LITHOS ENGINEERING

GEOTECHNICAL ENGINEERING REPORT

COLLEGE GREEN SINKHOLE REMEDIATION

GREELEY, COLORADO

June 14, 2016

Engineering from the ground down

12567 W Cedar Drive
Lakewood, CO 80228
303.625.9502
www.LithosEng.com

June 14, 2016
Project No. 16015-1

City of Greeley
1001 9th Avenue
Greeley, Colorado 80631

Attention: Ms. Heather Seitz, PE
Stormwater Manager

Regarding: Geotechnical Engineering Report
College Green Sinkhole Remediation
Greeley, Colorado

Ms. Seitz,

This report presents our Geotechnical Investigation for the College Green Sinkhole Remediation project. This study was conducted in general accordance with the agreement between Lithos Engineering and the City of Greeley, dated April 1, 2016. Contained herein are general subsurface conditions, opinions regarding the cause(s) of the sinkholes located above the corrugated aluminum pipe (CAP), and sinkhole mitigation recommendations.

If you have any questions regarding the contents of this report, please contact the undersigned.

Sincerely,
Lithos Engineering

COLORADO LICENSED
NATHAN C. SOULE
43365
6/14/16
PROFESSIONAL ENGINEER

Amara Meier, EIT
Staff Engineer

Nate Soule, PE, PG
Vice President

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EXECUTIVE SUMMARY

The following Geotechnical Engineering Report presents the results of our geotechnical investigation, opinions as to the causes of sinkholes at the site, and recommended mitigation options in support of the College Green Sinkhole Remediation project. Standard geotechnical drilling and sampling techniques were utilized in obtaining soil and bedrock samples used to describe the subsurface conditions and conduct geotechnical laboratory testing to define soil and bedrock engineering properties and behavior. The following summarizes our general conclusions and engineering mitigation recommendations:

1. The site consists of alluvial soil and trench backfill derived from alluvium underlain by claystone bedrock. The storm sewer appears to be bedded in poorly-graded gravel. Groundwater was encountered during the investigation at approximately 13 to 14 feet below the existing ground surface.

2. Sinkholes at the site do not appear to be related to fluctuations in groundwater levels as no correlation between groundwater levels and sinkhole occurrence was noted.

3. Sinkholes are caused by internal erosion from infiltrating surface water that mobilized soil particles down into the gravel pipe backfill and into holes and separations at several joints in the storm sewer.

4. Mitigation alternatives include addressing both the condition of the pipe and the gravel pipe backfill. Options presented in this report include 1) lining the pipe using CIPP or sliplining methods in combination with grout injection into the pipe backfill, or 2) complete replacement of the storm sewer and backfill.

5. Opinions of probable construction cost range from $500,000 to $734,200.

1 INTRODUCTION

College Green Crossing is a subdivision in the City of Greeley (City). A green space with a 54—inch corrugated aluminum pipe (CAP) storm sewer running under it has been experiencing sinkholes for the past several years. The City desires to remediate the site but prior efforts have proven unsuccessful at preventing additional sinkhole formation. This report presents Lithos Engineering's (Lithos) opinions of the causes of the sinkholes and provides recommendations for possible mitigation alternatives to prevent future sinkholes.

2 PROJECT BACKGROUND

2.1 Site Description

The project site is contained within the College Green neighborhood and runs through a grassy area that extends 680 feet north from the intersection of W 18th Street and 46th Avenue to the intersection of W 16th Street and 46th Avenue in Greeley, Colorado (Figure 1). The invert of the CAP is approximately 13 feet below grade, with 782 feet between two manhole structures located at the north and south end of the site. The area under the grass landscaping is approximately 680 feet. The southern manhole is a CAP manhole stubbed into the top of the pipe with access from 46th Avenue that appears in good condition. The northern manhole is a large concrete vault. The site is paralleled by residential structures to the east and a parking lot and additional residential structures to the west. Prior to our geotechnical investigation, there was an existing sinkhole located approximately 390 feet north of W 18th Street (or 320 feet south of W 16th Street) that formed at the ground surface during Fall 2015. The sinkhole was offset from the CAP alignment by about 6 feet to the east, and has since been backfilled with soil excavated during the geotechnical investigation. On May 20th, 2016, residents reported the formation of two new sinkholes approximately 225 feet north of W 18th Street.

In general, the topography of the site is relatively uniform with the CAP alignment serving as a local topographic low. There is also a moderate slope to the north from the south end of the site with a maximum change in elevation of approximately four feet. Homeowners have indicated that ponded water is often observed at the ground surface along the CAP alignment following severe rain events. The site is also regularly irrigated during the summer months.

2.2 History of Mitigation Attempts

Repairs to sinkholes in the area have been occurring for almost twenty years. The documented mitigation efforts include:

- Backfilling a sinkhole with compacted fill on unknown date prior to 1998.
- Backfilling a sinkhole with flowable fill on unknown date prior to 1998.
- Injecting urethane foam around the external circumference of the pipe in 1998.
- Installing four WEKO-SEAL internal pipe bands on pipe joints suspected of leaking in March 2014.
- Patching a hole located in an external CAP joint band. The access trench was backfilled with 20 cubic yards of flowable fill in October 2015.
- Most recently, backfilling a sinkhole with grout and using vibration to adequately distribute the grout into voids in Fall 2015.

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3 GEOTECHNICAL INVESTIGATION

Lithos conducted a subsurface investigation that included geotechnical drilling, a test pit, installation of four groundwater monitoring wells, and a subsequent geotechnical laboratory testing program. The geotechnical investigation provided the subsurface information presented in Section 4 and aided in determining causes of the recurring sinkholes as well as the recommended mitigation alternatives provided in Sections 5 and 6, respectively.

3.1 Subsurface Investigation

On April 11th, 2016, four geotechnical borings were conducted along the CAP alignment between W 16th Street and W 18th Street (Figure 1) in an effort to investigate the general subsurface conditions where sinkholes both have and have not been observed. Groundwater monitoring wells were installed at each boring location to facilitate future groundwater monitoring.

Geotechnical drilling was conducted by Vine Laboratories of Denver, Colorado utilizing a Central Mining Equipment (CME) 45 rubber track mounted drilling rig with oversight provided by Lithos. Drilling and sampling procedures were conducted in general accordance with ASTM D1586 – *Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils*. Continuous-flight hollow-stem augers were used to advance the boring to depths at least five feet below the invert of the CAP, such that the borings were drilled to depths of approximately 18 to 20 feet below existing grades. During drilling, split-spoon (1.5-inch inner diameter) and modified California barrel (2.0-inch inner diameter) samples were obtained in 2 to 5-foot intervals. In general, a modified California barrel sampler was utilized to obtain relatively undisturbed samples of cohesive materials for geotechnical laboratory testing and a split-spoon sampler is utilized to obtain disturbed samples of non-cohesive materials. The number of blows by a 140-pound hammer falling 30-inches required for 12 inches of sampler penetration (recorded in 6 inch increments) are presented on the boring logs (Appendix A). Blow counts with less than 6-inches of penetration are presented showing the number of blows for the resulting depth of penetration (e.g., 50/2" = 50 blows to drive the sampler 2-inches).

In addition to the borings, one test pit was excavated on April 22, 2016 at the location of the sinkhole that formed during Fall 2015. The test pit was excavated with a John Deere 410K backhoe with oversight provided by Lithos. The purpose of the test pit was to observe subsurface conditions and the geometry of the pipe backfill zone near the CAP. The final dimensions of the rectangular test pit were approximately 13 feet by 14 feet, and the test pit extended to a depth of approximately 12 feet below the ground surface. The crown of the pipe was observed at nine feet below the existing ground surface. There was no noticeable damage to, or deformation of, the portion of pipe that was exposed during excavation of the test pit.

3.2 Geotechnical Laboratory Testing

A geotechnical laboratory testing program was conducted on representative samples collected during the subsurface investigation. A laboratory summary table and graphical testing results are provided in Appendix B. Laboratory tests conducted in general accordance with associated ASTM standards are presented below in Table 3.1.

3.1 - Geotechnical Laboratory Testing	
Geotechnical Test	**ASTM Standard**
Fines Content (#200 Wash)	D 1140
Atterberg Limits	D 4318
One-Dimensional Swell or Collapse of Soils	D 4546

If field determined soil and bedrock descriptions differed from results indicated by laboratory classification testing, the boring logs presented in Appendix A were amended to reflect laboratory testing results. Geotechnical laboratory testing results were utilized in developing the sinkhole causes and recommended mitigation alternatives presented in this report.

4 SUBSURFACE CONDITIONS

Subsurface conditions were determined based on the subsurface investigation, discussed previously. Soil and bedrock descriptions noted on the boring and test pit logs, and described below, are in general accordance with ASTM D 2487 – *Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)* and D 2488 – *Standard Practice for Description and Identification of Soils (Visual-Manual Procedure)*. Boring and test pit logs, and supplementary boring log keys presenting details in addition to discussions included in this geotechnical engineering report are provided in Appendix A.

4.1 Subsurface Materials

Primary materials encountered during the subsurface investigation include: fill, pipe backfill, fine alluvium, coarse alluvium, and claystone bedrock. Groundwater was encountered in all four of the geotechnical borings.

4.1.1 Fill

Fill was encountered in borings LE-3 and LE-4 extending to 9.5 feet and 19.0 feet below the existing ground surface, respectively. Fill consisted of the following interlayered soil types:

- Olive brown silty-to-clayey Sand (SM-SC),
- Olive brown poorly-graded Gravel with Silt (GP-GM),
- Brown clayey Sand (SC),
- Brown lean clay with Sand (CL), and
- Olive brown silty Sand (SM)

Fill was moist to wet, did not emit an apparent odor, and fill comprising clay exhibited moderate plasticity.

4.1.2 Pipe Backfill

Pipe backfill material was encountered in Test Pit 1 from 8.5 feet to the bottom of the excavation at 12 feet below the ground surface. The pipe backfill consisted of grey to brown poorly-graded Gravel (GP). The grains were well rounded and the size of the gravel ranged from approximately 0.75 to 2 inches.

4.1.3 Fine Alluvium

Fine alluvium was encountered in borings LE-1, LE-2, and LE-3 starting at depths ranging from 9.5 to 19 feet below ground surface and extending to below the extent of exploration. Fine alluvium was classified as lean Clay with Sand (CL) and described as stiff, moist to wet, light-to dark brown with medium plasticity, and did not emit an apparent odor. Two samples of fine alluvium were tested for swelling properties and exhibited low-to-no expansive behavior upon inundation according to definitions provided by the Colorado Association of Geotechnical Engineers (CAGE, 1996).

4.1.4 Coarse Alluvium

Coarse alluvium was encountered in all four geotechnical borings and extended from the ground surface to between 12.5 and 19.0 feet below the ground surface in LE-2 and LE-1, respectively, and from approximately 19.0 to 20.0 feet below the ground surface in LE-3 and LE-4. Coarse alluvium was classified as:

- silty -to-clayey Sand (SM-SC) and
- silty Sand (SM)

Coarse alluvium was primarily described as olive to olive brown to brown, moist to wet, rounded, and did not emit an apparent odor.

4.1.5 Claystone Bedrock

Claystone bedrock of the Laramie Formation was encountered in two geotechnical borings, LE-3 and LE-4, between 19.5 and 20.0 feet below the existing ground surface to the maximum depth of exploration, approximately 20 to 20.5 feet below the existing ground surface. The bedrock was described as olive brown to olive gray with planar bedding and iron oxide staining, highly weathered, wet, and did not emit an apparent odor.

4.2 Groundwater

Groundwater was encountered in all four geotechnical borings during the subsurface investigation on April 11th, 2016. Groundwater levels were measured periodically between April 11 to May 16, 2016. The groundwater levels corresponding to the elapsed time since installation for each monitoring well are provided in Table 4.1.

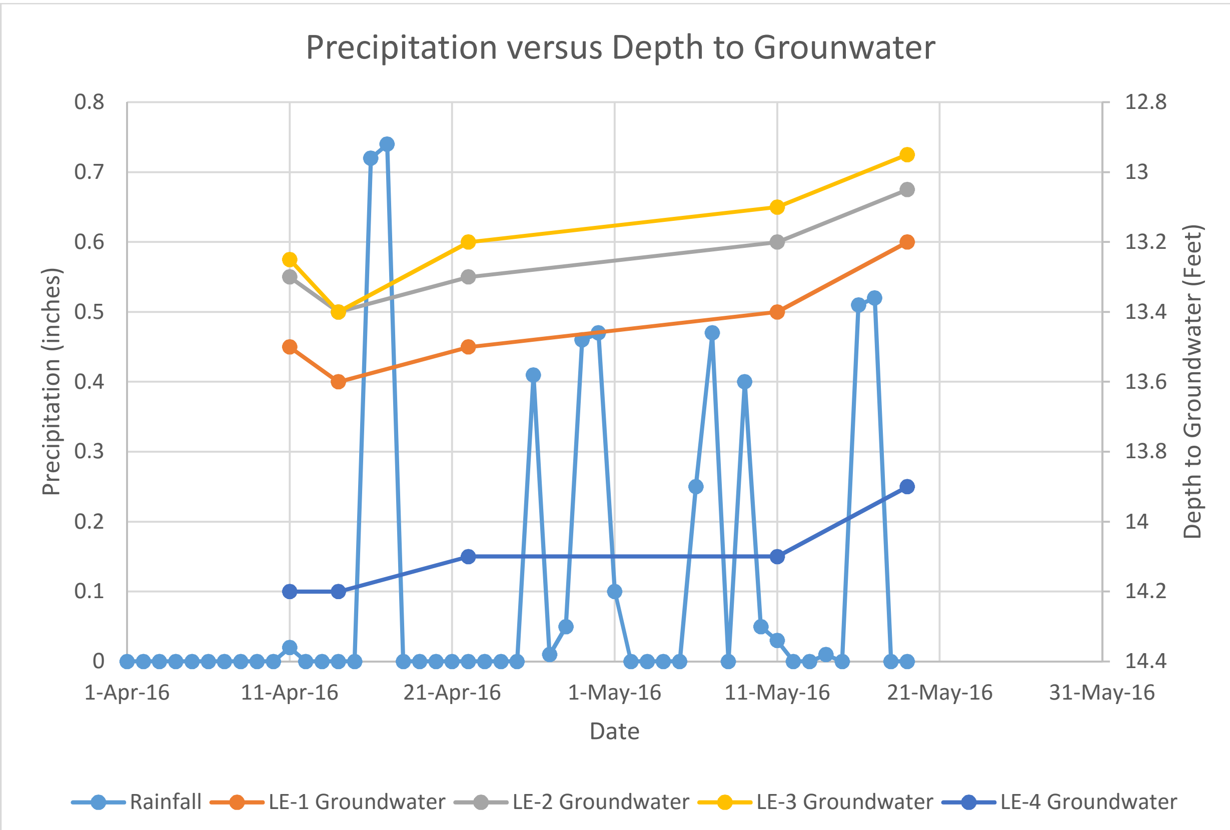
4.1 - Measured Groundwater Levels

Date	Elapsed Time[1]	Depth to Groundwater[2] (ft)			
		Boring ID			
		LE-1	LE-2	LE-3	LE-4
4/11/2016	0	12	12	14	12
4/11/2016	2 HOURS	13.5	13.3	13.25	14.2
4/14/2016	3 DAYS	13.6	13.4	13.4	14.2
4/22/2016	11 DAYS	13.5	13.3	13.2	14.1
5/11/2016	30 DAYS	13.4	13.2	13.1	14.1
5/19/2016	38 DAYS	13.2	13.05	12.95	13.9

[1]Elapsed time is measured from the time of well installation

[2]Depth is measured from the existing ground surface

The graph below shows the groundwater levels compared to precipitation events during the same time period. While it appears that groundwater is generally rising, as would be expected during late spring, there does not appear to be a correlation between groundwater levels and precipitation events. Were the sinkholes directly related to groundwater fluctuations, we would expect to see a significant reaction of the groundwater table shortly after a precipitation event. As discussed below in Section 5, we believe the sinkholes are generally independent to groundwater, and more closely related to surface water infiltration.



Precipitation data from U.S. Climate Data website for Greeley, Colorado

5 CAUSES OF RECURRING SINKHOLES

Our opinion as to potential causes of the sinkholes at the site are based on the locations and dates of historic sinkhole occurrences, the results of previous mitigation attempts, investigation of the subsurface conditions in the vicinity of the CAP, and measurements of local groundwater levels over the course of several months. We believe that the recurring sinkholes are the result of the following four factors:

- The local topographic low that exists along the CAP alignment. Surface runoff is channeled to the location above the CAP sometimes resulting in ponded water that infiltrates down, around, and into the CAP and mobilizes overlying soil particles along with it.
- The relatively low density of soils encountered during geotechnical investigation. The low density allows groundwater movement to more easily mobilize the soil particles.

- The existence of holes and separations between several joints in the CAP due to deformation and deterioration that allow water and soils to infiltrate the pipe.
- The large pore spaces and high permeability of the gravel pipe backfill create a zone of low hydraulic head allowing an increase in the velocity of the groundwater to mobilize overlying soil and erode or pipe it into the backfill material.

An inspection of the pipe by City crews on Saturday May 21, 2016 was conducted the day after two sinkholes opened up approximately 235 feet north of 18th Street. The inspectors found significant deposits of silt and sand inside the pipe downstream of the sinkholes. These sinkholes occurred after over one inch of precipitation fell on May 16 and 17 as well as heavy irrigation of the slope immediately west of the storm sewer. A local resident reported that the sprinklers were on for over four hours before he called the property owner who came and turned them off. We do not have an estimate of the amount of water the irrigation produced.

Previous sinkholes have occurred after heavy rain events according to local residents. Reportedly, standing water can be observed in the green space above the storm sewer after particularly heavy surface runoff. As surface water from rainfall and/or irrigation seeps into the ground it picks up fine particles of clay, silt, and fine sand and moves these particles down into the pipe backfill. Since the backfill is comprised only of coarse gravel, the sediment-laden water readily enters the pore spaces in the pipe backfill. From there, the water can freely move the soil particles down-slope (north) along the pipe backfill and will either deposit the material in the backfill or find a hole in the CAP and move the material into the pipe.

Through this process, the soil above the CAP is slowly eroded until a voids form above the CAP. The surface soil is held together through bridging due to the grass roots and the natural cohesion of the soil until a rain event and/or heavy irrigation erodes enough soil that the bridging can no longer support the overlying ground and a sinkhole appears to form almost instantaneously.

The sinkholes are therefore due both to the presence of the coarse gravel pipe backfill, lack of a separating material between the backfill and the soils, and holes in CAP. Were the pipe in new condition without any way for water or soil to enter it from above, the gravel pipe backfill would eventually clog with sediment and sinkholes would cease to occur. Additionally, if the pipe backfill was graded such that surrounding soil could not easily penetrate it, or a separating material was used, then holes in the CAP would be less of a problem since soil could not readily reach the holes. As it is however; the gravel backfill allows for sediment-laden water to easily move to holes in the CAP allowing for ongoing and repeated subsurface erosion.

6 RECOMMENDED MITIGATION ALTERNATIVES

Mitigation of the sinkholes will require addressing the two causes of the issue. First, the pipe backfill must be modified so that surrounding soil cannot penetrate as easily. And second, the holes and joint separations in the storm sewer pipe must be sealed. Lithos recommends one of two approaches to accomplish these goals: 1) line the existing CAP and grout the gravel pipe backfill, or 2) complete replacement of the CAP and pipe backfill.

6.1 Lining and Grouting

We understand that, if possible, the City would like to avoid open trench excavation of the pipe because the adjacent residents regularly use the greenspace and there are several mature trees along the alignment that would need to be removed. An option in this case would be to line the existing CAP and fill the voids in the backfill with grout. Two alternatives for lining the CAP include cured-in-place-pipe (CIPP) and sliplining. This would address the existing holes in the CAP that are allowing sediment to enter the pipe and facilitate erosion above. Once the pipe is repaired, the large pore spaces in the gravel backfill must still be filled. While over time, the surrounding soil may fill up the pore spaces, we estimate that there is over 130 cubic yards of pore space along the entire alignment. It would take a long time for soils to fill this space and additional sinkholes would be likely.

Risks associated with this approach are:

1. Collapsing the storm sewer pipe with excessive grout pressures during the grouting process.
2. Not filling all the pore spaces in the backfill during the grouting allowing for further soil infiltration and sinkhole formation.
3. Reduced flow capacity in the storm sewer, especially with sliplining

6.1.1 Cured-in-Place-Pipe (CIPP)

CIPP is widely used to rehabilitate aging pipelines. The lining is relatively thin and has a lower manning coefficient than the aluminum such that the reduction in flow capacity is little to none, and full-scale surface excavation is avoided. For storm sewer applications, we recommend installation of a UV-cured liner because there is no styrene emission that can cause environmental complications downstream. While the existing CAP appears to have some ovality, the integrity of the pipe appears generally sound. Some cost savings could be realized by accounting for some amount of structural support from the existing pipe such that a thinner CIPP lining could be used. Additionally, with this approach, no large entry pit is necessary as the materials can be lowered in through the existing manholes. Since workers will be in the pipe to construct the CIPP, it will be necessary to bypass storm water that may enter the pipe during construction.

6.1.2 Slip Lining

An alternative to CIPP is sliplining the existing CAP. This process involves installing a new pipe inside the existing one and placing grout in the annulus between the new and old pipes. Careful measurements will be necessary to determine the maximum size slipline pipe that can fit inside the existing pipe. For the purposes of the construction cost opinion below, we have assumed a 48-inch diameter HDPE pipe will fit. PVC pipe material could also be used if preferred, but would cost more. Due the reduced size of the new pipe, a flow analysis would be necessary to determine if the new pipe would have the flow capacity the storm sewer needs. Typically, the reduction in flow capacity is minimized due the lower manning coefficient of the new pipe. In order to install the slipline pipe, a relatively large entry pit is needed to be able to lower the pipe into position. Since workers will be in the pipe to construct the CIPP, it will be necessary to bypass storm water that may enter the pipe during construction.

6.1.3 Grouting of Pipe Backfill

Due to the large particle size of the pipe backfill, a cementitious grout should be able to fill most of the pore spaces. A series of grout holes will be necessary at regular intervals all along the alignment.

Schematically, we envision three to five grout holes spaced in a row. Each row would be approximately eight to ten feet apart along the length of the pipe. A possible grout hole orientation for each row would be two angled holes to get under the pipe, two vertical holes on either side of the pipe, and one vertical over the crown. Alternatively, it would be possible to do the grouting work from inside the CAP and drill holes radially outward. This would avoid any surface disruption. We recommend that vertical holes inject grout both in the pipe backfill and in the soil above to fill any existing voids that already exist that are future sinkholes in the making. While it is difficult to measure whether grout has completely filled the pore spaces in the pipe backfill, comparison of actual grout take versus a theoretical value should give approximate results.

6.2 Complete Replacement

Complete replacement of the CAP is the second option if the City does not want to use a trenchless approach. This option is the most invasive, but would provide the least risky solution to the recurring sinkholes in the area. Replacement of the CAP should be accompanied by replacement of the pipe backfill material. The backfill should either be wrapped in a permeable filter fabric if material similar to the existing gravel is used or consist of a well-graded material such as squeegee. This will inhibit the mobilization of the soil particles into the backfill.

Risks associated with this approach are:

1. The need to remove mature trees and manicured grass.
2. Impact to homeowners due construction activities and tree removal.

6.3 Drain Inlets

The greenspace overlying the CAP periodically holds standing water after significant storm events according to local residents. While not immediately addressing the sinkhole issues, installation of a series of drain inlets that feed into the storm sewer would reduce the standing water. There appears to be some sort of a surface drainage system already in place in the area, but it does not appear to be functional anymore.

7 OPINION OF PROBABLE CONSTRUCTION COST FOR MITIGATION ALTERNATIVES

The following opinions of probable construction cost (cost opinions) include the two options for addressing the sinkhole problems. We have not included costs to install the optional drain inlets. Table 7.1 provides the cost opinions.

7.1 – Cost Opinions for Mitigation Options				
Method	**Unit**	**Quantity**	**Unit Cost**	**Total**
CIPP with Grouting				
UV-Cured CIPP with structural Lining	LF	680	$440	$299,200
Grouting of Backfill	CY	150	$2900	$435,000
			Total	**$734,200**
Sliplining with Grouting				
Entry pit for sliplining	EA	1	$35,000	$35,000
Sliplining	LF	680	$290	$197,200
Annular Grout	CY	85	$260	$22,100
Grouting of Backfill	CY	150	$2900	$435,000
			Total	**$689,300**
Complete Replacement	EA	1	$500,000	$500,000
			Total	**$500,000**

Notes:

1. Lining and Replacement assumes only the area under the grass section between 16th and 18th Street
2. CIPP lining assumes no support is obtained from existing CAP. Cost could be lower if the CAP has some structural integrity
3. Sliplining assumes 48-inch diameter HDPE with sanded cement grout for annulus backfill between pipes.
4. Complete replacement cost is from the City.

8 LIMITATIONS

This study was conducted in accordance with generally accepted geotechnical engineering and engineering geologic practices and principals; no warranty, expressed or implied is made. The subsurface conditions described in this report were based on data obtained from exploratory borings, geotechnical laboratory testing, information provided by the client, engineering judgement, and our experience with similar subsurface conditions and projects. The boring logs presented in this report only depict the subsurface conditions at the actual boring locations. Subsurface conditions are typically variable, both laterally and vertically, and the nature and extent of the subsurface variations across the site may not become evident until construction. The boundaries between different soil types and bedrock presented in this report are approximate and in some cases may be more abrupt or gradational than described herein. Groundwater levels may vary with time, river levels, precipitation, and changes to the hydrogeological conditions at or surrounding the project site.

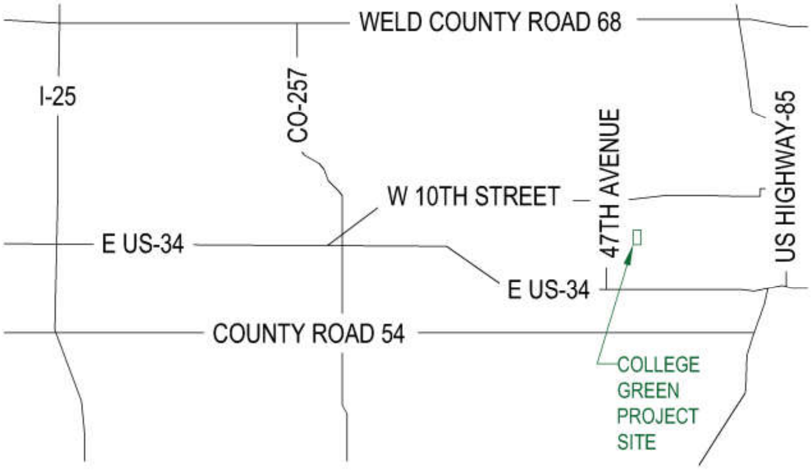
This report has been prepared exclusively for our client for recommendation purposes for the subject project. Lithos Engineering is not responsible for technical interpretations by others of the data presented in this report or use of this report by others for the subject project or other projects. If differing site conditions are encountered during further evaluation of the subsurface conditions by others or during construction, Lithos Engineering should be notified immediately to determine if any changes to our recommendations presented in this report are warranted.

An environmental assessment was not included in Lithos Engineering scope of work for this project. Any statements regarding the absence or presence of hazardous and/or toxic substances presented herein are only intended for informational purposes. If the client is concerned about the environmental conditions at the site, Lithos Engineering recommends the client and/or owner retain a qualified environmental firm to conduct an environmental site assessment.

9 REFERENCES

- ASTM Standards, ASTM International, West Conshohocken, PA (2012).
- Braddock, W.A., and Cole, J.C., 1978, Preliminary geologic map of the Greeley 1 degree x 2 degree quadrangle, Colorado and Wyoming: U.S. Geological Survey, Open-File Report OF-78-532, scale 1:250,000
- Thornton, C.I., Robeson, M.D., Girard, L.G., and Smith, B.A., 2005, Culvert Pipe Liner Guide and Specifications, Publication No. FHWA-CFL/TD-05-003
- Grand County Water and Sanitation District No.1: Engineering Standards, May 28th, 2002

FIGURES



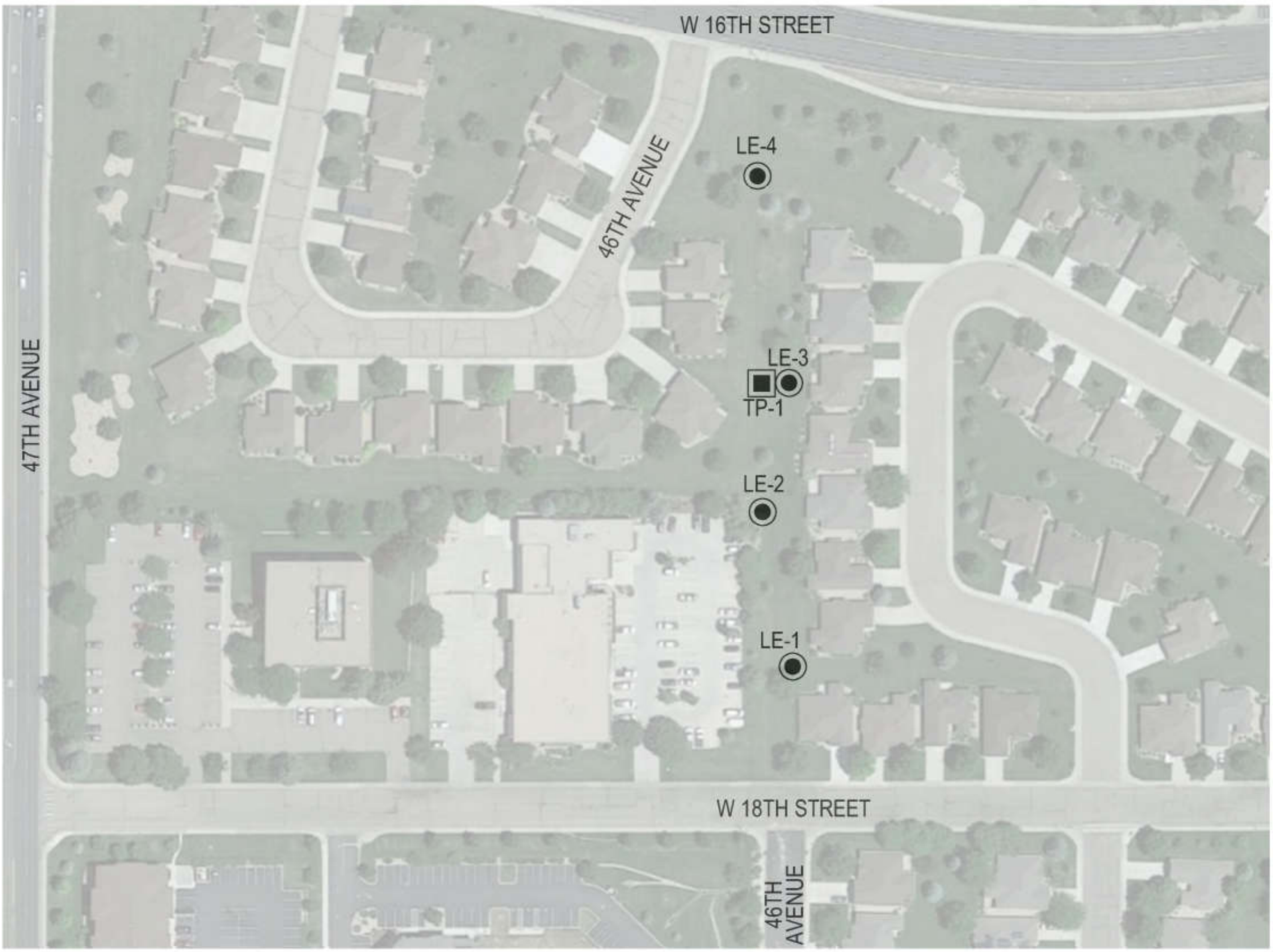
LEGEND:

- APPROXIMATE BORING LOCATION
- APPROXIMATE TEST PIT LOCATION

0 500 1000 2000 4000

SCALE 1" = 2000'

-- / - SITE VICINITY MAP



-- / - BORING LOCATION MAP

LITHOS ENGINEERING
2629 REDWING ROAD, SUITE 150
FORT COLLINS, COLORADO 80526
970.373.3195

PROJECT TITLE	COLLEGE GREEN SINKHOLE REMEDIATION
DRAWING TITLE	SITE VICINITY AND BORING LOCATION MAP

OWNER: City of Greeley Colorado

CLIENT: City of Greeley Colorado

PROJECT NO.:	16015-1	DRAWN BY:	AM
LOCATION:	Greeley, CO	DESIGNED BY:	AM
DATE:	June 14, 2016	CHECKED BY:	RD

FIGURE NUMBER

1

APPENDIX – A

Boring and Test Pit Logs

BORING LOG KEY

SOIL

Soil Classifications

Maximum Particle Size

Description	Particle Diameter (mm)
Boulders	>305
Cobbles	76 to 305
Coarse Gravel	19 to 76
Fine Gravel	4.75 to 19
Coarse Sand	2.00 to 4.75
Medium Sand	0.43 to 2.00
Fine Sand	0.074 to 0.43
Fines (Silt and Clay)	< 0.074

Gradation Estimates by Field Observation

Description	Quantity (%)
Trace	< 5
Few	5 to 10
Little	10 to 25
Some	25 to 50
Mostly	> 50

Relative density or consistency

Relative Density of Noncohesive Soils

Classification	Blows per 12 in
Very Loose	0 to 4
Loose	4 to 10
Medium Dense	10 to 30
Dense	30 to 50
Very Dense	>50

Consistency of Cohesive Soils

Classification	Blows per 12 in
Very Soft	0 to 2
Soft	2 to 4
Firm	4 to 8
Stiff	8 to 16
Very Stiff	16 to 32
Hard	>32

**Classifications of soils and corresponding blow count values are after Peck et al. (1953)*

Color: Sample colors are in general accordance with basic brown, red, yellow, and gray combinations

Description of Moisture

Description	Criteria
Dry	Absence of moisture, dusty, dry to the touch
Moist	Damp but no visible water
Wet	Visible free water, usually soil below the groundwater table

Description of Odor

Description	Criteria
No Organic Odor	Organic odor is not present
Trace Organic Odor	Mild organic odor; mixture of soil and organics
Strong Organic Odor	Prominent organic odor; sample is primarily organic

Other Descriptions

Plasticity

Description	Criteria
Nonplastic	A ⅛ in diameter thread cannot be rolled
Low	A ⅛ in diameter thread can be rolled with difficulty; a lump cannot be formed at a moisture lower than the plastic limit
Medium	A ⅛ in diameter thread can be rolled easily; a crumbly lump can be formed at a moisture lower than the plastic limit
High	A ⅛ in diameter thread can be rolled very easily; a lump can be formed at a moisture lower than the plastic limit

Cementation

Description	Criteria
Weak	Crumbles with light finger pressure
Moderate	Crumbles with considerable finger pressure
Strong	Will not crumble with finger pressure

General Notes

1) Soil sample ***Visual Material Descriptions*** are in general accordance with the Unified Soil Classification System or ASTM 2487.
2) Descriptions provided indicate conditions encountered at the location of the boring at the time of drilling, and at the specified sample location within the sample interval. Variation both laterally and vertically in the presented subsurface conditions should be anticipated.
3) The initial groundwater level indicated on the boring log was measured immediately after the completion of drilling. The initial groundwater level is dependent on the subsurface conditions, nearby site activities, and weather.

Geologic Interpretation

A ***Geologic Interpretation*** of encountered soil and bedrock units is provided for each specific ***Visual Material Description***. Examples of geologic interpretations for soil that may be presented include: FILL, ALLUVIUM, AEOLIAN, AND GLACIAL TILL, AND RESIDUUM. Rock geologic interpretations are referenced based on a combination of field classifications and applicable geologic maps.

Sample Graphics and Descriptions

California Barrel Sampler: Barrel sampler loaded with sample liners and driven to collect a relatively representative and intact specimen of soil or weak rock

Split-Spoon Sampler: Split-barrel sampler driven in accordance with ASTM D1586 used to provide visual material descriptions and collect a disturbed specimen

Shelby Tube Sampler: Thin wall tube hydraulically pushed into the subsurface to collect a representative and intact specimen of soil

Continuous Soil Sampler: Split-barrel sampler longer than a California Barrel Sampler and Slit-Spoon Sampler used to collect a continuous soil sample while drilling

Groundwater Monitoring Well Graphics

Riser Pipe with Auger Cuttings

Riser Pipe with Silica Sand

Well Screen with Silica Sand

Riser Pipe with Bentonite Chips

Concrete Flush Mounted Cap

Boring Abandonment Graphics

Bentonite Chips

Flowfill

Grout

LITHOS ENGINEERING

BORING: LE-1

Project Name: College Green Sinkhole Remediation
Project Number: 16015-1
Client's Name: City of Greeley
Owner's Name: City of Greeley
Drilling Subcontractor: Vine Laboratories, Inc.
Lithos Representative: Amara Meier
Date(s) of Drilling: 4/11/2016

Drilling and Sampling Methods

Drill Rig Make and Model: CME 45 Rubber Track
Drilling Method: Hollow-Stem Auger
Bit Type: Cutting Head
Casing Description: Hollow-Stem Auger
Hammer Weight (lbs) / Fall (in): 140 lbs / 30 in
Sampler Type(s): Split Spoon / California Barrel
Sampler Diameter(s): 1.5 in / 2 in Inner Diameter

LITHOS ENGINEERING

Boring Location: North of W 18th Street
Boring Elevation: 4836 ft
Notes:

Visual Material Description

Soil:
--GEOLOGIC INTERPRETATION--
USCS classification (group symbol), particle sizes, density or consistency, color, moisture, odor, other descriptions

Rock:
--GEOLOGIC INTERPRETATION--
Bedrock Classification, hardness, weathering, color, texture, joint size, other descriptions

Depth (ft)	Elevation (ft)	Blow Count / 6 in	Recovery (in) / RQD (%)	Visual Material Description	Fines Content (%)	Liquid Limit (%)	Plasticity Index (%)
0	4836						
~4.5		2, 2	6	**--COARSE ALLUVIUM--** *silty Sand to clayey Sand (SM-SC)*, mostly fine Sand, very loose, olive brown, dry to moist, no odor, rounded, low plasticity			
5	4831						
~7.5		2, 4	8	As above except loose, iron oxide staining	36	22	6
~9.5		3, 5	8	As above except loose			
10	4826						
~12.5		3, 2	0	As above except mostly medium Sand, loose, wet			
~14.5		3, 3, 3	11	As above except mostly medium Sand in top 4" of sample, mostly fine Sand in bottom 7" of sample, loose, wet	33	23	5
15	4821						
19				19 ft			
~19.5		4, 8	12	**--FINE ALLUVIUM--** *lean Clay with Sand (CL)*, some fine Sand, stiff, olive brown, wet, no odor, medium plasticity			
20	4816			End of Exploration 20 ft			
25	4811						
30	4806						

Groundwater Depth / Monitoring Well Configuration: (13.2 ft) (13.4 ft) (13.5 ft)

Laboratory Testing Results: In-Situ States (Moisture Content (%), Dry Unit Weight (pcf)); Index Data (Gravel Content (%), Sand Content (%), Fines Content (%), Liquid Limit (%), Plasticity Index (%)); Strength & Compressibility (UCS (psf), Inundation Pressure (psf), Swell Percent (%), Swell Pressure (psf))

General Notes:
1) Soil classifications are in general accordance with ASTM D 2487 Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)
2) The maximum particle size identified in the material description is dependent on sampler dimensions.
3) Additional information is provided on the Boring Log Key.

Groundwater Data:

Date:	Elapsed Time:	Depth to Groundwater:
4/11/16	2 hrs	13.5 ft
5/11/16	30 days	13.4 ft
5/19/16	38 days	13.2 ft

BORING: LE-2

Project Name: College Green Sinkhole Remediation
Project Number: 16015-1
Client's Name: City of Greeley
Owner's Name: City of Greeley
Drilling Subcontractor: Vine Laboratories, Inc.
Lithos Representative: Amara Meier
Date(s) of Drilling: 4/11/2016

Drilling and Sampling Methods

Drill Rig Make and Model: CME 45 Rubber Track
Drilling Method: Hollow-Stem Auger
Bit Type: Cutting Head
Casing Description: Hollow-Stem Auger
Hammer Weight (lbs) / Fall (in): 140 lbs / 30 in
Sampler Type(s): Split Spoon / California Barrel
Sampler Diameter(s): 1.5 in / 2 in Inner Diameter

LITHOS ENGINEERING

Boring Location: East of Parking Lot
Boring Elevation: 4836 ft
Notes:

Visual Material Description

Soil:
--GEOLOGIC INTERPRETATION--
USCS classification (group symbol), particle sizes, density or consistency, color, moisture, odor, other descriptions

Rock:
--GEOLOGIC INTERPRETATION--
Bedrock Classification, hardness, weathering, color, texture, joint size, other descriptions

Depth (ft)	Elevation (ft)	Sample Identification	Blow Count / 6 in	Recovery (in) / RQD (%)	Visual Material Description	Groundwater Depth / Monitoring Well Configuration	Moisture Content (%)	Dry Unit Weight (pcf)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Liquid Limit (%)	Plasticity Index (%)	UCS (psf)	Inundation Pressure (psf)	Swell Percent (%)	Swell Pressure (psf)
0	4836																
4.5		X	2, 2	6	**--COARSE ALLUVIUM--** *silty Sand to clayey Sand (SM-SC)*, mostly fine Sand, very loose, brown, dry to moist, no odor, rounded, low plasticity												
5	4831																
7.5		X	2, 4	8	As above except loose												
9.5		X	2, 5	8	As above except loose						45	25	7				
10	4826																
12.5		X	3, 3	11	As above except loose, wet (12.5 ft)	(13.05 ft) (13.2 ft) (13.3 ft)	23	104			53	31	14		500	-0.19	NA
12.5–19					**--FINE ALLUVIUM--** *lean Clay with Sand (CL)*, some fine Sand, medium stiff, light brown, wet, no odor, rounded sand, medium plasticity												
14.5		X	2, 11	0	As above except some Gravel, maximum particle size 1½", stiff												
15	4821																
19.5		X	21, 34	10	**--COARSE ALLUVIUM--** (19 ft) *silty Sand to clayey Sand (SM-SC)*, mostly fine Sand, dense, olive, wet, no odor, rounded, low plasticity												
20	4816				End of Exploration 20 ft												
25	4811																
30	4806																

General Notes:
1) Soil classifications are in general accordance with ASTM D 2487 Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)
2) The maximum particle size identified in the material description is dependent on sampler dimensions.
3) Additional information is provided on the Boring Log Key.

Groundwater Data:

Date:	Elapsed Time:	Depth to Groundwater:
4/11/16	2 hrs	13.3 ft
5/11/16	30 days	13.2 ft
5/19/16	38 days	13.05 ft

BORING: LE-3

Project Name: College Green Sinkhole Remediation
Project Number: 16015-1
Client's Name: City of Greeley
Owner's Name: City of Greeley
Drilling Subcontractor: Vine Laboratories, Inc.
Lithos Representative: Amara Meier
Date(s) of Drilling: 4/11/2016

Drilling and Sampling Methods

Drill Rig Make and Model: CME 45 Rubber Track
Drilling Method: Hollow-Stem Auger
Bit Type: Cutting Head
Casing Description: Hollow-Stem Auger
Hammer Weight (lbs) / Fall (in): 140 lbs / 30 in
Sampler Type(s): Split Spoon / California Barrel
Sampler Diameter(s): 1.5 in / 2 in Inner Diameter

LITHOS ENGINEERING

Boring Location: Adjacent to current sinkhole
Boring Elevation: 4835
Notes:

Visual Material Description

Soil:
--GEOLOGIC INTERPRETATION--
USCS classification (group symbol), particle sizes, density or consistency, color, moisture, odor, other descriptions

Rock:
--GEOLOGIC INTERPRETATION--
Bedrock Classification, hardness, weathering, color, texture, joint size, other descriptions

Depth (ft) / Elevation (ft): 0 – 4835; 5 – 4830; 10 – 4825; 15 – 4820; 20 – 4815; 25 – 4810; 30 – 4805

--FILL--
lean Clay (CL), some fine Sand, stiff, dark brown, moist, no odor, rounded sand, moderate plasticity

As above except olive gray, calcareous deposits

9.0 ft

--FILL--
silty Sand (SM), mostly fine Sand, trace Gravel, maximum particle size ½", loose, olive brown, moist to wet, no odor, rounded

9.5 ft

--FINE ALLUVIUM--
lean Clay with Sand (CL), some fine Sand, stiff, brown, moist to wet, no odor, rounded sand, medium plasticity, calcareous

As above except medium stiff

As above except medium stiff, wet

As above except medium stiff, wet

19.25 ft

--COARSE ALLUVIUM--
silty Sand (SM), mostly fine Sand, medium dense, olive brown, wet, no odor, rounded

19.5 ft

--LARAMIE FORMATION--
Claystone, highly weathered, iron oxide staining, planar bedding, olive brown to olive gray, wet, no odor

End of Exploration 20 ft

Groundwater Depth / Monitoring Well Configuration: (12.95 ft) (13.1 ft) (13.25 ft)

Sampling Data and Laboratory Testing Results

Sampling description	Blow Count / 6 in	Recovery (in) / RQD (%)	Moisture Content (%)	Dry Unit Weight (pcf)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Liquid Limit (%)	Plasticity Index (%)	UCS (psf)	Inundation Pressure (psf)	Swell Percent (%)	Swell Pressure (psf)
lean Clay (CL) fill	6, 8	10											
As above except olive gray, calcareous deposits	6, 8	7					66	39	21				
silty Sand (SM) fill	5, 9	8											
As above except medium stiff	3, 4	12											
As above except medium stiff, wet	3, 5	12	18	111			52	26	8		500	0.24	860
As above except medium stiff, wet	14, 25	12											

General Notes:
1) Soil classifications are in general accordance with ASTM D 2487 Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)
2) The maximum particle size identified in the material description is dependent on sampler dimensions.
3) Additional information is provided on the Boring Log Key.

Groundwater Data:

Date:	Elapsed Time:	Depth to Groundwater:
4/11/16	2 hrs	13.25 ft
5/11/16	30 days	13.1 ft
5/19/16	38 days	12.95 ft

BORING: LE-4

Project Name: College Green Sinkhole Remediation
Project Number: 16015-1
Client's Name: City of Greeley
Owner's Name: City of Greeley
Drilling Subcontractor: Vine Laboratories, Inc.
Lithos Representative: Amara Meier
Date(s) of Drilling: 4/11/2016

Drilling and Sampling Methods

Drill Rig Make and Model: CME 45 Rubber Track
Drilling Method: Hollow-Stem Auger
Bit Type: Cutting Head
Casing Description: Hollow-Stem Auger
Hammer Weight (lbs) / Fall (in): 140 lbs / 30 in
Sampler Type(s): Split Spoon / California Barrel
Sampler Diameter(s): 1.5 in / 2 in Inner Diameter

LITHOS ENGINEERING

Boring Location: South of W 16th Street
Boring Elevation: 4834 ft
Notes:

Depth (ft)	Elevation (ft)	Blow Count / 6 in	Recovery (in) / RQD (%)	Visual Material Description	Groundwater Depth / Monitoring Well Configuration	Moisture Content (%)	Dry Unit Weight (pcf)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Liquid Limit (%)	Plasticity Index (%)	UCS (psf)	Inundation Pressure (psf)	Swell Percent (%)	Swell Pressure (psf)
0	4834															
5	4829	4, 4	11	**--FILL--** *silty Sand to clayey Sand (SM-SC)*, mostly fine Sand, loose, olive brown, moist, no odor, rounded, low plasticity						30	20	5				
7		2, 2	7	**--FILL--** *clayey Sand (SC)*, mostly fine Sand, very loose, brown, moist, no odor, rounded, low plasticity	7 ft											
10	4824	3, 3	4	As above except some Gravel, maximum particle size ¾", loose, light brown						34	26	13				
12		2, 1	0	**--FILL--** *poorly-graded Gravel with Silt (GP-GM)*, maximum particle size 1 ¾", very loose, olive brown, wet, no odor	12 ft											
15	4819	2, 3, 5	12	As above except loose	(13.9 ft) (14.1 ft) (14.2 ft)											
19				**--COARSE ALLUVIUM--** *silty Sand (SM)*, mostly fine Sand, dense, olive, wet, no odor, rounded	19 ft											
20	4814	18, 27, 40	19	**--LARAMIE FORMATION--** *Claystone,* highly weathered, iron oxide staining, planar bedding, olive brown to olive gray, wet, no odor	20 ft											
20.5				End of Exploration 20.5 ft												
25	4809															
30	4804															

General Notes:
1) Soil classifications are in general accordance with ASTM D 2487 Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)
2) The maximum particle size identified in the material description is dependent on sampler dimensions.
3) Additional information is provided on the Boring Log Key.

Groundwater Data:

Date:	Elapsed Time:	Depth to Groundwater:
4/11/16	2 hrs	14.2 ft
5/11/16	30 days	14.1 ft
5/19/16	38 days	13.9 ft

TEST PIT: TP-1

Project Name: College Green Sinkhole Remediation
Project Number: 16015-1
Client's Name: City of Greeley
Owner's Name: City of Greeley
Excavation Contractor: City of Greeley
Lithos Representative: Nate Soule
Date(s) of Excavation: 11/09/2015

Excavation Details

Excavator Make: John Deere
Excavator Model: 410K
Time Start Excavation: 0900
Time Complete Excavation: 1330

LITHOS ENGINEERING

Test Pit Location: Current Sinkhole Location (LE-3)
Test Pit Elevation: 4835
Notes:

Sampling Data			Geologic Graphic	Visual Material Description	Groundwater Depth / Monitoring Well Configuration	Laboratory Testing Results										
				Soil: **--GEOLOGIC INTERPRETATION--** *USCS classification (group symbol)*, particle sizes, density or consistency, color, moisture, odor, other descriptions **Rock:** **--GEOLOGIC INTERPRETATION--** (*Bedrock Classification*, hardness, weathering, color, texture, joint size, other descriptions		In-Situ States		Index Data					Strength & Compressibility			
Depth (ft)	Elevation (ft)	Sample Identification				Moisture Content (%)	Dry Unit Weight (pcf)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Liquid Limit (%)	Plasticity Index (%)	UCS (psf)	Inundation Pressure (psf)	Swell Percent (%)	Swell Pressure (psf)
0	4835			**--FILL--** *silty Sand to lean Clay (SM-CL) with lenses of poorly-graded Sand (SP)*, trace Gravel, maximum particle size 3", loose, dark brown, moist, no odor, rounded												
5	4830															
				8.5 ft												
				--FILL-- *poorly-graded Gravel (GP) and lean Clay with Sand (CL)*, maximum particle size ¾" to 2", loose, light brown, moist to wet, no odor, rounded												
10	4825															
				End of Excavation 12.0 ft												
15	4820															

General Notes:
1) Soil classifications are in general accordance with ASTM D 2487 Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)
2) The maximum particle size identified in the material description is dependent on sampler dimensions.
3) Additional information is provided on the Boring Log Key.

Groundwater Data:

Date:	Elapsed Time:	Depth to Groundwater:
04/22/16	0 hrs	Not Encountered

APPENDIX – B

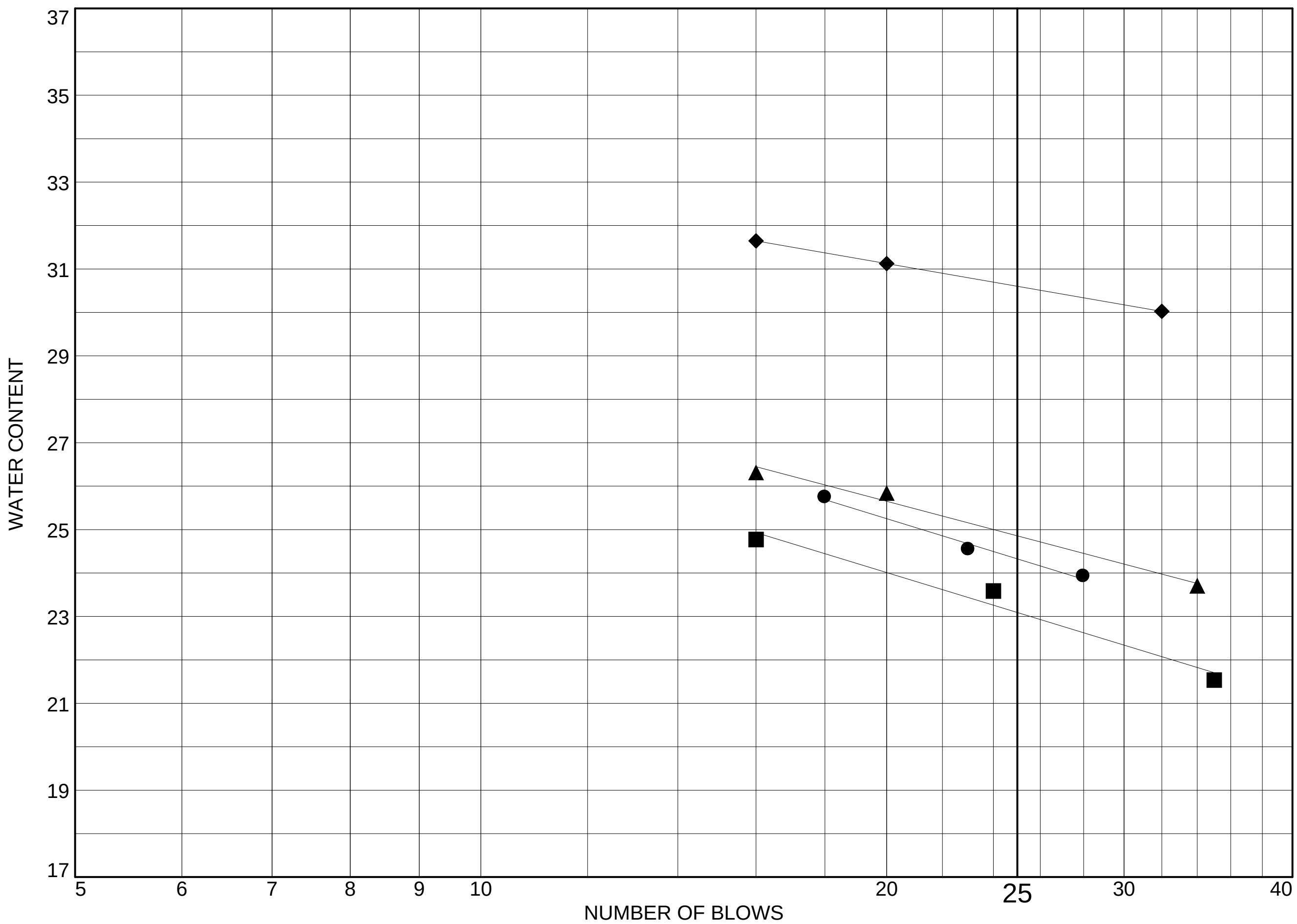
Geotechnical Laboratory Testing Results

Geotechnical Laboratory Testing Results

Geotechnical Laboratory Testing Results												
Sample		In-Place States		Material Classification and Index Testing					Stress Strain Behavior			USCS/Geologic Classification
				Atterberg Limits		Particle Size Distribution			One-Dimensional Swell and Consolidation[1]			
Boring	Sample Depth (ft)	Moisture Content (%)	Dry Density (pcf)	Liquid Limit	Plasticity Index	Gravel (%)	Sand (%)	Fines (%)	Inundation Pressure (psf)	Swell Percent (%)	Swell Pressure (psf)	
LE-1	7.0-8.0			22	6			36				silty to clayey Sand
LE-1	14.0-15.0			23	5			33				silty to clayey Sand
LE-2	9.0-10.0			25	7			45				silty to clayey Sand
LE-2	12.0-13.0	23	104	31	14			53	500	-0.19	N/A	lean Clay
LE-3	7.0-8.0			39	21			66				lean Clay
LE-3	14.0-15.0	18	111	26	8			52	500	0.24	860	lean Clay
LE-4	4.0-5.0			20	5			30				silty to clayey Sand
LE-4	9.0-10.0			26	13			34				clayey Sand

[1] A negative swell percent indicates non-expansive behavior of the sample upon wetting

LIQUID AND PLASTIC LIMITS TEST REPORT



	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	AASHTO
●		24	18	6		35.8	
■		23	18	5		32.8	
▲		25	18	7		44.5	
◆		31	17	14		52.5	

Project No. 16-0040 **Client:** Lithos Engineering

Project: College Green Sinkhole

LE Project 16015-1

●**Location:** LE-1, C-2 **Depth:** 7' **Sample Number:** 4687

■**Location:** LE-1, S-5 **Depth:** 14' **Sample Number:** 4688

▲**Location:** LE-2, C-3 **Depth:** 9' **Sample Number:** 4689

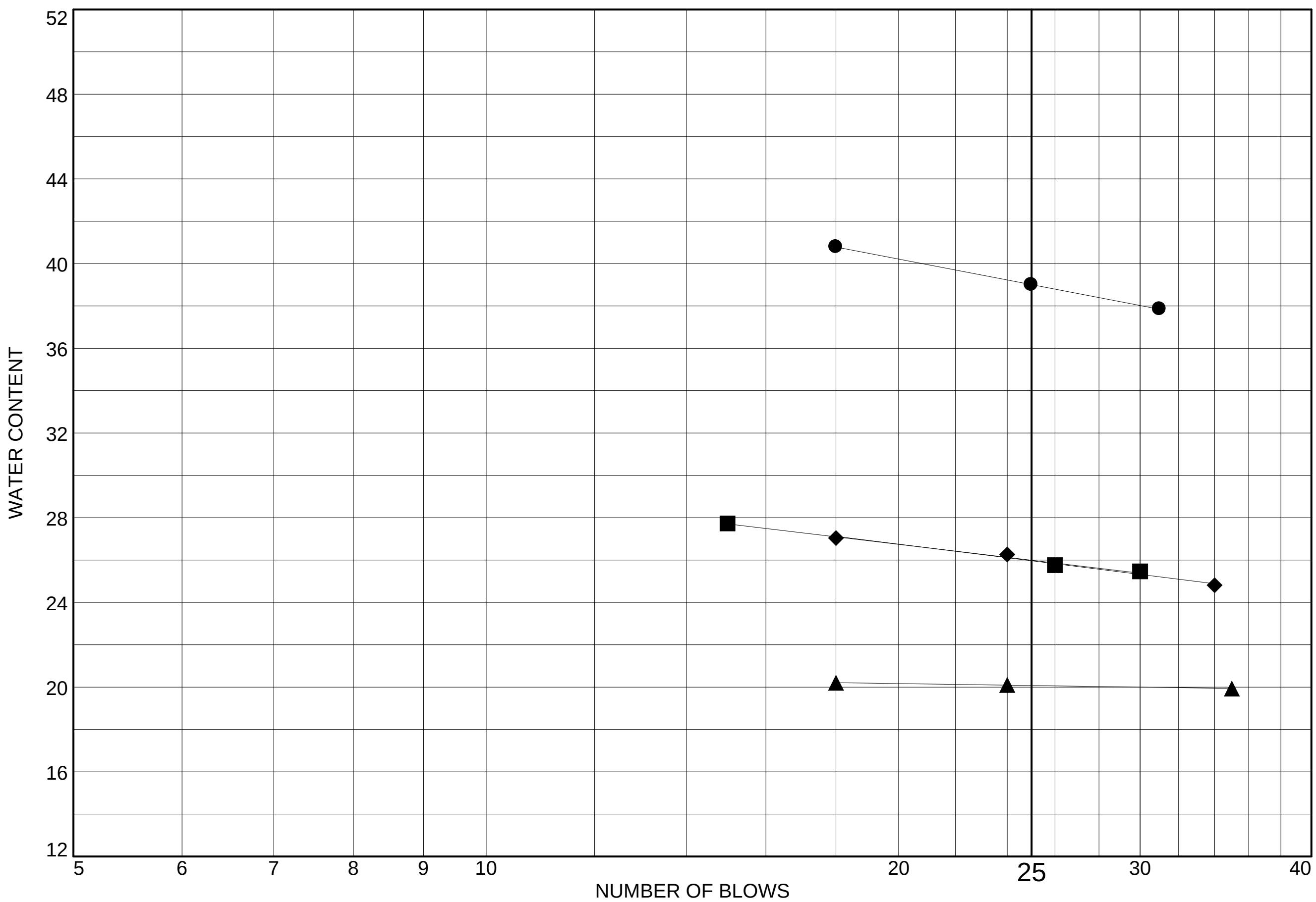
◆**Location:** LE-2, C-4 **Depth:** 12' **Sample Number:** 4690

Martinez Associates

Remarks:

Figure

LIQUID AND PLASTIC LIMITS TEST REPORT



	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	AASHTO
●		39	18	21		66.0	
■		26	18	8		51.6	
▲		20	15	5		29.9	
◆		26	13	13		33.6	

Project No. 16-0040 **Client:** Lithos Engineering

Project: College Green Sinkhole

LE Project 16015-1

●**Location:** LE-3, C-2 **Depth:** 7' **Sample Number:** 4691

■**Location:** LE-3, C-5 **Depth:** 14' **Sample Number:** 4692

▲**Location:** LE-4, C-1 **Depth:** 4' **Sample Number:** 4693

◆**Location:** LE-4, C-3 **Depth:** 9' **Sample Number:** 4694

Martinez Associates

Remarks:

Figure

Tested By: WS Greer **Checked By:** K. Runner

Martinez Associates
14828 West 6th Avenue, Unit 9-B
Golden, Colorado 80401
Phone: (303) 459-2216
Fax: (303) 482-2230

One Dimensional Swell/Consolidation (ASTM D 4546)

(Denver Area Swell/Consolidation Test)

Client Project No.: 16015-1   Proj. Name: College Green Sinkhole   Sampled By: LE
Martinez Job No.: 16-0040   Lab Tech: WSG   Test Date: 4/13/2016   Sample Date: Not Provided
Sample ID: 4690   Reviewed By: K. Runner
Sample Location: LE-2, C-4 @ 12'
Soil Description:
USCS:

Sample Data:

Ring No:	G	Dish No:	The
Ring Mass (g):	238.2	Dish Mass (g):	8.3
Sample Height (in):	0.75	Swell Machine #:	7.0
Pre-test Sample		**Post-test Sample**	
Ring + Sample (g):	311.9	Ring + Sample (g):	309.4
Dish wt:	8.3	Dish wt:	106.7
Wet wt (g):	326.8	Wet wt (g):	177.8
Dry wt (g):	267.5	Dry wt (g):	166.6

Results:

Moisture/Density

Pre-test Sample		**Post-test Sample**	
Moisture Content:	22.9%	Moisture Content:	18.7%
Wet Density (pcf):	127.2	Wet Density (pcf):	134.8
Dry Density (pcf):	103.5	Dry Density (pcf):	113.6

Swell/Consolidation

Load (ksf):	0.1	0.5	Add Water	0.5	1	2	4	8	4
Correction (x 10-4):	0	10		10	19	31	47	63	47
Dial Reading (x 10-4):	2019	1869		1855	1793	1661	1498	1292	1308
Swell/Consolidation %:	**0.0%**	**-1.9%**		**-2.1%**	**-2.8%**	**-4.4%**	**-6.3%**	**-8.9%**	**-8.9%**

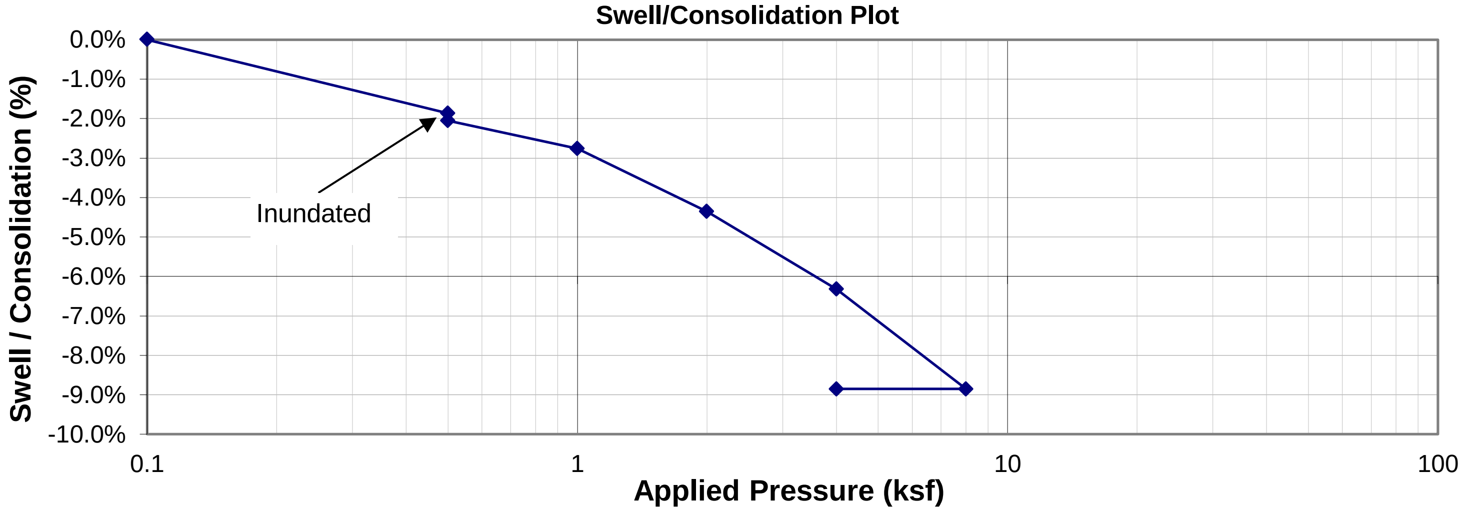
Results:

Settlemet Upon Wetting @ 500 psf: **-0.19%**

Swell Pressure (psf): **NA**

Tested By: WS Greer
Checked By: K. Runner

Swell/Consolidation Plot



Martinez Associates
14828 West 6th Avenue, Unit 9-B
Golden, Colorado 80401
Phone: (303) 459-2216
Fax: (303) 482-2230

One Dimensional Swell/Consolidation (ASTM D 4546)

(Denver Area Swell/Consolidation Test)

Client Project No.: 860 Proj. Name: College Green Sinkhole Sampled By: LE
Martinez Job No.: 16-0040 Lab Tech: WSG Test Date: 4/13/2016 Sample Date: 4/11/2016
Sample ID: 4691 Reviewed By: K. Runner
Sample Location: LE-3, C-2 @ 7'
Soil Description:
USCS:

Sample Data:

Ring No:	H	Dish No:	Ed
Ring Mass (g):	237.6	Dish Mass (g):	8.5
Sample Height (in):	0.75	Swell Machine #:	8.0
Pre-test Sample		**Post-test Sample**	
Ring + Sample (g):	313.6	Ring + Sample (g):	313.3
Dish wt:	8.5	Dish wt:	107.2
Wet wt (g):	329.8	Wet wt (g):	183.1
Dry wt (g):	279.8	Dry wt (g):	171.3

Results:

Moisture/Density

Pre-test Sample		**Post-test Sample**	
Moisture Content:	18.4%	Moisture Content:	18.4%
Wet Density (pcf):	131.1	Wet Density (pcf):	137.3
Dry Density (pcf):	110.7	Dry Density (pcf):	116.0

Swell/Consolidation

Load (ksf):	0.1	0.5	Add Water	0.5	1	2	4	8	4
Correction (x 10-4):	0	11		11	21	36	49	61	49
Dial Reading (x 10-4):	3027	2933		2951	2918	2855	2761	2588	2611
Swell/Consolidation %:	**0.0%**	**-1.1%**		**-0.9%**	**-1.2%**	**-1.8%**	**-2.9%**	**-5.0%**	**-4.9%**

Results:

Swell Upon Wetting @ 500 psf: **0.24%**

Swell Pressure (psf): **860**

Tested By: WS Greer
Checked By: K. Runner