Geotechnical Evaluation

FOR

Silver Street Interchange Utility Reconstruction Project

City of Rapid City
Project No. 12-2053 / CIP 50940

Companion Project to:

South Dakota Department of Transportation
Project IM 1902(61)0
Interstate 190 N and 190 S
Pennington County

February 21, 2014

PREPARED FOR:

City of Rapid City
Mr. Todd Peckosh, P.E.
City of Rapid City
300 6th Street
Rapid City, SD 57701

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February 21, 2014

City of Rapid City
Mr. Todd Peckosh, P.E.
Engineering Division
300 6th Street
Rapid City, SD 57701

RE: Silver Street Interchange Utility Reconstruction Project
Rapid City, SD

Dear Mr. Peckosh:

As part of the Silver Street Utility Reconstruction Project, we have completed a geotechnical evaluation of the project utility alignments. The purpose of this evaluation was to identify the subsurface conditions and provide geotechnical recommendations for the proposed construction. This report presents our findings and recommendations.

INTRODUCTION

The South Dakota Department of Transportation (SDDOT) plans to reconstruct the Interstate 190 – Silver Street interchange. The SDDOT project will replace the existing bridge and ramps to create a single point diamond interchange. The new interchange will greatly affect the City of Rapid City utility infrastructure and will require relocation and/or replacement of nearly all water and sanitary sewer facilities in the project area.

The SDDOT, through their engineering consultant HDR, will be completing the interchange and street design including, but not limited to; right-of-way (ROW) needs, traffic flow and control, pavement design, lighting, and storm water drainage.

The City of Rapid City will be addressing their water and sewer utility infrastructure in conjunction with the SDDOT project, and has retained FMG, Inc. to provide (1) review of the SDDOT plans, (2) analysis and design of the water system improvements, (3) analysis and design of sanitary sewer system improvements, (4) storm drainage analysis, including review of SDDOT and City design criteria differences and oversize recommendations to the design being prepared by SDDOT, (5) recommendation related to construction sequencing to coordinate street and utility reconstruction, and (6) a Geotechnical Evaluation for City Utilities.

This report presents our geotechnical evaluation of the proposed utility alignments and impacted areas of the project. If proposed construction or locations differ significantly from that described herein, our office should be contacted to re-evaluate the recommendations contained in this report.

Field and laboratory tests were generally accomplished in accordance with current ASTM and AASHTO procedures, where applicable. This report presents the geologic logs & the results of the lab testing. We have also included a discussion of our field sampling & testing procedures, laboratory testing procedures, materials present, and geotechnical recommendations and construction considerations.

FIELD SAMPLING & TESTING PROCEDURES

A total of 10 boreholes were drilled at the locations shown on Figure 1 to identify the subsurface characteristics and obtain soil samples for laboratory testing. The boreholes were drilled with a Mobile B57 drill rig equipped with an automatic hammer, and were observed and logged by an FMG, Inc. geologist. The borehole locations were selected by FMG, Inc. with respect to project alignments and avoidance of existing overhead and underground utilities. If, during subsequent planning, the utility alignments change significantly from that described in this report and shown on Figure 1, we recommend drilling additional boreholes to verify soil conditions in unexplored areas.

Geologic logs of the boreholes were maintained by a field geologist and the materials were classified in accordance with Figure 2. The geologic logs include the depths of the major changes in the character of the subsurface materials, visual description of the materials, field-testing data and locations, and groundwater data. In addition, the geologic logs include data from certain laboratory classification and physical property analyses. The geologic logs and a legend that describes the geologic log symbols and notes are presented as Appendix A.

The geologic logs and related information depict our approximation of the conditions, interfaces, and materials encountered at the specific borehole location and at the particular time designated on the logs. Soil conditions at other locations may be different from those encountered at the drilled borehole locations. Also, the passage of time may produce a changed subsurface and/or soil condition. We have extrapolated the data obtained from the boreholes and our conclusions and recommendations are based on the assumption that the materials encountered are representative of the soils that exist over the site. Anomalies may be present around the boreholes.

In addition to the field soil sampling and testing, field soil resistivity surveys were performed at 8 locations along the proposed water main alignments. The locations at which resistivity surveys were performed are shown on Figure 1. The soil resistivity was measured at the approximate depth of placement of the proposed water main at each location. The surveys were performed in general accordance with the draft City of Rapid City "Corrosion Control Design Manual", 2008 and ASTM G57 using the Wenner Four-Electrode Method. The results of the field soil resistivity surveys are presented as Appendix B. The indicated corrosivity ratings are based on Table 1 of the draft City of Rapid City "Corrosion Control Design Manual", 2008.

LABORATORY TESTING PROCEDURES

The laboratory analysis was directed towards the classification of the on-site soils, and was performed in general accordance with current ASTM and AASHTO procedures where applicable. We determined the moisture contents, the Atterberg Limits, grain size distributions, and electrical resistivity of some of the materials obtained from the site. We have also performed Proctor testing of the site materials. The results of the laboratory testing are presented on the geologic logs and as Appendix C.

The soil samples obtained for this project will not be stored. If the City wishes to receive the samples, we suggest that arrangements be made; otherwise the samples will be discarded.

MATERIALS PRESENT

The materials encountered varied along the proposed alignments. The soil profile encountered east of Interstate 190, from Van Buren St. south to Rapid Creek, generally consisted of a layer of moist lean clay underlain by coarse sands, gravels and cobbles of varying density. This profile is also accurate for Borehole 5 located west of 190 along the offramp to Silver Street. Although not encountered within our boreholes, boulders exist within the subsurface materials due to the depositional nature of the soils.

The soil profile encountered in Boreholes 6 and 7, west of Interstate 190 and between Philadelphia Street and Silver Street, generally consisted of variably thick layers of lean to fat clay underlain by weathered shale and hard competent shale. The materials were moist and ranged from stiff to hard with depth. Although not encountered

within our boreholes, cobble and boulder sized material may still exist within this portion of the alignment, specifically in the upper layers.

The soil profile encountered in Boreholes 9 and 10 in the southwest portion, generally consisted of variably thick layers of lean clay, underlain by gravel and cobbles, underlain by weathered shale. The lean clay was moist and had medium stiff consistency. The gravel and cobbles were coarse, saturated, with a hard consistency.

Borehole 8, also in the southwest portion, contained fill material from previous earthwork. This fill material consisted of lean clay with sand and gravel, was moist to saturated, and ranged from soft to stiff consistency.

The geologic logs indicate the specific soil characteristics observed throughout the profiles in the boreholes advanced along the proposed alignment.

GEOTECHNICAL RECOMMENDATIONS AND CONSTRUCTION CONSIDERATIONS

From our subsurface soil exploration and engineering analysis, we have arrived at the following conclusions and have the following recommendations with regard to the proposed construction. Geotechnical recommendations and construction considerations regarding groundwater, excavations, utility installations, and general material placement are presented as follows.

Groundwater

Groundwater was encountered in a majority of the boreholes drilled and will be encountered during construction. Groundwater levels were observed both during drilling and during a re-check of the boreholes more than 24 hours after completion of drilling. The groundwater levels encountered during our exploration are summarized below.

Borehole	*Depth to Groundwater (ft)* *Oct. 22, 2013*
1	Not Encountered
2	Not Encountered
3	Not Encountered
4	14
5	8
6	7
7	Not Encountered
8	6.5
9	6
10	6

Generally, the presence of a near surface groundwater table may make compaction and construction operations difficult. Where groundwater is encountered, we recommend excavating short stretches, installing the utility and backfilling immediately after the installation operations and/or constructing periodic sumps from which groundwater can be removed as it enters the excavation. However, due to high permeability gravels and shallow groundwater, we caution that aggressive dewatering techniques may be necessary throughout the alignment. We also caution that the excavated materials may require drying prior to backfilling to allow for proper compaction, even in areas where groundwater is not encountered.

Groundwater levels should be anticipated to fluctuate in response to seasonal and short-range changes in precipitation, snowmelt, landscape irrigation and land use, and may not be accurately delineated within the normal scope of a geotechnical evaluation. Piezometers were installed at Boreholes 9 and 10 in the southwest portion of the project, to facilitate longer term monitoring of groundwater levels in these areas only.

Excavations

Regarding excavations at the site, we recommend that they be sloped or shored in accordance with OSHA regulations, and to generally maintain adequate safety provisions on the job-site. The soils within the proposed alignments were deposited by alluvial processes, creating highly variable compositions of seemingly similar soil types. Consequently, the overlying lean clays, as well as the underlying sands and gravels throughout the site, should be considered OSHA Type C soils. Material in a portion of the project, bounded by Interstate 190 to the east, Philadelphia Street to the south, and Silver Street to the north, consisted of lean clay, underlain by weathered shale containing bentonite, underlain by competent formational shale. These materials can be considered OSHA Type B soils. It is the contractor's responsibility to maintain job-site safety, and the occasional or longer term presence of an FMG, Inc. representative at the site does not constitute a review or a responsibility regarding safety aspects.

Any excavations adjacent to existing foundations, utility lines, soft soils, or related structures should be maintained such that they are not "undermined" or caused to become unstable by loss of overburden pressure or lateral support. Temporary shoring or other techniques may be necessary to maintain the integrity of affected structures. Caving soil conditions were observed in one of the boreholes drilled. Temporary shoring may also be required to facilitate proper utility installation in some areas of the project.

Due to the depositional nature of the site soils, the specific material types will vary both horizontally and vertically throughout the project. Also, excavations can be expected to encounter cobbles, boulders, deleterious debris, objects, etc.

Utility Installation

Based on the results of our field exploration, utility excavations will be in a variety of soil types, ranging from sands, gravels, cobbles and boulders, to silts and clays. Recommendations regarding utility trench excavation are provided in the Excavations section of this report.

Pipe bedding materials should meet the requirements of the City of Rapid City, “Standard Specifications for Public Works Construction”, 2007 Edition. The contractor should not anticipate that on-site soils will be suitable for use as bedding materials.

Utility installations in portions of the proposed alignments will be in close proximity or below the groundwater table. Generally, the presence of a near surface groundwater table may make compaction and construction operations difficult. Where groundwater is encountered, we recommend excavating short stretches, installing the utility and backfilling immediately after the installation operations and/or constructing periodic sumps from which groundwater can be removed as it enters the excavation. **However due to the shallow groundwater conditions and elevated moisture contents, we caution that the excavated materials will require drying prior to backfilling, or imported fill materials may be necessary to allow for proper compaction, even in areas where groundwater is not encountered.**

Due to the locally soft and saturated nature of the site soils, soft unstable trench bottoms may be encountered. In some areas of the alignments, it may be necessary to stabilize the base of the utility excavations with a crushed foundation rock to allow for proper installation of the utility.

General Material Placement

Since the material composition and groundwater conditions vary along the proposed alignments, we have the following recommendations specific to portions of the alignment which exhibit similar subsurface conditions. The actual subsurface conditions encountered during construction will vary, as will the lateral extents to which the following recommendations apply.

In all cases, utility backfill soils should be free of vegetation, debris and other deleterious materials, and conform to the requirements of the City of Rapid City, "Standard Specifications for Public Works Construction", 2007 Edition. We suggest that sufficient density tests be taken by qualified personnel to indicate the degree of compaction being attained. It is our understanding that specifications will require fill and backfill compaction operations to meet the DOT Embankment Construction requirements that are located in Section 120 of the (2004) "Standard Specifications for Roads and Bridges".

East of Interstate 190 and near Rapid Creek (Boreholes 1-4, 9 and 10)

The subsurface conditions encountered east of Interstate 190 and near Rapid Creek generally consisted of lean clays underlain by gravels and cobbles. The lean clays were found to be wet, generally 7 or more percent above Proctor test optimum moisture contents. **Some drying of these materials will be necessary prior to use as properly compacted backfill.** In the event that drying of saturated or over-optimum backfill soils is not feasible, it may be necessary to import a backfill material. Any imported backfill material should consist of a non-expansive lean clay (CL) or well-graded clayey gravel or clayey sand (GW, GC, SW, SC) and should be tested and approved by the Geotechnical Engineer prior to transport to the site.

The gravels and cobbles, segregated from any deleterious material and oversized materials greater than 12 inches in maximum dimension, are generally suitable for use as trench backfill.

Also, as the utility excavations near Rapid Creek will be in close proximity to or below the groundwater table, we suggest that an imported clean crushed rock material be utilized as backfill from the pipe bedding material up to a point above the groundwater table, or to a point at which proper compaction of soils is possible. Even with dewatering efforts, wet conditions may make compaction of soils difficult or impossible at depths below the groundwater table. A clean crushed rock can be placed to a suitable density in these conditions.

West of Interstate 190 and north of Rapid Creek (Boreholes 5-8)

The subsurface conditions encountered west of Interstate 190 and north of Rapid Creek generally consisted of lean and fat clays overlying weathered shale or clayey sands. Lean clay fill materials were encountered in Borehole 8. Groundwater was encountered within 7 feet of the surface in these areas.

The lean and fat clays and weathered shale were found to be moist to wet. **As such, some drying of these materials will be necessary prior to use as properly compacted backfill.** In the event that drying of saturated or over-optimum backfill soils is not feasible, it may be necessary to import a backfill material. Any imported backfill material should consist of a non-expansive lean clay (CL) or well-graded clayey gravel or clayey sand (GW, GC, SW, SC) and should be tested and approved by the Geotechnical Engineer prior to transport to the site.

The underlying weathered shale may tend to excavate in a blocky or slabby nature. **Some processing of oversized shale fragments greater than 12 inches in maximum dimension may be necessary prior to placement as trench backfill.** The shale material and overlying fat clay was found to contain bentonite. While technically suitable for backfill when within moisture specifications, bentonite and bentonitic clays will provide difficulties for compaction, specifically with moisture contents and workability.

Oversized and/or deleterious materials or objects may be encountered within the fill materials. If encountered, said materials should be segregated from the soils prior to use as trench backfill.

Also, as the utility excavations will be in close proximity to or below the groundwater table, we suggest that an imported clean crushed rock material be utilized as backfill from the pipe bedding material up to a point above the groundwater table, or to a point at which proper compaction of soils is possible. Even with

dewatering efforts, wet conditions may make compaction of soils difficult or impossible at depths below the groundwater table. A clean crushed rock can be placed to a suitable density in these conditions.

CONCLUDING STATEMENT

In the event that any changes in the nature, design or location of the project are planned, the conclusions and recommendations contained in this report shall not be considered valid unless the changes are reviewed and conclusions of this report modified or verified in writing.

The findings and recommendations in this letter report were prepared following accepted soil mechanics procedures and practices. We make no other warranty, either implied or expressed. The conclusions and recommendations of this letter report are based upon the results of the field exploration boring, field tests, laboratory tests, and analysis. We have extrapolated the data obtained from the test borehole locations to the surrounding soils. Anomalies can exist around the borings. The data presented on the boring logs represent the conditions as encountered in that particular test hole on the date drilled and logged. If, during planning and construction, conditions are different from those indicated, please notify us so that we have the opportunity to modify the conclusions and recommendations.

We trust this information to be sufficient. If you have any questions or desire any additional information, please do not hesitate to contact us. *Thank you for the opportunity to be of continued service.*

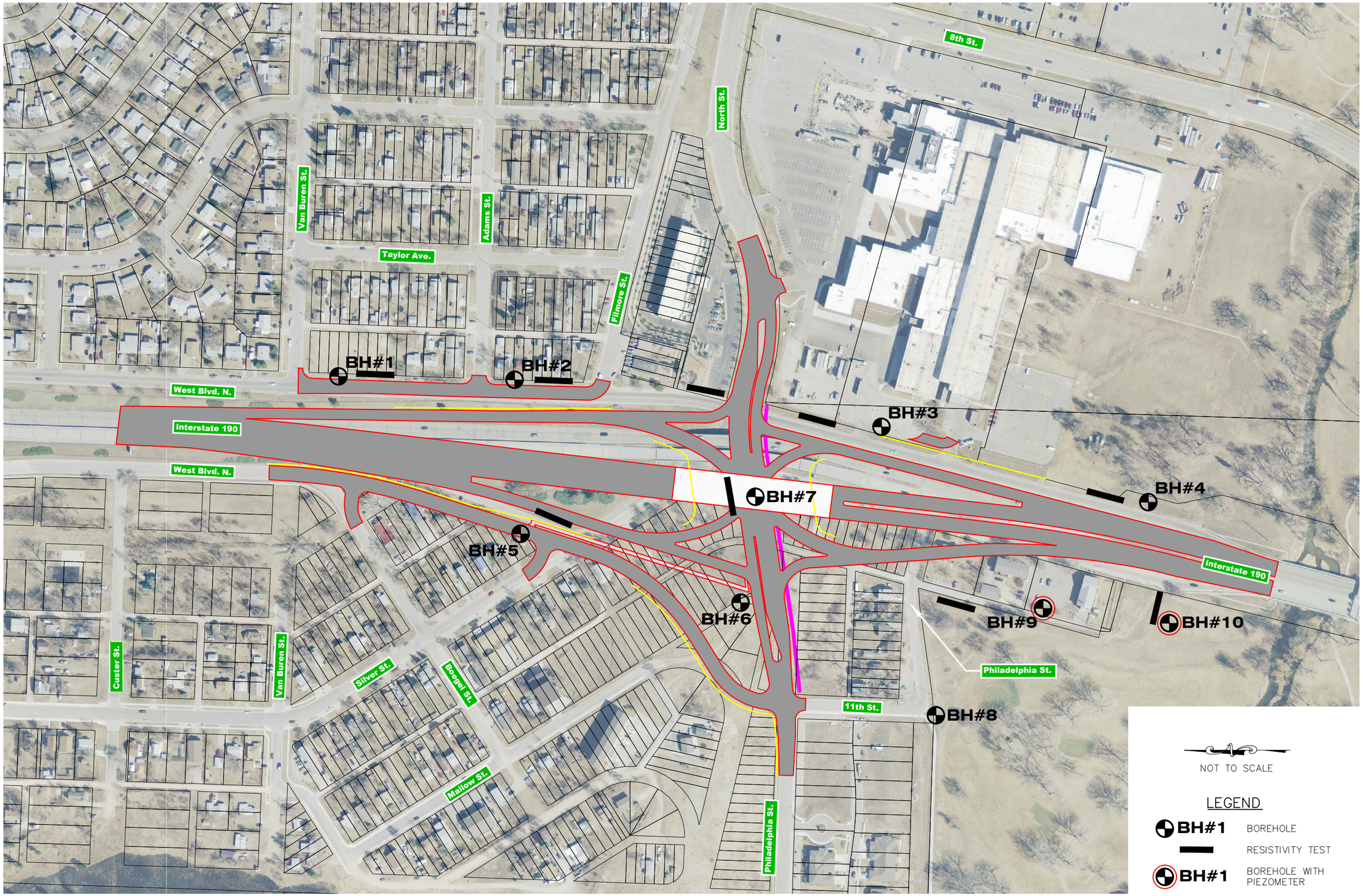
Respectfully submitted,

FMG, Inc.

REGISTERED PROFESSIONAL ENGINEER
REG. NO.
8461
ALEX M.
FISHER
SOUTH DAKOTA

Alex Fisher, P.E.

c: FMG File #130234
K:\Projects\Documents\130234 Silver Street Interchange Utilities\Design\Geotech



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File Number: 130234

Location:

Surveyed By:
Date:

Drawn By: JRK
Checked By: AMF

FEBRUARY 2014

SILVER STREET
INTERCHANGE UTILITIES
RAPID CITY, SOUTH DAKOTA

Revision / Date

Sheet Name:
BOREHOLE LOCATION MAP

Figure Number:
1

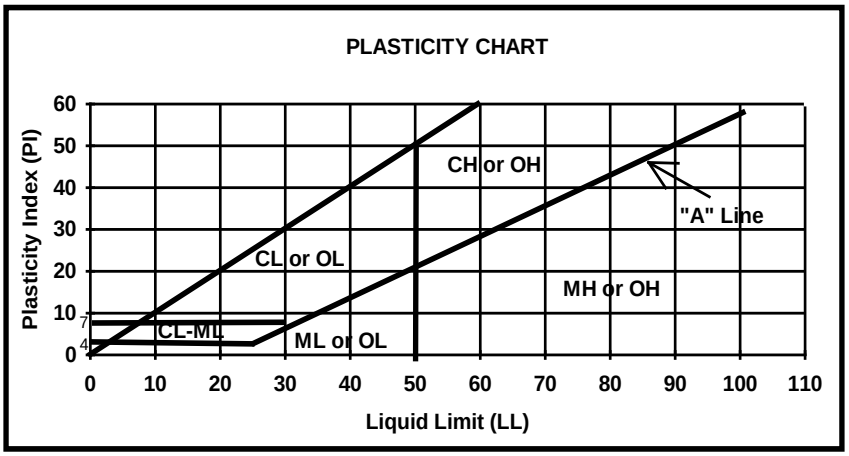
I:\Civil 3D Working Folder\130234 Silver Street Interchange\2053BH.dwg, Borehole Location Plan, 2/18/2014 8:09:02 AM

CLASSIFICATION OF SOILS FOR ENGINEERING PURPOSES

ASTM Designation: D 2487-90 and D 2488-90 (Unified Soil Classification System)

Criteria for Assigning Group Symbols and Group Names[A]				Soil Classification Group Symbol	Name[B]
COARSE-GRAINED SOILS More than 50% retained on the 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,J]
			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 soils	PI>7and 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 soils	Liquid limit-oven dried / Liquid limit-not dried ----------<.75	OL	Organic Clay[K,L,M,N] / Organic Silt[K,L,M,O]
	Silts and Clays Liquid limit 50 or more	inorganic soils	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 soils	Liquid limit-oven dried / Liquid limit-not dried ----------<.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-in. (75-mm) sieve.
B. If field sample contained cobbles or boulders, or both, add "with cobbles and 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. $Cu = D_{60}/D_{10}$ $Cc=(D_{30})^2/D_{10}xD_{60}$
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 hatched 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 "gravely" 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.



Equation of "A" - line: Horizontal at PI = 4 to LL = 25.5, then PI = 0.73(LL-20) (Chart is for general graphic presentation purposes only)

- Figure 2 –

Appendix A – Geologic Logs

PROJECT: Silver Street Interchange Utilities	**GEOLOGIC LOG OF** BOREHOLE 1	**BORING LOCATION:** See Figure 1
LOCATION: Rapid City, SD		**GROUND ELEVATION:** 3298
PROJECT #: 130234		**DATUM:** DOT Topo
DATE STARTED: 10-16-13 **COMP.:** 10-16-13		**BORING DIAMETER:** 4.5 Inches
CONTRACTOR: FMG, Inc.		**COLLAPSE DEPTH:**
DRILL METHOD: Solid Stem Auger	3700 Sturgis Road Rapid City, South Dakota 57702	**FILL DEPTH:** No Fill Observed

ELEVATION / DEPTH	WATER	GEOLOGY GRAPHIC	SAMPLE TYPE,#	USCS	DESCRIPTION	NM %	DD (pcf)	LL (%)	PI (%)	Qu (psf)	phi (deg)	Swell (%) (ksf)
0		Alluvium		HMA	Asphalt Pavement, 4" in Thickness.							
				CL	Lean Clay With Sand, Dark Brown, Moist, Low Plasticity, Medium Stiff.							
3295												
5				GW-GM	Well-Graded Gravel with Silt, Cobbles, Gray, Moist, Non-Plastic, Hard.							
					-End of Boring at 7 Feet, Auger Refusal on Cobbles. No Water Encountered During Drilling. Borehole Immediately Backfilled.							
3290												
10												
3285												
15												
3280												
20												
3275												
25												
3270												
30												
3265												

SEE ATTACHED KEY FOR ABBREVIATIONS, NOTES & DESCRIPTIONS

PROJECT: Silver Street Interchange Utilities	**GEOLOGIC LOG OF** BOREHOLE 2	**BORING LOCATION:** See Figure 1
LOCATION: Rapid City, SD		**GROUND ELEVATION:** 3295
PROJECT #: 130234		**DATUM:** DOT Topo
DATE STARTED: 10-16-13 **COMP.:** 10-16-13		**BORING DIAMETER:** 4.5 Inches
CONTRACTOR: FMG, Inc.		**COLLAPSE DEPTH:**
DRILL METHOD: Solid Stem Auger	3700 Sturgis Road Rapid City, South Dakota 57702	**FILL DEPTH:** No Fill Observed

ELEVATION / DEPTH	WATER	GEOLOGY GRAPHIC	SAMPLE TYPE,#	USCS	DESCRIPTION	NM %	DD (pcf)	LL (%)	PI (%)	Qu (psf)	phi (deg)	Swell (%) (ksf)
3295 — 0		Alluvium		HMA	Asphalt Pavement, 4" in Thickness							
				CL	Lean Clay With Sand, Dark Brown, Moist, Low Plasticity, Medium Stiff.							
3290 — 5				GW-GM	Well-Graded Gravel with Silt, Cobbles, Gray, Moist, Non-Plastic, Hard. -End of Boring at 6.5 Feet, Auger Refusal on Cobbles. No Water Encountered During Drilling. Borehole Immediately Backfilled.							
3285 — 10												
3280 — 15												
3275 — 20												
3270 — 25												
3265 — 30												

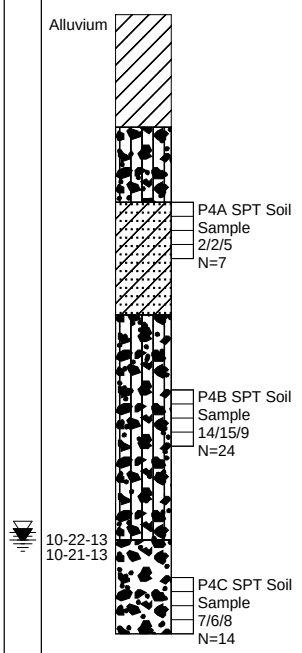
SEE ATTACHED KEY FOR ABBREVIATIONS, NOTES & DESCRIPTIONS

PROJECT: Silver Street Interchange Utilities	**GEOLOGIC LOG OF** BOREHOLE 3	**BORING LOCATION:** See Figure 1
LOCATION: Rapid City, SD		**GROUND ELEVATION:** 3241
PROJECT #: 130234		**DATUM:** DOT Topo
DATE STARTED: 10-16-13 **COMP.:** 10-16-13		**BORING DIAMETER:** 4.5 Inches
CONTRACTOR: FMG, Inc.		**COLLAPSE DEPTH:**
DRILL METHOD: Solid Stem Auger	3700 Sturgis Road Rapid City, South Dakota 57702	**FILL DEPTH:** No Fill Observed

ELEVATION / DEPTH	WATER	GEOLOGY GRAPHIC	SAMPLE TYPE,#	USCS	DESCRIPTION	NM %	DD (pcf)	LL (%)	PI (%)	Qu (psf)	phi (deg)	Swell (%) (ksf)
0				HMA	Asphalt Pavement, 6" in Thickness.							
3240		Alluvium	B3A Bulk Soil Sample	CL	Lean Clay With Sand and Silt, Dark Brown to Black, Wet, Low Plasticity, Soft.							
5 / 3235			P3A SPT Soil Sample 2/2/2 N=4	CL	Sandy Lean Clay, Dark Brown.	17.8		39	20			
					-Dark Grayish Brown							
10 / 3230			P3B SPT Soil Sample 3/4/5 N=9									
				SC	Clayey Sand with Gravel, Mottled, Moist, Non-Plastic to Low Plasticity, Dense.							
15 / 3225			P3C SPT Soil Sample 5/5/7 N=12	SC	Clayey Sand with Gravel, Gray.	8.5		29	11			
					-End of Boring at 16.5 Feet. No Water Encountered During Drilling. Dry After Re-Check on 10-22-13.							
20 / 3220												
25 / 3215												
30 / 3210												

SEE ATTACHED KEY FOR ABBREVIATIONS, NOTES & DESCRIPTIONS

PROJECT: Silver Street Interchange Utilities	**GEOLOGIC LOG OF** BOREHOLE 4	**BORING LOCATION:** Figure 1
LOCATION: Rapid City, SD	3700 Sturgis Road Rapid City, South Dakota 57702	**GROUND ELEVATION:** 3231
PROJECT #: 130234		**DATUM:** DOT Topo
DATE STARTED: 10-21-13 **COMP.:** 10-21-13		**BORING DIAMETER:** 4.5 Inches
CONTRACTOR: FMG, Inc.		**COLLAPSE DEPTH:**
DRILL METHOD: Solid Stem Auger		**FILL DEPTH:** No Fill Observed



ELEVATION / DEPTH	WATER	GEOLOGY GRAPHIC	SAMPLE TYPE,#	USCS	DESCRIPTION	NM %	DD (pcf)	LL (%)	PI (%)	Qu (psf)	phi (deg)	Swell (%) (ksf)
0 / 3230				CL	Lean Clay with Sand, Dark Brown, Moist, Low Plasticity, Soft to Medium Stiff.							
				GW-GM	Well-Graded Gravel with Silt, Cobbles, Gray, Moist, Non-Plastic, Hard.							
5 / 3225			P4A SPT Soil Sample 2/2/5 N=7	SC	Clayey Sand, Brown, Moist, Non-Plastic to Low Plasticity, Medium Stiff.							
				GW-GM	Well-Graded Gravel with Silt, Cobbles, Gray, Moist, Non-Plastic, Hard.							
10 / 3220			P4B SPT Soil Sample 14/15/9 N=24									
	10-22-13 10-21-13			GW	Well-Graded Gravel, Cobbles, Gray, Saturated, Non-Plastic, Hard.							
15 / 3215			P4C SPT Soil Sample 7/6/8 N=14		-End of Boring at 16.5 Feet. Water Encountered at 14 Feet During Drilling. Water at 13.8 Feet After Re-Check on 10-22-13.							
20 / 3210												
25 / 3205												
30 / 3200												

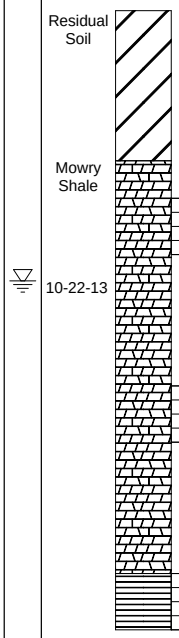
SEE ATTACHED KEY FOR ABBREVIATIONS, NOTES & DESCRIPTIONS

PROJECT: Silver Street Interchange Utilities	**GEOLOGIC LOG OF** BOREHOLE 5	**BORING LOCATION:** See Figure 1
LOCATION: Rapid City, SD		**GROUND ELEVATION:** 3260
PROJECT #: 130234		**DATUM:** DOT Topo
DATE STARTED: 10-16-13 **COMP.:** 10-16-13		**BORING DIAMETER:** 4.5 Inches
CONTRACTOR: FMG, Inc.		**COLLAPSE DEPTH:**
DRILL METHOD: Solid Stem Auger	3700 Sturgis Road Rapid City, South Dakota 57702	**FILL DEPTH:** No Fill Observed

ELEVATION / DEPTH	WATER	GEOLOGY GRAPHIC	SAMPLE TYPE,#	USCS	DESCRIPTION	NM %	DD (pcf)	LL (%)	PI (%)	Qu (psf)	phi (deg)	Swell (%) (ksf)
3260 — 0		Alluvium		CL	Lean Clay with Gravel, Dark Brown, Root Zone, Wet, Low Plasticity, Soft.							
3255 — 5	10-22-13		P5A SPT Soil Sample 2/1/2 N=3									
3250 — 10			P5B SPT Soil Sample 2/2/4 N=6	SC SC	Clayey Sand, Dark Yellowish Brown, Wet, Low Plasticity, Medium Stiff. Clayey Sand, Dark Yellowish Brown.	20.2		28	9			
3245 — 15			P5C SPT Soil Sample 50@4" N=100+	GW-GM	Well-Graded Gravel with Silt, Cobbles, Gray, Moist, Non-Plastic, Hard. -End of Boring at 15.5. No Water Encountered During Drilling. Water at 7.8 Feet After Re-Check on 10-22-13.							
3240 — 20												
3235 — 25												
3230 — 30												

SEE ATTACHED KEY FOR ABBREVIATIONS, NOTES & DESCRIPTIONS

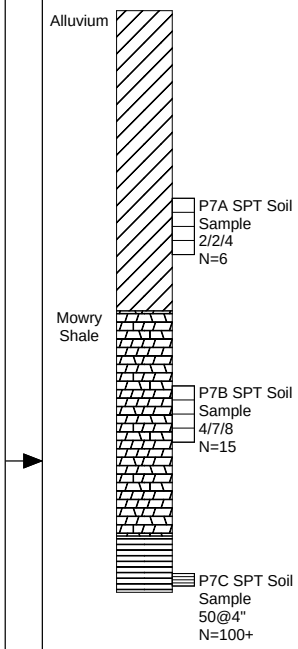
PROJECT: Silver Street Interchange Utilities	**GEOLOGIC LOG OF** BOREHOLE 6	**BORING LOCATION:** See Figure 1
LOCATION: Rapid City, SD		**GROUND ELEVATION:** 3252
PROJECT #: 130234		**DATUM:** DOT Topo
DATE STARTED: 10-21-13 **COMP.:** 10-21-13		**BORING DIAMETER:** 4.5 Inches
CONTRACTOR: FMG, Inc.		**COLLAPSE DEPTH:**
DRILL METHOD: Solid Stem Auger	3700 Sturgis Road Rapid City, South Dakota 57702	**FILL DEPTH:** No Fill Observed



ELEVATION / DEPTH	WATER	GEOLOGY GRAPHIC	SAMPLE TYPE,#	USCS	DESCRIPTION	NM %	DD (pcf)	LL (%)	PI (%)	Qu (psf)	phi (deg)	Swell (%) (ksf)
0		Residual Soil		CH	Fat Clay, Bentonitic, Mottled, Moist, High Plasticity, Stiff.							
3250												
5		Mowry Shale	P6A SPT Soil Sample 4/4/6 N=10	W. Shale CH	Weathered Shale, Bentonitic, Mottled Gray, Moist, High Plasticity, Stiff. Weathered Shale: Fat Clay, Dark Gray.	16.1		71	39			
3245	10-22-13											
10			P6B SPT Soil Sample 8/9/10 N=19									
3240												
15			P6C SPT Soil Sample 14/17/23	Shale	Shale, Dark Gray, Moist, High Plasticity, Hard. -End of Boring at 16.5 Feet. No Water Encountered During Drilling. Water at 7.2 Feet After Re-Check on 10-22-13.							
3235												
20												
3230												
25												
3225												
30												
3220												

SEE ATTACHED KEY FOR ABBREVIATIONS, NOTES & DESCRIPTIONS

PROJECT: Silver Street Interchange Utilities	**GEOLOGIC LOG OF** BOREHOLE 7	**BORING LOCATION:** See Figure 1
LOCATION: Rapid City, SD		**GROUND ELEVATION:** 3247
PROJECT #: 130234		**DATUM:** DOT Topo
DATE STARTED: 10-16-13 **COMP.:** 10-16-13		**BORING DIAMETER:** 4.5 Inches
CONTRACTOR: FMG, Inc.		**COLLAPSE DEPTH:** 12 Feet
DRILL METHOD: Solid Stem Auger	3700 Sturgis Road Rapid City, South Dakota 57702	**FILL DEPTH:** No Fill Observed



ELEVATION / DEPTH	WATER	GEOLOGY GRAPHIC	SAMPLE TYPE,#	USCS	DESCRIPTION	NM %	DD (pcf)	LL (%)	PI (%)	Qu (psf)	phi (deg)	Swell (%) (ksf)
0		Alluvium		CL	Lean Clay with Silt and Sand, Dark Brown, Moist, Low Plasticity, Medium Stiff.							
3245												
5			P7A SPT Soil Sample 2/2/4 N=6	CL	Lean Clay with Sand, Dark Brown.	13.5		36	19			
3240												
		Mowry Shale		W. Shale	Weathered Shale, Dark Gray, Moist, Medium to High Plasticity, Stiff to Very Stiff.							
10			P7B SPT Soil Sample 4/7/8 N=15									
3235	▶											
				Shale	Shale, Dark Gray, Moist, High Plasticity, Hard.							
15			P7C SPT Soil Sample 50@4" N=100+		-End of Boring at 15.5 Feet. No Water Encountered During Drilling. Collapse at 12 Feet After Re-Check on 10-22-13.							
3230												
20												
3225												
25												
3220												
30												
3215												

SEE ATTACHED KEY FOR ABBREVIATIONS, NOTES & DESCRIPTIONS

PROJECT: Silver Street Interchange Utilities	**GEOLOGIC LOG OF** BOREHOLE 8	**BORING LOCATION:** See Figure 1
LOCATION: Rapid City, SD		**GROUND ELEVATION:** 3234
PROJECT #: 130234		**DATUM:** DOT Topo
DATE STARTED: 10-21-13 **COMP.:** 10-21-13		**BORING DIAMETER:** 4.5 Inches
CONTRACTOR: FMG, Inc.		**COLLAPSE DEPTH:**
DRILL METHOD: Solid Stem Auger	3700 Sturgis Road Rapid City, South Dakota 57702	**FILL DEPTH:** 11.5 Feet

ELEVATION / DEPTH	WATER	GEOLOGY GRAPHIC	SAMPLE TYPE,#	USCS	DESCRIPTION	NM %	DD (pcf)	LL (%)	PI (%)	Qu (psf)	phi (deg)	Swell (%) (ksf)
0		Fill		HMA	Asphalt Pavement, 4" in Thickness.							
				GW-GM	Basecourse, 4" in Thickness.							
				CL	Fill: Lean Clay with Sand and Gravel, Moist, Low Plasticity, Soft.							
3230 / 5			P8A SPT Soil Sample 3/1/1 N=2		-Old Asphalt Pavement Fragments in Sample.							
	10-22-13											
3225 / 10	10-21-13		P8B SPT Soil Sample 4/6/7 N=13		-End of Boring at 11.5 Feet. Water Encountered at 10 Feet During Drilling. Water at 6.6 Feet After Re-Check on 10-22-13.							
3220 / 15												
3215 / 20												
3210 / 25												
3205 / 30												
3200												

SEE ATTACHED KEY FOR ABBREVIATIONS, NOTES & DESCRIPTIONS

PROJECT: Silver Street Interchange Utilities	**GEOLOGIC LOG OF** BOREHOLE 9	**BORING LOCATION:** See Figure 1
LOCATION: Rapid City, SD		**GROUND ELEVATION:** 3235
PROJECT #: 130234		**DATUM:** DOT Topo
DATE STARTED: 10-21-13 **COMP.:** 10-21-13		**BORING DIAMETER:** 4.5 Inches
CONTRACTOR: FMG, Inc.		**COLLAPSE DEPTH:**
DRILL METHOD: Solid Stem Auger	3700 Sturgis Road Rapid City, South Dakota 57702	**FILL DEPTH:** No Fill Observed

ELEVATION / DEPTH	WATER	GEOLOGY GRAPHIC	SAMPLE TYPE,#	USCS	DESCRIPTION	NM %	DD (pcf)	LL (%)	PI (%)	Qu (psf)	phi (deg)	Swell (%) (ksf)
3235 — 0		Alluvium		CL	Lean Clay, Dark Yellowish Brown, Moist, Low Plasticity, Soft to Medium Stiff.							
3230 — 5	10-22-13		P9A SPT Soil Sample 3/2/3 N=5	CL	Lean Clay with Sand, Dark Yellowish Brown.	20.4		37	17			
	10-21-13			GW-GM	Well-Graded Gravel with Silt, Cobbles, Gray, Moist to Saturated, Non-Plastic, Hard.							
3225 — 10		Mowry Shale		W. Shale	Weathered Shale, Saturated, Medium to High Plasticity, Stiff to Very Stiff.							
3220 — 15					-End of Boring at 15 Feet. Water Encountered at 8 Feet During Drilling. Water at 5.75 Feet After Re-Check on 10-22-13.							
3215 — 20												
3210 — 25												
3205 — 30												

SEE ATTACHED KEY FOR ABBREVIATIONS, NOTES & DESCRIPTIONS

PROJECT: Silver Street Interchange Utilities	**GEOLOGIC LOG OF** BOREHOLE 10	**BORING LOCATION:** See Figure 1
LOCATION: Rapid City, SD		**GROUND ELEVATION:** 3227
PROJECT #: 130234		**DATUM:** DOT Topo
DATE STARTED: 10-21-13 **COMP.:** 10-21-13		**BORING DIAMETER:** 4.5 Inches
CONTRACTOR: FMG, Inc.		**COLLAPSE DEPTH:**
DRILL METHOD: Solid Stem Auger	3700 Sturgis Road Rapid City, South Dakota 57702	**FILL DEPTH:** No Fill Observed

ELEVATION / DEPTH	WATER	GEOLOGY GRAPHIC	SAMPLE TYPE,#	USCS	DESCRIPTION	NM %	DD (pcf)	LL (%)	PI (%)	Qu (psf)	phi (deg)	Swell (%) (ksf)
0		Alluvium		CL	Lean Clay, Dark Brown, Wet, Low Plasticity, Soft.							
3225												
				GP-GM	Well-Graded Gravel with Silt, Cobbles, Gray, Moist to Saturated, Non-Plastic, Hard.							
5												
3220		10-22-13										
10		10-21-13										
3215												
		Mowry Shale		W. Shale	Weathered Shale, Gray to Dark Gray, Saturated, Medium to High Plasticity, Stiff to Very Stiff.							
15					-End of Boring at 15 Feet. Water Encountered at 10 Feet. Water at 6.15 Feet After Re-Check on 10-22-13.							
3210												
20												
3205												
25												
3200												
30												
3195												

SEE ATTACHED KEY FOR ABBREVIATIONS, NOTES & DESCRIPTIONS

KEY TO SYMBOLS

Symbol	Description
Strata symbols	
	Asphalt Paving
	Low plasticity clay
	Well graded gravel with silt
	Clayey sand
	Well graded gravel
	High plasticity clay
	Weathered Shale
	Shale
	Fill
	Poorly graded gravel with silt

Symbol	Description
Misc. Symbols	
	Water table at boring completion
	Water table during drilling
Soil Samplers	
	Bulk Sample
	Standard Penetration Test (SPT) Sample

Notes:

1. The exploratory borings were drilled on the dates presented on the geologic logs. Please refer to the attached Soils Classification System Chart for more detailed explanations of the soils and their properties.
2. The Geologic Logs of the Boreholes and related information depict only the conditions and materials encountered at the specific boring location and at the particular time designated on the Logs. Soil condidtions at other locations will vary from those indicated at each specific boring or sampling location. The given depths of material changes and the sample depths are approximate. Variations will occur.
3. These Logs are subject to the limitations, conclusions and recommendations provided in this report.
4. The numbers adjacent to the SPT sample locations are the blow/interval and represent the number of blows required to drive the 1" I.D. splitspoon sampler the given distance into the soil with a 140# automatic hammer that drops 30". The SPT test is perfomred for a length of 18". The "N" value for each given SPT is the number of blows required to drive the 1" I.D. sampler into the last 12" of soil.
5. Cobbles, Boulders and other large objects generally cannot be recovered from borings, and they may be present in the subsurface even if not noted on the Logs.
6. The topoil thicknesses indicated on the Logs are for general informational purposes only, are based on general color transisitons and very limited sampling points, and should not be used to calculate topsoil stripping depths or volumes. Significant variations in topsoil thickness will occur throughout the project.
7. The results of some tests conducted on samples recovered are reported on the Logs. Abbreviations used are:
   - NM = Natural Moisture Content of the Soil (%),
   - DD = Dry Density of the Soil (pcf),
   - LL = Atterberg Liquid Limit of the Soil (%),
   - PI = Atterberg Plasticity Index of the Soil (%),
   - phi = Internal Angle of Friction (degrees),
   - Qu = Unconfined Compressive Strength (psf),
   - Swell = (%) Percent Swell Against 100psf Surcharge Upon Saturation; (ksf) Maximum Swell Pressure.

Appendix B – Field Soil Resistivity

FMG Inc. 3700 Sturgis Road Rapid City, SD 57702 605-342-4105	Field Measurement of Soil Resistivity Using the Wenner Four-Electrode Method *ASTM G 57*

Project Number:	130234	**Date Performed:**	22-Oct-13
Client:	City of Rapid City	**Performed By:**	BS
Project Name:	Silver Street Interchange Utilities	**Performed By:**	
Sample Location:	As Noted	**Type of Utility:**	Water Main

Test Location	Depth (ft)	Initial Meter Reading	Meter Reading Multiplier	Final Reading (ohms)	Soil Resistivity (ohms-cm)	Risk Assessment or Soil Corrosivity Zone	Corrosivity Rating
Near BH-1	**6**	2.4	1	2.4	**2758**	**2**	**Very Corrosive**
Near BH-2	**6**	4.9	1	4.9	**5630**	**4**	**Moderately Corrosive**
Near BH-3	**6**	1.9	1	1.9	**2183**	**2**	**Very Corrosive**
Near BH-4	**6**	8.0	1	8	**9192**	**4**	**Moderately Corrosive**

City of Rapid City Corrosion Control Design Manual 2008

Risk Assessment or Soil Corrosivity Zone	Soil Resistivity (ohm-cm)	Corrosivity Rating
1	0-1500	Extremely Corrosive
2	1501-3000	Very Corrosive
3	3001-5000	Corrosive
4	5001-10000	Moderately Corrosive
5	10001+	Mildly Corrosive

FMG Inc. 3700 Sturgis Road Rapid City, SD 57702 605-342-4105	Field Measurement of Soil Resistivity Using the Wenner Four-Electrode Method *ASTM G 57*

Project Number:	130234	**Date Performed:**	22-Oct-13
Client:	City of Rapid City	**Performed By:**	BS
Project Name:	Silver Street Interchange Utilities	**Performed By:**	
Sample Location:	As Noted	**Type of Utility:**	Water Main

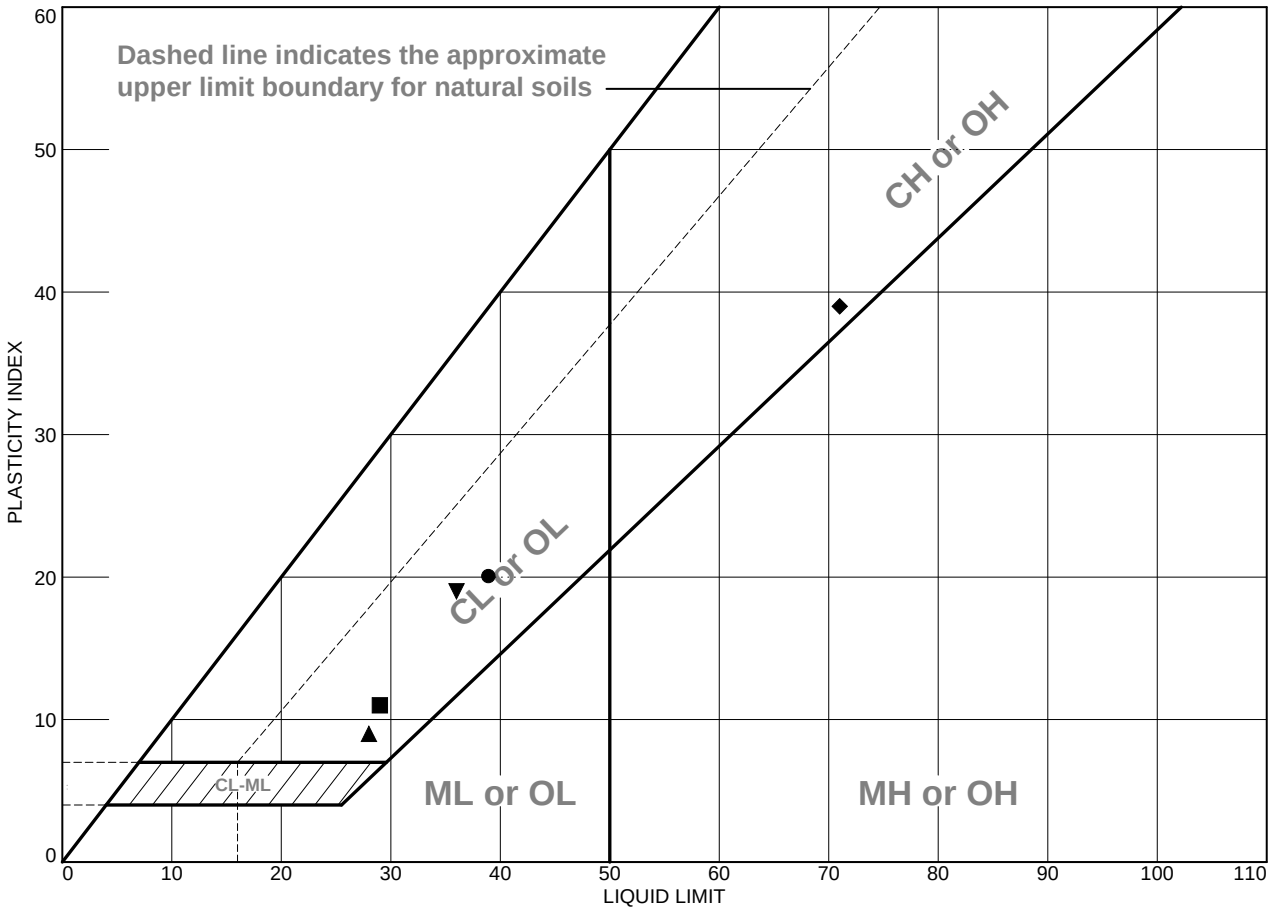
Test Location	Depth (ft)	Initial Meter Reading	Meter Reading Multiplier	Final Reading (ohms)	Soil Resistivity (ohms-cm)	Risk Assessment or Soil Corrosivity Zone	Corrosivity Rating
Near BH-5	**6**	2.3	1	2.3	**2643**	**2**	**Very Corrosive**
Near BH-7	**6**	2.0	1	2	**2298**	**4**	**Very Corrosive**
Near BH-9	**6**	3.3	1	3.3	**3792**	**2**	**Corrosive**
Near BH-10	**6**	1.5	10	15	**17235**	**4**	**Mildly Corrosive**

City of Rapid City Corrosion Control Design Manual 2008

Risk Assessment or Soil Corrosivity Zone	Soil Resistivity (ohm-cm)	Corrosivity Rating
1	0-1500	Extremely Corrosive
2	1501-3000	Very Corrosive
3	3001-5000	Corrosive
4	5001-10000	Moderately Corrosive
5	10001+	Mildly Corrosive

Appendix C – Laboratory Test Results

LIQUID AND PLASTIC LIMITS TEST REPORT



	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Sandy Lean Clay, Dark Brown.	39	19	20	96	59	CL
■	Clayey Sand with Gravel, Gray.	29	18	11	40	21	SC
▲	Clayey Sand, Dark Yellowish Brown.	28	19	9	99	47	SC
◆	Weathered Shale: Fat Clay, Dark Gray.	71	32	39	97	88	CH
▼	Lean Clay with Sand, Dark Brown.	36	17	19	98	72	CL

Project No. 130234 **Client:** City of Rapid City

Project: Silver Street Interchange Utilities

●**Source of Sample:** 3 **Depth:** 5 **Sample Number:** P3A SPT Soil Sample 2/2/2 N=4

■**Source of Sample:** 3 **Depth:** 15 **Sample Number:** P3C SPT Soil Sample 4/4/7 N=12

▲**Source of Sample:** 5 **Depth:** 10 **Sample Number:** P5B SPT Soil Sample 2/2/4 N=6

◆**Source of Sample:** 6 **Depth:** 5 **Sample Number:** P6A SPT Soil Sample 4/4/6 N=10

▼**Source of Sample:** 7 **Depth:** 5 **Sample Number:** P7A SPT Soil Sample 2/2/4 N=6

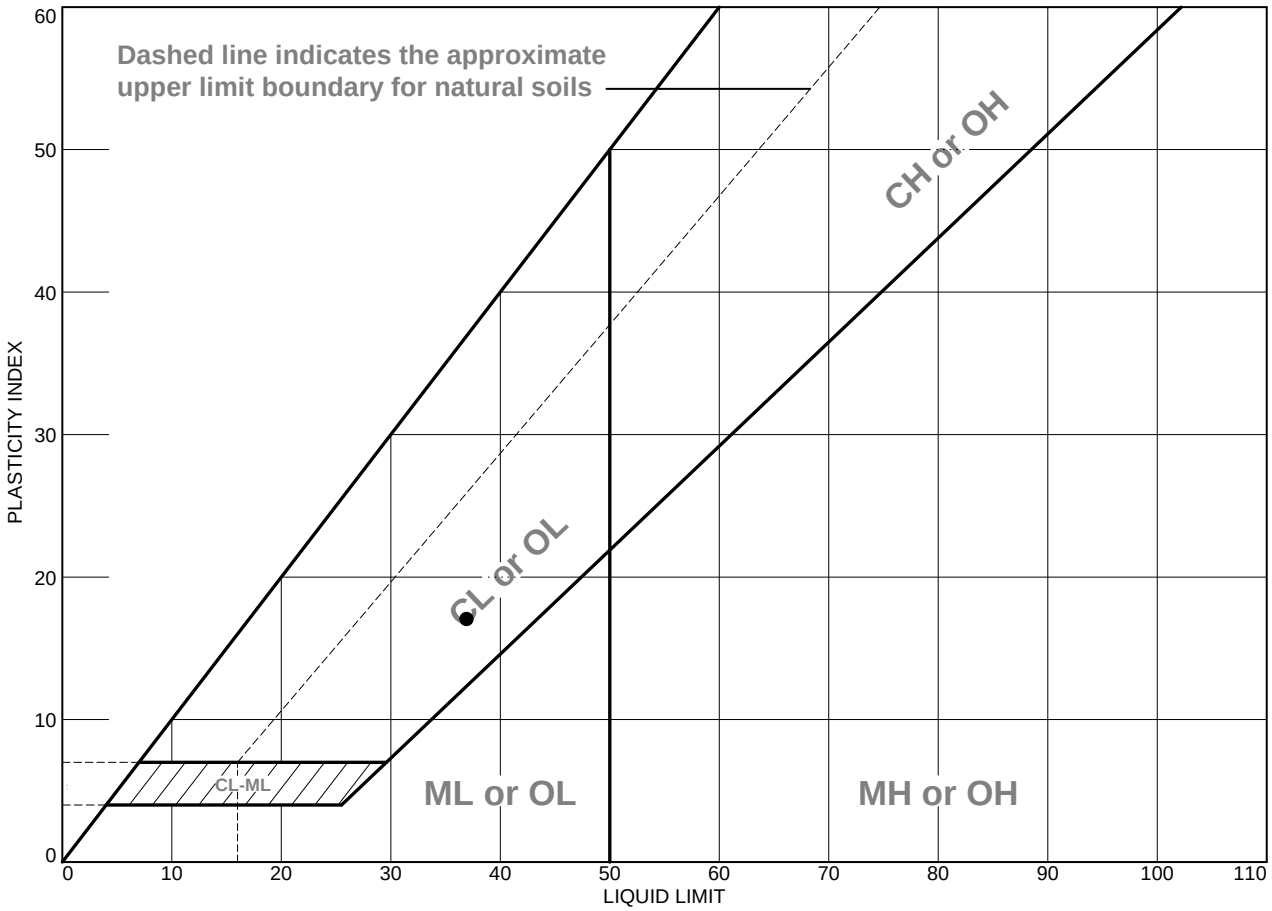
FMG, Inc.

Remarks:

Figure

Tested By: ○ Brandon Silver □ BS △ BS ◇ BS ▽ BS DL **Checked By:** DL

LIQUID AND PLASTIC LIMITS TEST REPORT



	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Lean Clay with Sand, Dark Yellowish Brown.	37	20	17	98	84	CL

Project No. 130234 **Client:** City of Rapid City

Project: Silver Street Interchange Utilities

●**Source of Sample:** 9 **Depth:** 5 **Sample Number:** P9A SPT Soil Sample 3/2/3 N=5

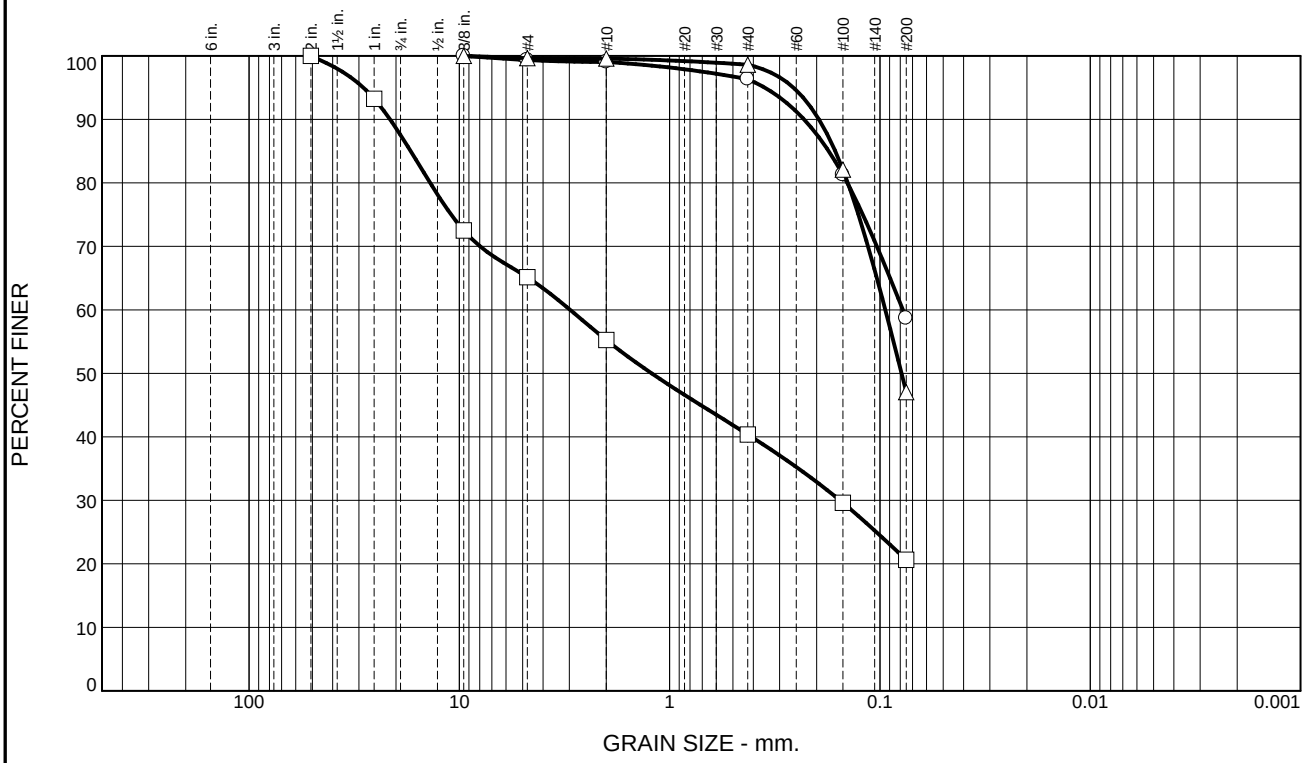
Remarks:

FMG, Inc.

Figure

Tested By: BS **Checked By:** DL

Particle Size Distribution Report



	+3"	% GRAVEL	% SAND	% SILT	% CLAY	USCS	AASHTO	PL	LL
○	0	1	40	59		CL	A-6(9)	19	39
□	0	35	44	21		SC	A-2-6(0)	18	29
△	0	0	53	47		SC	A-4(1)	19	28

SIEVE inches size	PERCENT FINER ○	□	△
2		100	
1		93	
3/8	100	73	100
	GRAIN SIZE		
D_{60}	0.0778	2.9730	0.0943
D_{30}		0.1550	
D_{10}			
	COEFFICIENTS		
C_c			
C_u			

SIEVE number size	PERCENT FINER ○	□	△
#4	99	65	100
#10	99	55	100
#40	96	40	99
#100	81	30	82
#200	59	21	47

Material Description

○ Sandy Lean Clay, Dark Brown.

□ Clayey Sand with Gravel, Gray.

△ Clayey Sand, Dark Yellowish Brown.

REMARKS:

○ F.M.=0.31

□ F.M.=3.60

△ F.M.=0.24

○ Source of Sample: 3 Depth: 5 Sample Number: P3A SPT Soil Sample

□ Source of Sample: 3 Depth: 15 Sample Number: P3C SPT Soil Sample

△ Source of Sample: 5 Depth: 10 Sample Number: P5B SPT Soil Sample

FMG, Inc.

Client: City of Rapid City

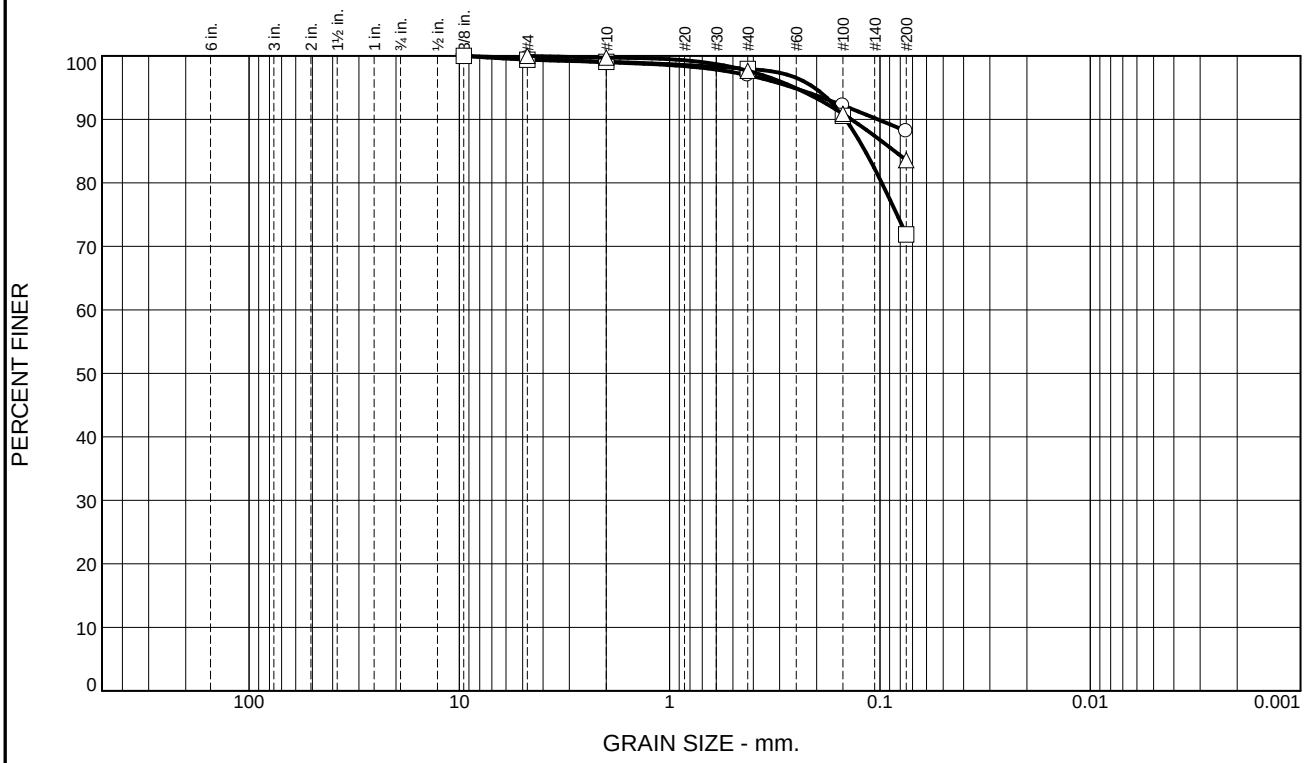
Project: Silver Street Interchange Utilities

Project No.: 130234

Figure

Tested By: Brandon Silver

Particle Size Distribution Report



	+3"	% GRAVEL	% SAND	% SILT	% CLAY	USCS	AASHTO	PL	LL
○	0	0	12	88		CH	A-7-5(40)	32	71
□	0	1	27	72		CL	A-6(12)	17	36
△	0	0	16	84		CL	A-6(14)	20	37

SIEVE inches size	PERCENT FINER ○	□	△
3/8	100	100	
GRAIN SIZE			
D_{60}			
D_{30}			
D_{10}			
COEFFICIENTS			
C_c			
C_u			

SIEVE number size	PERCENT FINER ○	□	△
#4	100	99	100
#10	99	99	100
#40	97	98	98
#100	92	91	91
#200	88	72	84

Material Description

○ Weathered Shale: Fat Clay, Dark Gray.

□ Lean Clay with Sand, Dark Brown.

△ Lean Clay with Sand, Dark Yellowish Brown.

REMARKS:

○ F.M.=0.17

□ F.M.=0.16

△ F.M.=0.15

○ Source of Sample: 6 Depth: 5 Sample Number: P6A SPT Soil Sample

□ Source of Sample: 7 Depth: 5 Sample Number: P7A SPT Soil Sample

△ Source of Sample: 9 Depth: 5 Sample Number: P9A SPT Soil Sample

FMG, Inc.

Client: City of Rapid City

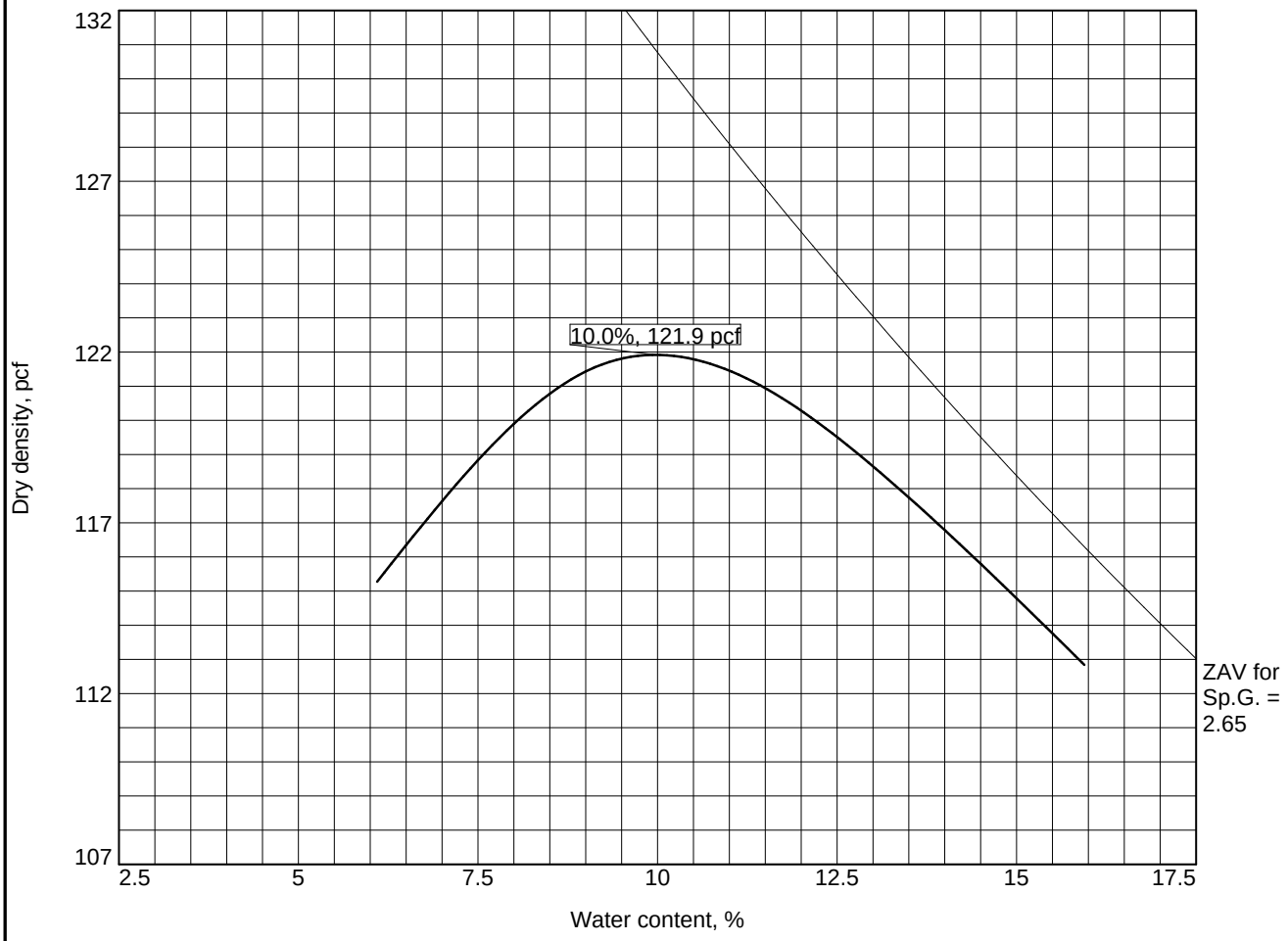
Project: Silver Street Interchange Utilities

Project No.: 130234

Figure

Tested By: Brandon Silver

Moisture Density Relationship For Curve No. MD 6417



Test specification: AASHTO T 180 Method D Modified

Elev/ Depth	Classification		Nat. Moist.	Sp.G.	LL	PI	% > 3/4 in.	% < No.200
	USCS	AASHTO						
.5	CL							

TEST RESULTS	MATERIAL DESCRIPTION
Maximum dry density = 121.9 pcf Optimum moisture = 10.0 %	Lean Clay With Sand and Silt, Dark Brown to Black, Wet, Low Plasticity, Soft.

Project No. 130234 **Client:** City of Rapid City
Project: Silver Street Interchange Utilities
Date: 11-5-13
○ **Source of Sample:** 3 **Sample Number:** B3A Bulk Soil Sample

Remarks:
Specific Gravity for Zero Air Voids is assumed.

FMG, Inc.

Figure

Tested By: BS & DL **Checked By:** DL