Geotechnical Engineering Report

County Bridge HP-10
Stranger Road over Rock Creek
Leavenworth, KS

October 4, 2013
Terracon Project No. 02135171

Prepared for:
Leavenworth County
Leavenworth, KS

Prepared by:
Terracon Consultants, Inc.
Lenexa, KS

October 4, 2013

Terracon

Leavenworth County
300 Walnut, Suite 7
Leavenworth, KS 66048

Attn: Mr. Mickey G. Schwartzkopf
E: mschartzkopf@leavenworthcounty.org

Re: Geotechnical Engineering Report
County Bridge HP-10
Stranger Road over Rock Creek
Leavenworth County, KS
Terracon Project Number: 02135171

Dear Mr. Schwartzkopf:

Terracon Consultants, Inc. (Terracon) has completed the geotechnical engineering services for the planned replacement of County Bridge HP-10 over Rock Creek in Leavenworth County, KS. This study was performed in general accordance with our proposal number P02130761 executed September 4, 2013. This report presents the findings of the subsurface exploration and provides geotechnical recommendations concerning earthwork and the design and construction of foundations for the proposed bridge replacement.

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.

BRETT W. LARSEN LICENSED 21707 KANSAS PROFESSIONAL ENGINEER

10/4/2013

Brett W. Larsen, P.E.
Geotechnical Engineer
KS: 21707

John A. Thomas, Jr., P.E.
Geotechnical Services Manager
KS: 20694

Enclosures
cc: 1 – Client (PDF)
1 – File

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GEOTECHNICAL ENGINEERING REPORT
COUNTY BRIDGE HP-10
STRANGER ROAD OVER ROCK CREEK
LEAVENWORTH COUNTY, KS

Terracon Project No. 02135171
October 4, 2013

1.0 INTRODUCTION

Terracon Consultants, Inc. (Terracon) has completed a subsurface exploration for the proposed County Bridge HP-10 over Rock Creek in Leavenworth County, KS. Two (2) borings were performed at this site to depths ranging from 40 to 45 feet. The boring location diagram, a site location diagram, site aerial and logs of borings are included in Appendix A of this report.

The purpose of these services is to provide information and geotechnical engineering recommendations relative to:

- subsurface soil conditions
- groundwater conditions
- earthwork
- foundation design and construction
- lateral earth pressures
- seismic considerations

2.0 PROJECT INFORMATION

2.1 Project Description

Item	Description
Site layout	See Appendix A, Exhibit A-3: Boring Location Diagram
Replacement bridge structure	The replacement structure is expected to be a precast concrete bridge, such as Conspan. Another alternative structure type being considered is an integral abutment bridge supported on driven piles.
Grading	We do not expect changes to the horizontal and vertical alignment of Stranger Road.
Cut and fill slopes	We understand that no instability of existing side slopes has been reported and that no significant alterations to the existing grades are planned.

2.2 Site Location and Description

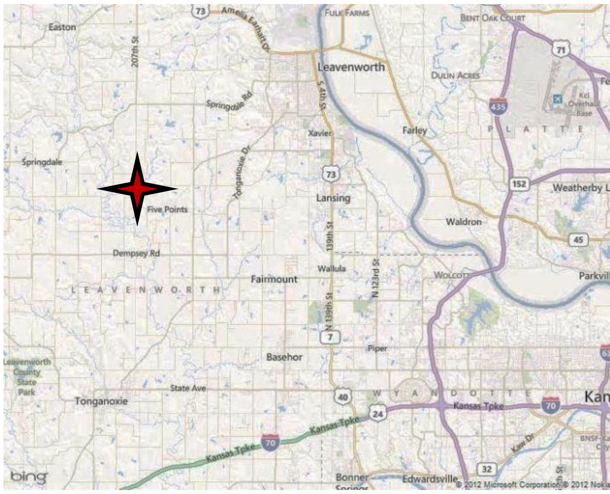


Figure 1. Site Location

Figure 2. Aerial of Site

Item	Description
Location	The bridge site is located on Stranger Road over Rock Creek in Leavenworth County, KS.
Existing conditions	Stranger Road is a gravel road in the vicinity of the existing county Bridge. The existing bridge spans approximately 26 feet across the creek.

Figure 3. Photo of existing bridge

Figure 4. Photo of existing bridge and creek

3.0 SUBSURFACE CONDITIONS

3.1 Typical Profile

Based on the results of the borings, subsurface conditions on the project site can be generalized as follows:

Stratum	Approximate Depth to Bottom of Stratum[1]	Material Description	Comments
1	12 inches	Fill	Gravel with clay
2	8 to 13 feet	Lean clay[2]	Trace sand, gray-brown, very stiff to hard
3	38.5 to 43.5 feet	Lean clay	Silty, occasionally with sand and gravel, gray, very soft to medium stiff
4	Not determined[3]	Shale	Moderately weathered, gray, medium hard

1. Depth as measured below the existing ground surface at the time the borings were conducted.
2. Lean clay is possible fill material.
3. Borings B-1 and B-2 were terminated at depths ranging from 40 to 45 feet in shale bedrock.

Subsurface conditions encountered at the boring locations are indicated on the attached 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.

3.2 Groundwater

The borings were observed while drilling and after completion for the presence of groundwater. Groundwater was observed at Borings B-1 and B-2 at depths of 10 and 13 feet, respectively. Long term observations in piezometers or observation wells sealed from influence of surface water would be required to develop additional groundwater information.

Groundwater levels fluctuate due to seasonal variations in the amount of rainfall, runoff, the water level in Rock Creek and other factors not evident at the time the borings were performed. Therefore, groundwater conditions at other times may be different than indicated on the boring logs.

4.0 RECOMMENDATIONS FOR DESIGN AND CONSTRUCTION

4.1 Geotechnical Considerations

Very soft to medium stiff silty lean clay soils were encountered below depths of about 10 to 12 feet and extended to depths of 35 to 40 feet. Footings supported on or above wet, very soft to medium stiff clay soils would likely be difficult to construct and would undergo post construction settlements greater than normal. In our opinion, the proposed bridge replacement should be supported H-Pile foundations that are driven to refusal in shale bedrock. Recommendations for design of pile foundations are presented below.

4.2 Bridge Foundation Design and Construction Considerations

We do not expect horizontal and vertical alignments of Stranger Road will be altered for this project. Due to the presence of soft clay soils to depths exceeding 35 feet, in our opinion, the new bridge should be supported on pile foundations extending to shale bedrock, which was encountered at depths ranging from 38.5 to 43.5 feet as observed at Borings B-1 and B-2, respectively. The pile installations should be observed by the geotechnical engineer.

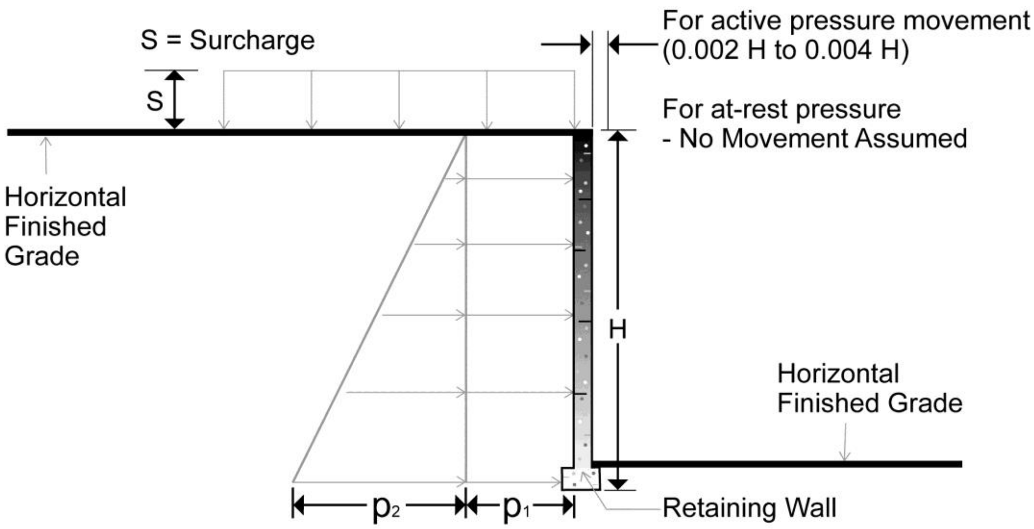
H section piles should be driven to refusal in native bedrock. The axial capacity of bearing piles, driven to refusal, will be limited to the allowable structural capacity of the pile. If piles are driven to practical refusal in bedrock, the stress of the pile cross section would control capacity. In our opinion, a resistance factor for structural strength, ϕ_s, equal to 0.5 should be considered for structural design of pile foundations in accordance with AASHTO and KDOT guidelines. No reduction factor is required for driven piles with minimum center-to-center spacing of three pile diameters.

Pile foundations designed and constructed as recommended above would be expected to experience post-construction total settlements on the order of ½ inch or less, in addition to elastic shortening of the pile materials. Differential settlements occur due to differences in subsurface and loading conditions. In our opinion, differential settlement should be on the order of ½ inch or less.

Frost action beneath pile caps and grade beams can cause uplift loads on the piles. To avoid the potential uplift loads, the base of the pile caps and grade beams should extend a minimum of 3 ½ feet below the lowest adjacent outside grade. Requirements of resistance to lateral and uplift loads for the structure were not provided. We estimate that piles driven through the native clays to refusal in shale bedrock would be capable of resisting lateral loads of at least 5 kips. If piles will be subjected to lateral loads greater than 5 kips, additional analyses, such as LPILE, should be performed to evaluate lateral load capacity.

4.3 Lateral Earth Pressures

Abutment and wing walls with unbalanced backfill levels on opposite sides should be designed for earth pressures at least equal to those indicated in the following table. Earth pressures will be influenced by structural design of the walls, conditions of wall restraint, methods of construction and/or compaction and the strength of the materials being restrained. Two wall restraint conditions are shown. Active earth pressure considers wall movement is permitted whereas, the at-rest condition considers wall movement is not permitted. The recommended design lateral earth pressures do not include a factor of safety and do not provide for possible hydrostatic pressure on the walls. In our opinion, at-rest parameters should be used to design abutment walls. If wing walls will connect to abutment walls such that movement is restricted, at-rest parameters should also be used to design wing walls.



EARTH PRESSURE COEFFICIENTS

EARTH PRESSURE CONDITIONS	COEFFICIENT FOR BACKFILL TYPE	EQUIVALENT FLUID DENSITY (pcf)	SURCHARGE PRESSURE, p_1 (psf)	EARTH PRESSURE, p_2 (psf)
Active (Ka)	Granular - 0.33	40	(0.33)S	(40)H
	Lean Clay - 0.42	50	(0.42)S	(50)H
At-Rest (Ko)	Granular - 0.42	50	(0.42)S	(50)H
	Lean Clay - 0.58	70	(0.58)S	(70)H

Applicable conditions to the above include:

- For active earth pressure, wall must rotate about base, with top lateral movements of about 0.002 **H** to 0.004 **H**, where **H** is wall height
- Uniform surcharge, where S is surcharge pressure
- In-situ soil backfill weight a maximum of 120 pcf
- Horizontal backfill, compacted between 95 and 98 percent of standard Proctor maximum dry density
- Loading from heavy compaction equipment not included
- No hydrostatic pressures acting on wall
- No dynamic loading
- No safety factor included in soil parameters

Backfill placed against structures should consist of granular soils or on-site cohesive soils. For the granular values to be valid, the granular backfill must extend out from the base of the wall at an angle of at least 45 degrees from vertical for the active and at at-rest cases. To calculate the resistance to sliding, a value of 0.3 should be used as the ultimate coefficient of friction between the footing and the clay.

To control hydrostatic pressure behind the walls we recommend a continuous subsurface drain line be installed behind the walls that drains freely to down gradient outlets and/or weep holes be installed through the walls. If backfill drainage is not possible, then walls should be designed to resist the combined hydrostatic and lateral earth pressures.

4.4 Seismic Considerations

Code Reference	Site Classification
2009 International Building Code (IBC)	D [1]

1. The 2009 International Building Code (IBC) site profile determination is based on average properties of the subsurface profile to a depth of 100 feet. Borings extended to a maximum depth of approximately 45 feet. Our opinion of site classification is based on our knowledge of local geology and geotechnical conditions.

4.5 Backfill and Compaction

Fills used to backfill behind the bridge abutments and wing walls should consist of approved materials, which are free of organic matter and debris. In general, the lean clay soils that will likely be excavated to accommodate construction of the bridge replacement could be used to construct engineered fills, provided any organic matter and debris is removed. Wet clay soils will likely need to be dried in order to achieve the recommended degree of compaction.

Samples of all proposed fill materials (site soils and imported materials) should be tested and approved prior to being incorporated into the work.

In our opinion, engineered fill should be placed and compacted as recommended in the table below.

Item	Description
Fill Lift Thickness	9-inches or less in loose thickness when heavy, self-propelled compaction equipment is used
	4 to 6 inches in loose thickness when small hand-guided equipment (i.e. jumping jack or plate compactor) is used
Compaction Requirements [1]	95% of the materials maximum standard Proctor dry density (ASTM D-698)
Moisture Content – Cohesive Soil	Within the range of -2% to +2% optimum moisture content as determined by the standard Proctor test.
Moisture Content – Granular Material	Sufficient to achieve satisfactory compaction without pumping when proof-rolled

1. We recommend that engineered fill be tested for moisture content and compaction during placement. Should the results of the in-place density tests indicate the specified moisture or 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.

5.0 GENERAL COMMENTS

Terracon 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 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 construction or 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 for this project 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.

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 express or implied, are intended or made. Site safety, excavation support, and dewatering requirements are the responsibility of others. In the event that 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 reviews the changes and either verifies or modifies the conclusions of this report in writing.

APPENDIX A
FIELD EXPLORATION

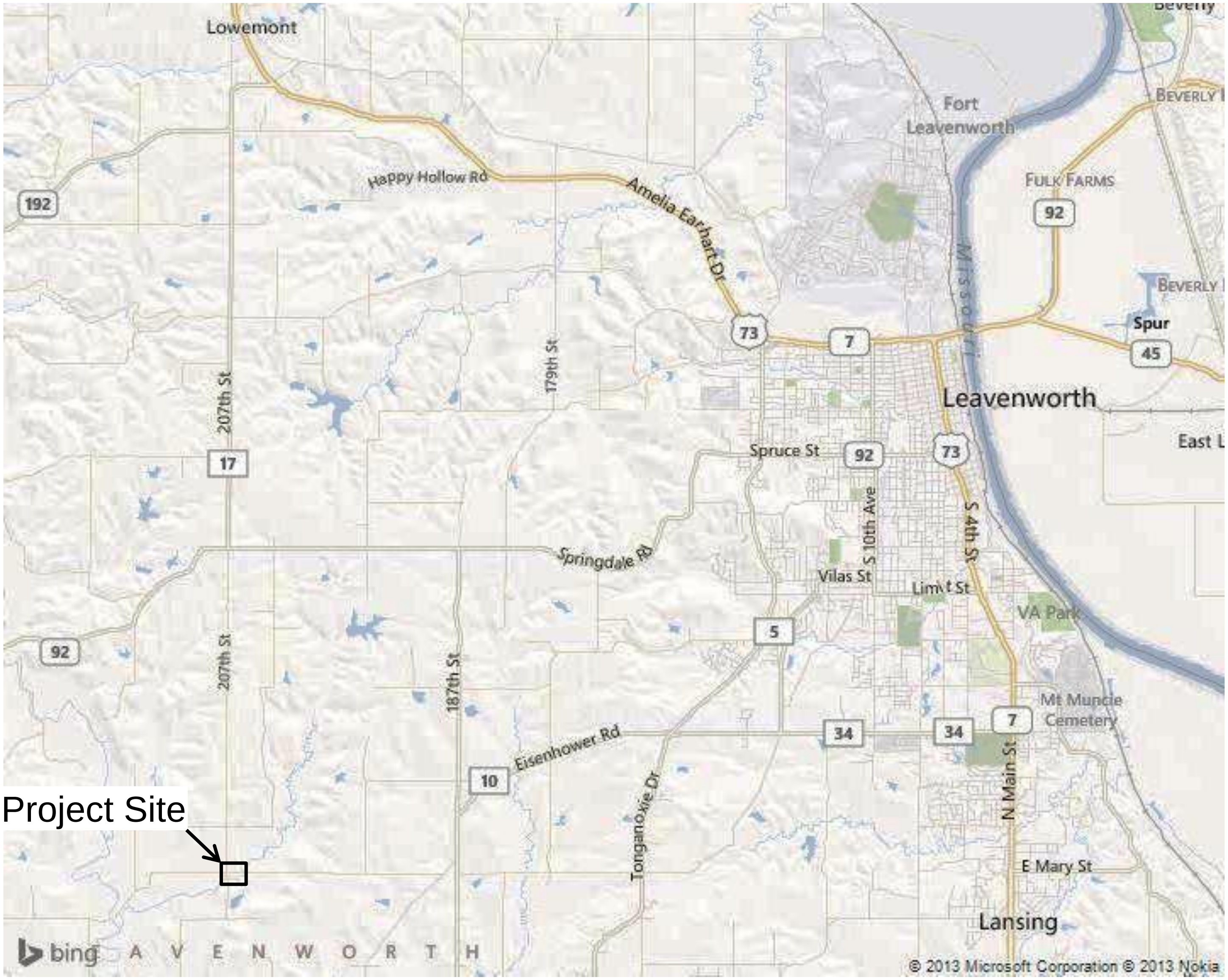


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DIAGRAM IS FOR GENERAL LOCATION ONLY, AND IS NOT INTENDED FOR CONSTRUCTION PURPOSES

Project Manager: BWL	Project No. 02135171
Drawn by: BWL	Scale: N.T.S.
Checked by: BWL	File Name: Boring Location (11x8.5).ppt
Approved by: BWL	Date: 10/1/2013

Terracon
Consulting Engineers & Scientists
13910 West 96th Terrace Lenexa, Kansas 66215
PH. (913) 492-7777 FAX. (913) 492-7443

SITE LOCATION DIAGRAM

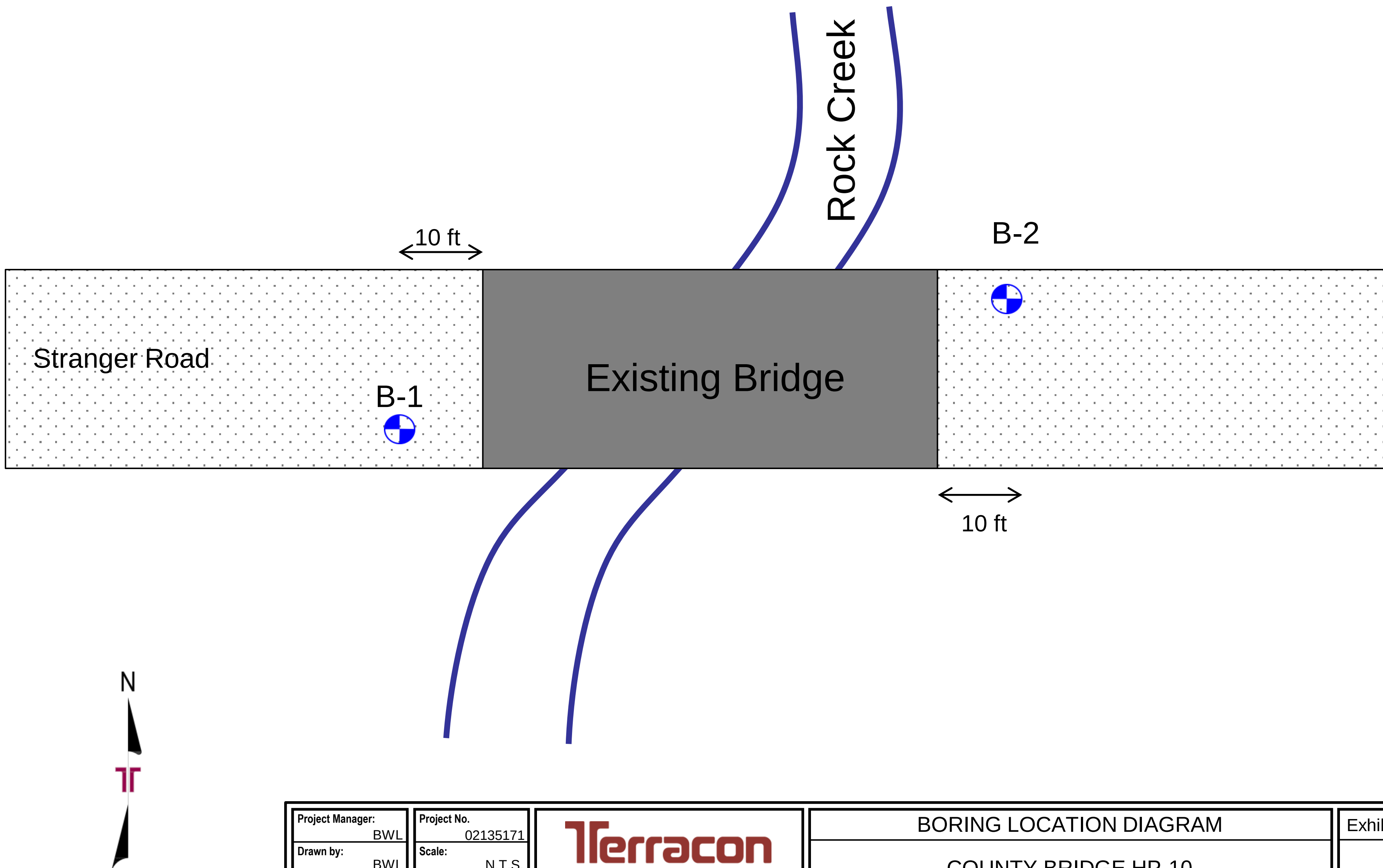
COUNTY BRIDGE HP-10
Stranger Road over Rock Creek
LEAVENWORTH COUNTY, KS

Exhibit
A-1

N

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

Project Manager: BWL	Project No. 02135171	Terracon Consulting Engineers & Scientists	SITE AERIAL
Drawn by: BWL	Scale: N.T.S.	13910 West 96th Terrace Lenexa, Kansas 66215	COUNTY BRIDGE HP-10 Stranger Road over Rock Creek LEAVENWORTH COUNTY, KS
Checked by: BWL	File Name: Boring Location (11x8.5).ppt	PH. (913) 492-7777 FAX. (913) 492-7443	Exhibit
Approved by: BWL	Date: 10/1/2013		A-2



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Drawn by: BWL	Scale: N.T.S.		
Checked by: BWL	File Name: Boring Location (11x8.5).ppt		
Approved by: BWL	Date: 10/1/2013		

Terracon
Consulting Engineers & Scientists
13910 West 96th Terrace Lenexa, Kansas 66215
PH. (913) 492-7777 FAX. (913) 492-7443

BORING LOCATION DIAGRAM

COUNTY BRIDGE HP-10
Stranger Road over Rock Creek
LEAVENWORTH COUNTY, KS

Exhibit
A-3

BORING LOG NO. B-1

PROJECT: County Bridge HP-10

CLIENT: Leavenworth Department of Public Works
Leavenworth, KS

SITE: Stranger Road over Rock Creek
Leavenworth County, KS

LOCATION See Exhibit A-3

Approximate Surface Elev: 99.5 (Ft.) +/-

DEPTH	DESCRIPTION	ELEVATION (Ft.)
1.0	**FILL - GRAVEL**, with clay	98.5+/-
8.0	**LEAN CLAY (CL)**, trace sand, gray-brown, very stiff (possible fill)	91.5+/-
38.5	**LEAN CLAY (CL)**, silty, gray-brown, very soft to medium stiff	61+/-
40.0	**SHALE**, moderately weathered, brown, medium hard	59.5+/-
	Boring Terminated at 40 Feet	

DEPTH (Ft.) (approx.)	WATER LEVEL OBSERVATIONS	RECOVERY (In.)	FIELD TEST RESULTS	LABORATORY TORVANE/HP (psf)	UNCONFINED COMPRESSIVE STRENGTH (psf)	WATER CONTENT (%)	DRY UNIT WEIGHT (pcf)
2				4500 (HP)		14	99
4				6000 (HP)		20	95
9					1203	28	92
11	▽						
14					520	27	97
19					285	27	98
24		18	2-2-3 N=5			32	
29		18	2-2-2 N=4			29	
34		18	2-1-2 N=3			28	
39		18	17-34-38 N=72			15	

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 SPT Hammer

Advancement Method:
0-40': Power Auger

Abandonment Method:
Boring backfilled with soil cuttings upon completion.

See Exhibit A-6 for description of field procedures

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

See Appendix C for explanation of symbols and abbreviations.

Elevations were measured in the field using an engineer's level and grade rod

Notes:

WATER LEVEL OBSERVATIONS

▽ *While drilling*

Terracon
13910 West 96th Terrace
Lenexa, Kansas

Boring Started: 9/9/2013 | Boring Completed: 9/9/2013

Drill Rig: CME 75 | Driller: JJ

Project No.: 02135171 | Exhibit: A-4

BORING LOG NO. B-2

PROJECT: County Bridge HP-10

**CLIENT: Leavenworth Department of Public Works
Leavenworth, KS**

**SITE: Stranger Road over Rock Creek
Leavenworth County, KS**

LOCATION See Exhibit A-3

Approximate Surface Elev: 100 (Ft.) +/-

DEPTH	Description	ELEVATION (Ft.)
1.0	**FILL - GRAVEL**, with clay	99+/-
13.0	**LEAN CLAY (CL)**, brown, trace sand, very stiff to hard (possible fill) - with broken rock below 8'	87+/-
33.5	**LEAN CLAY (CL)**, silty, gray, soft	66.5+/-
43.5	**LEAN CLAY (CL)**, with sand and gravel, brown, medium stiff	56.5+/-
45.0	**SHALE**, moderately weathered, gray, medium hard	55+/-
	Boring Terminated at 45 Feet	

Sample depth (approx. Ft.)	Sample type	RECOVERY (In.)	FIELD TEST RESULTS	LABORATORY TORVANE/HP (psf)	UNCONFINED COMPRESSIVE STRENGTH (psf)	WATER CONTENT (%)	DRY UNIT WEIGHT (pcf)
1–3	Shelby tube			+9000 (HP)		18	92
3–5	Shelby tube			+9000 (HP)		19	90
8–10	Shelby tube			5500 (HP)		18	
13–15	Shelby tube				975	30	96
18–20	Shelby tube			1000 (HP)		34	90
23–25	Shelby tube					29	95
28.5–30	Split spoon	18	1-2-2 N=4			32	
33.5–35	Split spoon	11	1-2-3 N=5			24	
38.5–40	Split spoon	18	2-3-4 N=7			19	
43.5–45	Split spoon	18	12-34-50/3" N=84/9"			19	

Water level observed while sampling at approximately 12.5 ft.

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 SPT Hammer

Advancement Method:
0-40': Power Auger

Abandonment Method:
Boring backfilled with soil cuttings upon completion.

See Exhibit A-6 for description of field procedures

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

See Appendix C for explanation of symbols and abbreviations.

Elevations were measured in the field using an engineer's level and grade rod

Notes:

WATER LEVEL OBSERVATIONS

While sampling

Terracon
13910 West 96th Terrace
Lenexa, Kansas

Boring Started: 9/9/2013 | Boring Completed: 9/9/2013
Drill Rig: CME 75 | Driller: JJ
Project No.: 02135171 | Exhibit: A-5

Field Exploration Description

The proposed boring locations were laid out in the field by a Terracon representative. Distances from existing site features were measured with a calibrated measuring wheel and right angles were estimated. Ground surface elevations indicated on the boring logs were measured in the field using a surveyor's level and grade rod. The elevations were referenced to the bridge deck elevation at the east end of the bridge and are rounded to the nearest ½ foot. This temporary benchmark was assigned an arbitrary elevation of 100.0 feet. The locations and elevations of the borings should be considered accurate only to the degree implied by the means and methods used to define them.

The borings were drilled with a truck-mounted rotary drill rig using flight augers to advance the boreholes. Samples of the soil encountered in the borings were obtained using the thin-walled tube and split-barrel sampling procedures.

In the thin-walled tube sampling procedure, a 2-inch diameter, steel-tube with a sharp cutting edge is pushed hydraulically into the soil to obtain a relatively undisturbed sample. In the split-barrel sampling procedure, a standard 2-inch O.D. split-barrel sampling spoon is driven into the ground by a 140 pound 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.

The samples were tagged for identification, sealed to reduce moisture loss, and taken to our laboratory for further examination, testing, and classification. The borings were backfilled with auger cuttings upon completion.

A field log of each boring was prepared by the drill crew to record data including visual classifications of the materials encountered during drilling as well as the driller's interpretation of the subsurface conditions between samples. Final boring logs included with this report represent the engineer's interpretation of the subsurface conditions based on field laboratory data and observation of the samples.

APPENDIX B
SUPPORTING INFORMATION

Laboratory Testing

Representative soil samples were tested in the laboratory to measure their natural water content, dry unit weight and unconfined compressive strength. A calibrated penetrometer was used to estimate the approximate unconfined compressive strength of other samples. The test results are provided on the boring logs included in Appendix A.

Descriptions of the soils indicated on the boring logs are in accordance with the enclosed General Notes and the Unified Soil Classification System. A Unified Soil Classification Group Symbol is shown for each sample. A brief description of this classification system is in Appendix C. All classification was by visual manual procedures.

Descriptions of bedrock indicated on the boring logs are in accordance with the enclosed General Notes – Description of Rock Properties.

APPENDIX C
SUPPORTING DOCUMENTS

GENERAL NOTES

DESCRIPTION OF SYMBOLS AND ABBREVIATIONS

SAMPLING

Auger	Split Spoon
Shelby Tube	Macro Core
Ring Sampler	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

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				BEDROCK		
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.**	**Ring Sampler Blows/Ft.**	**Standard Penetration or N-Value Blows/Ft.**	**Descriptive Term (Consistency)**
Very Loose	0 - 3	0 - 6	Very Soft	less than 500	0 - 1	< 3	< 30	< 20	Weathered
Loose	4 - 9	7 - 18	Soft	500 to 1,000	2 - 4	3 - 4	30 - 49	20 - 29	Firm
Medium Dense	10 - 29	19 - 58	Medium-Stiff	1,000 to 2,000	4 - 8	5 - 9	50 - 89	30 - 49	Medium Hard
Dense	30 - 50	59 - 98	Stiff	2,000 to 4,000	8 - 15	10 - 18	90 - 119	50 - 79	Hard
Very Dense	> 50	≥ 99	Very Stiff	4,000 to 8,000	15 - 30	19 - 42	> 119	>79	Very Hard
			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

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UNIFIED SOIL CLASSIFICATION SYSTEM

Criteria for Assigning Group Symbols and Group Names Using Laboratory Tests [A]				Soil Classification: Group Symbol	Soil Classification: Group Name [B]
Coarse Grained Soils: More than 50% retained on No. 200 sieve	**Gravels:** More than 50% of coarse fraction retained on No. 4 sieve	**Clean Gravels:** Less than 5% fines [C]	Cu ≥ 4 and 1 ≤ Cc ≤ 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 ≥ 6 and 1 ≤ Cc ≤ 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 / Liquid limit - not dried < 0.75	OL	Organic clay [K,L,M,N]
					Organic silt [K,L,M,O]
	Silts and Clays: Liquid limit 50 or more	**Inorganic:**	PI plots on or above "A" line	CH	Fat clay [K,L,M]
			PI plots below "A" line	MH	Elastic Silt [K,L,M]
		Organic:	Liquid limit - oven dried / Liquid limit - not dried < 0.75	OH	Organic clay [K,L,M,P]
					Organic silt [K,L,M,Q]
Highly organic soils:	Primarily organic matter, dark in color, and organic odor			PT	Peat

[A] Based on the material passing the 3-inch (75-mm) sieve

[B] If field sample contained cobbles or boulders, or both, add "with cobbles or boulders, or both" to group name.

[C] Gravels with 5 to 12% fines require dual symbols: GW-GM well-graded gravel with silt, GW-GC well-graded gravel with clay, GP-GM poorly graded gravel with silt, GP-GC poorly graded gravel with clay.

[D] 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.

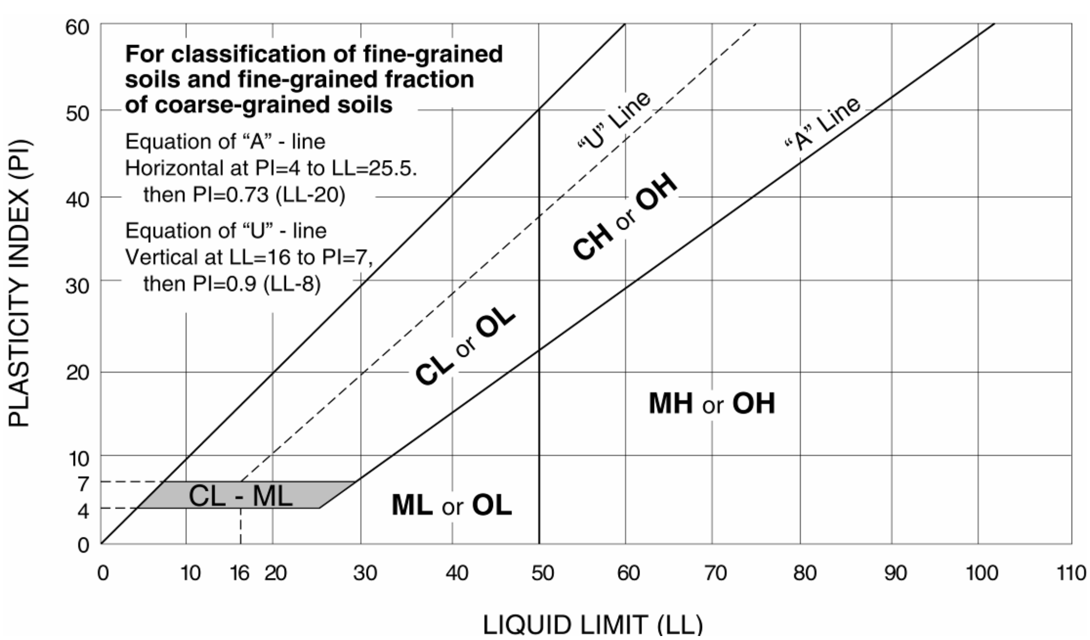
[M] If soil contains ≥ 30% plus No. 200, predominantly gravel, add "gravelly" to group name.

[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.



DESCRIPTION OF ROCK PROPERTIES

WEATHERING

Fresh	Rock fresh, crystals bright, few joints may show slight staining. Rock rings under hammer if crystalline.
Very slight	Rock generally fresh, joints stained, some joints may show thin clay coatings, crystals in broken face show bright. Rock rings under hammer if crystalline.
Slight	Rock generally fresh, joints stained, and discoloration extends into rock up to 1 in. Joints may contain clay. In granitoid rocks some occasional feldspar crystals are dull and discolored. Crystalline rocks ring under hammer.
Moderate	Significant portions of rock show discoloration and weathering effects. In granitoid rocks, most feldspars are dull and discolored; some show clayey. Rock has dull sound under hammer and shows significant loss of strength as compared with fresh rock.
Moderately severe	All rock except quartz discolored or stained. In granitoid rocks, all feldspars dull and discolored and majority show kaolinization. Rock shows severe loss of strength and can be excavated with geologist's pick.
Severe	All rock except quartz discolored or stained. Rock "fabric" clear and evident, but reduced in strength to strong soil. In granitoid rocks, all feldspars kaolinized to some extent. Some fragments of strong rock usually left.
Very severe	All rock except quartz discolored or stained. Rock "fabric" discernible, but mass effectively reduced to "soil" with only fragments of strong rock remaining.
Complete	Rock reduced to "soil". Rock "fabric" not discernible or discernible only in small, scattered locations. Quartz may be present as dikes or stringers.

HARDNESS (for engineering description of rock – not to be confused with Moh's scale for minerals)

Very hard	Cannot be scratched with knife or sharp pick. Breaking of hand specimens requires several hard blows of geologist's pick.
Hard	Can be scratched with knife or pick only with difficulty. Hard blow of hammer required to detach hand specimen.
Moderately hard	Can be scratched with knife or pick. Gouges or grooves to ¼ in. deep can be excavated by hard blow of point of a geologist's pick. Hand specimens can be detached by moderate blow.
Medium	Can be grooved or gouged 1/16 in. deep by firm pressure on knife or pick point. Can be excavated in small chips to pieces about 1-in. maximum size by hard blows of the point of a geologist's pick.
Soft	Can be gouged or grooved readily with knife or pick point. Can be excavated in chips to pieces several inches in size by moderate blows of a pick point. Small thin pieces can be broken by finger pressure.
Very soft	Can be carved with knife. Can be excavated readily with point of pick. Pieces 1-in. or more in thickness can be broken with finger pressure. Can be scratched readily by fingernail.

Joint, Bedding, and Foliation Spacing in Rock [a]

Spacing	Joints	Bedding/Foliation
Less than 2 in.	Very close	Very thin
2 in. – 1 ft.	Close	Thin
1 ft. – 3 ft.	Moderately close	Medium
3 ft. – 10 ft.	Wide	Thick
More than 10 ft.	Very wide	Very thick

a. Spacing refers to the distance normal to the planes, of the described feature, which are parallel to each other or nearly so.

Rock Quality Designator (RQD) a

RQD, as a percentage	Diagnostic description
Exceeding 90	Excellent
90 – 75	Good
75 – 50	Fair
50 – 25	Poor
Less than 25	Very poor

a. RQD (given as a percentage) = length of core in pieces 4 in. and longer/length of run.

Joint Openness Descriptors

Openness	Descriptor
No Visible Separation	Tight
Less than 1/32 in.	Slightly Open
1/32 to 1/8 in.	Moderately Open
1/8 to 3/8 in.	Open
3/8 in. to 0.1 ft.	Moderately Wide
Greater than 0.1 ft.	Wide

References: American Society of Civil Engineers. Manuals and Reports on Engineering Practice - No. 56. Subsurface Investigation for Design and Construction of Foundations of Buildings. New York: American Society of Civil Engineers, 1976. U.S. Department of the Interior, Bureau of Reclamation, Engineering Geology Field Manual.