



Geotechnical Engineering Report

**E. 91st Street S. Widening
Memorial Drive to Mingo Road
Tulsa, Oklahoma**

June 12, 2020

Terracon Project No. 04195149

Prepared for:

Garver, LLC
Tulsa, Oklahoma

Prepared by:

Terracon Consultants, Inc.
Tulsa, Oklahoma



June 12, 2020

Garver, LLC
6450 South Lewis Avenue, Suite 300
Tulsa, Oklahoma 74136



Attn: Mr. Michael Winterscheidt, P.E.
P: (918) 858-3797
E: mjwinterscheidt@garverusa.com

Re: Geotechnical Engineering Report
E. 91st Street S. Widening
Memorial Drive to Mingo Road
Tulsa, Oklahoma
Terracon Project No. 04195149

Dear Mr. Winterscheidt:

We have performed Geotechnical Engineering services for the above referenced project. This study was performed in general accordance with Terracon Proposal No. P04195149 dated July 8, 2019. This report presents the findings of the subsurface exploration and provides geotechnical recommendations for the proposed project.

We appreciate the opportunity to be of service to you on this project. If you have any questions concerning this report or if we may be of further service, please contact

Sincerely,

Terracon Consultants, Inc.

Cert. of Auth. #CA-4531 exp. 6/30/21

A handwritten signature in black ink that reads "Alec N. Strassburg".

Alec N. Strassburg, P.E. (KS)
Project Engineer



Michael H.
6/15/2020
Senior Principal
Oklahoma No. 15777

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Environmental

Facilities

Geotechnical

Materials

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Note: This report was originally delivered in a web-based format. **Orange Bold** text in the report indicates a referenced section heading. The PDF version also includes hyperlinks which direct the reader to that section and clicking on the **GeoReport** logo will bring you back to this page. For more interactive features, please view your project online at client.terracon.com.

ATTACHMENTS

EXPLORATION AND TESTING PROCEDURES
SITE LOCATION AND EXPLORATION PLANS
EXPLORATION RESULTS
SUPPORTING INFORMATION

Note: Refer to each individual Attachment for a listing of contents.

Geotechnical Engineering Report

E. 91st Street S. Widening Memorial Drive to Mingo Road

Tulsa, Oklahoma

Terracon Project No. 04195149

June 12, 2020

INTRODUCTION

This report presents the results of our subsurface exploration and geotechnical engineering services performed for the proposed roadway widening and improvements planned along E. 91st Street S. from Memorial Drive to Mingo Road in Tulsa, Oklahoma. The purpose of these services is to provide information and geotechnical engineering recommendations relative to:

- Subsurface conditions
- Site preparation and earthwork
- Pavement subgrade preparation
- Pavement section thickness

The geotechnical engineering Scope of Services for this project included the advancement of 7 pavement cores/borings to a depth of 5 feet below existing site grades.

Maps showing the site and core/boring locations are shown in the **Site Location** and **Exploration Plan** section. The results of the laboratory testing performed on soil samples obtained from the site during the field exploration are included on the core/boring logs and as separate graphs in the **Exploration Results** section.

SITE CONDITIONS

The following description of site conditions is derived from our site visit in association with the field exploration.

Item	Description
Project Location	The project alignment is located along E. 91 st Street S. between Memorial Drive and Mingo Road in Tulsa, Oklahoma. See Site Location
Existing Improvements	Most of the existing alignment consists of 2 lanes with limited-width shoulders. Existing pavement along E. 91 st Street S. consists of asphalt and concrete. Existing commercial structures, residential neighborhoods, parking and drive areas, and sidewalks are located along the north and south sides of the E. 91 st Street S.
Existing Topography	Based on provided preliminary plans, ground surface elevations along the centerline of E. 91 st Street S. range from about 665 to 708 feet.

PROJECT DESCRIPTION

Our final understanding of the project conditions is as follows:

Item	Description
<p>Project Description</p>	<p>We understand that E. 91st Street S. between Memorial Drive and Mingo Road will be widened and improved. We anticipate that the roadway will be widened to include at least 2 lanes of traffic in the westbound and east bound directions with shoulders. The existing bridge located on E. 91st Street S. about 800 feet west of the intersection with Mingo Road will not be replaced as part of this project.</p> <p>To meet the final planned grades along the project alignment, we understand that 3 retaining walls are planned. These retaining walls will likely consist of concrete, cast-in-place (CIP) walls or sheet pile walls. Recommendations for these walls will be addressed in a separate report.</p>
<p>Pavements (Traffic data provided by Garver, LLC)</p>	<p>Based on our communication with the client, we anticipate that the pavement section will consist of rigid (concrete) pavement based on City of Tulsa standard pavement sections for arterial streets. Traffic data are as follows:</p> <ul style="list-style-type: none"> ■ Traffic volume: approximately 17,046 vehicles per day (vpd) in 2020 (assumed to be two-way; based on INCOG data) ■ Percent trucks: 5 percent ■ Annual growth rate: 2 percent ■ Traffic life: 20 years

GEOTECHNICAL CHARACTERIZATION

Site Geology

Based on information published in the Oklahoma Department of Transportation (ODOT) manual, “Engineering Classification of Geologic Materials: Division 8”, the project alignment is mapped as underlain by the Nowata Unit. The Nowata Unit consists of shale with minor amounts of sandstone and limestone.

Soil Conditions

The subsurface conditions encountered in the cores/borings are shown on the logs found in the **Exploration Results** section and are briefly described in the following table. The stratification lines shown on the cores/boring logs represent the approximate boundary between material types; in-situ, the transition between materials may be gradual and indistinct.

Stratum	Approximate Depth to Bottom of Stratum	Material Description	Consistency/Density
Surface 1	6 to 16¾ inches	Asphalt and concrete pavement	N/A
1A	13 to 15½ inches in cores/borings P-1, P-3 and P-6	Pulverized asphalt and soil mixed and compacted	N/A
1B	16½ to 22 inches in cores/borings P-4, P-5 and P-7	Chemically treated soil subgrade	N/A
2	3.5 feet in core/boring P-7; Undetermined ¹ in core/boring P-6	Existing fill consisting of lean clay with sand and sandy lean clay	N/A
3	Undetermined ² in borings P-1 to P-5 and P-7	Native fat clay, lean clay, and lean clay with variable amounts for sand	Very soft to hard

1. Core/boring P-6 terminated in stratum 2 at a planned depth of 5 feet.
2. Core/borings P-1 to P-5 and P-7 terminated in stratum 3 at a planned depth of 5 feet.

Laboratory tests were conducted on selected soil samples. The test results are presented on the boring logs and on test report forms in **Exploration Results**.

Groundwater

The boreholes were observed while drilling and after drilling for the presence and level of groundwater. We observed groundwater at the following depths and times of the structure borings.

Core/Boring	Approximate Depth to Groundwater While Drilling ¹ , feet	Approximate Depth to Groundwater After Drilling ¹ , feet
P-1 to P-3 and P-5 to P-7	Not encountered	Not encountered
P-4	3	3

1. Below ground surface

The groundwater level observations made during our exploration provide an indication of the groundwater conditions at the time the borings were drilled. Long-term monitoring with observation wells, sealed from the influence of surface water, would be required to accurately define the potential range of groundwater conditions. Fluctuations in the groundwater level should be expected due to seasonal variations in the amount of rainfall, runoff, creek level, and other factors not apparent at the time the borings were drilled. The possibility of groundwater level

fluctuations and the presence of perched water should be considered when designing and developing the construction plans for the project.

Existing Pavement Thickness

The thicknesses of the pavement cores performed at the core locations are summarized in the following table. Logs of the pavement cores are also included in **Exploration Results**.

Core/Boring ID	Asphalt Layer Thickness (inch)	Portland Cement Concrete Layer Thickness (inch)	Chemically Treated Soil Layer Thickness (inch)	Pulverized Asphalt and Soil Mixture Thickness (inch)
P-1	11½	NE	NE	4
P-2	16¾	NE	NE	NE
P-3	10¼	NE	NE	5¼
P-4	14	NE	8	NE
P-5	12½	NE	4	NE
P-6	6	NE	NE	7
P-7	NE	10½	8½	NE

1. NE = Not encountered

GEOTECHNICAL OVERVIEW

We understand that E. 91st Street S. from Memorial Drive to Mingo Road will be widened and improved. The project improvements will include full-depth concrete widening and reconstruction. The existing grades will be modified to meet the planned final grades.

Based on our experience, high moisture content and unstable soils are often found beneath pavements after demolition. If wet conditions occur during construction, the surficial soils will likely be unstable. Unstable soils should be removed and replaced with engineered fill unless they are chemically stabilized in-place.

Groundwater was encountered at core/boring location P-4 at relatively shallow depth of 3 feet below existing grades. Very soft to soft, low strength, wet soils were associated with the shallow groundwater. Low strength soils were encountered to depths of 5 feet and possibly greater at core/boring P-4 and are not suitable for supporting new fill or pavements. Preferably, the full-depth of the low strength, unstable soils would be removed and replaced with engineered fill. However, because of the depths of the low strength soils and presence of shallow groundwater, full-depth removal of the low strength soils could present significant construction difficulties. Options for providing a stable pavement subgrade are provided if the soils cannot be removed and replaced.

Existing fill was encountered at cores/borings P-6, and P-7 to depths of about 3.5 to 5 feet and possibly greater below the existing top of pavement elevation. Existing fill could also be encountered along the roadway alignment at locations away from the core/boring locations. Because of the potential for variation in the composition and quality of existing fill and unsuitable materials to be buried in existing fills, there is an inherent risk of unpredictable post-construction settlement of pavements constructed over existing fill. That risk cannot be eliminated unless the existing fill is completely removed and replaced with tested and approved, new engineered fill. However, the risk can be reduced by thorough observation and testing of the existing fill by the Geotechnical Engineer during construction.

Based on the results of our field exploration, subgrade soils consist mainly of medium stiff to very stiff clay soils (A-4, A-6, and A-7-6 AASHTO classification). Therefore, we recommend that full-depth pavement sections incorporate a layer of aggregate base beneath the pavement to improve long-term pavement support. In addition, proper moisture conditioning and compaction of the subgrade materials will be required during construction to develop the pavement subgrade. The **Pavements** section addresses the design of project pavements.

Recommendations regarding earthwork and site preparation, pavement subgrade preparation, and pavement thicknesses are provided in the following sections. The **General Comments** section provides an understanding of the report limitations.

EARTHWORK

Site Preparation

Areas within the limits of construction should be stripped and cleared of existing pavement, surface vegetation, topsoil, trees, and any other deleterious material. Grubbing should include complete removal of tree stumps and major root systems. In addition, any existing site features encountered along the project alignment (such as existing pavements, sidewalks, or other structures), and any loose, soft, or otherwise unsuitable materials should be removed from the proposed construction areas. Any organic soils removed during site preparation should not be used as fill beneath pavements.

Roadway sections that do not include curb and gutter should utilize properly constructed drainage ditches parallel to the roadway. Drainage ditches should be sufficiently deep and sloped to remove water in an expedient manner. Standing water in ditches can lead to pavement subgrade failure.

After stripping of organic soils, grubbing, demolition/removal of any existing features, removal of any unsuitable materials, completing necessary grading cuts and overexcavations, but prior to placing any new engineered fill, the subgrade should be proofrolled to aid in locating soft, unstable areas. Proofrolling should be performed with a loaded tandem axle dump truck weighing at least

25 tons. Areas too small to proofroll should be evaluated by the Geotechnical Engineer. Unstable soils identified by proofrolling or subgrade evaluation should be undercut full-depth and replaced with suitable engineered fill, if they cannot be adequately stabilized in-place.

After completion of proofrolling, and before placing fill, the exposed subgrade should be scarified to a minimum depth of 8 inches, moisture conditioned, and compacted prior to placing any fill as recommended in the **Fill Compaction Requirements** section.

It should be anticipated that special subgrade stabilization procedures, beyond scarification and compaction, will be required at core/boring P-4 to develop a sufficiently stable subgrade for supporting engineered fills after removal of the low strength, unstable soils, which extended to depths of about 5 feet and possibly greater, due to the presence of relatively shallow groundwater at a depth of 3 feet. Subsurface conditions (i.e., depth of low strength, unstable soils and relatively shallow groundwater) similar to that observed at core/boring P-4 could be present at other locations.

If the exposed subgrade becomes unstable, methods outlined below can be considered.

- **Scarification and Compaction** – It may be feasible to scarify, dry and compact the exposed soils. The success of this procedure would depend primarily upon favorable weather and sufficient time to dry the soils. Stable subgrades likely would not be achievable if the thickness of the unstable soil is greater than about 1 foot, if the unstable soil is at or near the groundwater level, or if construction is performed during a period of wet or cool weather when drying is difficult.
- **Crushed Stone** – The use of crushed stone or crushed gravel is the most common procedure to improve subgrade stability. Typical undercut depths would be expected to range from about 6 to 30 inches below the finished subgrade elevation. The use of high modulus geosynthetics (i.e., geotextile or geogrid) can also be considered after underground work such as utility construction is completed. Prior to placing the geotextile or geogrid, we recommend that all below-grade construction, such as utility line installation, be completed to avoid damaging the geosynthetics. Equipment should not be operated above the geosynthetics until one full lift of crushed stone fill is placed above it. The maximum particle size of granular material placed over the geosynthetics should conform to the manufacturer's recommendations and generally should but exceed 1½ inches.

Further evaluation of the need for subgrade stabilization should be provided by a qualified geotechnical engineer during construction as the subgrade conditions are exposed on a broad scale.

Fill Material Types

Soils used as engineered fill should meet the following material property requirements:

Soil Type ¹	USCS Classification	Acceptable Location for Placement
Select Fill Material	Lean clays (CL) or clayey sands (SC) (A-6 to A-2-6 soil types under AASHTO Soil Classification System, AASHTO M145), with a Plasticity Index (PI) of 8 to 20	All locations and elevations
On-site Clay Soils	On-site soils which do not meet the Select Fill criteria above	These soils are not recommended as select fill, unless chemically treated or blended.
ODOT Type A Aggregate Base ²	GW-GC, GW-GM	All locations and elevations

1. Engineered fill should consist of approved materials that are free of organic matter and debris, and contain a maximum rock size of 3 inches. Frozen material should not be used, and fill should not be placed on a frozen subgrade. A sample of each material type should be submitted to the Geotechnical Engineer for evaluation prior to use on this site.
2. Conforming to section 703.01 of the Oklahoma Department of Transportation (ODOT) Standard Specifications for Highway Construction.

Fill Compaction Requirements

The scarified and compacted subgrade and engineering fill should be moisture conditioned and compacted using recommendations in the following table.

Item	Description
Subgrade Scarification Depth	8 inches
Maximum Fill Lift Thickness ¹	8 inches or less in loose lifts
Compaction Requirements ²	At least 95% of the material's maximum standard Proctor dry density (AASHTO T-99)
Moisture Content	<p><u>Select Fill</u>: A level within -2 to +2 percent of the material's optimum moisture content, determined in accordance with AASHTO T-99 (standard Proctor).</p> <p><u>ODOT Type A Aggregate Base</u>: Sufficient to achieve maximum density without pumping when proofrolled.</p>

1. Thinner lifts are recommended in confined areas or when hand-operated compaction equipment is used.
2. We recommend that engineered fill and scarified, compacted subgrade be tested for moisture content and compaction during placement. If the results of the in-place density tests indicate the specified moisture and compaction limits have not been met, the area represented by the test should be reworked and retested as required until the specified moisture and compaction requirements are achieved.

The recommended moisture content should be maintained in the scarified and compacted subgrade and any engineered fill until earthwork operations are completed, and pavements are constructed.

Earthwork Construction Considerations

At core/boring P-4, low strength soils were observed to a depth of 5 feet and possibly greater. Groundwater was also observed at core/boring P-4 at a depth of 3 feet. Due to the presence of the groundwater at a relatively shallow depth, it should be anticipated that special subgrade stabilization procedures, involving the use of a layer of crushed aggregate base underlain by a geogrid mat or incorporating surge rock into the subgrade, could be required at core/boring P-4 to develop a sufficiently stable subgrade for supporting new pavements. Subsurface conditions (i.e., depth of low strength, unstable soils and relatively shallow groundwater) similar to that observed at core/boring P-4 could be present at other locations. We provided subgrade stabilization options in the previous **Site Preparation** section.

Based on our experience, high moisture content and unstable soils are often found beneath pavements after demolition. If wet conditions occur during construction, the surficial soils will likely be unstable. Unstable soils should be removed and replaced with engineered fill unless they are chemically stabilized in-place.

Upon completion of filling and grading, care should be taken to maintain the subgrade water content prior to construction of pavements. Construction traffic over the completed subgrades should be avoided. The site should also be graded to prevent ponding of surface water on the prepared subgrades or in excavations. Water collecting over or adjacent to construction areas should be removed. If the subgrade freezes, desiccates, saturates, or is disturbed, the affected material should be removed, or the materials should be scarified, moisture conditioned, and recompacted prior to pavement construction.

As a minimum, excavations should be performed in accordance with OSHA 29 CFR, Part 1926, Subpart P, "Excavations" and its appendices, and in accordance with any applicable local, and/or state regulations.

Construction site safety is the sole responsibility of the contractor who controls the means, methods, and sequencing of construction operations. Under no circumstances shall the information provided herein be interpreted to mean Terracon is assuming responsibility for construction site safety, or the contractor's activities; such responsibility shall neither be implied nor inferred.

The Geotechnical Engineer should be retained during the construction phase of the project to provide observation and testing during subgrade preparation and earthwork.

PAVEMENTS

General Pavement Comments

Pavement designs are provided for the traffic conditions noted in **Project Description** and in the following sections of this report. A critical aspect of pavement performance is site preparation. We recommend pavement subgrades be prepared as discussed in the **Earthwork** section and in the following sections of this report.

Based on the results of our field exploration, subgrade soils consist mainly of clay soils (A-4, A-6, and A-7-6 AASHTO classification). Therefore, we recommend that full-depth pavement sections incorporate a layer of aggregate base beneath the pavement to improve long-term pavement support.

Full-Depth Pavement Recommendations

Our analysis is based on the 1993 AASHTO Guide for Design of Pavement Structures. Other pavement sections could be considered. The recommended pavement section is based on a 2020 Average Daily Traffic (ADT) volume of approximately 17,046 vehicles (two-way) and 5 percent truck traffic as provided by the client. For analysis purposes, the truck traffic was assumed to consist of full concrete trucks with a gross weight of 68,000 pounds or equivalent traffic loading.

Our pavement analysis is based on a 20-year traffic life and a composite modulus of subgrade reaction (k) value of 160 pci on top of the aggregate base layer for Portland cement concrete (PCC) pavement. The composite k value considers placement of a minimum of 12 inches of compacted aggregate over the stabilized and compacted subgrade soils per City of Tulsa design requirements. Periodic maintenance should be expected to realize the anticipated traffic life. Additional AASHTO pavement section design parameters used in our analysis include:

- Total ESALs = 19.35×10^6 (rigid)
- Lane Distribution Factor = 80%
- Initial Serviceability = 4.5 (rigid)
- Terminal Serviceability = 2.5
- Reliability = 85%
- Standard Deviation = 0.35 (rigid)
- Drainage Coefficient = 1.0 for Aggregate Base

The following table provides recommended thicknesses for PCC pavement.

Portland Cement Concrete Minimum Pavement Recommendations	
4,000 psi Air Entrained Portland Cement Concrete over Aggregate Base over Compacted, Stabilized Subgrade	10" Doweled, Jointed Portland Cement Concrete (PCC) (Doweled at longitudinal and transverse joints per City of Tulsa Construction Standards with tied concrete curb and gutter)
	12.0" Aggregate Base ¹
	Geotextile Separation Fabric
	8.0" Compacted Subgrade

¹. ODOT Standard Specifications.

Pavement Drainage

Pavements should be sloped to provide rapid drainage of surface water. Water allowed to pond on or adjacent to the pavements could saturate the subgrade and contribute to premature pavement deterioration.

Pavement Maintenance

The pavement sections presented above represent minimum recommended thicknesses and, as such, periodic maintenance should be anticipated. Therefore, preventive maintenance should be planned and provided for through an on-going pavement management program. Preventative maintenance activities are intended to slow the rate of pavement deterioration and to preserve the pavement investment. Preventative maintenance consists of both localized maintenance (e.g., crack and joint sealing and patching) and global maintenance (e.g., surface sealing). Preventative maintenance is usually the priority when implementing a pavement maintenance program. Prior to implementing any maintenance, additional engineering observation is recommended to determine the type and extent of a cost-effective program. Even with periodic maintenance, some movements and related cracking may still occur, and repairs may be required.

GENERAL COMMENTS

Our analysis and opinions are based upon our understanding of the project, the geotechnical conditions in the area, and the data obtained from our site exploration. Natural variations will occur between exploration point locations or due to the modifying effects of construction or weather. The nature and extent of such variations may not become evident until during or after construction. Terracon should be retained as the Geotechnical Engineer, where noted in this report, to provide observation and testing services during pertinent construction phases. If variations appear, we can provide further evaluation and supplemental recommendations. If variations are noted in the absence of our observation and testing services on-site, we should be immediately notified so that we can provide evaluation and supplemental recommendations.

Geotechnical Engineering Report

E. 91st Street S. Widening ■ Tulsa, Oklahoma
June 12, 2020 ■ Terracon Project No. 04195149



Our Scope of Services does not include either specifically or by implication any environmental or biological (e.g., mold, fungi, bacteria) assessment of the site or identification or prevention of pollutants, hazardous materials or conditions. If the owner is concerned about the potential for such contamination or pollution, other studies should be undertaken.

Our services and any correspondence or collaboration through this system are intended for the sole benefit and exclusive use of our client for specific application to the project discussed and are accomplished in accordance with generally accepted geotechnical engineering practices with no third-party beneficiaries intended. Any third-party access to services or correspondence is solely for information purposes to support the services provided by Terracon to our client. Reliance upon the services and any work product is limited to our client, and is not intended for third parties. Any use or reliance of the provided information by third parties is done solely at their own risk. No warranties, either express or implied, are intended or made.

Site characteristics as provided are for design purposes and not to estimate excavation cost. Any use of our report in that regard is done at the sole risk of the excavating cost estimator as there may be variations on the site that are not apparent in the data that could significantly impact excavation cost. Any parties charged with estimating excavation costs should seek their own site characterization for specific purposes to obtain the specific level of detail necessary for costing. Site safety, and cost estimating including, excavation support, and dewatering requirements/design are the responsibility of others. If changes in the nature, design, or location of the project are planned, our conclusions and recommendations shall not be considered valid unless we review the changes and either verify or modify our conclusions in writing.

ATTACHMENTS

EXPLORATION AND TESTING PROCEDURES

Field Exploration

Number of Cores/Borings	Core/Boring Depth (feet)	Core/Boring Location
7 (P-1 to P-7)	5	Along E. 91 st Street S.

Boring Layout and Elevations: The core/boring locations were laid out in the field by a Terracon representative using a handheld GPS unit. Ground surface elevations were not determined at the core/boring locations. The locations of the cores/borings should be considered accurate only to the degree implied by the means and methods used to define them.

Subsurface Exploration Procedures: We used a core machine with a diamond-bit core barrel to core the pavement. After coring, we advanced the cores/borings with a truck-mounted rotary drill rig using continuous flight augers. Samples of the soils encountered in the cores/borings were obtained using the split-barrel sampling procedure. In the split-barrel sampling procedure, a standard 2-inch outer diameter split-barrel sampling spoon was driven into the ground by a 140-pound automatic hammer falling a distance of 30 inches. The number of blows required to advance the sampling spoon the last 12 inches of a normal 18-inch penetration is recorded as the Standard Penetration Test (SPT) resistance value. The SPT resistance values, also referred to as N-values, are indicated on the boring logs at the test depths. These values are used to estimate the in-situ relative density of cohesionless soils and consistency of cohesive soils. The samples were tagged for identification, sealed to reduce moisture loss, and transported to our laboratory for examination, testing, and classification. In addition, we observed and recorded groundwater levels during drilling and sampling, and immediately after completion of drilling. For safety purposes, all cores/borings were backfilled with sand, auger cuttings, and/or bentonite chips and capped with cold-mix asphalt or quick-set grout after their completion.

The sampling depths, penetration distances, and other sampling information was recorded on the field logs. Our exploration team prepared field logs as part of the drilling operations. These field logs included visual classifications of the materials encountered during drilling and the driller's interpretation of the subsurface conditions between samples. Final core/boring logs were prepared from the field logs. The final core/boring logs represent the Geotechnical Engineer's interpretation of the subsurface conditions encountered at the core/boring locations based on field and laboratory data and observation of the samples.

Laboratory Testing

The project engineer reviewed the field data and assigned laboratory tests to understand the engineering properties of the various soil strata, as necessary, for this project. Samples obtained from the site were tested for the following engineering properties:

- Water (moisture) content
- Atterberg limits
- Particle-size analysis

The laboratory testing program often included examination of soil samples by an engineer. Based on the material's texture and plasticity, we described and classified the soil samples in accordance with the Unified Soil Classification System.

The laboratory testing program included examination of soil samples by an engineer. Based on the material's texture and plasticity, we described and classified the soil samples in accordance with the Unified Soil Classification System (USCS) and American Association of State Highway and Transportation Officials (AASHTO) classification system described in the **Supporting Information** section.

SITE LOCATION AND EXPLORATION PLANS

Contents:

Site Location Plan

Exploration Plan (2 pages)

Note: All attachments are one page unless noted above.

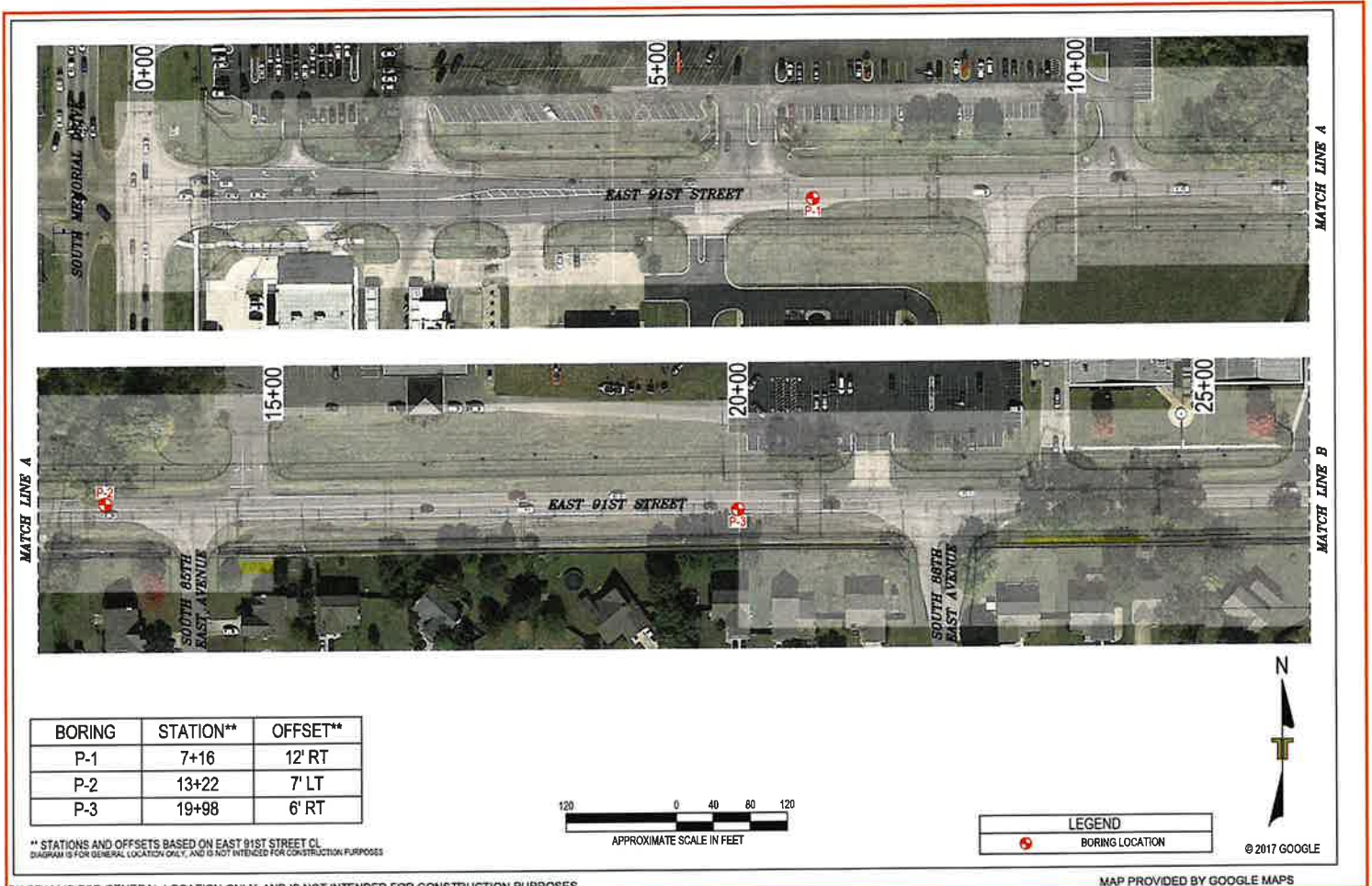
SITE LOCATION

E. 91st Street S. Widening ■ Tulsa, Oklahoma
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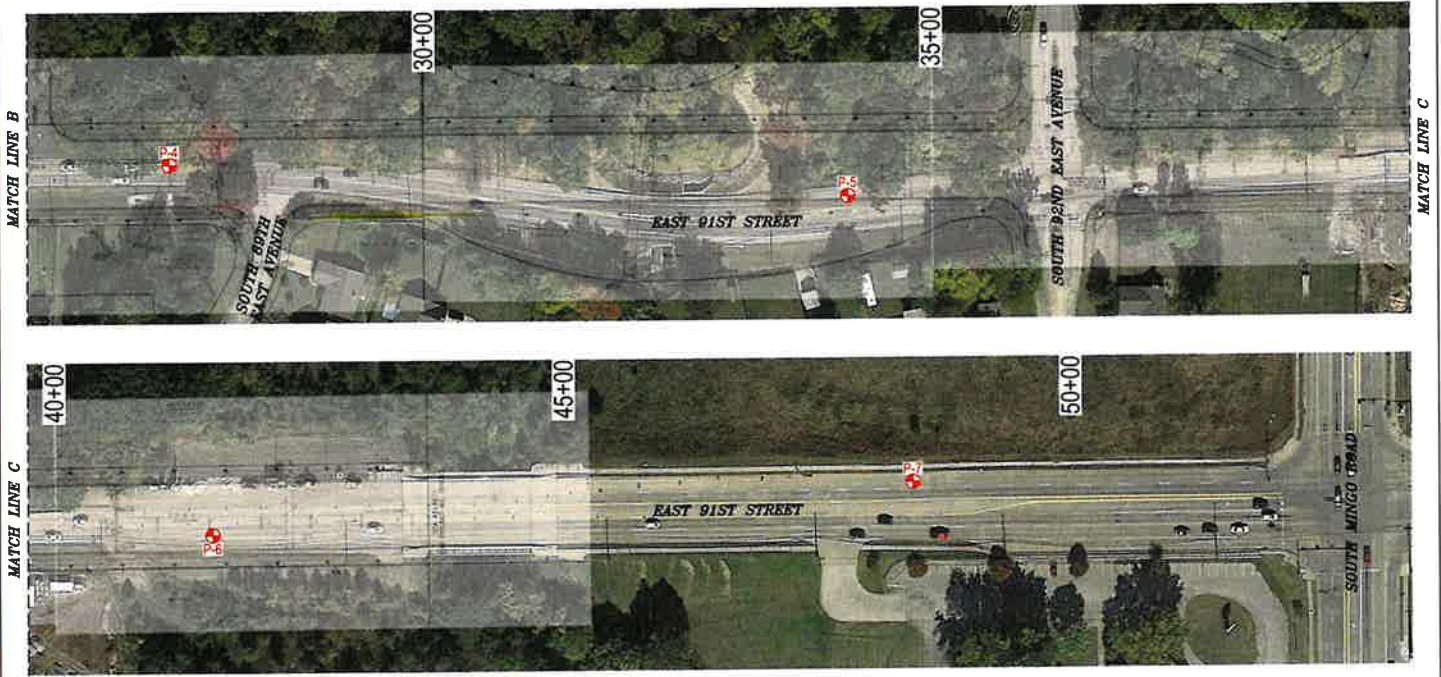
EXPLORATION PLAN

E. 91st Street S. Widening ■ Tulsa, Oklahoma
 June 12, 2020 ■ Terracon Project No. 04195149



EXPLORATION PLAN

E. 91st Street S. Widening ■ Tulsa, Oklahoma
 June 12, 2020 ■ Terracon Project No. 04195149



BORING	STATION**	OFFSET**
P-4	27+50	8' LT
P-5	34+17	30' RT
P-6	41+54	18' RT
P-7	48+46	29' LT

** STATIONS AND OFFSETS BASED ON EAST 91ST STREET CL.
 DIAGRAM IS FOR GENERAL LOCATION ONLY, AND IS NOT INTENDED FOR CONSTRUCTION PURPOSES



LEGEND	
	BORING LOCATION



© 2017 GOOGLE

DIAGRAM IS FOR GENERAL LOCATION ONLY, AND IS NOT INTENDED FOR CONSTRUCTION PURPOSES

MAP PROVIDED BY GOOGLE MAPS

EXPLORATION RESULTS

Contents:

Core/Boring Logs with Pavement Core Photographs (P-1 through P-7)
Grain Size Distribution (2 pages)

Note: All attachments are one page unless noted above.

BORING LOG NO. P-1

PROJECT: E. 91st Street S. Widening

CLIENT: Garver, LLC
Tulsa, Oklahoma

SITE: E. 91st Street S.: Memorial Drive to Mingo Road
Tulsa, Oklahoma

GRAPHIC LOG	LOCATION See Exploration Plan Latitude: 36.0318° Longitude: -95.8839° Station: 7+16 Offset: 12' RT	DEPTH (FL)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (in.)	FIELD TEST RESULTS	ATTERBERG LIMITS		PERCENT FINES
							WATER CONTENT (%)	LL-PL-PI	
0.9	11-1/2" ASPHALT								
1.3	4" PULVERIZED ASPHALT AND SOIL MIXTURE								
5.0	FAT CLAY (CH) , gray with olive brown to yellow brown, stiff to very stiff - A-7-6 (31)				18	2-3-5 N=8	24	51-17-34	87
5.0	Boring Terminated at 5 Feet	5			17	5-7-10 N=17	20		

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL_04195149 91ST STREET WIDEN.GPJ TERRACON_DATATEMPLATE.GDT 5/8/20



Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic
+Classification estimated from disturbed samples. Core samples and petrographic analysis may reveal other rock types.

Advancement Method:
Diamond Core Bit thru Asphalt, Power Auger below Asphalt

Abandonment Method:
Boring backfilled with sand; Surface capped with asphalt upon completion.

See [Exploration and Testing Procedures](#) for a description of field and laboratory procedures used and additional data (if any).

See [Supporting Information](#) for explanation of symbols and abbreviations.

Notes:

WATER LEVEL OBSERVATIONS

Not Encountered While Drilling

Not Encountered After Boring

9522 E 47th Pl, Ste D
Tulsa, OK

Boring Started: 04-29-2020

Drill Rig: ATV 747

Project No.: 04195149

Boring Completed: 04-29-2020

Driller: RP

BORING LOG NO. P-2

PROJECT: E. 91st Street S. Widening

CLIENT: Garver, LLC
Tulsa, Oklahoma

SITE: E. 91st Street S.: Memorial Drive to Mingo Road
Tulsa, Oklahoma

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL 04195149 91ST STREET WIDEN.GPJ TERRACON_DATATEMPLATE.GDT 5/8/20

GRAPHIC LOG	LOCATION See Exploration Plan Latitude: 36.0319° Longitude: -95.8819° Station: 13+22 Offset: 7' LT	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	WATER CONTENT (%)		PERCENT FINES
							ATTERBERG LIMITS		
							LL-PL-PI		
16-3/4" ASPHALT									
1.4	LEAN CLAY , with sand, brown to brown gray, medium stiff								
- A-4 (6)					15	5-3-3 N=6	19	27-18-9	82
3.5	LEAN CLAY (CL) , dark gray with olive brown to yellow brown, stiff								
5.0	Boring Terminated at 5 Feet	5				18	4-5-7 N=12	20	



Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic
+Classification estimated from disturbed samples. Core samples and petrographic analysis may reveal other rock types.

Advancement Method:
Diamond Core Bit thru Asphalt, Power Auger below Asphalt

See [Exploration and Testing Procedures](#) for a description of field and laboratory procedures used and additional data (if any).

Notes:

Abandonment Method:
Boring backfilled with sand; Surface capped with asphalt upon completion.

See [Supporting Information](#) for explanation of symbols and abbreviations.

WATER LEVEL OBSERVATIONS

Not Encountered While Drilling
Not Encountered After Boring



Boring Started: 04-29-2020

Boring Completed: 04-29-2020

Drill Rig: ATV 747

Driller: RP

Project No.: 04195149

BORING LOG NO. P-3

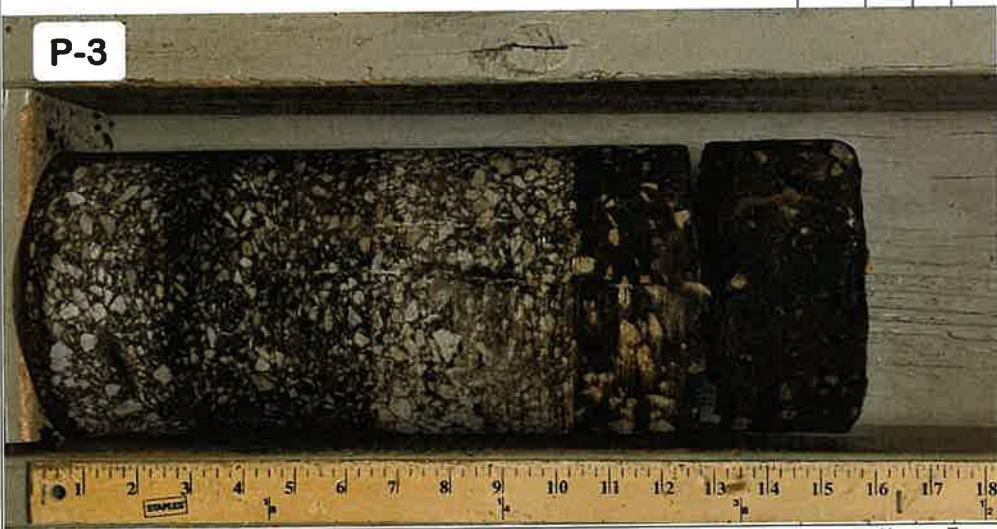
PROJECT: E. 91st Street S. Widening

CLIENT: Garver, LLC
Tulsa, Oklahoma

SITE: E. 91st Street S.: Memorial Drive to Mingo Road
Tulsa, Oklahoma

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL 04195149 91ST STREET WIDEN GPJ TERRACON_DATATEMPLATE.GDT 5/8/20

GRAPHIC LOG	LOCATION See Exploration Plan Latitude: 36.0319° Longitude: -95.8796° Station: 19+98 Offset: 6' RT	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (in.)	FIELD TEST RESULTS	WATER CONTENT (%)		PERCENT FINES
							ATTERBERG LIMITS		
							LL-PL-PI		
0.8	10-1/4" ASPHALT								
1.3	5-1/4" PULVERIZED ASPHALT AND SOIL MIXTURE								
3.0	LEAN CLAY , with sand, dark brown gray, medium stiff				16	2-3-4 N=7	22		
5.0	LEAN CLAY , gray with olive brown to yellow brown, stiff - A-7-6 (29)				12	4-7-8 N=15	23	47-16-31	91
	Boring Terminated at 5 Feet	5							



Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic
+Classification estimated from disturbed samples. Core samples and petrographic analysis may reveal other rock types.

Advancement Method:
Diamond Core Bit thru Asphalt, Power Auger below Asphalt

Abandonment Method:
Boring backfilled with sand; Surface capped with asphalt upon completion.

See [Exploration and Testing Procedures](#) for a description of field and laboratory procedures used and additional data (If any).

See [Supporting Information](#) for explanation of symbols and abbreviations.

Notes:

WATER LEVEL OBSERVATIONS

Not Encountered While Drilling

Not Encountered After Boring



Boring Started: 04-29-2020	Boring Completed: 04-29-2020
Drill Rig: ATV 747	Driller: RP
Project No.: 04195149	

BORING LOG NO. P-4

PROJECT: E. 91st Street S. Widening

CLIENT: Garver, LLC
Tulsa, Oklahoma

SITE: E. 91st Street S.: Memorial Drive to Mingo Road
Tulsa, Oklahoma

GRAPHIC LOG	LOCATION See Exploration Plan Latitude: 36.0319° Longitude: -95.877° Station: 27+50 Offset: 8' LT	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	ATTERBERG LIMITS		PERCENT FINES
							WATER CONTENT (%)	LL-PL-PI	
14" ASPHALT									
8" CHEMICALLY TREATED SOIL SUBGRADE		1.2							
LEAN CLAY (CL), brown to dark brown gray, soft - A-4 (8)		1.8							
		5.0	▽		13	6-2-1 N=3	21	30-20-10	90
					18	1-1-1 N=2	30		
Boring Terminated at 5 Feet		5							



Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic
+Classification estimated from disturbed samples. Core samples and petrographic analysis may reveal other rock types.

Advancement Method:
Diamond Core Bit thru Asphalt, Power Auger below Asphalt

Abandonment Method:
Boring backfilled with sand; Surface capped with asphalt upon completion.

See [Exploration and Testing Procedures](#) for a description of field and laboratory procedures used and additional data (if any).

See [Supporting Information](#) for explanation of symbols and abbreviations.

Notes:

WATER LEVEL OBSERVATIONS
▽ 3 Feet While Drilling
▽ 3 Feet After Boring

9522 E 47th Pl, Ste D
Tulsa, OK

Boring Started: 04-29-2020	Boring Completed: 04-29-2020
Drill Rig: ATV 747	Driller: RP
Project No.: 04195149	

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL_ 04195149 91ST STREET WIDEN GPJ TERRACON_DATATEMPLATE.GDT 5/8/20

BORING LOG NO. P-5

PROJECT: E. 91st Street S. Widening

CLIENT: Garver, LLC
Tulsa, Oklahoma

SITE: E. 91st Street S.: Memorial Drive to Mingo Road
Tulsa, Oklahoma

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL_04195149 91ST STREET WIDEN.GPJ TERRACON_DATATEMPLATE.GDT 5/8/20

GRAPHIC LOG	LOCATION See Exploration Plan Latitude: 36.0318° Longitude: -95.8748° Station: 34+17 Offset: 30' RT	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	ATTERBERG LIMITS		PERCENT FINES
							WATER CONTENT (%)	LL-PL-PI	
	12-1/2" ASPHALT								
	1.0								
	4" CHEMICALLY TREATED SOIL SUBGRADE								
	1.4								
	LEAN CLAY (CL) , dark gray to dark gray brown, stiff								
	3.5				18	6-7-7 N=14	19		
	LEAN CLAY (CL) , brown to yellow brown with gray brown, very stiff								
	- A-7-6 (25)				13	8-8-9 N=17	20	41-15-26	94
	5.0	5							
	Boring Terminated at 5 Feet								



Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic
+Classification estimated from disturbed samples. Core samples and petrographic analysis may reveal other rock types.

Advancement Method:
Diamond Core Bit thru Asphalt, Power Auger below Asphalt

See [Exploration and Testing Procedures](#) for a description of field and laboratory procedures used and additional data (if any).

Notes:

Abandonment Method:
Boring backfilled with sand; Surface capped with asphalt upon completion.

See [Supporting Information](#) for explanation of symbols and abbreviations.

WATER LEVEL OBSERVATIONS

Not Encountered While Drilling
Not Encountered After Boring



Boring Started: 04-29-2020

Boring Completed: 04-29-2020

Drill Rig: ATV 747

Driller: RP

Project No.: 04195149

BORING LOG NO. P-6

PROJECT: E. 91st Street S. Widening

CLIENT: Garver, LLC
Tulsa, Oklahoma

SITE: E. 91st Street S.: Memorial Drive to Mingo Road
Tulsa, Oklahoma

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL 04195149 91ST STREET WIDEN.GPJ TERRACON_DATATEMPLATE.GDT 5/8/20

GRAPHIC LOG	LOCATION See Exploration Plan Latitude: 36.0319° Longitude: -95.8723° Station: 41+54 Offset: 18' RT	DEPTH (ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	WATER CONTENT (%)	ATTERBERG LIMITS LL-PL-PI	PERCENT FINES
0.5	6" ASPHALT								
1.1	7" PULVERIZED ASPHALT AND SOIL MIXTURE								
5.0	FILL - LEAN CLAY , with sand, dark brown gray to brown - A-6 (8)				14	8-9-10 N=19	15	28-17-11	85
5.0	Boring Terminated at 5 Feet	5			13	9-8-8 N=16	19		



Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic
+Classification estimated from disturbed samples. Core samples and petrographic analysis may reveal other rock types.

Advancement Method:
Diamond Core Bit thru Asphalt, Power Auger below Asphalt

See [Exploration and Testing Procedures](#) for a description of field and laboratory procedures used and additional data (if any).

Notes:

Abandonment Method:
Boring backfilled with sand; Surface capped with asphalt upon completion.

See [Supporting Information](#) for explanation of symbols and abbreviations.

WATER LEVEL OBSERVATIONS
Not Encountered While Drilling
Not Encountered After Boring

9522 E 47th Pl, Ste D
Tulsa, OK

Boring Started: 04-29-2020
Drill Rig: ATV 747
Project No.: 04195149

Boring Completed: 04-29-2020
Driller: RP


BORING LOG NO. P-7

PROJECT: E. 91st Street S. Widening

CLIENT: Garver, LLC
Tulsa, Oklahoma

SITE: E. 91st Street S.: Memorial Drive to Mingo Road
Tulsa, Oklahoma

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL 04195149 91ST STREET WIDEN.GPJ TERRACON_DATATEMPLATE.GDT 5/8/20

GRAPHIC LOG	LOCATION See Exploration Plan Latitude: 36.032° Longitude: -95.67° Station: 48+46 Offset: 29' LT	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	WATER CONTENT (%)	ATTERBERG LIMITS LL-PL-PI	PERCENT FINES
DEPTH									
	10-1/2" CONCRETE								
0.9									
	8-1/2" CHEMICALLY TREATED CLAY SUBGRADE								
1.6									
	FILL - SANDY LEAN CLAY (CL) , dark gray with gray brown								
- A-6 (4)									
3.5									
	SANDY LEAN CLAY (CL) , light brown to brown gray, very stiff								
5.0									
Boring Terminated at 5 Feet		5							
									

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic
+Classification estimated from disturbed samples. Core samples and petrographic analysis may reveal other rock types.

Advancement Method:
Diamond Core Bit thru Asphalt, Power Auger below Asphalt

See **Exploration and Testing Procedures** for a description of field and laboratory procedures used and additional data (if any).

Notes:

Abandonment Method:
Boring backfilled with sand; Surface capped with asphalt upon completion.

See **Supporting Information** for explanation of symbols and abbreviations.

WATER LEVEL OBSERVATIONS
Not Encountered While Drilling
Not Encountered After Boring

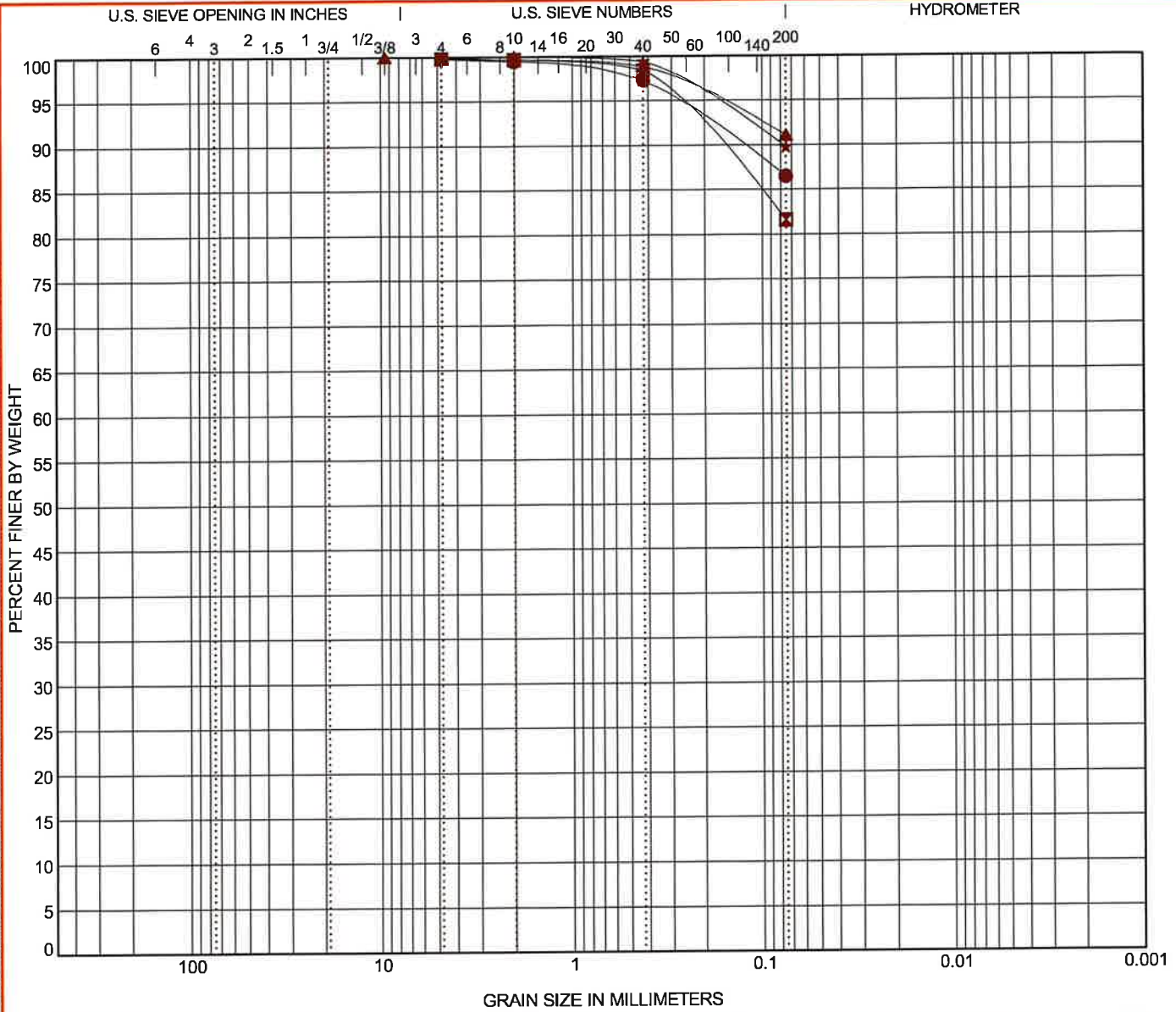
9522 E 47th Pl, Ste D
Tulsa, OK

Boring Started: 04-29-2020
Drill Rig: ATV 747
Project No.: 04195149

Boring Completed: 04-29-2020
Driller: RP

GRAIN SIZE DISTRIBUTION

ASTM D422 / ASTM C136



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Boring ID	Depth	USCS Classification	AASHTO Classification	WC (%)	LL	PL	PI	Cc	Cu
● P-1	2 - 3.5	FAT CLAY (CH)	A-7-6 (31)	24	51	17	34		
☒ P-2	2 - 3.5	LEAN CLAY with SAND (CL)	A-4 (6)	19	27	18	9		
▲ P-3	3.5 - 5	LEAN CLAY (CL)	A-7-6 (29)	23	47	16	31		
★ P-4	2 - 3.5	LEAN CLAY (CL)	A-4 (8)	21	30	20	10		

Boring ID	Depth	D ₁₀₀	D ₆₀	D ₃₀	D ₁₀	%Gravel	%Sand	%Silt	%Fines	%Clay
● P-1	2 - 3.5	4.75					13.3		86.5	
☒ P-2	2 - 3.5	4.75					18.2		81.6	
▲ P-3	3.5 - 5	9.5				0.1	8.8		91.1	
★ P-4	2 - 3.5	2				0.0	10.2		89.8	

PROJECT: E. 91st Street S. Widening

SITE: E. 91st Street S.: Memorial Drive to Mingo Road
Tulsa, Oklahoma



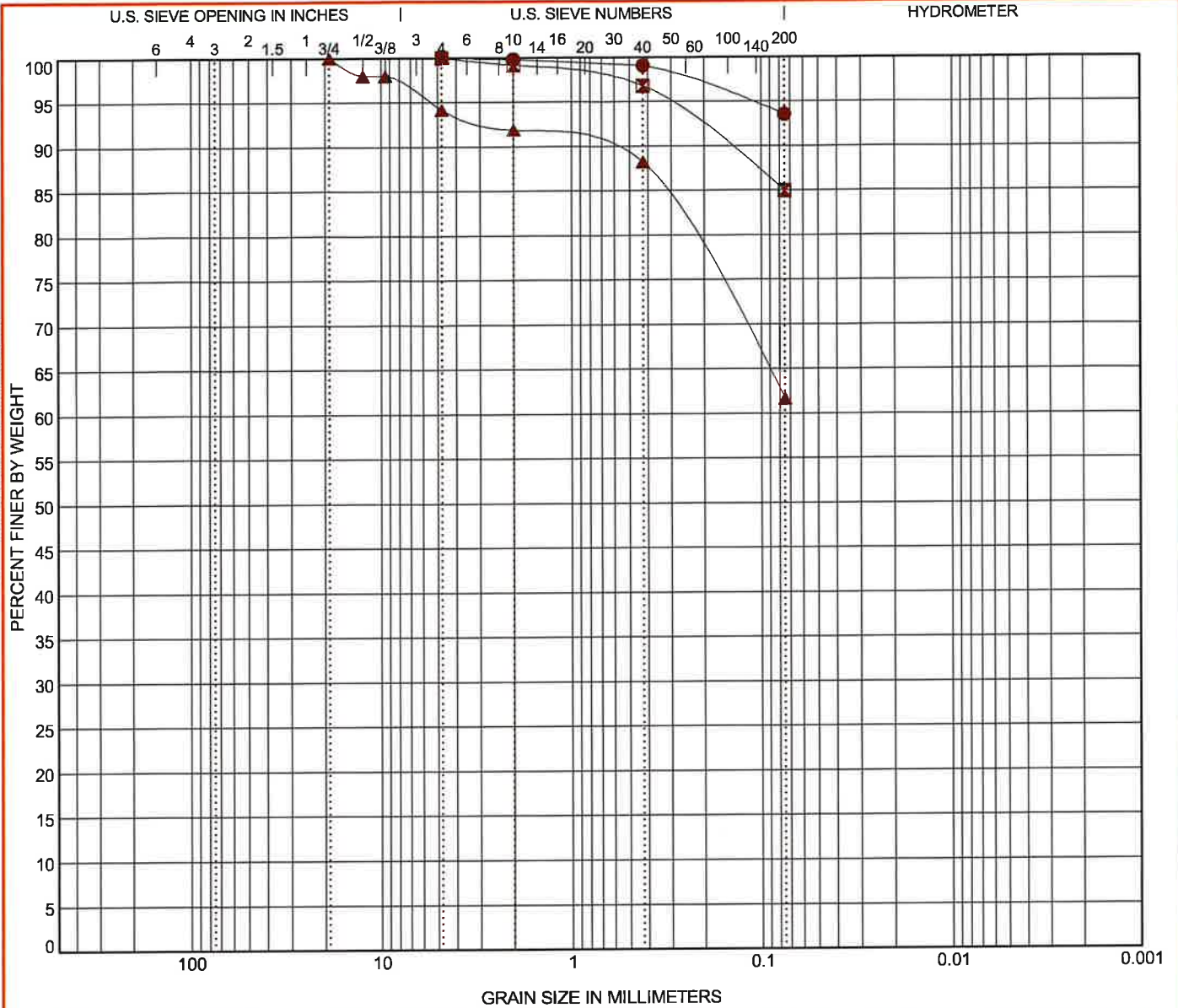
PROJECT NUMBER: 04195149

CLIENT: Garver, LLC
Tulsa, Oklahoma

LABORATORY TESTS ARE NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GRAIN SIZE: USCS & AASHTO DESC COMBINED 04195149 91ST STREET WIDEN.GPJ TERRACON_DATATEMPLATE.GDT 05/06/20

GRAIN SIZE DISTRIBUTION

ASTM D422 / ASTM C136



SUPPORTING INFORMATION

Contents:







General Notes
Unified Soil Classification System
AASHTO Classification System

Note: All attachments are one page unless noted above.

GENERAL NOTES

DESCRIPTION OF SYMBOLS AND ABBREVIATIONS

E. 91st Street S. Widening ■ Tulsa, Oklahoma
Terracon Project No. 04195149

SAMPLING	WATER LEVEL	FIELD TESTS
 Rock Core  Standard Penetration Test	 Water Initially Encountered  Water Level After a Specified Period of Time  Water Level After a Specified Period of Time  Cave In Encountered Water levels indicated on the soil boring logs are the levels measured in the borehole at the times indicated. Groundwater level variations will occur over time. In low permeability soils, accurate determination of groundwater levels is not possible with short term water level observations.	N Standard Penetration Test Resistance (Blows/Ft.) (HP) Hand Penetrometer (T) Torvane (DCP) Dynamic Cone Penetrometer UC Unconfined Compressive Strength (PID) Photo-Ionization Detector (OVA) Organic Vapor Analyzer

DESCRIPTIVE SOIL CLASSIFICATION

Soil classification as noted on the soil boring logs is based Unified Soil Classification System. Where sufficient laboratory data exist to classify the soils consistent with ASTM D2487 "Classification of Soils for Engineering Purposes" this procedure is used. ASTM D2488 "Description and Identification of Soils (Visual-Manual Procedure)" is also used to classify the soils, particularly where insufficient laboratory data exist to classify the soils in accordance with ASTM D2487. In addition to USCS classification, coarse grained soils are classified on the basis of their in-place relative density, and fine-grained soils are classified on the basis of their consistency. See "Strength Terms" table below for details. The ASTM standards noted above are for reference to methodology in general. In some cases, variations to methods are applied as a result of local practice or professional judgment.

LOCATION AND ELEVATION NOTES

Exploration point locations as shown on the Exploration Plan and as noted on the soil boring logs in the form of Latitude and Longitude are approximate. See [Exploration and Testing Procedures](#) in the report for the methods used to locate the exploration points for this project. Surface elevation data annotated with +/- indicates that no actual topographical survey was conducted to confirm the surface elevation. Instead, the surface elevation was approximately determined from topographic maps of the area.

STRENGTH TERMS

RELATIVE DENSITY OF COARSE-GRAINED SOILS (More than 50% retained on No. 200 sieve.) Density determined by Standard Penetration Resistance		CONSISTENCY OF FINE-GRAINED SOILS (50% or more passing the No. 200 sieve.) Consistency determined by laboratory shear strength testing, field visual-manual procedures or standard penetration resistance		
Descriptive Term (Density)	Standard Penetration or N-Value Blows/Ft.	Descriptive Term (Consistency)	Unconfined Compressive Strength Qu, (psi)	Standard Penetration or N-Value Blows/Ft.
Very Loose	0 - 3	Very Soft	less than 3.50	0 - 1
Loose	4 - 9	Soft	3.5 to 7.0	2 - 4
Medium Dense	10 - 29	Medium Stiff	7.0 to 14.0	4 - 8
Dense	30 - 50	Stiff	14.0 to 28.0	8 - 15
Very Dense	> 50	Very Stiff	28.0 to 55.5	15 - 30
		Hard	> 55.5	> 30

RELEVANCE OF SOIL BORING LOG

The soil boring logs contained within this document are intended for application to the project as described in this document. Use of these soil boring logs for any other purpose may not be appropriate.

Criteria for Assigning Group Symbols and Group Names Using Laboratory Tests ^A				Soil Classification	
				Group Symbol	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	$Cu \geq 4$ and $1 \leq Cc \leq 3$ ^E	GW	Well-graded gravel ^F
		Gravels with Fines: More than 12% fines ^C	$Cu < 4$ and/or $[Cc < 1$ or $Cc > 3.0]$ ^E	GP	Poorly graded gravel ^F
			Fines classify as ML or MH	GM	Silty gravel ^{F, G, H}
		Sands: 50% or more of coarse fraction passes No. 4 sieve	Clean Sands: Less than 5% fines ^D	$Cu \geq 6$ and $1 \leq Cc \leq 3$ ^E	SW
	$Cu < 6$ and/or $[Cc < 1$ or $Cc > 3.0]$ ^E			SP	Poorly graded sand ^I
	Sands with Fines: More than 12% fines ^D		Fines classify as ML or MH	SM	Silty sand ^{G, H, I}
			Fines classify as CL or CH	SC	Clayey sand ^{G, H, 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	CL
$PI < 4$ or plots below "A" line ^J				ML	Silt ^{K, L, M}
Organic:			Liquid limit - oven dried < 0.75	OL	Organic clay ^{K, L, M, N}
			Liquid limit - not dried < 0.75		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:	Liquid limit - oven dried < 0.75	OH	Organic clay ^{K, L, M, P}
			Liquid limit - not dried < 0.75		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 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.

$$E \quad Cu = D_{60}/D_{10} \quad Cc = \frac{(D_{30})^2}{D_{10} \times D_{60}}$$

^F If soil contains $\geq 15\%$ sand, add "with sand" to group name.

^G If fines classify as CL-ML, use dual symbol GC-GM, or SC-SM.

^H If fines are organic, add "with organic fines" to group name.

^I If soil contains $\geq 15\%$ gravel, add "with gravel" to group name.

^J If Atterberg limits plot in shaded area, soil is a CL-ML, silty clay.

^K If soil contains 15 to 29% plus No. 200, add "with sand" or "with gravel," whichever is predominant.

^L If soil contains $\geq 30\%$ plus No. 200 predominantly sand, add "sandy" to group name.

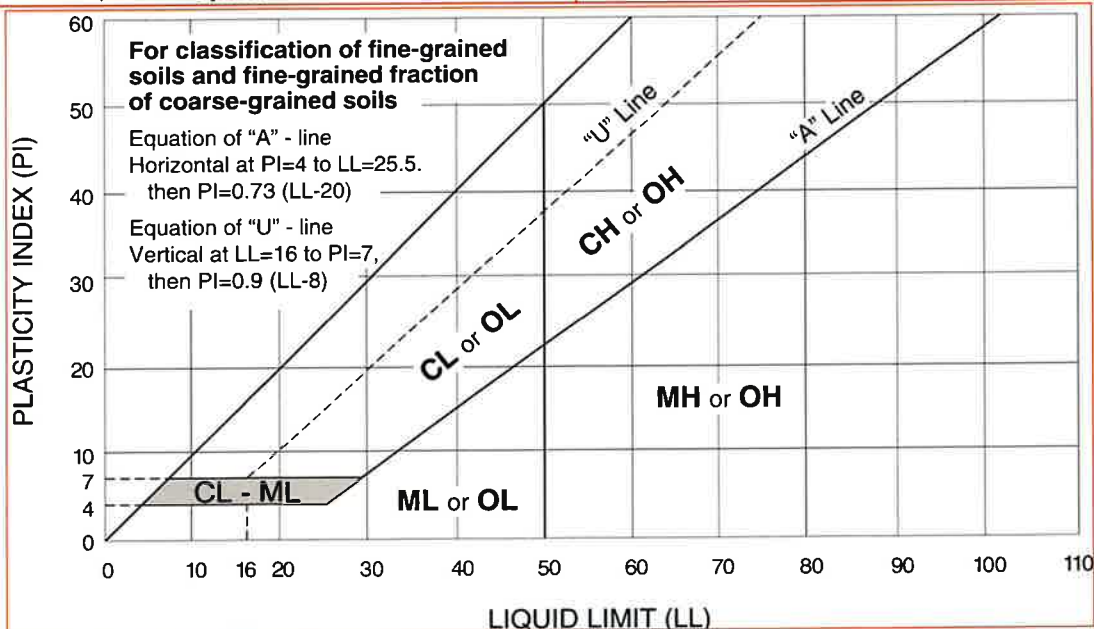
^M If soil contains $\geq 30\%$ plus No. 200, predominantly gravel, add "gravelly" to group name.

^N $PI \geq 4$ 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.



AASHTO SOIL CLASSIFICATION SYSTEM

GENERAL CLASSIFICATION	GRANULAR MATERIALS (35% OR LESS PASSING 0.075 SIEVE)						SILT-CLAY MATERIALS (MORE THAN 35% PASSING 0.075 SIEVE)				
GROUP CLASSIFICATION	A-1		A-3	A-2				A-4	A-5	A-6	A-7-5 A-7-6
	A-1-a	A-1-b		A-2-4	A-2-5	A-2-6	A-2-7				
SIEVE ANALYSIS, PERCENT PASSING: 2.00 mm (No. 10) 0.425 mm (No. 40) 0.075 mm (No. 200)	≤ 50	—	—	—	—	—	—	—	—	—	—
	≤ 30	≤ 50	≥ 51	—	—	—	—	—	—	—	—
	≤ 15	≤ 25	≤ 10	≤ 35	≤ 35	≤ 35	≤ 35	≥ 36	≥ 36	≥ 36	≥ 36
CHARACTERISTICS OF FRACTION PASSING 0.425 SIEVE (No. 40): LIQUID LIMIT PLASTICITY INDEX *	— 6 max		— NP	≤ 40 ≤ 10	≥ 41 ≤ 10	≤ 40 ≥ 11	≥ 41 ≥ 11	≤ 40 ≤ 10	≥ 41 ≤ 10	≤ 40 ≥ 11	≥ 41 ≥ 11
USUAL TYPES OF CONSTITUENT MATERIALS	STONE FRAGM.TS. GRAVEL, SAND		FINE SAND	SILTY OR CLAYEY GRAVEL AND SAND				SILTY SOILS		CLAYEY SOILS	
GENERAL RATING AS A SUBGRADE	EXCELLENT TO GOOD						FAIR TO POOR				

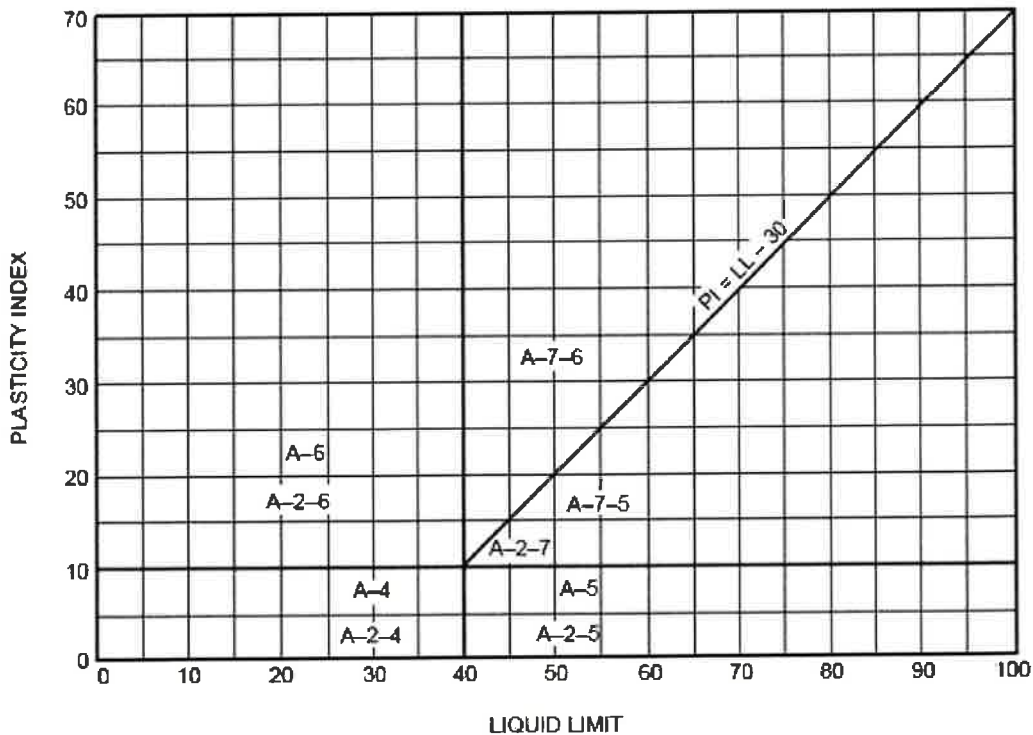
*Plasticity index of A-7-5 subgroup is equal to or less than LL-30. Plasticity index of A-7-6 subgroup is greater than LL-30.
NP = Non-plastic (use '0'). Symbol '-' means that the particular sieve analysis is not considered for that classification.

If the soil classification is A4-A7, then calculate the group index (GI) as shown below and report with classification. The higher the GI, the less suitable the soil. Example: A-6 with GI = 15 is less suitable than A-6 with GI = 10.

$$GI = (F - 35) [0.2 + 0.005 (LL - 40)] + 0.01 (F - 15) (PI - 10)$$

- where: F = Percent passing No. 200 sieve, expressed as a whole number. This percentage is based only on the material passing the No. 200 sieve.
LL = Liquid limit
PI = Plasticity index

If the computed value of GI < 0, then use GI = 0.



GENERAL NOTES

Sedimentary Rock Classification

DESCRIPTIVE ROCK CLASSIFICATION:

Sedimentary rocks are composed of cemented clay, silt and sand sized particles. The most common minerals are clay, quartz and calcite. Rock composed primarily of calcite is called limestone; rock of sand size grains is called sandstone, and rock of clay and silt size grains is called mudstone or claystone, siltstone, or shale. Modifiers such as shaly, sandy, dolomitic, calcareous, carbonaceous, etc. are used to describe various constituents. Examples: sandy shale; calcareous sandstone.

- LIMESTONE** Light to dark colored, crystalline to fine-grained texture, composed of CaCO₃, reacts readily with HCl.
- DOLOMITE** Light to dark colored, crystalline to fine-grained texture, composed of CaMg(CO₃)₂, harder than limestone, reacts with HCl when powdered.
- CHERT** Light to dark colored, very fine-grained texture, composed of micro-crystalline quartz (SiO₂), brittle, breaks into angular fragments, will scratch glass.
- SHALE** Very fine-grained texture, composed of consolidated silt or clay, bedded in thin layers. The unlaminated equivalent is frequently referred to as siltstone, claystone or mudstone.
- SANDSTONE** Usually light colored, coarse to fine texture, composed of cemented sand size grains of quartz, feldspar, etc. Cement usually is silica but may be such minerals as calcite, iron-oxide, or some other carbonate.
- CONGLOMERATE** Rounded rock fragments of variable mineralogy varying in size from near sand to boulder size but usually pebble to cobble size (½ inch to 6 inches). Cemented together with various cementing agents. Breccia is similar but composed of angular, fractured rock particles cemented together.

PHYSICAL PROPERTIES:

DEGREE OF WEATHERING

- Slight** Slight decomposition of parent material on joints. May be color change.
- Moderate** Some decomposition and color change throughout.
- High** Rock highly decomposed, may be extremely broken.

HARDNESS AND DEGREE OF CEMENTATION

Limestone and Dolomite:

- Hard** Difficult to scratch with knife.
- Moderately Hard** Can be scratched easily with knife, cannot be scratched with fingernail.
- Soft** Can be scratched with fingernail.

Shale, Siltstone and Claystone

- Hard** Can be scratched easily with knife, cannot be scratched with fingernail.
- Moderately Hard** Can be scratched with fingernail.
- Soft** Can be easily dented but not molded with fingers.

Sandstone and Conglomerate

- Well Cemented** Capable of scratching a knife blade.
- Cemented** Can be scratched with knife.
- Poorly Cemented** Can be broken apart easily with fingers.

BEDDING AND JOINT CHARACTERISTICS

Bed Thickness	Joint Spacing	Dimensions
Very Thick	Very Wide	> 10'
Thick	Wide	3' - 10'
Medium	Moderately Close	1' - 3'
Thin	Close	2" - 1'
Very Thin	Very Close	.4" - 2"
Laminated	—	.1" - .4"

Bedding Plane A plane dividing sedimentary rocks of the same or different lithology.

Joint Fracture in rock, generally more or less vertical or transverse to bedding, along which no appreciable movement has occurred.

Seam Generally applies to bedding plane with an unspecified degree of weathering.

SOLUTION AND VOID CONDITIONS

- Solid** Contains no voids.
- Vuggy (Pitted)** Rock having small solution pits or cavities up to ½ inch diameter, frequently with a mineral lining.
- Porous** Containing numerous voids, pores, or other openings, which may or may not interconnect.
- Cavernous** Containing cavities or caverns, sometimes quite large.

