situ soils for light- and heavy-duty pavements, respectively.</u>

Table 4. Recommended Allowable ESAL's per Concrete Depth Thickness*

Portland Cement Concrete Thickness (in)	Recommended Maximum Allowable ESAL's
6 inches	150,000
7 inches	350,000
8 inches	750,000
9 inches	1,500,000
10 inches	3,000,000

*Values provided with an assumed concrete compressive strength of 3,600 psi and a CBR value of 5.

In calculating the number of expected ESALs, a standard city bus is expected to apply about 2.2 to 2.3 ESALs per pass. In developing this estimate we assumed a terminal serviceability of 2.0, 100 percent of traffic in the design lane, and the same number of vehicles present 7 days per week, 52 weeks per year.

C.1.d. Pavement Subgrade Preparation and Treatment

All topsoil, vegetation remnants, pavement debris, and any unsuitable materials should be removed. Before subgrade treatment, the pavement areas should be cut or filled to the required elevation and proof rolled with a fully loaded tandem axle dump truck or similar pneumatic-tire equipment to locate areas of loose subgrade. In areas to be cut, the proof roll should be performed after the final grade is established. In areas to be filled, the proof roll should be performed before placement of fill and after subgrade elevation has been achieved. Areas of loose or soft subgrade observed while proof rolling should be removed and replaced with fill, or moisture treated (dried or wetted as needed) and compacted in place.

Subgrade treatment should be completed in two stages; an initial lime-treatment step to neutralize elevated sulfates and partially reduce the soils' plasticity index, and a second treatment consisting of cement treatment to add strength and improve performance. The improved subgrade should achieve a 28-day minimum compressive strength of at least 75 psi. The site appears to be a good candidate for a two-stage lime- and cement-treatment.

We recommend applying lime to the entire alignment with four to six percent lime and allowing five days to mellow. The surface should then be reviewed by experienced personnel for indications of sulfate heave. Any areas that appeared to heave, should have an additional application of lime with sufficient mellowing time to further react with any remaining sulfates. This may only be needed in very limited areas. From there, the cement treatment can be conducted. Five to eight percent cement can be assumed for budgetary purposes. A cement series should be conducted before stabilization to confirm that this approach will achieve the recommended minimum compressive strength.

Lime treatment should be performed in general accordance with TxDOT Standard Specifications for Construction and Maintenance of Highways, Streets, and Bridges – Item 260 Lime Treatment (Road Mixed). The contractor should be aware that additional lime might need to be applied to account for losses associated with windy conditions, overmixing, or other field losses.

Cement treatment should be performed in general accordance with the Texas Department of Transportation (TxDOT) Standard Specifications for Construction and Maintenance of Highways, Streets, and Bridges – Item 275 Cement Treatment (Road Mixed) after the hydrated lime treatment has been successfully completed. The actual cement percentage should be confirmed by a soil-cement test (TEX-120-E) once grading has been completed. The contractor should be aware that additional cement might need to be applied to account for losses associated with blowing, overmixing, or other field losses.

The soil and lime or cement, as appropriate, should be thoroughly blended with a Pulvermixer, water added, and the mixture compacted. The treated soil should be lightly compacted following lime treatment to “seal” the soil surface, and to at least 95 percent of the standard Proctor optimum dry density (ASTM D 698) and within the range of optimum moisture to 4 percentage points above the mixture's optimum moisture content following the application of Portland cement. Compaction must be completed within 2 hours of application of water following the addition of Portland cement and water and thorough mixing with a Pulvermixer or approved alternate equipment. Please note that the Portland cement and water must be applied on the same day, and the application of the water must occur within an hour of applying the Portland cement. Failure to follow these guidelines may result in an ineffective application of Portland cement and could result in failure to achieve the desired compressive strength.

Fly ash or CKD may also be considered in lieu of Portland cement depending on availability and cost of additives. Fly ash and CKD are also cementitious additives and may provide similar results; however, these are uncontrolled by-products of power generation, and results may vary. The contractor must demonstrate these materials will meet the project performance criteria and are sufficiently uniform for use.

It should be understood that lime and cement treating the upper 8 to 12 inches of subgrade soils will not reduce the shrinking and swelling of the subgrade below the treated zone which occurs with normal seasonal moisture fluctuations. Some differential vertical movements of the pavements should be expected. The treatment will provide a working platform during construction and create a less erodible, non-pumping subgrade for pavement support. This will reduce the potential for voids to develop beneath the pavement which increases the risk of pavement distress and possible failure.

The treated subgrade should extend a minimum of 24 inches outside the curb line. This will improve the support edge of the pavement and lessen the edge effect associated with shrinkage during dry periods. The use of sand or select fill as a leveling course beneath the pavement should be prohibited as these more porous soils allow water inflow between the pavement and subgrade causing heave and strength loss of the subgrade. Utility trenches that lie beneath the pavement must be properly compacted before the treatment of the pavement subgrade, and clay plugs must be constructed at every location where utility lines cross the perimeter of the pavement. The clay plugs should completely fill the trench, surround the utility, and extend at least 3 feet beyond the transition point in both directions.

C.1.e. Bond-breaking Asphalt Layer

As the lime- and cement-treated subgrade ages, chemical reactions between the clays, lime, and Portland cement will continue. Shrinkage of the treated zone will likely occur which could result in the development of reflective cracking in the pavement wearing surface. Utilization of a "bond breaker" layer of asphalt between the modified subgrade and the Portland cement concrete will provide better crack resistance and help prolong pavement life.

C.1.f. Concrete Pavements

We recommend rigid paving consist of Jointed Reinforced Concrete Pavement (JRCP). The concrete compressive strength should be a minimum of 3,600 psi for light-duty and 4,500 psi for heavy-duty pavements. All concrete pavements should be designed with 4.5% ± 1.5% entrained air to improve workability and durability.

A relatively close pavement joint spacing of 12½ to 15 feet is preferred. Local area practice often includes the use of No. 4 or larger reinforcing steel bars for the light-duty pavements, and No. 5 or larger reinforcing steel bars for the heavy-duty pavements, in each direction at spacing of 18 to 24 inches in order to aid in control of cracking. The minimum rebar spacing is intended to facilitate the placement of concrete in the field. Rebar spacing of less than 16 inches will likely result in workers damaging the rebar placement since there may not have adequate spacing for their feet.

Control joints should be sawn prior to shrinkage cracking occurring. Expansion joints should typically be placed on 60 to 80-foot centers however the final placement of all joints is a factor of the finished pavement geometry. The design civil engineer should determine the pavement joint spacing and location. We also recommended the drive aisles within the proposed parking area be poured separately from the parking spaces to maintain linear pours. Sequencing the pours in this manner should allow the contractor better control of the saw-cut joint installation and reduce the potential for uncontrolled shrinkage cracking of the concrete. The saw joints promote control of the concrete shrinkage cracking within the joint minimizing uncontrolled cracking and providing a receiver for properly sealing the joints. Additional details for this process can be provided upon request.

Proper design, construction, and sealing of joints will help limit surface water infiltration to the supporting moisture-sensitive subgrade. The pavement subgrade and finished surficial pavement should be properly graded and drain to the proposed stormwater collection system to minimize pooling and possible trapping of water under the pavement. Proper concrete finishing and curing practices must be employed. All paving materials should comply with the Texas Department of Transportation Standard Specifications for Construction of Highways, Streets, and Bridges, Item 360, 1993. Loading (traffic, construction equipment/machinery, etc.) must not be allowed on the completed paving until the concrete has reached at least 75 percent of its design strength.

C.1.g. HMA/WMA Pavement Materials

Although not provided in this letter, light-duty HMA/WMA pavements recommendations can be provided if requested. Please note that if HMA/WMA pavements are utilized, that they be utilized only within the footprint of the designated light-duty parking areas and drive lanes. Note that HMA/WMA pavements will require significantly more maintenance than concrete pavements.

C.1.h. Performance and Maintenance of Concrete Pavements

We based the above pavement designs on a 30-year performance life for concrete pavement types. This is the amount of time before we anticipate the pavement will require reconstruction. This performance life assumes routine maintenance, such as seal coating, joint repair, and crack sealing. The actual pavement life will vary depending on variations in weather, traffic conditions, and maintenance.

Many conditions affect the overall performance of the exterior slabs and pavements. Some of these conditions include the environment, loading conditions, and the level of ongoing maintenance. We recommend developing a regular maintenance plan for filling cracks in exterior slabs and pavements to lessen the potential impacts of warm weather distress due to the wetting and drying of the subgrade.

C.1.i. Excavated Slopes

Since the work addressed in this report consists of pavements, excavations deeper than 2 feet are not expected. The following information is only included for completeness, should unexpected excavations deeper than 4 feet become necessary. Based on the borings, we anticipate on-site soils in excavations will consist primarily of disturbed material consisting of clayey sand. Soils consisting predominantly of this material should be considered Type C soils under OSHA (Occupational Safety and Health

Administration) guidelines. OSHA guidelines indicate unsupported excavations five feet or deeper in Type C soils should have a gradient no steeper than 1H:1V. Slopes constructed in this manner may still exhibit surface sloughing. OSHA requires an engineer to evaluate all slopes and excavations over 20 feet in depth.

An OSHA-approved qualified person should review the soil classification in the field. Excavations must comply with the requirements of OSHA 29 CFR, Part 1926, Subpart P, "Excavations and Trenches." This document states excavation safety is the responsibility of the contractor. The project specifications should reference these OSHA requirements.

C.1.j. Excavation Dewatering

Groundwater was not observed in our soil boring. Extensive dewatering of the site is not expected for the roadway and pavement reconstruction since the excavations for the roadway are expected to be no more than a few feet in depth. We recommend removing groundwater from the excavations. Project planning should include temporary sumps and pumps for excavations in low-permeability soils, such as clays.

C.1.k. Reuse of On-Site Soils

We anticipate that the in-situ soils may meet the requirements for select fill. Fill soils intended for reuse should be segregated on-site, confirmed as meeting the select fill criteria through laboratory analysis, and approved. We do not recommend reusing existing fill that contains debris, organic material, or more than 500 ppm sulfates as fill unless these soils are properly treated with hydrated lime and Portland cement.

C.1.l. Fill Materials and Compaction

General fill materials should consist of on-site soils or imported fill materials that have been previously reviewed and approved by the Geotechnical Engineer. All soils must be free of roots, vegetation, organic matter, and other deleterious or undesirable material. Rock sizes over four inches in diameter must be removed and should not be placed within the fill. After areas to receive fill have been properly prepared, the exposed subgrade should be proof-rolled using a fully loaded, tandem-axle dump truck or similar equipment to locate areas of unsuitable subgrade. Unsuitable subgrade should be remediated prior to lime- and cement-treatment of the in-situ soils.

Table 5. Material and Compaction Recommendations

Reference	Plasticity Requirement/Other Requirements	Recommended Compaction, percent (ASTM D698)	Moisture Content Variance from Optimum, percentage points
General Fill (native or imported)	Liquid limit less than 60 < 2% organics 100% Passing 3-inch sieve	95 – 100	0 to +4
Select fill (native or imported)	PI 10 to 20 LL less than 40 Consisting of a sulfate content less than 500 ppm and meeting a Soaked CBR of 5	Min 95	-1 to +3
Lime treated on-site clay soils below pavements	See TxDOT Item 260.	*	+3 to +8 (for proper chemical reaction)
Cement treated pavement subgrade	TxDOT Item 275	95 – 100	0 to +4

* Compaction not specified – the treated subgrade will still require treatment with Portland cement before compaction.

C.2. Flatwork

Flatwork elements, including sidewalk areas and paving, are subject to distress resulting from the aforementioned potential vertical soil movements. Flatwork should not be rigidly connected to structures, and joints between flatwork and structures are completely filled with an elastomeric material.

Adequate drainage should be provided so that runoff is not allowed to collect in areas where intrusion into subgrade soils may occur. Unless excavation of existing soils extends beyond the pavement areas, encompassing flatwork elements, some movement-related soil heave or shrinkage can be expected. Areas outside any emergency exits for buildings (not included in this study) require special attention to reduce the risk of exit doors being blocked by heave of the flatwork.

Thank you for making Braun Intertec your geotechnical consultant for this project. If you have questions about this letter, please contact us at 940.232.2003, or email RDeatherage@braunintertec.com.

Jarod Erlandson, E.I.T.
Staff Engineer

John A. Focht III, P.E.
Principal Engineer, Technical Leader

STATE OF TEXAS
John A. Focht, III
60313
LICENSED
PROFESSIONAL ENGINEER

Attachments:
Log of Boring Sheets P-01
Descriptive Terminology of Soils

BRAUN INTERTEC
The Science You Build On.

LOG OF BORING

See Descriptive Terminology sheet for explanation of abbreviations

Project Number B2208058
Geotechnical Evaluation
Trinity Lakes Station - Parking Lot & Turnaround
Fort Worth , TX

BORING:	**P-01**		
LOCATION: See attached sketch			
DATUM: WGS 84			
LATITUDE: 32.83546		LONGITUDE: -97.20775	
DRILLER: M.Hill	LOGGED BY: J.Hardin	START DATE: 01/25/23	END DATE: 01/25/23
SURFACE ELEVATION: 498.0 ft	RIG: 45	METHOD: Power Auger	
SURFACING: Clay	WEATHER: Clear		

Elev./ Depth ft	Water Level	Description of Materials (Soil-ASTM D2488 or 2487; Rock-USACE EM 1110-1-2908)	Sample	Blows (Blows/ft) Recovery	q_p tsf	MC %	%Pass No. 200	Atterberg Limits LL	PL	PI	Dry Unit Wt. pcf	Un. Com. Str. tsf	Tests or Remarks
		FILL: CLAYEY SAND (SC), trace Gravel, brown and gray											
				SH	3.00	15							
		with Sand seams at 3 feet		SH	3.00	16	26	37	15	22			
		brownish gray and Gravely below 4 feet											
5				SH	3.00	13							
492.0 6.0		END OF BORING Boring then backfilled with auger cuttings											

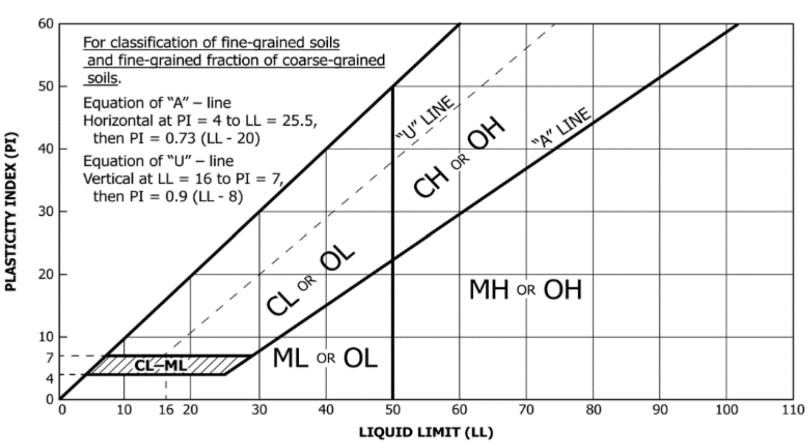
Water not observed while drilling.

Descriptive Terminology of Soil

Based on Standards ASTM D 2487-11/2488-09a
(Unified Soil Classification System)

Criteria for Assigning Group Symbols and Group Names Using Laboratory Tests[A]				Soil Classification: Group Symbol	Soil Classification: Group Name[B]
Coarse-grained Soils (more than 50% retained on No. 200 sieve)	**Gravels** (More than 50% of coarse fraction retained on No. 4 sieve)	**Clean Gravels** (Less than 5% fines[C])	$C_u \geq 4$ and $1 \leq C_c \leq 3$[D]	GW	Well-graded gravel[E]
			$C_u < 4$ and/or ($C_c < 1$ or $C_c > 3$)[D]	GP	Poorly graded gravel[E]
		Gravels with Fines (More than 12% fines[C])	Fines classify as ML or MH	GM	Silty gravel[E F G]
			Fines Classify as CL or CH	GC	Clayey gravel[E F G]
	Sands (50% or more coarse fraction passes No. 4 sieve)	**Clean Sands** (Less than 5% fines[H])	$C_u \geq 6$ and $1 \leq C_c \leq 3$[D]	SW	Well-graded sand[I]
			$C_u < 6$ and/or ($C_c < 1$ or $C_c > 3$)[D]	SP	Poorly graded sand[I]
		Sands with Fines (More than 12% fines[H])	Fines classify as ML or MH	SM	Silty sand[F G I]
			Fines classify as CL or CH	SC	Clayey sand[F G I]
Fine-grained Soils (50% or more passes the No. 200 sieve)	**Silts and Clays** (Liquid limit less than 50)	Inorganic	PI > 7 and plots on or above "A" line[J]	CL	Lean clay[K L M]
			PI < 4 or plots below "A" line[J]	ML	Silt[K L M]
		Organic	$\frac{\text{Liquid Limit – oven dried}}{\text{Liquid Limit – not dried}} < 0.75$	OL	Organic clay [K L M N] / Organic silt [K L M O]
	Silts and Clays (Liquid limit 50 or more)	Inorganic	PI plots on or above "A" line	CH	Fat clay[K L M]
			PI plots below "A" line	MH	Elastic silt[K L M]
		Organic	$\frac{\text{Liquid Limit – oven dried}}{\text{Liquid Limit – not dried}} < 0.75$	OH	Organic clay [K L M P] / Organic silt [K L M Q]
Highly Organic Soils		Primarily organic matter, dark in color, and organic odor		PT	Peat

A. Based on the material passing the 3-inch (75-mm) sieve.
B. If field sample contained cobbles or boulders, or both, add "with cobbles or boulders, or both" to group name.
C. Gravels with 5 to 12% fines require dual symbols:
   - GW-GM well-graded gravel with silt
   - GW-GC well-graded gravel with clay
   - GP-GM poorly graded gravel with silt
   - GP-GC poorly graded gravel with clay
D. $C_u = D_{60} / D_{10}$ $C_c = (D_{30})^2 / (D_{10} \times D_{60})$
E. If soil contains ≥ 15% sand, add "with sand" to group name.
F. If fines classify as CL-ML, use dual symbol GC-GM or SC-SM.
G. If fines are organic, add "with organic fines" to group name.
H. Sands with 5 to 12% fines require dual symbols:
   - SW-SM well-graded sand with silt
   - SW-SC well-graded sand with clay
   - SP-SM poorly graded sand with silt
   - SP-SC poorly graded sand with clay
I. If soil contains ≥ 15% gravel, add "with gravel" to group name.
J. If Atterberg limits plot in hatched area, soil is CL-ML, silty clay.
K. If soil contains 15 to < 30% plus No. 200, add "with sand" or "with gravel", whichever is predominant.
L. If soil contains ≥ 30% plus No. 200, predominantly sand, add "sandy" to group name.
M. If soil contains ≥ 30% plus No. 200 predominantly gravel, add "gravelly" to group name.
N. PI ≥ 4 and plots on or above "A" line.
O. PI < 4 or plots below "A" line.
P. PI plots on or above "A" line.
Q. PI plots below "A" line.



Particle Size Identification

Boulders.............. over 12"
Cobbles................ 3" to 12"
Gravel
- Coarse............. 3/4" to 3" (19.00 mm to 75.00 mm)
- Fine................. No. 4 to 3/4" (4.75 mm to 19.00 mm)

Sand
- Coarse.............. No. 10 to No. 4 (2.00 mm to 4.75 mm)
- Medium........... No. 40 to No. 10 (0.425 mm to 2.00 mm)
- Fine.................. No. 200 to No. 40 (0.075 mm to 0.425 mm)

Silt........................ No. 200 (0.075 mm) to .005 mm
Clay...................... < .005 mm

Relative Proportions[L, M]

trace............................. 0 to 5%
little.............................. 6 to 14%
with.............................. ≥ 15%

Inclusion Thicknesses

lens............................... 0 to 1/8"
seam............................. 1/8" to 1"
layer.............................. over 1"

Apparent Relative Density of Cohesionless Soils

Very loose .... 0 to 4 BPF
Loose .... 5 to 10 BPF
Medium dense.............. 11 to 30 BPF
Dense............................ 31 to 50 BPF
Very dense.................... over 50 BPF

Consistency of Cohesive Soils	Blows Per Foot	Approximate Unconfined Compressive Strength
Very soft	0 to 1 BPF	< 0.25 tsf
Soft	2 to 4 BPF	0.25 to 0.5 tsf
Medium	5 to 8 BPF	0.5 to 1 tsf
Stiff	9 to 15 BPF	1 to 2 tsf
Very Stiff	16 to 30 BPF	2 to 4 tsf
Hard	over 30 BPF	> 4 tsf

Moisture Content:

Dry: Absence of moisture, dusty, dry to the touch.
Moist: Damp but no visible water.
Wet: Visible free water, usually soil is below water table.

Drilling Notes:

Blows/N-value: Blows indicate the driving resistance recorded for each 6-inch interval. The reported N-value is the blows per foot recorded by summing the second and third interval in accordance with the Standard Penetration Test, ASTM D1586.

Partial Penetration: If the sampler could not be driven through a full 6-inch interval, the number of blows for that partial penetration is shown as #/x" (i.e. 50/2"). The N-value is reported as "REF" indicating refusal.

Recovery: Indicates the inches of sample recovered from the sampled interval. For a standard penetration test, full recovery is 18", and is 24" for a thinwall/shelby tube sample.

WOH: Indicates the sampler penetrated soil under weight of hammer and rods alone; driving not required.

WOR: Indicates the sampler penetrated soil under weight of rods alone; hammer weight and driving not required.

Water Level: Indicates the water level measured by the drillers either while drilling (▽), at the end of drilling (▼), or at some time after drilling (▼).

Laboratory Tests

DD	Dry density, pcf	**OC**	Organic content, %	**PL**	Plastic limit
WD	Wet density, pcf	q_p	Pocket penetrometer strength, tsf	**LL**	Liquid limit
P200	% Passing #200 sieve	**MC**	Moisture content, %	**PI**	Plasticity index
		q_U	Unconfined compression test, tsf		