Geotechnical Engineering Report

Retaining Walls
Interstate 35 over Waterloo Road
Oklahoma and Logan Counties, Oklahoma
Engineering Contract No. EC-1500N

Job Piece No. 29843(04)

September 11, 2020
Terracon Project No. 03205038 Rev. 1

Prepared for:
Garver, LLC
Tulsa, Oklahoma

Prepared by:
Terracon Consultants, Inc.
Oklahoma City, Oklahoma

September 11, 2020

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

Attn: Mr. Jenny Sallee
P: [918] 858 4166
E: jesallee@garverusa.com

Re: Geotechnical Engineering Report
Retaining Walls
Interstate 35 over Waterloo Road
Oklahoma and Logan Counties, Oklahoma
Job Piece No. 29843(04)
Engineering Contract No. EC-1500N
Terracon Project No. 03205038 Rev. 1

Dear Ms. Sallee:

Terracon Consultants, Inc. (Terracon) has completed the geotechnical engineering services for the above referenced project. The scope of our services was outlined in Engineering Contract No. EC-1500N. We were given authorization to proceed on February 12, 2020.

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 us.

Sincerely,
Terracon Consultants, Inc.
Cert. Of Auth. #CA-4531 exp. 6/30/21

REGISTERED PROFESSIONAL ENGINEER
JEFFERY LYNN DEAN
16998
OKLAHOMA

Jeffery Dean, P.E.
Oklahoma No. 16998

Norman Tan, P.E.
Department Manager

9/14/2020
JD:NT\kld\n:\projects\2020\03205038\project documents\jul2020

Copies to: Addressee (1 via email)

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GEOTECHNICAL ENGINEERING REPORT
RETAINING WALLS
INTERSTATE 35 OVER WATERLOO ROAD
OKLAHOMA AND LOGAN COUNTIES, OKLAHOMA
ENGINEERING CONTRACT NO. EC-1500N
JOB PIECE NO. 29843(04)

Terracon Project No. 03205038 Rev. 1

September 11, 2020

1.0 INTRODUCTION

This report presents the results of our geotechnical engineering services performed for the proposed retaining walls that are part of the bridge replacement project at the interchange of Interstate 35 over Waterloo Road at the Oklahoma and Logan County line in Oklahoma. Terracon's geotechnical scope of work for this report included the advancement of four test borings ranging in depth from approximately 10 feet to 26 feet below existing site grades. This report includes the borings for Cast in Place, CIP, retaining walls A and B which were included in the original scope of this project as well as the borings for CIP retaining walls C and D that are currently in the initial planning stage.

This report describes the subsurface conditions encountered in the borings, reports test results, and provides boring logs with Standard Penetration Test results.

2.0 PROJECT INFORMATION

2.1 Project Description

Item	Description
Site Layout	See Appendix A, Exhibits A-1 to A-4.
Structures	This project will involve constructing two Cast in Place (CIP) retaining walls (Walls A & B) according to AASHTO standards. Based on the cross-sections provided, the CIP walls will have maximum total design heights ranging from 4 to 7 feet. The length of the CIP walls varies from approximately 80 feet to 126. We understand that the walls will be designed using the AASHTO Load and Resistance Factor Design (LFRD) method. Information regarding the details of retaining walls C and D were not provided at the time of this report.

2.2 Site Location and Description

Item	Description
Location	The project is located on Waterloo Road at the interchange with Interstate 35.

3.0 SUBSURFACE CONDITIONS

3.1 Geology

The geology of this site consists of the red, clay shales, red, sandy shales and red, massive, commonly cross-bedded, lenticular, sandstones of the Garber Unit. The sandstones are more prominent in the southern portion of ODOT's Division 4 which would include this project site. Northward, the sandstones become thinner and shales become more prominent. The Garber unit outcrops in a 12 to 24 mile band across Grant, Garfield, Kingfisher, Logan, Noble, and Oklahoma Counties. Topographically, the unit generally forms rolling to gently rolling hills capped with sandstones and covered with thick growths of blackjack oak and post oak trees.

3.2 Typical Subsurface Profile

Specific conditions encountered at each boring location are indicated on the individual boring logs. Stratification boundaries on the boring logs represent the approximate location of changes in soil and rock types; in-situ, the transition between materials may be gradual. Details for each of the borings can be found on the boring logs included in Appendix A of this report. Based on the results of the borings, subsurface conditions on the project site can be generalized as follows:

Description	Approximate Depth to Bottom of Stratum (feet)	Material Encountered	Consistency/Density
Stratum 1	1.5 to 15.0	Sand with varying amounts of silt	Very loose to medium dense
		Lean clay with varying amounts of silt and sand	Medium stiff to hard
Stratum 2[1]	Below the boring termination depths, borings WA-1, WC-1 and WD-1	Weathered sandstone and siltstone	Cemented to well cemented
	15.0 feet boring WB-1		

Description	Approximate Depth to Bottom of Stratum (feet)	Material Encountered	Consistency/Density
Stratum 3	Below the boring termination depths, boring WB-1	Weathered shale	Hard

[1] Bedrock was relatively shallow in borings WA-1, WB-1, and WD-1. Bedrock was deeper at the location of boring WC-1.

Laboratory tests were conducted on selected soil samples and the test results are presented on the borings logs in Appendix A and on the report form in Appendix B.

The following table indicates the ground surface elevations and the approximate elevations of stratification changes at the respective boring locations.

Approximate Stratification Boundary Elevations (feet)				
Strata	**WA-1**	**WB-1**	**WC-1**	**WD-1**
Overburden Soils (ground elevation)	1108.6	1101.0	1083.9	1106.7
Weathered sandstone/siltstone	1107.0	1097.5	1069.0	1101.5
Boring Termination elevation	1098.5	1085.0	1057.0	1089.5

3.3 Groundwater

The borings were monitored while drilling and immediately after completing the drilling activities for the presence and level of groundwater. At these times, groundwater was observed at the following depths:

Boring No.	Water Level While Drilling Depth (ft.) / Elevation (ft.)	Water Level After Boring Completion[1] Depth (ft.) / Elevation (ft.)
WA-1	Dry	Dry
WB-1	Dry	Dry
WC-1	Dry	7.0
WD-1	Dry	14.0

[1] Groundwater was not measured 24 hours after boring completion, because the borings were located on the roadway and therefore, they were backfilled immediately after completion.

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 at this site. Fluctuations in the groundwater level should be expected due to seasonal variations in the amount of rainfall, runoff, and other factors not apparent at the time the borings were drilled. The

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

4.0 ANALYSIS AND RECOMMENDATIONS

4.1 Geotechnical Design Parameters

Soil parameters were estimated based on the results of our field exploration, visual classification of soils, laboratory test results (soil classification and index parameters), literature review, and our experience with similar materials and projects with similar scope. The details of retaining walls C and D were not finalized at the time of this report and were not included in our analysis.

4.1.1 Soil Shear Strength Parameters

The following design shear strength parameters were used to perform the stability analyses summarized in Section **4.2 Retaining Wall Stability Analysis**. Effective strength parameters (friction angle and cohesion) are based on drained conditions to account for the long-term stability and total stress parameters are based on undrained cohesion to account for short-term stability.

Material Type	Total Unit Weight (pcf)	Effective Stress (Drained) Shear Strength Parameters		Total Stress (Undrained) Shear Strength Parameters	
		c′, psf	ϕ′, degrees	c, psf	ϕ, degrees
Retained Zone[1] (New Fill)	120	0	28	0	28
Retained Zone[1] (Existing Lean Clay with Sand)	120	0	28	500	0
Retained Zone[1] (Silty Sand)	120	0	32	0	32
Foundation Zone (Weathered Siltstone/Weathered Sandstone)	140	0	34	0	34
Cast-In- Place (CIP) Wall[2]	150	5,000	45	5,000	45

1. The soil parameters provided are based on average values for the sandy lean clay and silty-clayey sand encountered in the borings.
2. c = 5,000 psf used for global stability analyses of the CIP walls to prevent the failure surface from extending through the wall.

4.2 Retaining Wall Stability Analyses

Our analyses of the Cast-In-Place (CIP) walls considered the following:

- We considered the proposed fill behind the CIP walls would consist of locally available borrow soils having a Plasticity Index (PI) of 20 or less, similar to the on-site soils encountered in the test borings.
- A traffic surcharge load of 240 psf was applied in our analyses of Wall A and 150 psf for Wall B in accordance with AASHTO guidelines.
- Embedment depths were considered based on the cross-section drawings provide by the client.
- Global stability analyses were performed using the Morgenstern-Price method.
- Long-term global stability analyses for the proposed wall structures were performed based upon drained parameters.
- Short-term global slope stability analyses for the proposed wall structures were performed based upon undrained parameters.
- Load and resistance factors used in our analysis were in accordance with the AASHTO LRFD Bridge Design Specifications, 7th Edition, 2014. There have been no significant changes between the 7th and 8th Editions.
- Our external stability analyses included evaluation of direct sliding, base eccentricity and foundation bearing capacity in accordance with AASHTO guidelines.

4.2.1 Global Stability Analysis of Retaining Walls

The AASHTO LRFD Bridge Design Specifications recommends that global (overall) stability of the retaining wall, retained slope, and foundation soil be evaluated using limiting equilibrium methods of analysis, in which a single Factor of Safety (FOS) is generated by slope stability software.

The computer program SLOPE/W® 2016 (Version 8.16) developed by Geo-Slope International was used to evaluate global stability of the MSE retaining walls. In the program SLOPE/W®, the Morgenstern-Price method with half-sine function was selected to calculate the factor of safety. The graphical outputs of the global stability analyses are included in Appendix C. A summary of the results of our global stability analyses for the cross-sections analyzed is given in Section **4.2.2 Summary of Retaining Wall Stability Analyses**.

4.2.2 Summary of Retaining Wall Stability Analyses

Shallow weathered sandstone was encountered in borings drilled for the CIP retaining walls at depths varying from 1 to 6 feet. Footing foundations bearing on the weathered sandstone or dense sand over weathered silty sandstone can be designed using the parameters listed in the following table:

DESCRIPTION	Continuous footings bearing on Soil/Bedrock
Bearing Material	Retaining Wall A : Weathered siltstone/ sandstone Retaining Wall B: Weathered sandstone
Nominal Bearing Resistance[1]	Retaining Wall A: 8,000 psf Retaining Wall B: 8,000 psf
Resistance Factor for Bearing, φ_b[2]	0.55
Coefficient of Friction Value, (tan δ)[3]	Retaining Wall A: 0.6 Retaining Wall B: 0.6
Resistance Factor for Sliding Resistance, φ_t[2]	Retaining Wall A: 1.0 Retaining Wall B: 1.0
Minimum Width[4]	Retaining Wall A: 6.5 ft Retaining Wall B: 8.7 ft
Minimum Embedment Depth Below Finished Grade[4]	Retaining Wall A: 1 ft Retaining Wall B: 0.67 ft
Shear Key Depth[4]	Retaining Wall A: 1.5 ft Retaining Wall B: 1 ft

1. AASHTO LRFD Bridge Design Specifications, 7th Edition, 2014
2. Table 11.5.7-1 AASHTO LRFD Bridge Design Specifications, 7th Edition, 2014
3. Lateral loads can be resisted by frictional resistance between the base of the footing and the underlying bearing materials. The nominal sliding resistance between the base of the footing and the underlying bearing materials can be calculated using the coefficient of friction value. Lateral loads are also resisted by the passive pressure acting on the vertical face of the footings.
4. Based on drawings provided by Garver.

Terracon should observe and test the footing excavations to verify that the recommended bearing materials are encountered. If loose sand or other unsuitable materials are encountered at the footing bearing elevation the unsuitable materials should be overexcavated sufficiently until suitable material is encountered. Overexcavations beneath footings should extend laterally at least 8 inches for each 12 inches of depth below the bearing level.

Footing excavations should be free of all loose materials, debris, rock fragments and water at the time concrete is placed. Sloping or temporary shoring of the sides of excavation may be required to prevent caving of the sandy materials. Concrete should be placed as soon as possible after excavations are completed to reduce the potential for wetting, drying, and disturbance of the bearing surface.

Retaining wall	Soil Boring Utilized	WL (feet)	[1]E_m (feet)	H_D (feet)	B (feet)	D_K (feet)	CDR DS	CDR_B C	e_{ecc} (feet)	FOS_{GS} (Exhibit No.)
Wall A	WA-1	None	1	8	6.5	1.5	1.0	6.0	<B/3	1.51 (C-2)
Wall B	WB-1	None	0.7	4.7	8.7	1.0	1.0	66.9	<B/3	1.51 (C-4)

Table notes:
WL = Water Level elevation
E_m = Approximate embedment depth (the soil thickness above the top of foundation slab was not considered in our analyses)
H_D = Design height (total wall height = Face of the wall plus embedment depth)
B = Footing Width
D_K = Shear Key Depth
CDR = Capacity Demand Ratio in accordance to AASHTO LRFD 2014
DS = Direct Sliding
BC = Bearing Capacity
e_{ecc} = Eccentricity
FOS = Factor of Safety for global stability based on Allowable Stress Design (ASD) methodology, in accordance with AASHTO LRFD 2014
GS = Global Stability

4.3 Settlement of Retaining Walls

The wall settlement will depend upon the variations within the subsurface soil profile, the structural loading conditions and the quality of the earthwork operations. Because of the variations associated with these parameters, Terracon cannot accurately estimate settlements under all design scenarios. Assuming the retaining walls are founded on competent weathered siltstone/sandstone as illustrated in our subsurface data, it is our opinion that the maximum total settlements will be on the order of less than 1 inch along the CIP retaining walls. The maximum differential settlements are not expected to exceed half of the total settlement for the CIP walls. However, these values should be evaluated by the wall designer to confirm that the wall can tolerate this magnitude of total and differential settlement. The estimated total maximum settlements are presented in the following table:

Retaining wall	**Total Settlement Estimates** (inches)
A	<1.0
B	<1.0

4.4 Wall Drainage Recommendations

Care should be taken in the design and during construction to develop and maintain rapid, positive drainage away from the retaining wall areas. Water should not be allowed to pond adjacent to either the upslope or downslope sides of the retaining walls. We recommend that drainage swales with sufficient gradients be constructed along both the upslope and downslope sides of the wall to direct surface water away from the walls. Proper surface drainage is needed to prevent water from flowing over the face of the walls and saturating either the fill behind the wall or the subgrade soils at the base of the walls.

If Oklahoma Department of Transportation (ODOT) Granular Backfill material is used to construct the new fill in the retained zone, we recommend that a backslope drain, comprised of a geocomposite drainage blanket, be attached to the face of the cut backslope and extend down to a collector drain pipe placed along the bottom of the reinforced zone at the base of the cut slope. The collector drain should consist of a perforated PVC pipe that is placed in free-draining aggregate such as No. 57 stone, with the stone wrapped in a geotextile filter fabric. The collector drain should be sloped to drain out beyond one or both ends of the retaining wall. The geocomposite drainage blanket should be cut off at a depth of 2 feet below the finished ground surface at the back of the reinforced backfill zone to allow a minimum cover of 2 feet of compacted clayey soil over the drain to prevent the infiltration of surface water into the backslope drain.

Alternatively, select drainable aggregate fill material consisting of crushed No. 57 stone could be imported to construct the entire new fill zone. If the crushed No. 57 stone is used to construct the reinforced backfill zone, we recommend that a geotextile filter fabric, such as Mirafi 140N be placed between the face of the existing embankment slope and the reinforced backfill zone to prevent the migration of fines from the native soils into the free-draining No. 57 stone.

4.5 Construction Considerations

The construction specifications should provide the backfill material description and design strength parameters that are required for the different fill zones so that unsuitable materials are not placed.

Areas within the limits of construction should be stripped and cleared of topsoil, vegetation, and any other deleterious material.

All excavations should meet all OSHA and other applicable safety regulations. Site grading should develop positive drainage away from open excavations.

After stripping and completing any cuts, the subgrade should be proofrolled to aid in locating soft, unstable or otherwise unsuitable soils. Terracon should observe and test the footing excavations to verify that the recommended bearing materials are encountered. If loose sand or other unsuitable materials are encountered at the footing bearing elevation the unsuitable materials should be overexcavated sufficiently until suitable material is encountered. Overexcavations beneath footings should extend laterally at least 8 inches for each 12 inches of depth below the bearing level.

Footing excavations should be free of all loose materials, debris, rock fragments and water at the time concrete is placed. Sloping or temporary shoring of the sides of excavation may be required to prevent caving of the sandy materials. Concrete should be placed as soon as possible after excavations are completed to reduce the potential for wetting, drying, and disturbance of the bearing surface.

We anticipate that excavations for the retaining walls construction will extend into weathered bedrock. Rock formations that have standard penetration test results of 4 or more inches per 50 blows can usually be excavated with heavy excavation equipment equipped with ripping teeth. Rock formations that have standard penetration test results of 3 inches or less per 50 blows usually require either pneumatic equipment or blasting to remove. However, variations in hardness of rock can occur with depth and distance from the borings.

There is an existing retaining wall approximately 20 to 25 feet from the face of the proposed retaining wall B. Since we anticipate the crest of the 2H:1V excavation slope during construction will be approximately 15 feet from the existing wall, we do not anticipate there to be any construction related issues for Wall B.

4.6 Seismic Considerations

Description	Value
2009 International Building Code Site Classification (IBC)	**C**

Note: In general accordance with the *2009 International Building Code,* Table 1613.5.2. The 2009 International Building Code (IBC) uses a site soil profile determination extending to a depth of 100 feet for seismic site classification. The current scope does not include the 100 foot soil profile determination. Borings extended to a maximum depth of 126 feet. This seismic site class definition considers that weathered shale and sandstone continues below the maximum depth of the subsurface exploration. Additional exploration to deeper depths would be necessary to confirm the conditions below the current depth of exploration.

5.0 GENERAL COMMENTS

Terracon Consultants, Inc. should be retained to review the final design plans and specifications so comments can be made regarding interpretation and implementation of our geotechnical recommendations in the design and specifications. Terracon Consultants, Inc. also should be retained to provide observation and testing services during grading, excavation, foundation construction and other earth-related construction phases of the project.

The analysis and recommendations presented in this report are based upon the data obtained from the borings performed at the indicated locations and from other information discussed in this report. This report does not reflect variations that may occur between borings, across the site, or due to the modifying effects of weather. The nature and extent of such variations may not become evident until during or after construction. If variations appear, we should be immediately notified so that further evaluation and supplemental recommendations can be provided.

The scope of services of this project does not include either specifically or by implication any environmental assessment of the site or identification of contaminated or hazardous materials or conditions. If the owner is concerned about the potential of such contamination, other studies should be undertaken.

This report has been prepared for the exclusive use of our client for specific application to the project discussed and has been prepared in accordance with generally accepted geotechnical engineering practices. No warranties, either expressed or implied, are intended or made. Site safety, excavation support, and dewatering requirements are the responsibility of others. In the event that any changes in the nature, design, or location of the project as outlined in this report are planned, the conclusions and recommendations contained in this report shall not be considered valid unless Terracon Consultants, Inc. reviews the changes, and either verifies or modifies the conclusions of this report in writing.

APPENDIX A
FIELD EXPLORATION

AERIAL FROM GOOGLE MAPS

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

Project Mngr:	JLD
Drawn By:	CAN
Checked By:	JLD
Approved By:	NKT

Project No.	03205038
Scale:	NTS
File No.	03205038 (A1-A4)
Date:	APR 2020

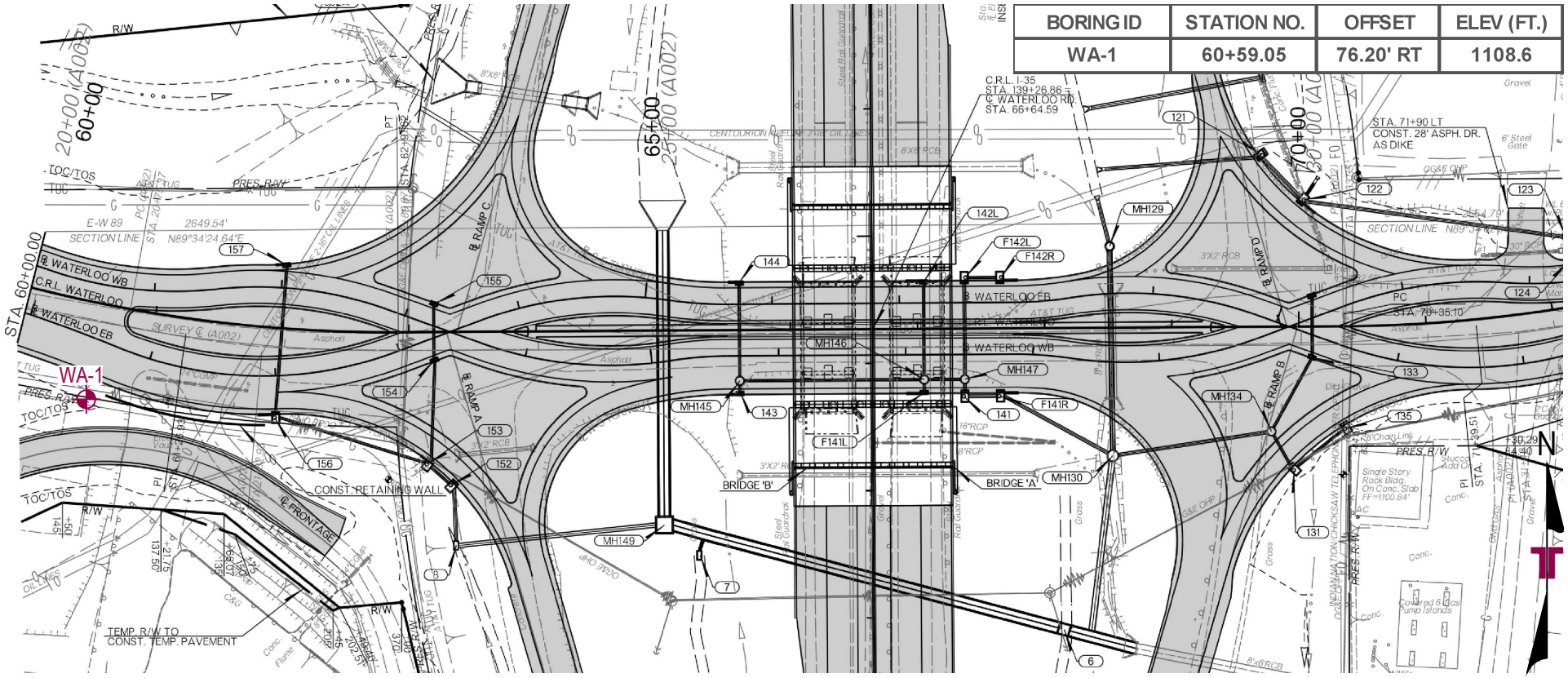
Terracon
Consulting Engineers and Scientists
4701 N STILES AVE OKLAHOMA CITY, OKLAHOMA 73105
PH. (405) 525-0453 FAX. (405) 557-0549

SITE LOCATION PLAN

RETAINING WALLS
INTERSTATE 35 AND WATERLOO ROAD
OKLAHOMA AND LOGAN COUNTIES, OKLAHOMA

EXHIBIT

A1



BORING ID	STATION NO.	OFFSET	ELEV (FT.)
WA-1	60+59.05	76.20' RT	1108.6

LEGEND

BORING LOCATION

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

Project Mngr:	JLD
Drawn By:	CAN
Checked By:	JLD
Approved By:	NKT

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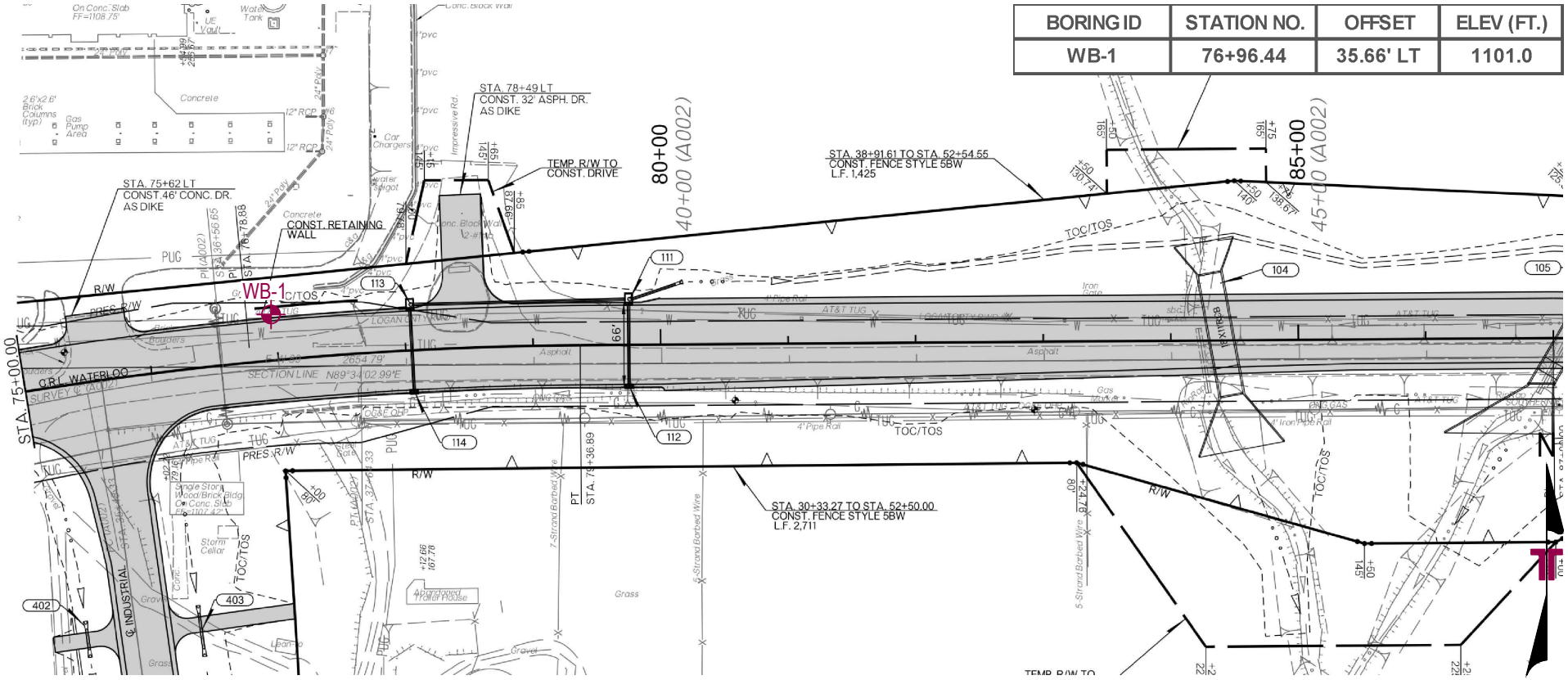
EXPLORATION PLAN

RETAINING WALLS
INTERSTATE 35 AND WATERLOO ROAD
OKLAHOMA AND LOGAN COUNTIES, OKLAHOMA

EXHIBIT

A2

BORING ID	STATION NO.	OFFSET	ELEV (FT.)
WB-1	76+96.44	35.66' LT	1101.0



LEGEND

BORING LOCATION

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Drawn By:	CAN
Checked By:	JLD
Approved By:	NKT

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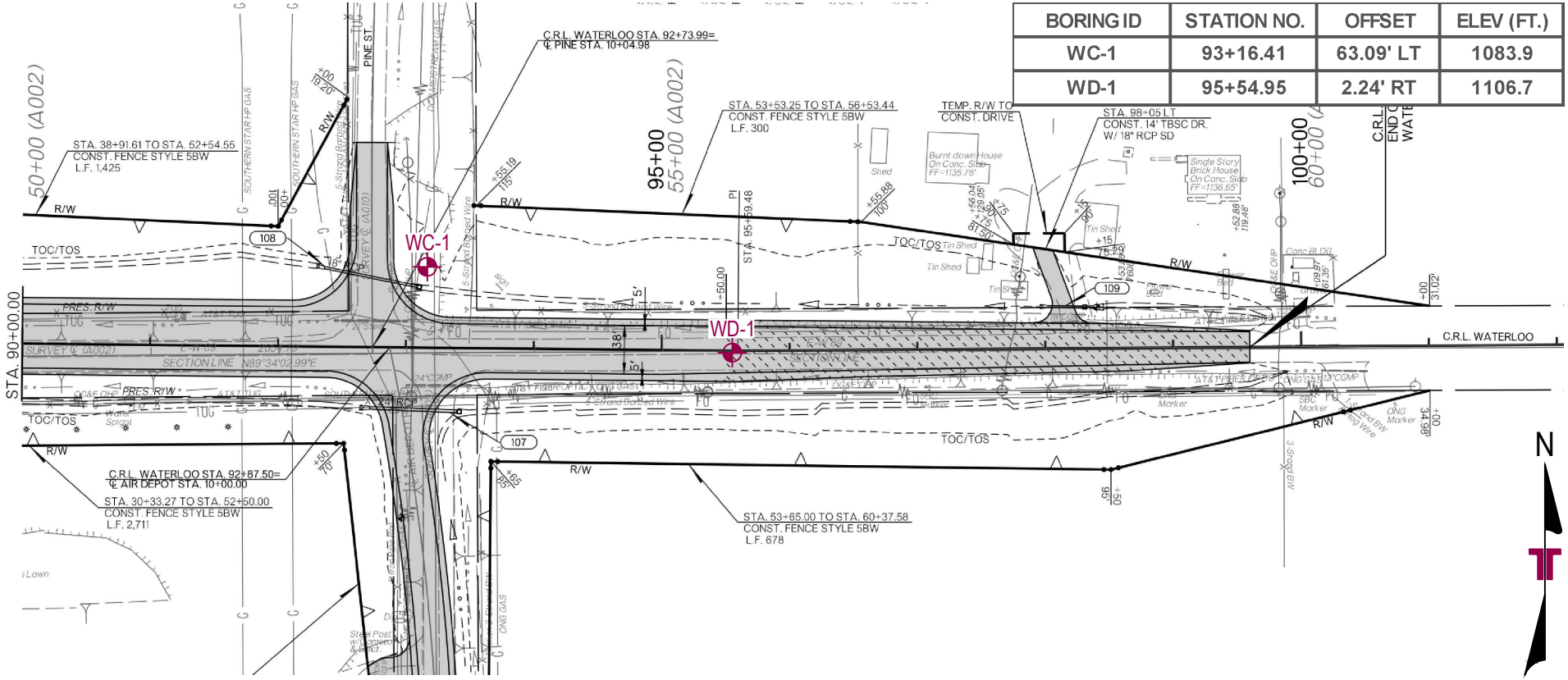
EXPLORATION PLAN

RETAINING WALLS
INTERSTATE 35 AND WATERLOO ROAD
OKLAHOMA AND LOGAN COUNTIES, OKLAHOMA

EXHIBIT

A3

BORING ID	STATION NO.	OFFSET	ELEV (FT.)
WC-1	93+16.41	63.09' LT	1083.9
WD-1	95+54.95	2.24' RT	1106.7



LEGEND

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EXPLORATION PLAN

RETAINING WALLS
INTERSTATE 35 AND WATERLOO ROAD
OKLAHOMA AND LOGAN COUNTIES, OKLAHOMA

EXHIBIT

A4

Field Exploration Description

Terracon personnel located the borings in the field by use of a hand held GPS device using the plans provided by the Client. The boring locations were offset from the original coordinates a maximum of 25 feet for site access purposes. The locations of the borings should be considered accurate only to the degree implied by the methods used to define them. The stations, offsets, and elevations for each boring were provided by Garver based upon the boring coordinates. These coordinates were correlated to the stationing and elevation data developed by the project surveyor.

Based on this survey data, the ground surface elevations at the boring locations ranged from 1083.9 to 1108.6 feet. The elevations shown on the logs have been rounded to the nearest 0.1 foot. The boring locations and elevations should be considered accurate only to the degree implied by the methods used to define them.

The borings were advanced with an all-terrain mounted rotary drill rig. The borings were advanced using wash boring techniques. Representative soil samples were obtained using the split-barrel sampling procedure. The bedrock at borings WC-1, and WD-1 was cored with a NX-size diamond bit core barrel.

Disturbed samples of the overburden soils were obtained by the split-barrel sampling procedure by driving a 2-inch O.D. split-barrel sampling spoon into the ground using a 140-pound, automatic hammer falling 30 inches. The number of blows required to advance the sampling spoon were recorded in the field and are shown on the boring logs as the standard penetration resistance (N) value. The number of blows required to advance the sampling spoon the final 12 inches or less of a standard 18-inch sampling interval indicate the in-place relative density of granular soils and, to a lesser degree of accuracy, the consistency of cohesive soils and hardness of weathered rock. The sampling depths, penetration distances, and the N values are reported on the boring logs. The percent recovery and Rock Quality Designation (RQD) for each core run was determined. The samples were tagged for identification, sealed to reduce moisture loss and returned to the laboratory for further examination and classification.

An automatic drive hammer was used to advance the split-barrel. A greater efficiency is achieved with the automatic drive hammer compared to the conventional safety drive hammer operated with a cathead and rope.

The drilling operation was supervised by engineer who prepared field logs. The boring logs include visual classifications of the materials encountered during drilling and the engineer's interpretation of subsurface conditions between samples. Based on the material's texture, the soil samples were described according to the attached General Notes and classified in accordance with the Unified Soil Classification System. A brief description of the Unified System

is included in the appendix. Rock descriptions are in general accordance with the General Notes for Sedimentary Rock. Petrographic analysis of the rock cores may reveal other rock types.

As required by the Oklahoma Water Resources Board, any borings deeper than 20 feet, or borings which encounter groundwater or contaminated materials must be grouted or plugged in accordance with Oklahoma State statutes. One boring log must also be submitted to the Oklahoma Water Resources Board for each 10 acres of project site area. Terracon grouted the borings and submitted a log in order to comply with the Oklahoma Water Resources Board requirements.

BORING LOG NO. WA-1

PROJECT: Retaining Walls I-35 over Waterloo Road Interchange

CLIENT: Garver LLC
Tulsa, Oklahoma

SITE: Interstate 35 & Waterloo Road
Oklahoma & Logan Counties, Oklahoma

LOCATION See Exhibit A-2

Latitude: 35.7249° Longitude: -97.4184°

Station: 60+59.05 Offset: 76.20' RT

Approximate Surface Elev.: 1108.6 (Ft.) +/-

DEPTH	ELEVATION (Ft.)	DEPTH (Ft.)	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	WATER CONTENT (%)	ATTERBERG LIMITS LL-PL-PI	PERCENT FINES
0.4 **Approx. 5" Asphalt Concrete Pavement**	1108+/-							
1.5 **LEAN CLAY WITH SAND (CL)**, dusky red (10R 3/3), hard	1107+/-			15	9-31-50/3"	11.3	24-16-8	71
WEATHERED SILTSTONE, red (10R 4/6), cemented								
5.0	1103.5+/-	5		4	50/4"	6.8		39
WEATHERED SILTSTONE/SANDSTONE, red (10R 4/6), cemented								
8.5	1100+/-							
WEATHERED SANDSTONE, red (10R 4/6) and dusky red (10R 3/3, cemented								
10.3	1098.5+/-	10		3	50/3"			
Boring Terminated at 10.3 Feet								

Stratification lines are approximate. In-situ, the transition may be gradual.
Classification of rock estimated from disturbed samples. Core samples and petrographic analysis may reveal other rock types.

Hammer Type: Automatic

Advancement Method:
Power Auger

Abandonment Method:
Boring backfilled with soil cuttings upon completion.

See Exhibit A-5 for description of field procedures

See Appendix B for description of laboratory procedures and additional data (if any).

See Appendix D for explanation of symbols and abbreviations.

Notes:

WATER LEVEL OBSERVATIONS

No free water observed

Terracon
4701 N Stiles Ave
Oklahoma City, OK

Boring Started: 03-27-2020 Boring Completed: 03-27-2020

Drill Rig: 880 Driller: R. Smalley

Project No.: 03205038 Exhibit: A-6

BORING LOG NO. WB-1

PROJECT: Retaining Walls I-35 over Waterloo Road Interchange

CLIENT: Garver LLC
Tulsa, Oklahoma

SITE: Interstate 35 & Waterloo Road
Oklahoma & Logan Counties, Oklahoma

LOCATION See Exhibit A-3

Latitude: 35.7254° Longitude: -97.4128°

Station: 76+96.44 Offset: 35.66' LT

Approximate Surface Elev.: 1101.0 (Ft.) +/-

DEPTH	ELEVATION (Ft.)	DEPTH (Ft.)	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	WATER CONTENT (%)	ATTERBERG LIMITS LL-PL-PI	PERCENT FINES
SILTY SAND (SM), dark red (10R 3/6) and reddish brown (5YR 5/4), medium dense				18	6-6-14 N=20	11.1	NP	16
3.5	1097.5+/-							
WEATHERED SANDSTONE, red (2.5YR 5/8), cemented		5		4	50/4"	6.5	NP	12
-dusky red (10R 3/4), well cemented below 10'		10		1	50/1"			
15.0	1086+/-							
WEATHERED SHALE, red (10R 5/6) and dusky red (10R 3/3), soft to moderately hard		15		9	40-50/3"	10.4	23-14-9	53
16.0	1085+/-							
Boring Terminated at 16 Feet								

Stratification lines are approximate. In-situ, the transition may be gradual.
Classification of rock estimated from disturbed samples. Core samples and petrographic analysis may reveal other rock types.

Hammer Type: Automatic

Advancement Method:
Power Auger

Abandonment Method:
Boring backfilled with auger cuttings upon completion.

See Exhibit A-5 for description of field procedures

See Appendix B for description of laboratory procedures and additional data (if any).

See Appendix D for explanation of symbols and abbreviations.

Notes:
Vegetation at Surface

WATER LEVEL OBSERVATIONS

No free water observed

Terracon
4701 N Stiles Ave
Oklahoma City, OK

Boring Started: 03-27-2020 Boring Completed: 03-27-2020

Drill Rig: 880 Driller: R. Smalley

Project No.: 03205038 Exhibit: A-7

BORING LOG NO. WC-1

PROJECT: Retaining Walls I-35 over Waterloo Road Interchange

CLIENT: Garver LLC
Tulsa, Oklahoma

SITE: Interstate 35 & Waterloo Road
Oklahoma & Logan Counties, Oklahoma

LOCATION See Exhibit A-4

Latitude: 35.7255° Longitude: -97.4074°

Station: 93+16.41 Offset: 63.09' LT

Approximate Surface Elev.: 1083.9 (Ft.) +/-

DEPTH	ELEVATION (Ft.)	DESCRIPTION	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	WATER CONTENT (%)	DRY UNIT WEIGHT (pcf)	ATTERBERG LIMITS LL-PL-PI	PERCENT FINES
		SILTY SAND (SM), dark reddish brown (5YR 3/4), loose				6	2-4-4 N=8	5.9		NP	15
		-very loose below 5'	5	▽		8	2-2-0 N=2	18.0		NP	17
		-dusky red (10R 3/4) and light red (10R 6/8), medium dense below 10'	10			12	25-20-8 N=28	16.6		NP	23
15.0	1069+/-	**WEATHERED SANDSTONE**, light red (10R 6/8), cemented	15			3	50/3"	19.3			27
		-light red (10R 6/8) and very dusky red (7.5R 2.5/3), well cemented below 20'	20			2	50/2"				
			25			53	RQD= 45 (%)				
26.0	1058+/-					2	50/2"	24.4			21
		Boring Terminated at 26 Feet									

Stratification lines are approximate. In-situ, the transition may be gradual.
Classification of rock estimated from disturbed or core samples. Petrographic analysis may reveal other rock types.

Hammer Type: Automatic

Advancement Method:
0' - 20.5' Wash boring
20.5' - 25.5' Rock core

Abandonment Method:
Boring backfilled with cuttings above 4'; grouted 4' to 14'; backfilled with cuttings from 14' to termination depth.

See Exhibit A-5 for description of field procedures

See Appendix B for description of laboratory procedures and additional data (if any).

See Appendix D for explanation of symbols and abbreviations.

Notes:
Vegetation at Surface

WATER LEVEL OBSERVATIONS

▽ *7' after completion*

Terracon
4701 N Stiles Ave
Oklahoma City, OK

Boring Started: 04-17-2020 | Boring Completed: 04-17-2020

Drill Rig: 578 | Driller: P. Hacker

Project No.: 03205038 | Exhibit: A-8

BORING LOG NO. WD-1

PROJECT: Retaining Walls I-35 over Waterloo Road Interchange

CLIENT: Garver LLC
Tulsa, Oklahoma

SITE: Interstate 35 & Waterloo Road
Oklahoma & Logan Counties, Oklahoma

LOCATION See Exhibit A-4

Latitude: 35.7253° Longitude: -97.4066°

Station: 95+54.95 Offset: 2.24' RT

Approximate Surface Elev.: 1106.7 (Ft.) +/-

DEPTH	ELEVATION (Ft.)	Description	RECOVERY (In.)	FIELD TEST RESULTS	WATER CONTENT (%)	DRY UNIT WEIGHT (pcf)	ATTERBERG LIMITS LL-PL-PI	PERCENT FINES
0.4	1106.5+/-	**Approx. 5" Asphalt Concrete Pavement**						
		SANDY SILTY CLAY WITH GRAVEL (CL-ML), dark brown (7.5YR 3/4) and light red (2.5YR 6/8), medium stiff	2	7-5-6 N=11	5.6			52
5.0	1101.5+/-	**WEATHERED SANDSTONE**, light red (2.5YR 6/8), poorly cemented	6	50/6"	17.7		NP	48
			41	RQD=0 (%)				
		-light red (10R 6/8) and very dusky red (7.5R 2.5/3), cemented below 11'	4	50/4"	21.9		NP	25
			48	RQD=20 (%)				
17.3	1089.5+/-	-very dusky red (7.5R 2.5/3) below 17'	3	50/3"	23.3		NP	23
		Boring Terminated at 17.3 Feet						

Stratification lines are approximate. In-situ, the transition may be gradual.
Classification of rock estimated from disturbed or core samples. Petrographic analysis may reveal other rock types.

Hammer Type: Automatic

Advancement Method:
0' - 5.5' Wash boring
5.5' - 17' Rock core

Abandonment Method:
Boring backfilled with cuttings above 4'; grouted 4' to 14'; backfilled with cuttings from 14' to termination depth.

See Exhibit A-5 for description of field procedures

See Appendix B for description of laboratory procedures and additional data (if any).

See Appendix D for explanation of symbols and abbreviations.

Notes:

WATER LEVEL OBSERVATIONS

▽ *14' after completion*

Terracon
4701 N Stiles Ave
Oklahoma City, OK

Boring Started: 04-17-2020 | Boring Completed: 04-17-2020
Drill Rig: 578 | Driller: P. Hacker
Project No.: 03205038 | Exhibit: A-9

APPENDIX B
LABORATORY TESTING

Laboratory Testing

Samples retrieved during the field exploration were taken to the laboratory for further observation by the project geotechnical engineer. Soil samples were classified in accordance with the Unified Soil Classification System (USCS) described in Appendix C. Samples of bedrock were classified in accordance with the general notes for Sedimentary Rock Classification. In the laboratory, the field descriptions were confirmed or modified as necessary and an applicable laboratory testing program was formulated to determine engineering properties of the subsurface materials.

Selected soil and bedrock samples obtained from the site were tested for the following engineering properties:

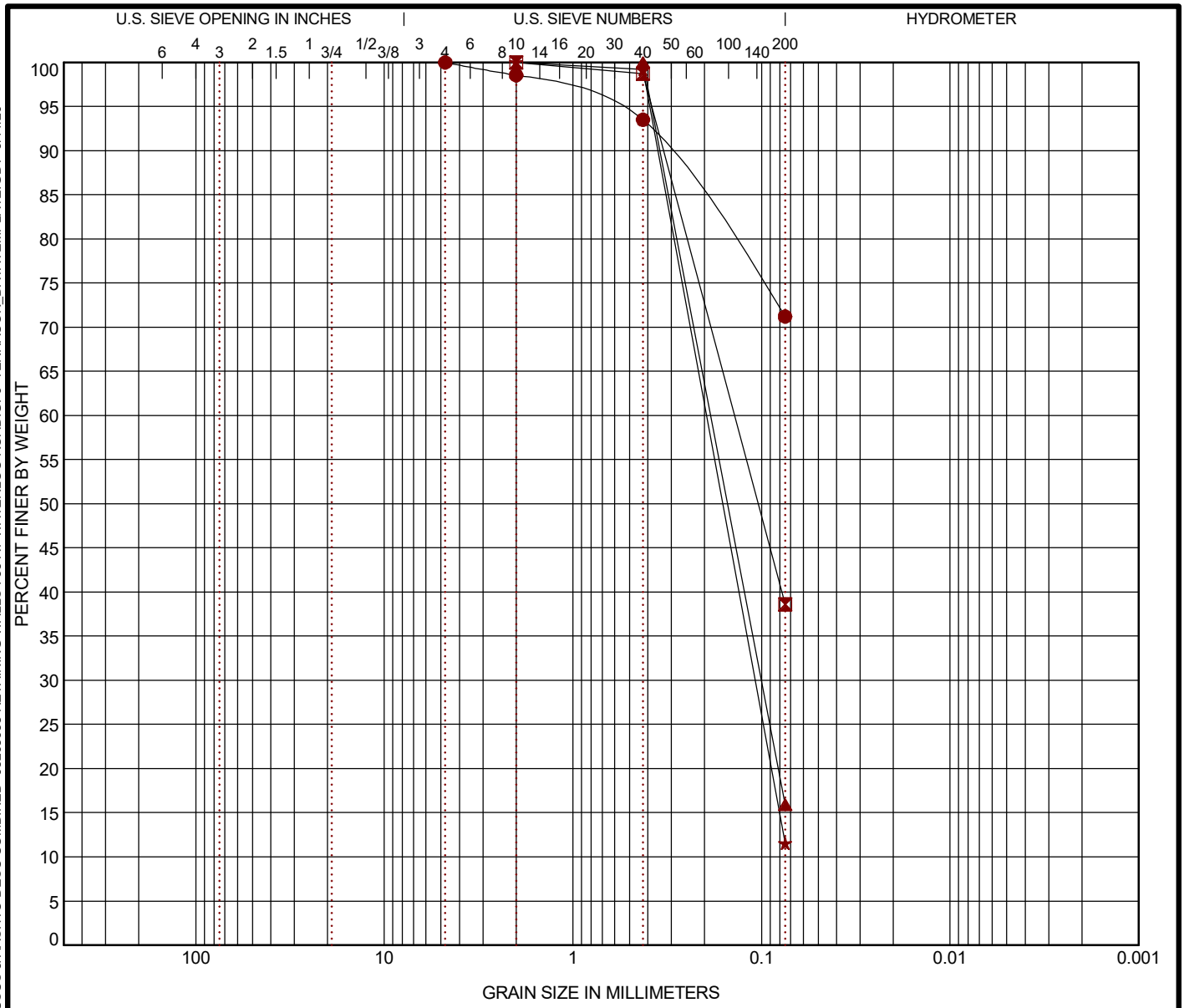
- In-situ Water Content
- Atterberg Limits
- Sieve Analysis

The laboratory test results are reported on the boring logs in Appendix A. Sieve analysis grain size distribution curves are provided in Appendix B.

Procedural 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.

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
●	WA-1	0.6 - 1.9	LEAN CLAY with SAND (CL)	A-4 (3)	11.3	24	16	8		
⊠	WA-1	5 - 5.3			6.8					
▲	WB-1	0 - 1.5	SILTY SAND (SM)	A-2-4 (0)	11.1	NP	NP	NP		
★	WB-1	5 - 5.3	POORLY GRADED SAND with SILT (SP-SM)	A-2-4 (0)	6.5	NP	NP	NP	0.82	2.69

	Boring ID	Depth	D_{100}	D_{60}	D_{30}	D_{10}	%Gravel	%Sand	%Silt	%Fines	%Clay
●	WA-1	0.6 - 1.9	4.75				0.0	28.8		71.2	
⊠	WA-1	5 - 5.3	2	0.139			0.0	61.4		38.6	
▲	WB-1	0 - 1.5	0.425	0.186	0.1		0.0	84.1		15.9	
★	WB-1	5 - 5.3	2	0.196	0.108		0.0	88.5		11.5	

PROJECT: Retaining Walls I-35 over Waterloo Road Interchange

SITE: Interstate 35 & Waterloo Road
Oklahoma & Logan Counties, Oklahoma

Terracon
4701 N Stiles Ave
Oklahoma City, OK

PROJECT NUMBER: 03205038

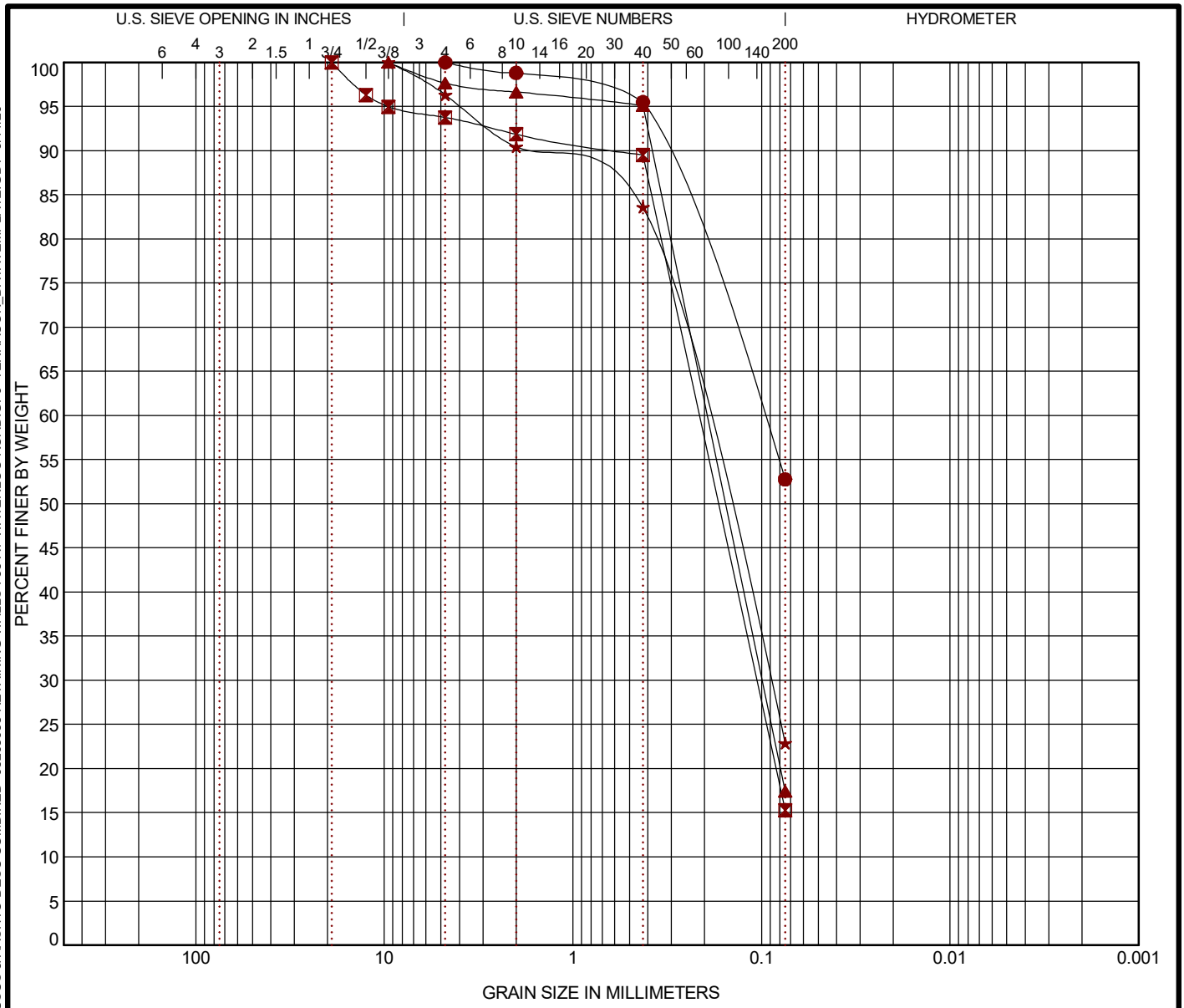
CLIENT: Garver LLC
Tulsa, Oklahoma

EXHIBIT: B-2

LABORATORY TESTS ARE NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GRAIN SIZE: USCS & AASHTO DESC COMBINED 03205038 RETAINING WALLS I-35 AT WATERLOO ROAD.GPJ TERRACON_DATATEMPLATE.GDT 9/11/20

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
●	WB-1	15 - 15.8	SANDY LEAN CLAY (CL)	A-4 (2)	10.4	23	14	9		
⊠	WC-1	0 - 1.5	SILTY SAND (SM)	A-2-4 (0)	5.9	NP	NP	NP		
▲	WC-1	5 - 6.5	SILTY SAND (SM)	A-2-4 (0)	18.0	NP	NP	NP		
★	WC-1	10 - 11.5	SILTY SAND (SM)	A-2-4 (0)	16.6	NP	NP	NP		

	Boring ID	Depth	D_{100}	D_{60}	D_{30}	D_{10}	%Gravel	%Sand	%Silt	%Fines	%Clay
●	WB-1	15 - 15.8	4.75	0.101			0.0	47.2		52.8	
⊠	WC-1	0 - 1.5	19	0.213	0.106		6.2	78.5		15.3	
▲	WC-1	5 - 6.5	9.5	0.194	0.099		2.3	80.2		17.4	
★	WC-1	10 - 11.5	9.5	0.217	0.092		3.7	73.5		22.9	

PROJECT: Retaining Walls I-35 over Waterloo Road Interchange

SITE: Interstate 35 & Waterloo Road
Oklahoma & Logan Counties, Oklahoma

Terracon
4701 N Stiles Ave
Oklahoma City, OK

PROJECT NUMBER: 03205038

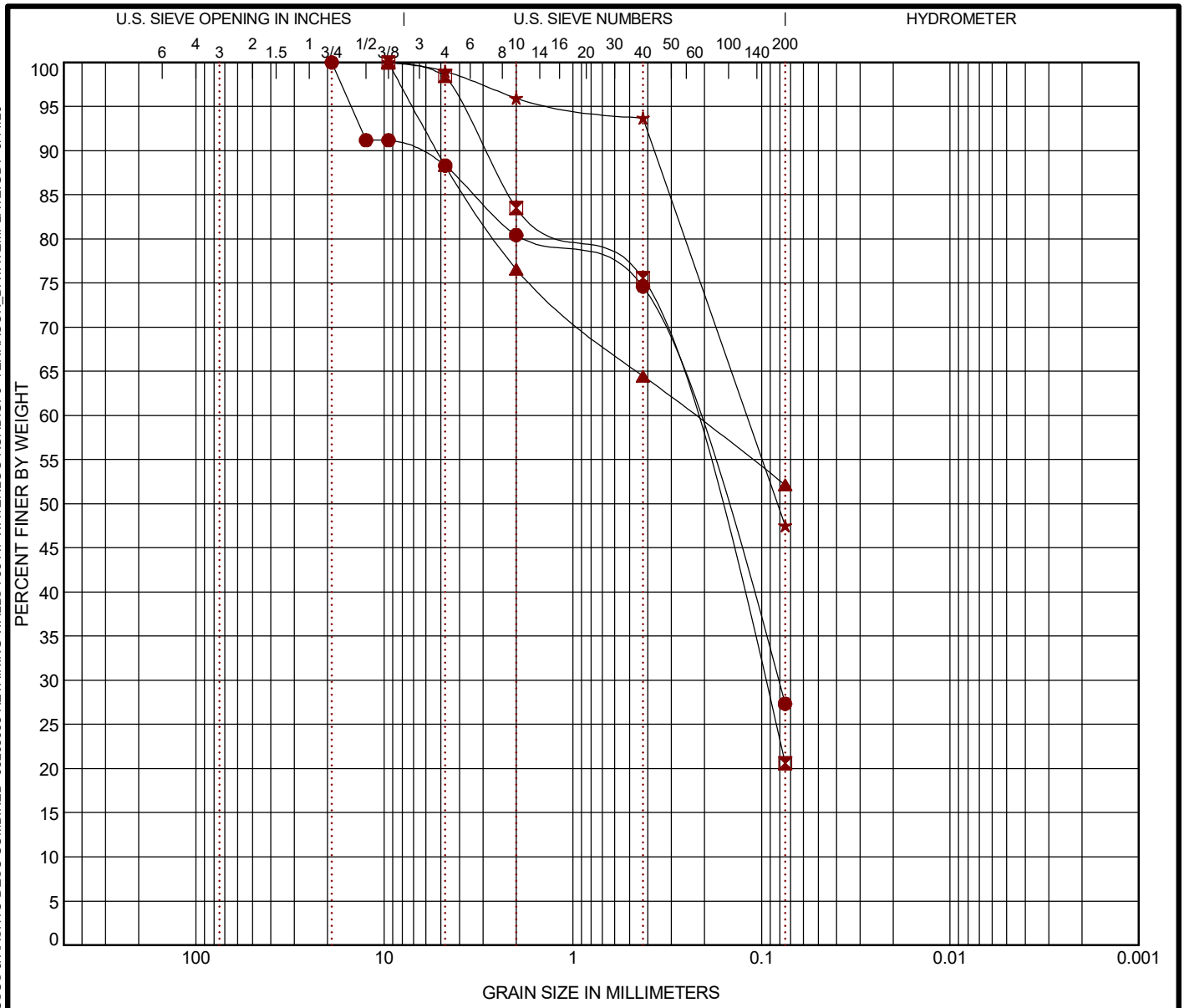
CLIENT: Garver LLC
Tulsa, Oklahoma

EXHIBIT: B-3

LABORATORY TESTS ARE NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GRAIN SIZE: USCS & AASHTO DESC COMBINED 03205038 RETAINING WALLS I-35 AT WATERLOO ROAD.GPJ TERRACON_DATATEMPLATE.GDT 9/11/20

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
●	WC-1	15 - 15.3			19.3					
⊠	WC-1	25.5 - 25.7			24.4					
▲	WD-1	0 - 1.5			5.6					
★	WD-1	5 - 5.5	SILTY SAND (SM)	A-4 (0)	17.7	NP	NP	NP		

	Boring ID	Depth	D_{100}	D_{60}	D_{30}	D_{10}	%Gravel	%Sand	%Silt	%Fines	%Clay
●	WC-1	15 - 15.3	19	0.249	0.083		11.7	61.0		27.3	
⊠	WC-1	25.5 - 25.7	9.5	0.26	0.101		1.5	77.9		20.6	
▲	WD-1	0 - 1.5	9.5	0.227			11.7	36.2		52.1	
★	WD-1	5 - 5.5	9.5	0.12			1.0	51.5		47.5	

PROJECT: Retaining Walls I-35 over Waterloo Road Interchange

SITE: Interstate 35 & Waterloo Road
Oklahoma & Logan Counties, Oklahoma

Terracon
4701 N Stiles Ave
Oklahoma City, OK

PROJECT NUMBER: 03205038

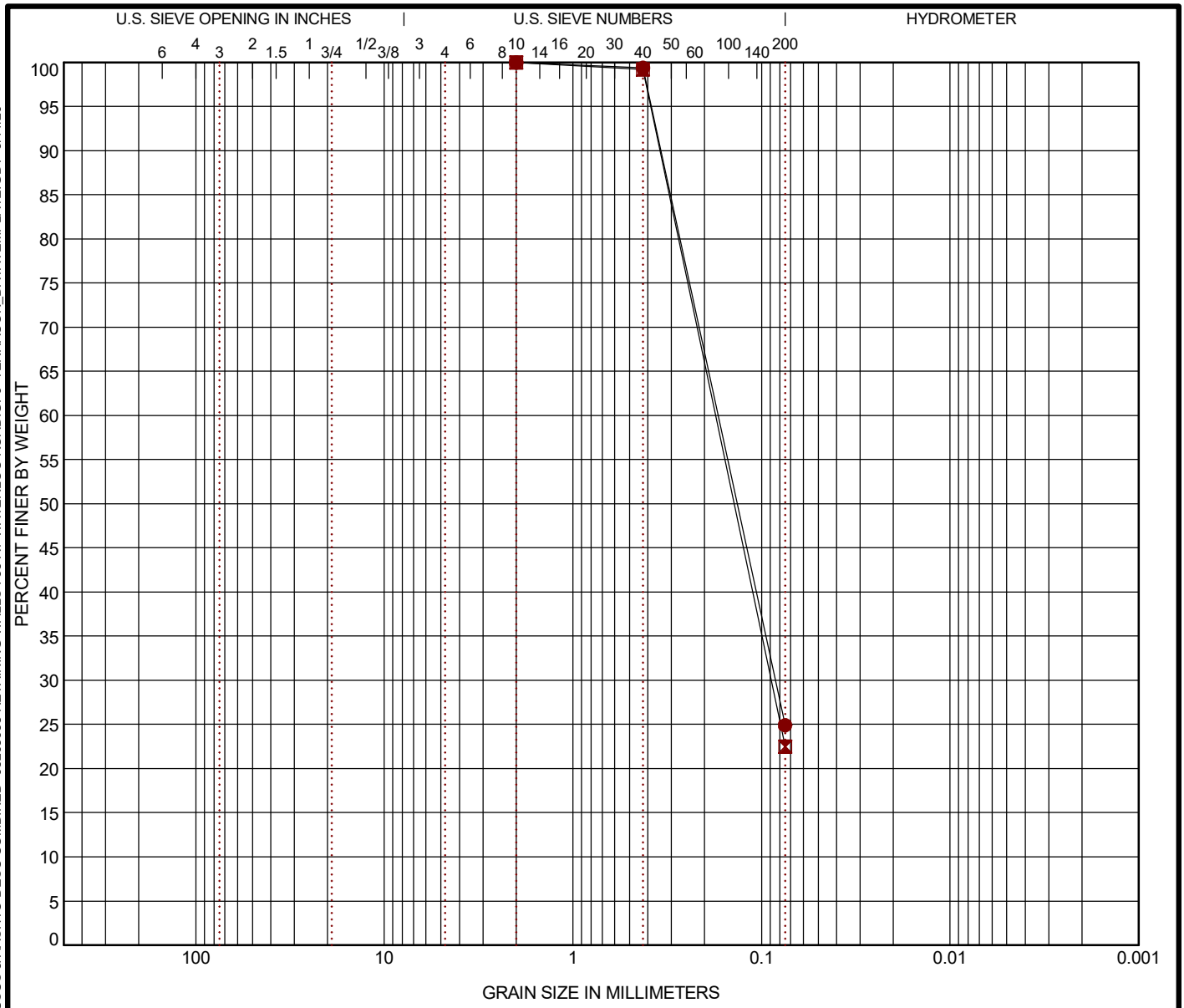
CLIENT: Garver LLC
Tulsa, Oklahoma

EXHIBIT: B-4

LABORATORY TESTS ARE NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GRAIN SIZE: USCS & AASHTO DESC COMBINED 03205038 RETAINING WALLS I-35 AT WATERLOO ROAD.GPJ TERRACON_DATATEMPLATE.GDT 9/11/20

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
●	WD-1	11 - 11.3	SILTY SAND (SM)	A-2-4 (0)	21.9	NP	NP	NP		
⊠	WD-1	17 - 17.3	SILTY SAND (SM)	A-2-4 (0)	23.3	NP	NP	NP		

	Boring ID	Depth	D_{100}	D_{60}	D_{30}	D_{10}	%Gravel	%Sand	%Silt	%Fines	%Clay
●	WD-1	11 - 11.3	2	0.17	0.084		0.0	75.1		24.9	
⊠	WD-1	17 - 17.3	2	0.175	0.089		0.0	77.5		22.5	

PROJECT: Retaining Walls I-35 over Waterloo Road Interchange

SITE: Interstate 35 & Waterloo Road
Oklahoma & Logan Counties, Oklahoma

Terracon
4701 N Stiles Ave
Oklahoma City, OK

PROJECT NUMBER: 03205038

CLIENT: Garver LLC
Tulsa, Oklahoma

EXHIBIT: B-5

LABORATORY TESTS ARE NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GRAIN SIZE: USCS & AASHTO DESC COMBINED 03205038 RETAINING WALLS I-35 AT WATERLOO ROAD.GPJ TERRACON_DATATEMPLATE.GDT 9/11/20

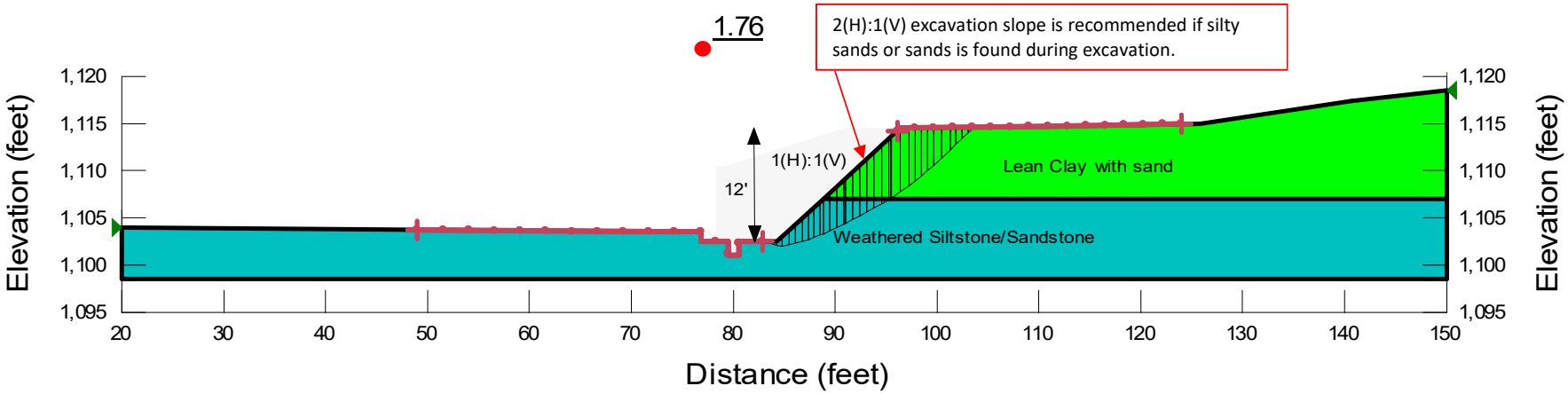
APPENDIX C

GLOBAL SLOPE STABILITY ANALYSES

RETAINING WALL A (DURING CONSTRUCTION CONDITION)

Project: Retaining Walls I-35 Over Waterloo Road Interchange
Location: Oklahoma & Logan Counties, Oklahoma
Terracon Project No. : 03205038
File Name: Wall A_Updated.gsz
Created By: Khatri, Deep K
Date: 7/8/2020

Color	Name	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Lean Clay with sand (undrained)	120	500	0
	Weathered Siltstone/Sandstone	140	0	34

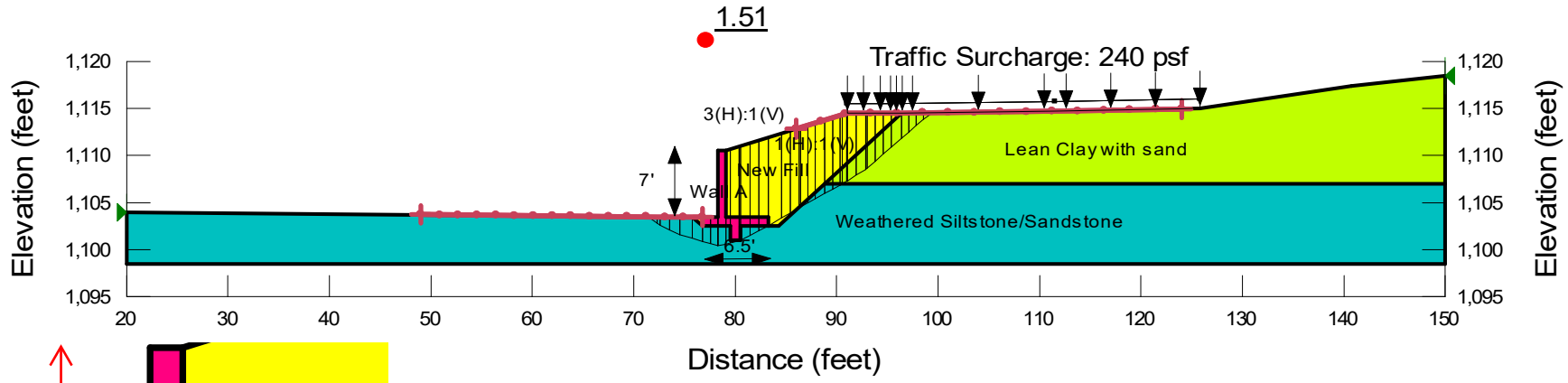


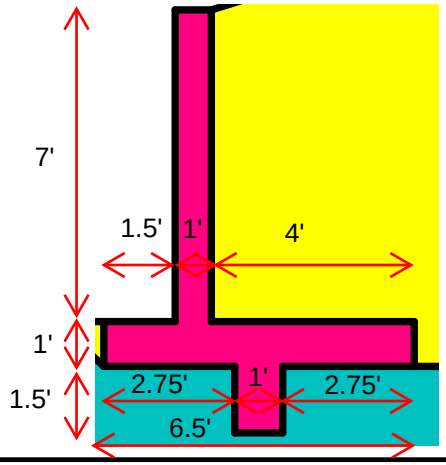
Drawn by: DKK	Exhibit C-1
Reviewed by: JD	Global Slope Stabiltiy Analysis
Scale: As Shown	Retaining Walls I-35 Over Waterloo Road Interchange Oklahoma and Logan Counties, Oklahoma
Terracon Project No. 03205038	Terracon

RETAINING WALL A (LONG-TERM CONDITION)

Project: Retaining Walls I-35 Over Waterloo Road Interchange
Location: Oklahoma & Logan Counties, Oklahoma
Terracon Project No. : 03205038
File Name: Wall A_Updated.gsz
Created By: Khatri, Deep K
Date: 7/8/2020

Color	Name	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Lean Clay w ith sand	120	0	28
	New Fill	120	0	28
	Wall A	150	5,000	45
	Weathered Siltstone/Sandstone	140	0	34



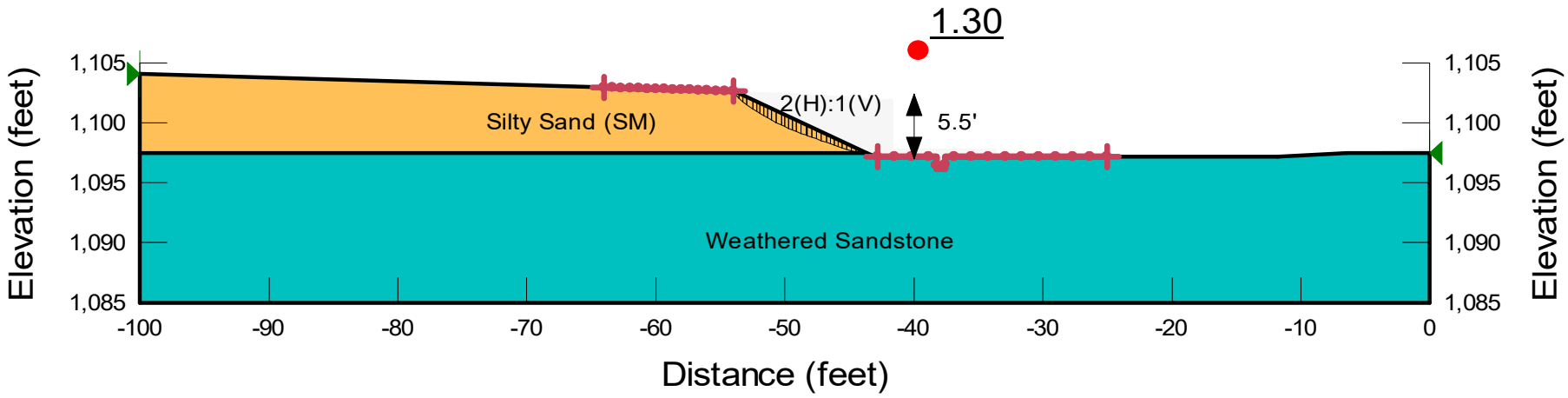


Drawn by: DKK	Exhibit C-2
Reviewed by: JD	Global Slope Stabiltiy Analysis
Scale: As Shown	Retaining Walls I-35 Over Waterloo Road Interchange Oklahoma and Logan Counties, Oklahoma
Terracon Project No. 03205038	Terracon

RETAINING WALL B (DURING CONSTRUCTION CONDITION)

Project: Retaining Walls I-35 Over Waterloo Road Interchange
Location: Oklahoma & Logan Counties, Oklahoma
Terracon Project No. : 03205038
File Name: Wall B.gsz
Created By: Khatri, Deep K
Date: 7/7/2020

Color	Name	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Silty Sand (SM)	120	0	32
	Weathered Sandstone	140	0	34

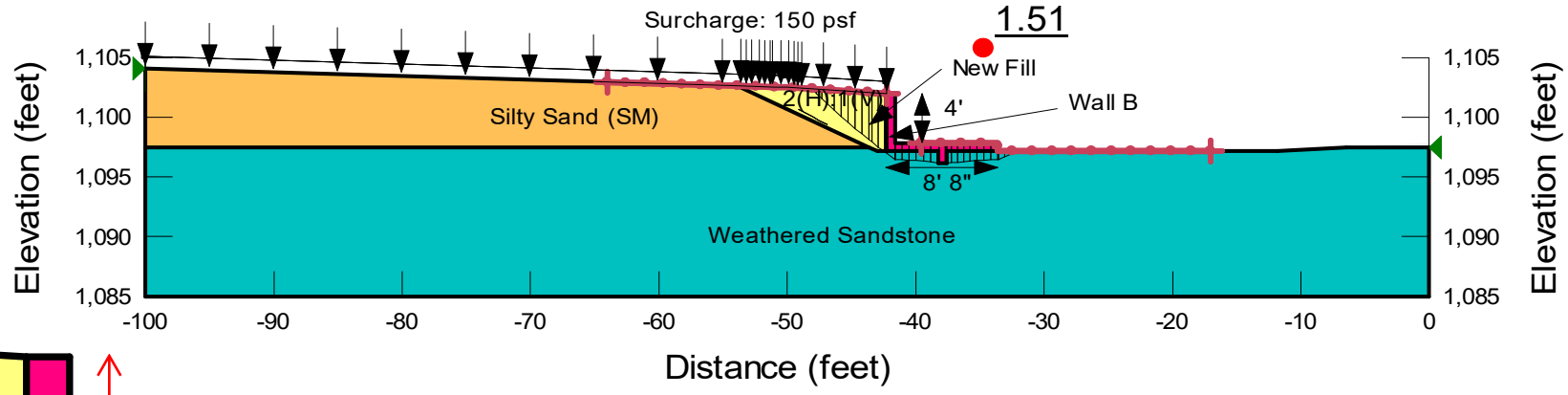


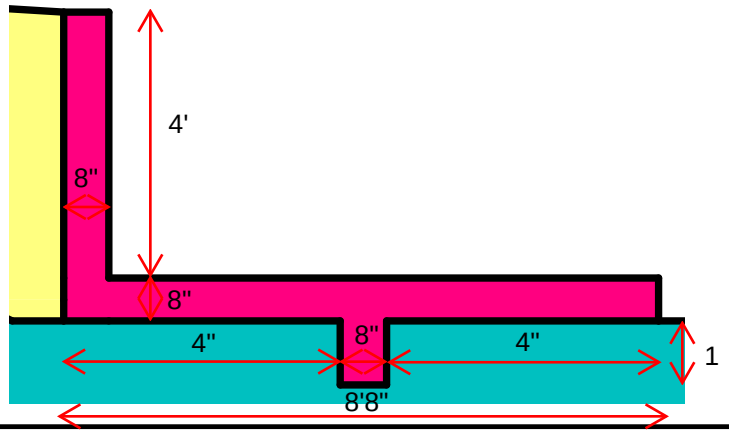
Drawn by:	Exhibit C-3
DKK	
Reviewed by:	Global Slope Stabiltiy Analysis
JD	Retaining Walls I-35 Over Waterloo Road Interchange
Scale:	Oklahoma and Logan Counties, Oklahoma
As Shown	
Terracon Project No.	
03205038	

RETAINING WALL B (LONG-TERM CONDITION)

Project: Retaining Walls I-35 Over Waterloo Road Interchange
Location: Oklahoma & Logan Counties, Oklahoma
Terracon Project No. : 03205038
File Name: Wall B.gsz
Created By: Khatri, Deep K
Date: 7/7/2020

Color	Name	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	New Fill	120	0	28
	Silty Sand (SM)	120	0	32
	Wall B	150	5,000	45
	Weathered Sandstone	140	0	34





Drawn by: DKK	Exhibit C-4
Reviewed by: JD	Global Slope Stabiltiy Analysis
Scale: As Shown	Retaining Walls I-35 Over Waterloo Road Interchange Oklahoma and Logan Counties, Oklahoma
Terracon Project No. 03205038	Terracon

APPENDIX D

SUPPORTING DOCUMENTS

GENERAL NOTES

DESCRIPTION OF SYMBOLS AND ABBREVIATIONS

SAMPLING


Auger


Split Spoon


Shelby Tube


Pressure Meter


Texas Cone


Rock Core


Grab Sample


No Recovery

WATER LEVEL


Water Initially Encountered


Water Level After a Specified Period of Time


Water Level After a Specified Period of Time

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.

FIELD TESTS

(HP)	Hand Penetrometer
(T)	Torvane
(b/f)	Standard Penetration Test (blows per foot)
(PID)	Photo-Ionization Detector
(OVA)	Organic Vapor Analyzer
(TCP)	Texas Cone Penetrometer

DESCRIPTIVE SOIL CLASSIFICATION

Soil classification is based on the Unified Soil Classification System. Coarse Grained Soils have more than 50% of their dry weight retained on a #200 sieve; their principal descriptors are: boulders, cobbles, gravel or sand. Fine Grained Soils have less than 50% of their dry weight retained on a #200 sieve; they are principally described as clays if they are plastic, and silts if they are slightly plastic or non-plastic. Major constituents may be added as modifiers and minor constituents may be added according to the relative proportions based on grain size. In addition to gradation, coarse-grained soils are defined on the basis of their in-place relative density and fine-grained soils on the basis of their consistency.

LOCATION AND ELEVATION NOTES

Unless otherwise noted, Latitude and Longitude are approximately determined using a hand-held GPS device. The accuracy of such devices is variable. 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 Includes gravels, sands and silts.			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.**	**Ring Sampler Blows/Ft.**	**Descriptive Term (Consistency)**	**Unconfined Compressive Strength, Qu, psf**	**Standard Penetration or N-Value Blows/Ft.**	**Ring Sampler Blows/Ft.**
Very Loose	0 - 3	0 - 6	Very Soft	less than 500	0 - 1	< 3
Loose	4 - 9	7 - 18	Soft	500 to 1,000	2 - 4	3 - 4
Medium Dense	10 - 29	19 - 58	Medium-Stiff	1,000 to 2,000	4 - 8	5 - 9
Dense	30 - 50	59 - 98	Stiff	2,000 to 4,000	8 - 15	10 - 18
Very Dense	> 50	≥ 99	Very Stiff	4,000 to 8,000	15 - 30	19 - 42
			Hard	> 8,000	> 30	> 42

RELATIVE PROPORTIONS OF SAND AND GRAVEL

Descriptive Term(s) of other constituents	Percent of Dry Weight
Trace	< 15
With	15 - 29
Modifier	> 30

GRAIN SIZE TERMINOLOGY

Major Component of Sample	Particle Size
Boulders	Over 12 in. (300 mm)
Cobbles	12 in. to 3 in. (300mm to 75mm)
Gravel	3 in. to #4 sieve (75mm to 4.75 mm)
Sand	#4 to #200 sieve (4.75mm to 0.075mm
Silt or Clay	Passing #200 sieve (0.075mm)

RELATIVE PROPORTIONS OF FINES

Descriptive Term(s) of other constituents	Percent of Dry Weight
Trace	< 5
With	5 - 12
Modifier	> 12

PLASTICITY DESCRIPTION

Term	Plasticity Index
Non-plastic	0
Low	1 - 10
Medium	11 - 30
High	> 30

Terracon

UNIFIED SOIL CLASSIFICATION SYSTEM

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]
			$Cu < 4$ and/or $1 > Cc > 3$ [E]		GP	Poorly graded gravel [F]
		Gravels with Fines: More than 12% fines [C]	Fines classify as ML or MH		GM	Silty gravel [F,G,H]
			Fines classify as CL or CH		GC	Clayey 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	Well-graded sand [I]
			$Cu < 6$ and/or $1 > Cc > 3$ [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 [J]		CL	Lean clay [K,L,M]
			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			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			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] $Cu = D_{60}/D_{10}$ $\quad Cc = \dfrac{(D_{30})^2}{D_{10} \times D_{60}}$

[F] If soil contains ≥ 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 ≥ 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 ≥ 30% plus No. 200 predominantly sand, add "sandy" to group name.

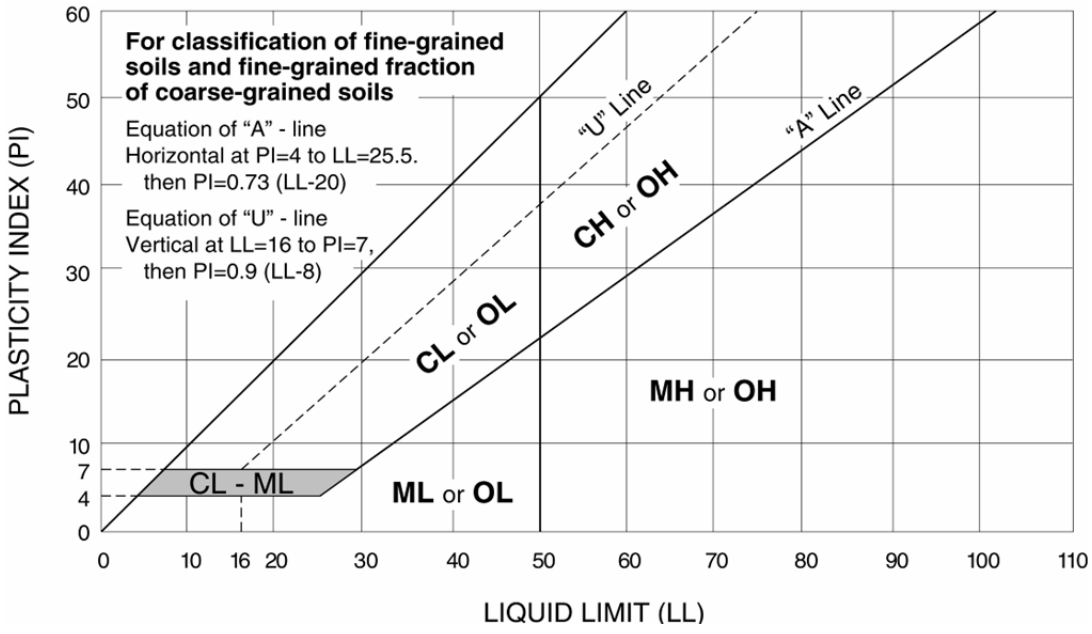
[M] If soil contains ≥ 30% plus No. 200, predominantly gravel, add "gravelly" to group name.

[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.



Terracon

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 $CaCo_3$, reacts readily with HCl.
DOLOMITE	Light to dark colored, crystalline to fine-grained texture, composed of $CaMg(CO_3)_2$, harder than limestone, reacts with HCl when powdered.
CHERT	Light to dark colored, very fine-grained texture, composed of micro-crystalline quartz ($Si0_2$), 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.