GEOTECHNICAL ENGINEERING AND PAVEMENT DESIGN REPORT

EAST 144th AVENUE WIDENING AND IMPROVEMENTS
EAST 144th AVENUE BETWEEN YORK STREET & COLORADO BLVD
THORNTON, COLORADO

PREPARED FOR:

Drexel Barrell & Co.
1800 38th Street
Boulder, CO 80301

PREPARED BY:

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CGG Project No. 18.22.099
June 20, 2018

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June 20, 2018

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Attn: Mr. Garrett Lingreen, P.E.
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Re: Geotechnical Engineering and Pavement Thickness Design Report
144th Avenue Widening and Improvements
East 144th Avenue between York Street & Colorado Boulevard
Thornton, Co1orado
CGG Project No. 18.22.099

Cole Garner Geotechnical (CGG) has completed geotechnical engineering investigation for improvements to approximately 5,250 lineal feet portion of East 144th Avenue east of York Street and west of Colorado Boulevard in Thornton, Colorado. These services were performed in general accordance with our proposal number P18.22.081, dated March 13, 2018.

This geotechnical summary should be used in conjunction with the entire report for design and/or construction purposes. It should be recognized that specific details were not included or fully developed in this section, and the report must be read in its entirety for a comprehensive understanding of the items contained herein. The section titled General Comments should be read for an understanding of the report limitations.

- **Subsurface Conditions:** The following summarizes the conditions encountered in our borings for this study. Other specific information regarding the lithology encountered is noted on the Boring Logs.
  - **Existing Pavement Materials:** Cores of the existing asphalt concrete materials were completed at Boring Nos. 1, 4, 6, 9, and 11. Existing asphalt concrete (AC) thicknesses ranged from about 12 to 14 inches between York St. and Madison St., and about 5 to 6 inches between Madison St. and Colorado Blvd.
  - **Existing Man-made Fill:** Existing man-made fill (likely related to existing roadway and utility construction) was encountered in several of our borings and extended to depths ranging from about 3-½ feet to 10 feet below the existing roadway surface. The fill was variable, but was primarily comprised of sandy lean clay with lenses of clayey sand, claystone fragments and gravel.
  - **Native Soils:** Native soils encountered underlying the fill soil consisted of predominantly sandy lean clay and clayey sand. Silty sand was observed in Boring No. 11.
  - **Sedimentary Sandstone and Claystone Bedrock:** Claystone and sandstone bedrock was encountered just below the ground surface in Boring No. 3 and underlying the native soils at a depth of about 8 feet below the ground surface in Boring Nos. 1, 9, and 11.
  - **Groundwater:** Groundwater was not encountered during drilling. The borings were backfilled upon completion of drilling for safety reasons.

- **Expansive Soils and Bedrock:** As discussed, approximately 3-½ to 10 feet of existing fill was encountered in our borings for this current study. This fill was likely placed during development of the existing roadway and utilities. However, the clay fill soils exhibited low to high expansive potential in their current condition and the claystone bedrock encountered at the site exhibited moderate expansive potential when subjected to wetting in our laboratory. Even low expansive materials may heave upon additional wetting, potentially resulting in pavement distress and other movement causing common cosmetic distress such as edge cracking, uneven curb and gutter, etc. ***We believe that some heave-related distress should be anticipated during the design life of the pavement. In our opinion, there is not a reasonable method to eliminate this risk, but we have provided recommendations that we believe will limit distress to the magnitudes normally acceptable in the region.***

  In order to reduce the potential for movement and distress of the proposed improvements, we recommend that subgrade preparation along the proposed alignment include subexcavation, moisture-conditioning, and recompaction of the existing soils to a minimum depth of 3 feet below pavement subgrade elevation, as per the Standards. Other design and construction recommendations for the proposed pavements are outlined below.

- **Pavement Thickness:** Based on the design methods presented in the City of Thornton Standards, the minimum pavement section thickness alternatives for the proposed public roadways are summarized below:

Traffic Area	Alternative*	Pavement Section Thickness (Inches)			
		Asphalt Concrete Surface	Aggregate Base Course	Portland Cement Concrete	Total
Minor Arterial ***East 144th Avenue*** $ESAL_{20}$=3,394,500	A	7-½	15-½	--	23
	B	12-½	--	--	12-½
	C	--	--	9-½	9-½

Details regarding design methods and other recommendations are included in the report. Please do not hesitate to contact us if you have any questions concerning this report or any of our testing, inspection, design and consulting services.

Sincerely,
Cole Garner Geotechnical

Patrick Maloney, G.I.T.
Staff Geologist/Project Manager

Andrew J. Garner, P.E.
Principal, COO

COLORADO REGISTERED PROFESSIONAL ENGINEER
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Geotechnical Engineering and Pavement Thickness Design Report

East 144th Avenue Widening and Improvements
East 144th Avenue between York Street and Colorado Boulevard
Thornton, Colorado

CGG Project No. 18.22.099
June 20, 2018

INTRODUCTION

This report contains the results of our geotechnical engineering exploration for improvements to a portion East 144th Avenue in Thornton, Colorado. The purpose of these services is to provide information and geotechnical engineering recommendations relative to:

- Subsurface soil and bedrock conditions
- Groundwater conditions
- Pavement structural sections
- Earthwork
- Drainage

The recommendations contained in this report are based upon the results of field and laboratory testing, engineering analyses, our experience with similar soil conditions and structures, and current City of Thornton *Standards and Specifications for the Design and Construction of Public and Private Improvements* (herein referred to as the Standards).

PROJECT INFORMATION

Project Description: We understand that the City of Thornton desires to widen and improve East 144th Avenue between the York Street and Colorado Boulevard to Major Arterial standards. Currently, this section of East 144th Avenue includes one lane of travel in the east- and westbound directions along with a left turn lane at York Street, a left and right turn lane at Elizabeth Court, a left and right turn lane at Detroit Street, and a left and right turn lane at Madison Street. The left turn lanes transition into an unused center lane between the RTD Right-Of-Way (ROW) and Madison Street. We understand that all widening is to occur within the existing ROW, if possible, but that the exact locations of widening to accommodate the new typical cross-section is still in the conceptual stages at this time. The planned improvements, although conceptual at the moment, will include the addition of one travel lane in each direction (Minor Arterial: 4 travel lanes total), center left turn lanes at some intersecting streets, and a bike-lane in each direction.

New drainage may be constructed in areas where widening alters or interferes with existing drainage facilities (swales). The existing pavements are to be rehabilitated with a mill and overlay and new curb and gutter is planned along the alignment, where needed. We presume the roadway widening will included flexible pavement sections construction in accordance with the City of Thornton Development Standards.

If our assumptions above are not accurate, or if you have additional useful information, please inform us as soon as possible.

Site Information and Conditions: As discussed, at the time of our exploration, the roadway alignments consisted of one lane of travel in the east and westbound directions along with right and left turn lanes in areas and an unused center lane between the RTD ROW and Madison Street. Existing pavement conditions and thicknesses varied along the alignment. Swales were present in the shoulders in unimproved areas. Curb and gutter leading to landscaping and a sidewalk was present on the southern side of the road for approximately 1,900 feet between Detroit Street and Madison Street adjacent to the Fallbrook Farms subdivision. Elevation drops gradually to the west, ranging from about 5,250 to 5,170 feet between Colorado Blvd. and York St., according to USGS mapping.

SITE EXPLORATION PROCEDURES

The scope of the services performed for this project included site reconnaissance by a field engineer, a subsurface exploration program, laboratory testing and engineering analysis.

Field Exploration: Our scope of services included geotechnical exploration of the subsurface materials at eleven (11) locations along the existing alignment. These exploratory test borings were drilled on either side of East 144th Avenue at approximately 500 feet centers for pavement design in accordance with the referenced Standards. Asphalt concrete (AC) cores and aggregate base course (ABC) measurements were performed at five (5) select locations for existing pavement condition assessments along the alignment. The borings were advanced to depths ranging from approximately 5 to 10 feet below the existing roadway surface in accordance with City of Thornton requirements. Please refer to the attached Boring Location Diagram in Appendix A for specific boring locations.

Borings were advanced with a truck-mounted drilling rig utilizing 4-inch diameter, solid stem auger. A lithologic log of each boring was recorded by our field personnel during the drilling operations. At selected intervals, samples of the subsurface materials were obtained by driving standard split-spoon or modified California barrel samplers. Penetration resistance measurements were obtained by driving the sample barrel into the subsurface materials with a 140-pound automatic hammer falling 30 inches. The penetration resistance value is a useful index to the consistency, relative density or hardness of the materials encountered.

Groundwater measurements were obtained in the borings during exploration and then the borings were backfilled immediately thereafter for safety considerations. Where the borings were performed in existing pavements, they were backfilled with non-shrink grout mixed with sand and the pavement was patched with non-shrink grout or temporary cold-mix asphalt, according to the required Standards.

Laboratory Testing: Samples retrieved during the field exploration were returned to the laboratory for observation by the project geotechnical engineer, and were visually-manually classified in general accordance with the Unified Soil Classification System described in Appendix C. Bedrock is described according the notes on Bedrock Classification. At that time, an applicable laboratory-testing program was formulated to determine engineering properties of the subsurface materials. Following the completion of the laboratory testing, the field descriptions were confirmed or modified as necessary, and Boring Logs were prepared. These logs are presented in Appendix A.

Laboratory test results are presented in Appendix B. These results were used for the geotechnical engineering analyses and the development of foundation and earthwork recommendations. Laboratory tests were performed in general accordance with the applicable local or other accepted standards.

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

- Water content
- Dry density
- Swell/Consolidation potential
- R-value
- Grain size
- Plasticity Index
- Water-soluble sulfates

SUBSURFACE CONDITIONS

Geology: Surficial geologic conditions at the site, as mapped by the U.S. Geological Survey (USGS) ([1]Trimble & Machette, 1979), consist of Colluvium of Upper Holocene Age. This material is described as unconsolidated materials deposited on slopes by gravity and sheetwash that is generally variable with a thickness over 1.5 meters.

Bedrock underlying the surface units consists of the upper transition member of the Dawson and Arapahoe Formations (TKda) of Paleocene and Upper Cretaceous Age. This unit is described as arkosic sandstone, siltstone, claystone, and/or minor amounts of conglomerate. Where the formation underlies the Denver Formation it is called the Arapahoe Formation. The formation is noted as being as much as 610 meters in thickness.

[1] Trimble, Donald E., Machette, Michael N., ***Geologic Map of the Greater Denver Area, Front Range Urban Corridor, Colorado***, United States Geological Survey, Miscellaneous Investigations Series, Map I-856-H.

Due to the relatively flat nature of this section of 144th Avenue, risk due to geologic hazards at the site are anticipated to be low. Seismic activity in the area is anticipated to be low, and the alignment should be relatively stable from a structural standpoint. With proper site grading erosional problems at the site should be reduced.

Mapping completed by the Colorado Geological Survey ([2]Hart, 1972) indicates the site is located in an area of "High to Very High Swell Potential." Potentially expansive materials mapped in this area include bedrock, weathered bedrock, and colluvium (surficial units).

Typical Subsurface Profile: The following summarizes the conditions encountered in our borings for this study. Other specific information regarding the lithology encountered is noted on the Boring Logs.

- **Existing Pavement Materials:** Cores of the existing asphalt concrete materials were completed at Boring Nos. 1, 4, 6, 9, and 11. Existing asphalt concrete (AC) thicknesses ranged from about 12 to 14 inches between York St. and Madison St., and about 5 to 6 inches between Madison St. and Colorado Blvd.
- **Existing Man-made Fill:** Existing man-made fill (likely related to existing roadway and utility construction) was encountered in several of our borings and extended to depths ranging from about 3-½ feet to 10 feet below the existing roadway surface. The fill was variable, but was primarily comprised of sandy lean clay with lenses of clayey sand, claystone fragments and gravel.
- **Native Soils:** Native soils encountered underlying the fill soil consisted of predominantly sandy lean clay and clayey sand. Silty sand was observed in Boring No. 11.
- **Sedimentary Sandstone and Claystone Bedrock:** Claystone and sandstone bedrock was encountered just below the ground surface in Boring No. 3 and underlying the native soils at a depth of about 8 feet below the ground surface in Boring Nos. 1, 9, and 11.

Groundwater Conditions: Groundwater was not encountered during drilling. The borings were backfilled upon completion of drilling for safety reasons.

Based upon review of U.S. Geological Survey Maps, ([3]Hillier, et al, 1979), regional groundwater beneath the project area is expected to be encountered in the Arapahoe Aquifer at depths generally greater than 20 feet and commonly more than 100 feet below the existing ground surface.

[2] Hart, Stephen S., 1972, ***Potentially Swelling Soil and Rock in the Front Range Urban Corridor, Colorado***, Colorado Geological Survey, Sheet 1 of 4.

[1] Hillier, Donald E.; and Schneider, Paul A., Jr., 1979, ***Depth to Water Table (1976-1977) in the Boulder-Fort Collins-Greeley Area, Front Range Urban Corridor, Colorado***, United States Geological Survey, Map I-855-I.

Current groundwater observations may not be indicative of seasonal “high water” conditions. Groundwater fluctuations are dependent upon several factors including hydrologic conditions, type of site development, irrigation demands on or adjacent to the site, fluctuations in water features, seasonal and weather conditions. ***The possibility of groundwater fluctuations should be considered when developing design and construction plans for the project.***

Laboratory Test Results: Samples of the subgrade soils were submitted to the laboratory for classification testing including percent passing the #200 sieve and Atterberg Limits. The subgrade soils along the alignment typically classify as A-7-6 and A-6 lean clay soils under AASHTO guidelines with the exception of a sample from Boring No. 11 that classified as A-2-4 soils. Laboratory test results indicate that the A-6 and A-7-6 subgrade materials are of moderate plasticity with Plasticity Indices (PI) ranging from 13 to 26. Group Indices of the A-6 and A-7-6 soils ranged from 2 to 22, and the A-2-4 soil type had a group index of 0. Water-soluble sulfate testing of select samples indicated concentrations ranging from 400 to 1,200 parts per million (ppm).

As required by the Standards, swell/expansion testing was conducted on select relatively undisturbed subgrade sample(s). The A-6 and A-7-6 samples tested exhibited swell potential generally ranging from +0.3 to +7.0 percent when inundated under a surcharge load of 200 psf. The swell potential of the underlying claystone bedrock is considered moderate to high.

A sample of the poorest quality A-7-6 soils with the highest group index was submitted for R-value testing in accordance with the Standards, results of which indicated an R-value of “less than 5”. ***These clayey subgrade soils are considered to provide poor support for pavements.***

RECOMMENDATIONS FOR DESIGN AND CONSTRUCTION

Geotechnical Considerations: In our opinion, the site appears suitable for the proposed roadway reconstruction/rehabilitation as long as the recommendations included herein are incorporated into the design and construction aspects of the project. The primary geotechnical concerns at the site include the presence of weak clay soils, clay soils and claystone bedrock with high swell potential, variable existing asphalt thicknesses and the proper site preparation for the proposed construction.

Pavement Design and Construction: Design of pavements for the public roadways has been performed in general accordance with the City of Thornton ***Standards and Specifications for the Design and Construction of Public and Private Improvements*** (Standards). These Standards are based in part on methods outlined in the 1993 *Guide for Design of Pavement Structures* by the American Association of State Highway and Transportation Officials (AASHTO) and the 2017 *Pavement Design Manual* by the Colorado Department of Transportation (CDOT).

- **Expansive Subgrade Mitigation:** As discussed, approximately 3-½ to 10 feet of existing fill was encountered in our borings for this current study. This fill was likely placed during development of the existing roadway and utilities and appears similar to the native soil types encountered along the alignment. The clay subgrade soils (both fill and native soils) exhibited low to high expansive potential in their current condition and the claystone bedrock encountered at the site exhibited moderate expansive potential when subjected to wetting in our laboratory. ***In our opinion, there is not a reasonable method to eliminate this risk, but we have provided recommendations that we believe will limit distress to the magnitudes normally acceptable in the region.***

  In general terms, the clay samples obtained between York Street and Madison Street exhibited higher expansive potential. Because of the limited sampling and testing east of Madison Street, we believe it is prudent to expect similar subgrade soils are present there as well. Even low expansive materials may heave upon additional wetting, potentially resulting in pavement distress and other movement causing common cosmetic distress such as edge cracking, uneven curb and gutter, etc.

  In order to reduce the potential for movement and distress of the proposed improvements beneath all newly constructed travel lanes and infrastructure, we recommend that subgrade preparation along the proposed alignments should include subexcavation, moisture-conditioning, and recompaction of the existing soils to a minimum depth of 3 feet below pavement subgrade elevation, as per the Standards (CDOT Pavement Manual, Table 2.5).

  Based on the conditions encountered and our experience in the region, some soft and yielding subgrade soils may be encountered at the base of the subexcavation. These areas should be observed by the geotechnical engineer in order to provide specific recommendations for remediation. In general terms, it should be feasible to stabilize these soft soils by compacting thin lifts of crushed aggregate or recycled concrete into the resulting subgrade. Use of 3 to 4-inch crushed concrete is generally more successful in achieving stability within a few lifts.

  Where existing utilities prevent completing the subexcavation to the recommended extents, we recommend the contractor complete subexcavation to within a safe distance of such facilities. The remaining materials over and around the existing utility should be evaluated by the geotechnical engineer in order to confirm or modify our recommendations as needed.

- **Subgrade Soli Support:** The soils classify as A-7-6 and A-6 lean clay soils under AASHTO guidelines with the exception of one A-2-4 sample (Boring No. 11). ***The clayey subgrade soils are considered to provide poor support for pavements and will require mitigation in accordance with CDOT guidelines as discussed above.***

At current moisture contents, these fill soils exhibit predominantly moderate to high expansive potential and the underlying shallow claystone bedrock exhibits low to moderate expansive potential. Even low expansive materials may heave upon additional wetting, potentially resulting in pavement distress and other movement causing common cosmetic distress such as edge cracking, uneven curb and gutter, etc. We believe that some heave-related distress should be anticipated during the design life of the pavement even with subgrade mitigation.

As outlined in the Standards, the pavement thickness design is based on the poorest quality subgrade soils present along each roadway. As discussed, AASHTO A-7-6 soils are present along the proposed alignments. Therefore, pavement thickness calculations were based on R-value testing of these poor-quality materials. Results of R-value testing indicated a value of less than 5. A correlated Resilient Modulus (M_R) of 3,025 psi for the A-7-6 subgrade soils was used for design per the Standards.

- **Design Traffic Values:** Design traffic values, used to determine pavement thickness are defined as 18-kip equivalent daily load applications ($EDLA_{20}$) and 18-kip equivalent single axle loads ($ESAL_{20}$) based on a 20-year design, per the Standards. The pavement rehabilitation alternatives were developed to provide a 20- year design life. We understand that proposed public roadway within the alignment are to be re-classified Minor Arterial Streets with four (4) lanes of travel, per the City of Thornton Transportation Plan 2009. Using the values from Table 500-4 from the Standards an $EDLA_{20}$/$ESAL_{20}$ were determined to be as follows:

Minor Arterial $EDLA_{20}$ = 465
Minor Arterial $ESAL_{20}$ = 3,394,500

- **Recommended Pavement Sections:** Using the correlated design M_R value and the $EDLA_{20}$/$ESAL_{20}$ value outlined above, the required structural number (SN) for the proposed Public Streets was determined using appropriate methods and the appropriate design Nomographs provided by CDOT and AASHTO. Other factors utilized for design included a drainage coefficient of 1.0, a reliability of 90 percent, a standard deviation of 0.44, and a serviceability loss of 2.5. Using these values, a minimum Structural Number (Design SN) was calculated using the AASHTO equations.

We understand that the City of Thornton typically prefers composite asphalt sections for public roadways. As outlined in the Standards, structural coefficients of 0.44 and 0.14 were used for each inch of asphalt concrete (AC) and aggregate base course (ABC), respectively. The thickness calculations are included in Appendix D. The following table summarizes the recommended pavement sections. Recommended pavement sections meet the minimum pavement sections as put forth in the Standards.

<table>
<tr><th rowspan="2">Traffic Area</th><th rowspan="2">Alt.</th><th colspan="4">Pavement Section Thickness (Inches)</th></tr>
<tr><th>Asphalt Concrete Surface</th><th>Aggregate Base Course</th><th>Portland Cement Concrete</th><th>Total</th></tr>
<tr><td rowspan="3">Minor Arterial
East 144th Avenue
ESAL$_{20}$=3,394,500</td><td>A</td><td>7-½</td><td>15-½</td><td>--</td><td>23</td></tr>
<tr><td>B</td><td>12-½</td><td>--</td><td>--</td><td>12-½</td></tr>
<tr><td>C</td><td>--</td><td>--</td><td>9-½</td><td>9-½</td></tr>
</table>

*Base course should extend to back-of-curb or back-of-walk for attached walks. See below for draining the base course layer at inlet locations.

** In our opinion, full-depth asphalt sections may be structurally equivalent, but may result in premature cracking of the sections. Typically, these cracks are longitudinal in nature and do not constitute structural failure of the pavement, but should be sealed right away.

- **Pavement Rehabilitation:** It is our understanding that the City wishes to maintain the existing road crown and mill and overlay the existing pavements, where possible. Asphalt thicknesses at the boring locations are included in the table below and presented on the Boring Logs in Appendix A.

<table>
<tr><th>Boring Location</th><th>Asphalt Concrete Thickness (in.)</th><th>Average Thickness for Design</th></tr>
<tr><td>1</td><td>12</td><td rowspan="3">York Street to Madison Street: 13 inches</td></tr>
<tr><td>4</td><td>14</td></tr>
<tr><td>6</td><td>13-½</td></tr>
<tr><td>9</td><td>6</td><td rowspan="2">Madison Street to Colorado Blvd.: 5.5 inches</td></tr>
<tr><td>11</td><td>5</td></tr>
</table>

In our opinion, milling and overlaying of the existing pavements in conjunction with road widening is feasible along the portion of the alignment from York Street to Madison Street, provided the recommendations provided in this report are followed. ***However, asphalt concrete conditions and thicknesses east of Madison Street may not be sufficient for proper milling operations. An average mill depth of 2 inches is recommended.***

Although not included within the currently authorized scope of work, determination of the existing pavement structure strength could be determined by competing falling weight deflection (FWD) analysis. Accordingly, design capacity and associated life expectancy of the portion of the roadway to be rehabilitated could be determined. In addition, various alternatives for mill/overlay thickness could be evaluated and presented for consideration by the City. If the City desires to have FWD testing and analysis completed please contact our office.

In order to calculate overlay thickness, we utilized a structural coefficient of 0.30 for each inch of existing asphalt pavement (after a mill of 2 inches). Assuming that crack sealing and patching is performed as discussed below, the following overlay thickness are recommended:

Traffic Area	Pavement Overlay Thickness (Inches)			
	Existing Average Asphalt	Mill Depth	New Asphalt Overlay	Total New Thickness
East 144th Avenue York St. to Madison St.	13	2	5	16
East 144th Avenue Madison St. to Colorado Blvd.	5.5	2	10	15.5

Based upon existing pavement structure thickness and existing distress, crack filling, limited full depth patching in certain structural distress areas will likely be required prior to overlay placement. In order to provide a more uniform overlay thickness, patching could be performed in limited areas, prior to new overlay pavement. ***Full depth patching is recommended for the alignment east of Madison Street and medium to high severity longitudinal, transverse, alligator and block cracking, and where medium to high severity patches and utility cut patches are present***. ***Full-depth asphalt patches should meet the minimum pavement thickness excluding the pavement of the overlay***.

Low severity longitudinal and transverse cracking, and existing patches should be cleaned with pressurized air and filled with a rubberized asphalt crack filler. All cracks greater than ¼ inch in width but less than ½ inch should be routed to a minimum depth of ½ inch. Cracks which are ½ inch or larger should be cleaned with high velocity compressed air to a depth of at least two times the width of the crack. Once cleaned, the cracks should be filled with the asphalt-rubber mixture, and placed at temperatures where consistency is that of a semi-fluid material. After patching and crack sealing is complete, application of a tack coat should be placed upon the asphalt pavement areas. A full pavement condition assessment is outside the scope of this current study.

A simple overlay will eventually result in a similar crack pattern as the old cracks reflect through to the surface and/or longitudinal cracks at the joint between existing and new pavements. Prior to overlaying, the City should give consideration to installing a crack reducing interlayer product at the joints. We would be happy to give detailed design recommendations, if desired.

- **Subsurface Drainage:** In our experience, surface water (from precipitation and irrigation) tends to collect behind curbs, attached sidewalks, etc. and this water infiltrates the subsurface over time. This water, if allowed to pond adjacent to roadways for extended periods, can cause:

    - minor swell of the clayey pavement subgrade soils, which has been known to cause cracking approximately 1 to 3 feet from the edge of curb and gutter (commonly known as edge cracking) and
    - softening of the subgrade soils, particularly in areas of the roads that are lowest in elevation. These soft subgrade soils commonly cause localized alligator cracking and structural failure.

  In our experience, the use of composite sections (HMA over ABC) often reduce the potential for these subgrade issues, however, in those areas that are lowest in elevation (particularly where storm sewer inlets are located) this subsurface water may collect and pool within the base course.

  To reduce the potential for this water to build up and cause structural failure, we recommend that all storm inlets be perforated just below the base of the aggregate base course layer. These perforations should be 2-inch diameter holes, spaced two feet on-center on the front face and uphill sides of each inlet. Holes should be drilled at an angle similar to the standard Type-R inlet details. The holes should be protected from intrusion of fines by a filter fabric or gravel-filled “rock sock” prior to backfilling the inlet and placement of the base course layer.

- **Subgrade Preparation:** Over-excavated fill, scarified subgrade, and pavement subgrade soils should be placed and compacted in horizontal lifts, using equipment and procedures that will produce recommended moisture contents and densities throughout the lift, as described in the Earthwork section below.

  All pavement areas should be rough graded and then thoroughly proof rolled with a loaded tandem axle dump truck, water truck, or other heavy equipment approved by the observing engineer within 24 hours prior to paving. Particular attention should be paid to high traffic areas that were rutted and disturbed earlier and to areas where backfilled trenches are located. Areas where unsuitable conditions are located should be repaired by removing and replacing the materials with properly compacted engineered fills or additional base course. At a minimum, all subgrade soils should be scarified, moisture conditioned, and recompacted just prior to paving.

- **Pavement Materials:** Materials and construction of pavements for the project should be in accordance with the requirements and specifications of the City of Thornton. Materials should be submitted to the City of Thornton for approval prior to use on the site.

Aggregate base course should consist of a blend of sand and gravel that meets strict specifications for quality and gradation with a minimum R-value of 78. Use of materials meeting CDOT Class aggregate base specifications is required. Aggregate base course should be placed in lifts not exceeding 6 inches and compacted to a minimum of 95 percent modified Proctor density (AASHTO T180/ASTM D1557). Moisture should be uniformly added as necessary during compaction to obtain moisture content within 1 percent of optimum moisture content.

Asphalt concrete should be composed of a mixture of aggregate, filler and additives (if required) and approved bituminous material. Asphalt concrete should be obtained from City of Thornton approved mix designs stating the Hveem properties, optimum asphalt content, job mix formula (JMF), and recommended mixing and placing temperatures. Aggregate used in asphalt concrete should meet a particular gradation. Asphalt concrete should consist of Grading SX for the top lift and Grading S or SG for the lower lifts, as outlined in the Standards. Mix designs should be submitted prior to construction to verify their adequacy. The asphalt mix should be designed for 100 gyratory design revolutions and the binder grade should conform with PG 64-22, per CDOT specifications. Asphalt material should be placed in maximum 3-inch lifts and compacted within a range of 92 to 96 percent of the theoretical maximum (Rice) density (AASHTO T209).

Portland cement concrete (PCC) pavements, if used, should be obtained from an approved mix design conforming to CDOT Class P specifications. Concrete should be deposited by truck mixers or agitators and placed a maximum of 90 minutes from the time the water is added to the mix. Longitudinal and transverse joints should be provided as needed in concrete pavements for expansion/contraction and isolation. The location and extent of joints should be based upon the final pavement geometry. Sawed joints should be cut within 24 hours of concrete placement and should be a minimum depth of 25 percent of slab thickness plus 1/4 inch. All joints should be sealed to prevent entry of foreign material and doweled where necessary for load transfer. Where dowels cannot be used at joints accessible to wheel loads, pavement thickness should be increased by 25 percent at the joints and tapered to regular thickness in 5 feet.

Earthwork:

- **General Considerations:** The following presents recommendations for site preparation, excavation, subgrade preparation and placement of engineered fills on the project.

  All earthwork on the project should be observed and evaluated by CGG. The evaluation of earthwork should include observation and testing of engineered fills, subgrade preparation, foundation bearing soils and other geotechnical conditions exposed during the construction of the project.

- **Demolition and Site Preparation:** Strip and remove vegetation, existing foundations and pavements, any unsuitable existing fills, or any other deleterious materials from the site. Stripped materials consisting of vegetation and organic materials should be wasted from the site or used to revegetate landscaped areas or exposed slopes after completion of grading operations. Asphalt or concrete materials removed as part of site reclamation may be re-used on the site. We recommend that these materials be crushed to a maximum size of 4 to 6 inches and used to stabilize any soft soils that may be encountered.

  Based on the conditions encountered and our experience in the region, some soft and yielding subgrade soils may be encountered at the base of the subexcavation. These areas should be observed by the geotechnical engineer in order to provide specific recommendations for remediation. In general terms, it should be feasible to stabilize these soft soils by compacting thin lifts of crushed aggregate or recycled concrete into the resulting subgrade. Use of 3 to 4-inch crushed concrete is generally more successful in achieving stability within a few lifts.

  Where existing utilities prevent completing the subexcavation to the recommended extents, we recommend the contractor complete subexcavation to within a safe distance of such facilities. The remaining materials over and around the existing utility should be evaluated by the geotechnical engineer in order to confirm or modify our recommendations as needed.

- **Fill Materials:** On-site soils may be used for general site grading. Imported fill materials, if needed, should be similar to the on-site soils, and in general, should conform to the following requirements:

Gradation	**Percent finer by weight (ASTM C136)**
2"	100
No. 4 Sieve	30-100
No. 40 Sieve	10-60
No. 200 Sieve	65 maximum
Liquid Limit	40 maximum
Plasticity Index	20 maximum

- **Fill Placement and Compaction:** Engineered fill should be placed and compacted in horizontal lifts, using equipment and procedures that will produce recommended moisture contents and densities throughout the lift. Engineered fills should be placed and compacted according to the recommendations in the following table:

Criteria	Recommended values
Lift thickness	8 inches or less in loose thickness, depending on equipment
Moisture content range	Pavement Subgrade (onsite clays): Optimum to +2% percent above optimum Non-plastic sands/ABC: -2% percent below to +2% percent above optimum
Compaction	Pavement Subgrade (onsite clays): 95 percent minimum standard Proctor dry density (AASHTO T99) Non-plastic sands/ABC: 95 percent minimum modified Proctor dry density (AASHTO T180)

Observation and compaction testing should be performed by a qualified Geotechnical Engineer during subgrade preparation, backfill and other earthwork operations. Should the results of the in-place density tests indicate the specified moisture or compaction limits have not been met, the area represented by the test should be reworked and retested as required until the specified moisture and compaction requirements are achieved.

- **Excavations:** Caving soils and groundwater are present at the site. The individual contractor(s) should be made responsible for designing and constructing stable, temporary excavations, as required, in order to maintain stability of both the excavation sides and bottom. All excavations should be sloped or shored in the interest of safety following local and federal regulations, including current OSHA excavation and trench safety standards.

  As a safety measure, it is recommended that all vehicles and soil piles be kept to a minimum lateral distance from the crest of the slope equal to no less than the slope height. The exposed slope face should be protected against the elements.

Additional Recommendations:

- **Concrete Corrosion Protection:** Water soluble sulfate testing indicates sulfate concentration ranging from about 400 to 1,200 parts per million (ppm). ***ACI rates the measured concentrations as being a moderate risk of concrete sulfate attack. Therefore, Type II Portland cement, or equivalent, should be used for concrete on and below grade.*** Project concrete should be designed for moderate risk of attack in accordance with the provisions of the *ACI Design Manual*, Section 318, Chapter 4.
- **Drainage and Landscaping:** All grades should be adjusted to provide positive drainage away from the roadways during construction. Ponding of water on the subgrade should be avoided where possible. After roadway construction is completed, it is imperative that backfill placed against the back of the curb be moisture conditioned and well compacted. Grades should be established that direct surface water away from or onto pavements and these grades should be maintained throughout the life of the development. Water permitted to pond near or adjacent to the perimeter of the roadway (either during or post-construction) can result in excessive distress.

Landscaping irrigation adjacent to the roadways should be limited to only the amount needed to establish vegetation and sustain growth. Irrigation systems should be reviewed frequently to fix leaks and minimize over-spray.

GENERAL COMMENTS AND LIMITATIONS

CGG should be retained to review the final design plans and specifications so comments can be made regarding interpretation and implementation of our geotechnical recommendations in the design and specifications. CGG should also be retained to provide testing and observation during the over-excavation, subgrade preparation, and other construction phases of the project.

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

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

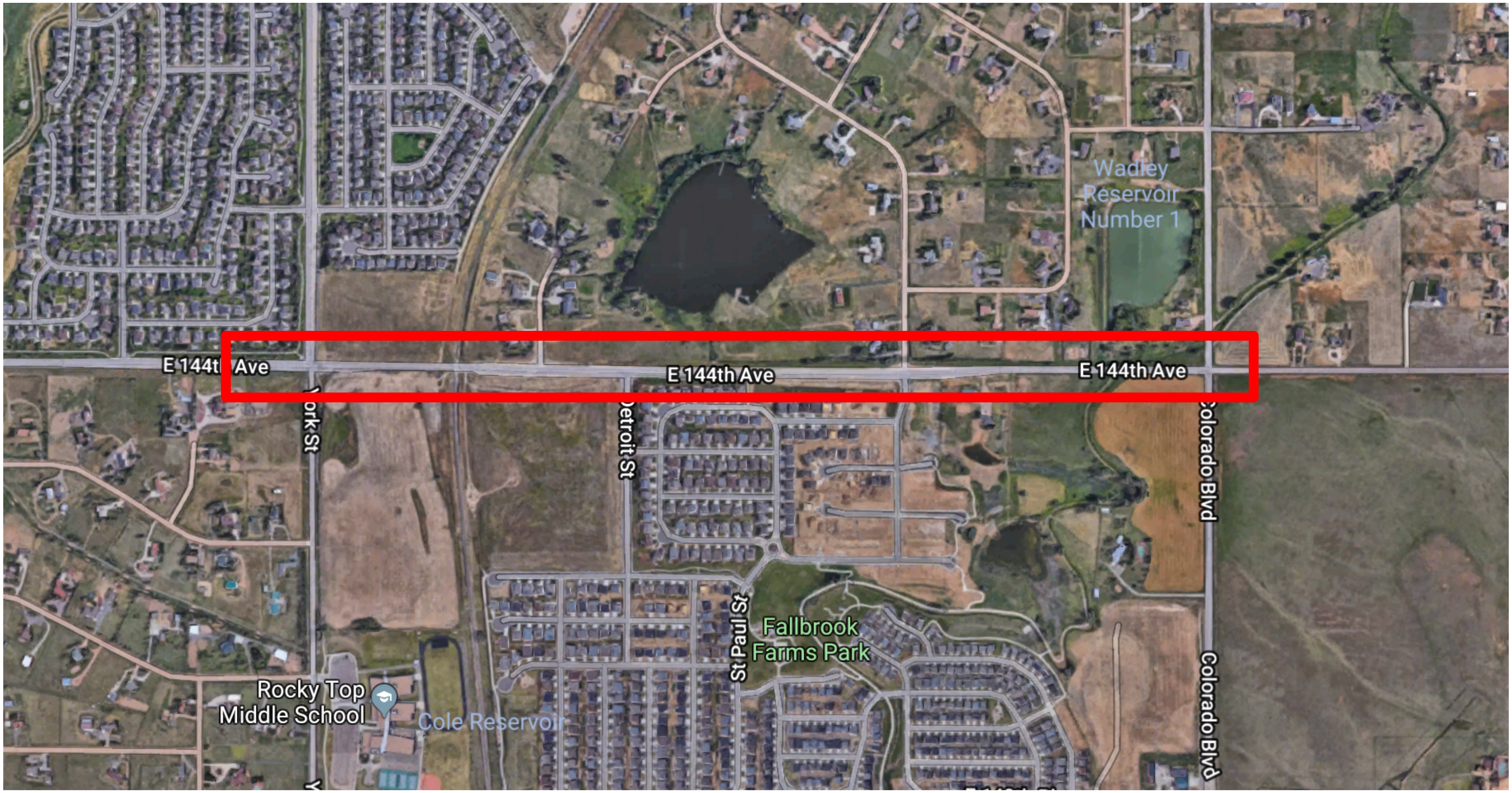
This report has been prepared for the exclusive use of our client for specific application to the project discussed and has been prepared in accordance with generally accepted geotechnical engineering practices. No warranties, express or implied, are intended or made. Site safety, excavation support,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

APPENDIX A

VICINITY MAP

BORING LOCATION DIAGRAM

LOGS OF BORINGS



ROADWAY SECTION TO BE IMPROVED

FIGURE 1 – VICINITY MAP
PAVEMENT THICKNESS DESIGN
144th AVENUE WIDENING
THRONTON, COLORADO
CGG PROJECT NO. 18.22.099

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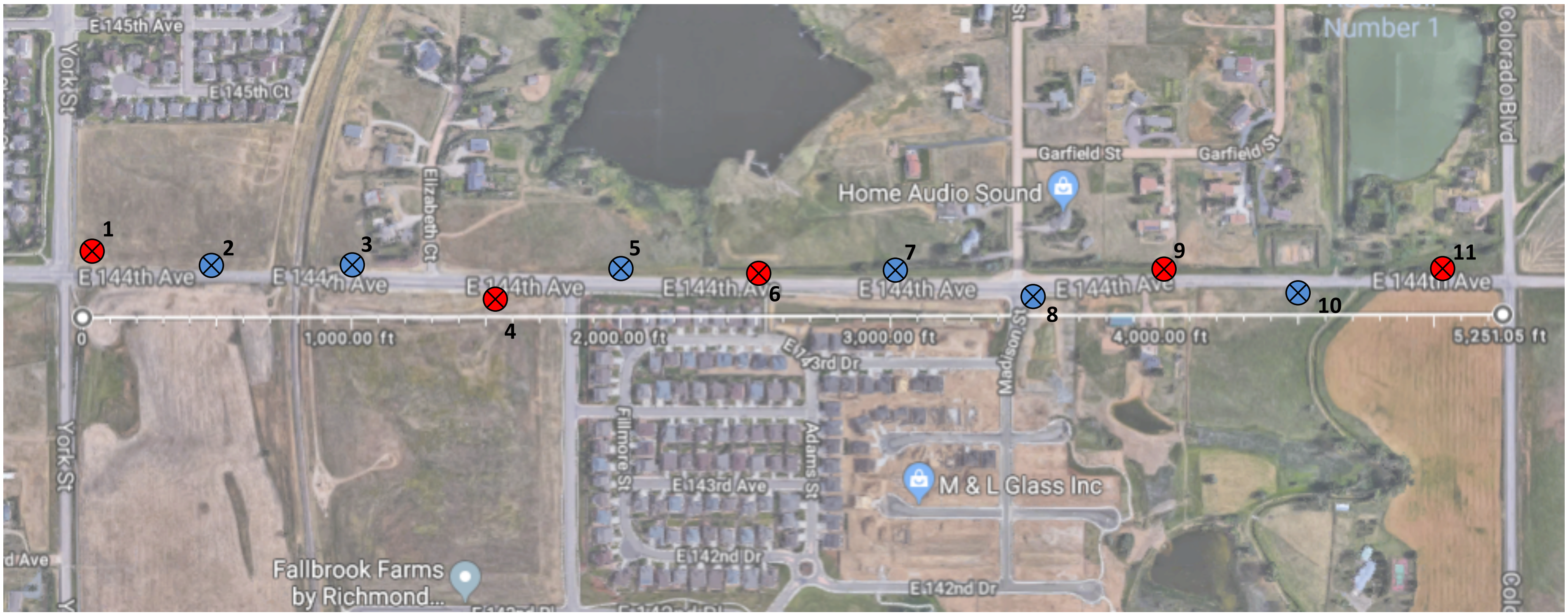

PAVEMENT DESIGN INVESTIGATION

1 APPROXIMATE BORING LOCATIONS

1 DENOTES BORING W/ ASPHALT CORE SAMPLE

FIGURE 2 - BORING LOCATION DIAGRAM
PAVEMENT THICKNESS DESIGN
144th AVENUE WIDENING
THORNTON, COLORADO
CGG PROJECT NO. 18.22.099

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Westminster, CO 80234
Telephone: 303.996.2999

BORING NUMBER 1

CLIENT Drexel Barrell
PROJECT NAME East 144th Avenue Widening Project
PROJECT NUMBER 18.22.099
PROJECT LOCATION East 144th Avenue between York St. and Colorado Blvd.
DATE STARTED 5/11/18 **COMPLETED** 5/11/18
GROUND SURFACE ELEV. **PROPOSED ELEV.** Not Provided
DRILLING CONTRACTOR Vine Laboratories
SURFACE CONDITIONS Approximately 12 inches of asphalt pavement
DRILLING METHOD CME-55 / Solid Stem Auger
GROUND WATER LEVELS:
HAMMER TYPE Automatic
DURING DRILLING None
LOGGED BY KF **CHECKED BY** AG
AFTER DRILLING Backfilled - 5/11/18

GRAPHIC LOG	MATERIAL DESCRIPTION	DEPTH (ft)	USCS SYMBOL	SAMPLE TYPE	RECOVERY %	PENETRATION blows/in	MOISTURE CONTENT (%)	DRY UNIT WT. (pcf)	SWELL-CONSOL /SURCHARGE LOAD, %psf
	ASPHALT CONCRETE, approximately 12"	0.0							
1	**FILL - LEAN CLAY with SAND**, brown, calcareous, moist, stiff								
		2.5	CL	CB	100	15 / 12	17.5	110	+0.9/200
			CL	CB	100	14 / 12	19.5	108	+4.1/200
5.5	**SANDY LEAN CLAY**, brown, moist	5.0							
8	**CLAYSTONE BEDROCK**, grey, iron-stained, moist, weathered	7.5							
10		10.0	-	CB	100	21 / 12	20.7	108	

Approximate bottom of borehole at 10.0 feet.

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BORING NUMBER 2

CLIENT Drexel Barrell

PROJECT NAME East 144th Avenue Widening Project

PROJECT NUMBER 18.22.099

PROJECT LOCATION East 144th Avenue between York St. and Colorado Blvd.

DATE STARTED 5/11/18 **COMPLETED** 5/11/18

GROUND SURFACE ELEV. **PROPOSED ELEV.** Not Provided

DRILLING CONTRACTOR Vine Laboratories

SURFACE CONDITIONS Low to moderate growth of grass and weeds

DRILLING METHOD CME-55 / Solid Stem Auger

GROUND WATER LEVELS:

HAMMER TYPE Automatic

DURING DRILLING None

LOGGED BY KF **CHECKED BY** AG

AFTER DRILLING Backfilled - 5/11/18

GRAPHIC LOG	MATERIAL DESCRIPTION	DEPTH (ft)	USCS SYMBOL	SAMPLE TYPE	RECOVERY %	PENETRATION blows/in	MOISTURE CONTENT (%)	DRY UNIT WT. (pcf)	SWELL-CONSOL /SURCHARGE LOAD, %psf
	SANDY LEAN CLAY, brown, calcareous, dry to moist, stiff to very stiff	0.0							
		2.5	CL	CB	100	32 / 12	6.7	122	+7.0/200
5		5.0	CL	CB	100	14 / 12	15.8	111	

Approximate bottom of borehole at 5.0 feet.

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BORING NUMBER 3

CLIENT Drexel Barrell
PROJECT NAME East 144th Avenue Widening Project
PROJECT NUMBER 18.22.099
PROJECT LOCATION East 144th Avenue between York St. and Colorado Blvd.
DATE STARTED 5/11/18 **COMPLETED** 5/11/18
GROUND SURFACE ELEV. **PROPOSED ELEV.** Not Provided
DRILLING CONTRACTOR Vine Laboratories
SURFACE CONDITIONS Low to moderate growth of grass and weeds
DRILLING METHOD CME-55 / Solid Stem Auger
GROUND WATER LEVELS:
HAMMER TYPE Automatic
DURING DRILLING None
LOGGED BY KF **CHECKED BY** AG
AFTER DRILLING Backfilled - 5/11/18

GRAPHIC LOG	MATERIAL DESCRIPTION	DEPTH (ft)	USCS SYMBOL	SAMPLE TYPE	RECOVERY %	PENETRATION blows/in	MOISTURE CONTENT (%)	DRY UNIT WT. (pcf)	SWELL-CONSOL /SURCHARGE LOAD, %psf
	CLAYEY SANDSTONE BEDROCK, light brown to brown, iron-stained, moist, firm	0.0							
		2.5	-	CB	100	34 / 12	27.9	95	
		5.0	-	CB	100	32 / 12	28.7	95	
		7.5							
8	**CLAYSTONE BEDROCK**, grey, iron-stained, moist, medium hard								
10		10.0	-	CB	100	37 / 12	20.3	105	+6.8/200

Approximate bottom of borehole at 10.0 feet.

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Westminster, CO 80234
Telephone: 303.996.2999

BORING NUMBER 4

CLIENT Drexel Barrell
PROJECT NAME East 144th Avenue Widening Project
PROJECT NUMBER 18.22.099
PROJECT LOCATION East 144th Avenue between York St. and Colorado Blvd.
DATE STARTED 5/11/18 **COMPLETED** 5/11/18
GROUND SURFACE ELEV. **PROPOSED ELEV.** Not Provided
DRILLING CONTRACTOR Vine Laboratories
SURFACE CONDITIONS Approximately 14 inches of asphalt pavement
DRILLING METHOD CME-55 / Solid Stem Auger
GROUND WATER LEVELS:
HAMMER TYPE Automatic
DURING DRILLING None
LOGGED BY KF **CHECKED BY** AG
AFTER DRILLING Backfilled - 5/11/18

GRAPHIC LOG	MATERIAL DESCRIPTION	DEPTH (ft)	USCS SYMBOL	SAMPLE TYPE	RECOVERY %	PENETRATION blows/in	MOISTURE CONTENT (%)	DRY UNIT WT. (pcf)	SWELL-CONSOL /SURCHARGE LOAD, %psf
		0.0							
1.2	**ASPHALT CONCRETE**, approximately 14"								
	FILL - CLAYEY SAND to SANDY LEAN CLAY, brown to dark brown, iron-stained, calcareous, moist, soft to medium stiff	2.5	SC	CB	100	8 / 12	20.6	100	
5		5.0	SC/CL	CB	100	4 / 12	21.6	100	+1.3/200

Approximate bottom of borehole at 5.0 feet.

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BORING NUMBER 5

CLIENT Drexel Barrell
PROJECT NAME East 144th Avenue Widening Project
PROJECT NUMBER 18.22.099
PROJECT LOCATION East 144th Avenue between York St. and Colorado Blvd.
DATE STARTED 5/11/18 **COMPLETED** 5/11/18
GROUND SURFACE ELEV. **PROPOSED ELEV.** Not Provided
DRILLING CONTRACTOR Vine Laboratories
SURFACE CONDITIONS Low to moderate growth of grass and weeds
DRILLING METHOD CME-55 / Solid Stem Auger
GROUND WATER LEVELS:
HAMMER TYPE Automatic
▽ **DURING DRILLING** None
LOGGED BY KF **CHECKED BY** AG
▼ **AFTER DRILLING** Backfilled - 5/11/18

GRAPHIC LOG	MATERIAL DESCRIPTION	DEPTH (ft)	USCS SYMBOL	SAMPLE TYPE	RECOVERY %	PENETRATION blows/in	MOISTURE CONTENT (%)	DRY UNIT WT. (pcf)	SWELL-CONSOL /SURCHARGE LOAD, %psf
	FILL - CLAYEY SAND, with some gravel, fine-grained, reddish-brown, grey, iron-stained, moist, loose	0.0							
		2.5	SC	CB	100	7 / 12	15.3		
3.5	**FILL - LEAN CLAY with SAND**, brown, moist, soft to stiff								
		5.0	CL	CB	100	5 / 12	21.6	102	+5.4/200
		7.5							
10		10.0	CL	CB	100	13 / 12	21.4	99	

Approximate bottom of borehole at 10.0 feet.

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BORING NUMBER 6

CLIENT Drexel Barrell
PROJECT NAME East 144th Avenue Widening Project
PROJECT NUMBER 18.22.099
PROJECT LOCATION East 144th Avenue between York St. and Colorado Blvd.
DATE STARTED 5/11/18 **COMPLETED** 5/11/18
GROUND SURFACE ELEV. **PROPOSED ELEV.** Not Provided
DRILLING CONTRACTOR Vine Laboratories
SURFACE CONDITIONS Approximtely 13.5 inches of asphalt pavement
DRILLING METHOD CME-55 / Solid Stem Auger
GROUND WATER LEVELS:
HAMMER TYPE Automatic
DURING DRILLING None
LOGGED BY KF **CHECKED BY** AG
AFTER DRILLING Backfilled - 5/11/18

GRAPHIC LOG	MATERIAL DESCRIPTION	DEPTH (ft)	USCS SYMBOL	SAMPLE TYPE	RECOVERY %	PENETRATION blows/in	MOISTURE CONTENT (%)	DRY UNIT WT. (pcf)	SWELL-CONSOL /SURCHARGE LOAD, %psf
	ASPHALT CONCRETE, approximately 13.5"	0.0							
1.1	**FILL - SANDY LEAN CLAY**, brown, calcareous, iron-stained, moist, stiff								
		2.5	CL	CB	100	13 / 12	18.5	107	
5		5.0	CL	CB	100	14 / 12	19.5	105	+4.2/200

Approximate bottom of borehole at 5.0 feet.

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Westminster, CO 80234
Telephone: 303.996.2999

BORING NUMBER 7

CLIENT Drexel Barrell
PROJECT NAME East 144th Avenue Widening Project
PROJECT NUMBER 18.22.099
PROJECT LOCATION East 144th Avenue between York St. and Colorado Blvd.
DATE STARTED 5/11/18 **COMPLETED** 5/11/18
GROUND SURFACE ELEV. **PROPOSED ELEV.** Not Provided
DRILLING CONTRACTOR Vine Laboratories
SURFACE CONDITIONS Low to moderate growth of grass and weeds
DRILLING METHOD CME-55 / Solid Stem Auger
GROUND WATER LEVELS:
HAMMER TYPE Automatic
DURING DRILLING None
LOGGED BY KF **CHECKED BY** AG
AFTER DRILLING Backfilled - 5/11/18

GRAPHIC LOG	MATERIAL DESCRIPTION	DEPTH (ft)	USCS SYMBOL	SAMPLE TYPE	RECOVERY %	PENETRATION blows/in	MOISTURE CONTENT (%)	DRY UNIT WT. (pcf)	SWELL-CONSOL /SURCHARGE LOAD, %psf
	FILL - SANDY LEAN CLAY, with Claystone fragments, brown, grey, iron-stained, moist, medium stiff	0.0							
		2.5	CL	CB	100	10 / 12	15.1	108	+0.3/200
		5.0	CL	CB	100	9 / 12	20.1	101	
6	**SANDY LEAN CLAY**, organic-rich, brown to dark brown, grey, iron-stained, moist, soft								
		7.5							
10		10.0	CL	CB	100	4 / 12	21.4	100	

Approximate bottom of borehole at 10.0 feet.

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BORING NUMBER 8

CLIENT Drexel Barrell
PROJECT NAME East 144th Avenue Widening Project
PROJECT NUMBER 18.22.099
PROJECT LOCATION East 144th Avenue between York St. and Colorado Blvd.
DATE STARTED 5/11/18 **COMPLETED** 5/11/18
GROUND SURFACE ELEV. **PROPOSED ELEV.** Not Provided
DRILLING CONTRACTOR Vine Laboratories
SURFACE CONDITIONS Low to moderate growth of grass and weeds
DRILLING METHOD CME-55 / Solid Stem Auger
GROUND WATER LEVELS:
HAMMER TYPE Automatic
▽ **DURING DRILLING** None
LOGGED BY KF **CHECKED BY** AG
▼ **AFTER DRILLING** Backfilled - 5/11/18

GRAPHIC LOG	MATERIAL DESCRIPTION	DEPTH (ft)	USCS SYMBOL	SAMPLE TYPE	RECOVERY %	PENETRATION blows/in	MOISTURE CONTENT (%)	DRY UNIT WT. (pcf)	SWELL-CONSOL /SURCHARGE LOAD, %psf
	SANDY LEAN CLAY to CLAYEY SAND, light brown to brown, calcareous, moist, stiff/loose	0.0							
		2.5	CL	CB	100	12 / 12	14.9	112	+1.1/200
5		5.0	CL/SC	CB	100	11 / 12	13.3	113	

Approximate bottom of borehole at 5.0 feet.

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Westminster, CO 80234
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BORING NUMBER 9

CLIENT Drexel Barrell
PROJECT NAME East 144th Avenue Widening Project
PROJECT NUMBER 18.22.099
PROJECT LOCATION East 144th Avenue between York St. and Colorado Blvd.
DATE STARTED 5/11/18 **COMPLETED** 5/11/18
GROUND SURFACE ELEV. ______ **PROPOSED ELEV.** Not Provided
DRILLING CONTRACTOR Vine Laboratories
SURFACE CONDITIONS Approximately 6 inches of asphalt pavement
DRILLING METHOD CME-55 / Solid Stem Auger
GROUND WATER LEVELS:
HAMMER TYPE Automatic
DURING DRILLING None
LOGGED BY KF **CHECKED BY** AG
AFTER DRILLING Backfilled - 5/11/18

GRAPHIC LOG	MATERIAL DESCRIPTION	DEPTH (ft)	USCS SYMBOL	SAMPLE TYPE	RECOVERY %	PENETRATION blows/in	MOISTURE CONTENT (%)	DRY UNIT WT. (pcf)	SWELL-CONSOL /SURCHARGE LOAD, %psf
0.5	**ASPHALT CONCRETE**, approximately 6"	0.0							
	SANDY LEAN CLAY, light brown to brown, grey, iron-stained, calcareous, moist, medium stiff to stiff	2.5	CL	CB	100	10 / 12	18.8	105	+0.5/200
		5.0	CL	CB	100	16 / 12	25.2	97	
8		7.5							
10	**CLAYEY SANDSTONE BEDROCK**, brown, grey, moist, medium hard	10.0	-	CB	100	41 / 12	20.0	107	

Approximate bottom of borehole at 10.0 feet.

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BORING NUMBER 10

CLIENT Drexel Barrell
PROJECT NAME East 144th Avenue Widening Project
PROJECT NUMBER 18.22.099
PROJECT LOCATION East 144th Avenue between York St. and Colorado Blvd.
DATE STARTED 5/11/18 **COMPLETED** 5/11/18
GROUND SURFACE ELEV. **PROPOSED ELEV.** Not Provided
DRILLING CONTRACTOR Vine Laboratories
SURFACE CONDITIONS Low to moderate growth of grass and weeds
DRILLING METHOD CME-55 / Solid Stem Auger
GROUND WATER LEVELS:
HAMMER TYPE Automatic
DURING DRILLING None
LOGGED BY KF **CHECKED BY** AG
AFTER DRILLING Backfilled - 5/11/18

GRAPHIC LOG	MATERIAL DESCRIPTION	DEPTH (ft)	USCS SYMBOL	SAMPLE TYPE	RECOVERY %	PENETRATION blows/in	MOISTURE CONTENT (%)	DRY UNIT WT. (pcf)	SWELL-CONSOL /SURCHARGE LOAD, %psf
	SANDY LEAN CLAY, brown, grey, iron-stained, calcareous, moist, medium stiff	0.0							
		2.5	CL	CB	100	9 / 12			
5		5.0	CL	CB	100	9 / 12	24.6	97	

Approximate bottom of borehole at 5.0 feet.

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BORING NUMBER 11

CLIENT Drexel Barrell
PROJECT NAME East 144th Avenue Widening Project
PROJECT NUMBER 18.22.099
PROJECT LOCATION East 144th Avenue between York St. and Colorado Blvd.
DATE STARTED 5/11/18 **COMPLETED** 5/11/18
GROUND SURFACE ELEV. **PROPOSED ELEV.** Not Provided
DRILLING CONTRACTOR Vine Laboratories
SURFACE CONDITIONS Approximately 5 inches of asphalt pavement
DRILLING METHOD CME-55 / Solid Stem Auger
GROUND WATER LEVELS:
HAMMER TYPE Automatic
DURING DRILLING None
LOGGED BY KF **CHECKED BY** AG
AFTER DRILLING Backfilled - 5/11/18

GRAPHIC LOG	MATERIAL DESCRIPTION	DEPTH (ft)	USCS SYMBOL	SAMPLE TYPE	RECOVERY %	PENETRATION blows/in	MOISTURE CONTENT (%)	DRY UNIT WT. (pcf)	SWELL-CONSOL /SURCHARGE LOAD, %psf
0.5	**ASPHALT CONCRETE**, approximately 5"	0.0							
8	**CLAYEY SAND to SILTY SAND**, light brown to brown, grey, iron-stained, moist, medium dense	2.5	SM	CB	100	16 / 12	8.5	120	
		5.0	SC/SM	CB	100	17 / 12	15.8	113	
10	**CLAYSTONE BEDROCK**, grey, olive-brown, iron-stained, moist, weathered	7.5							
		10.0	-	CB	100	15 / 12	21.7	102	+3.6/200

Approximate bottom of borehole at 10.0 feet.

APPENDIX B

LABORATORY TEST RESULTS

SOIL SUBGRADE AND ESAL DIAGRAM

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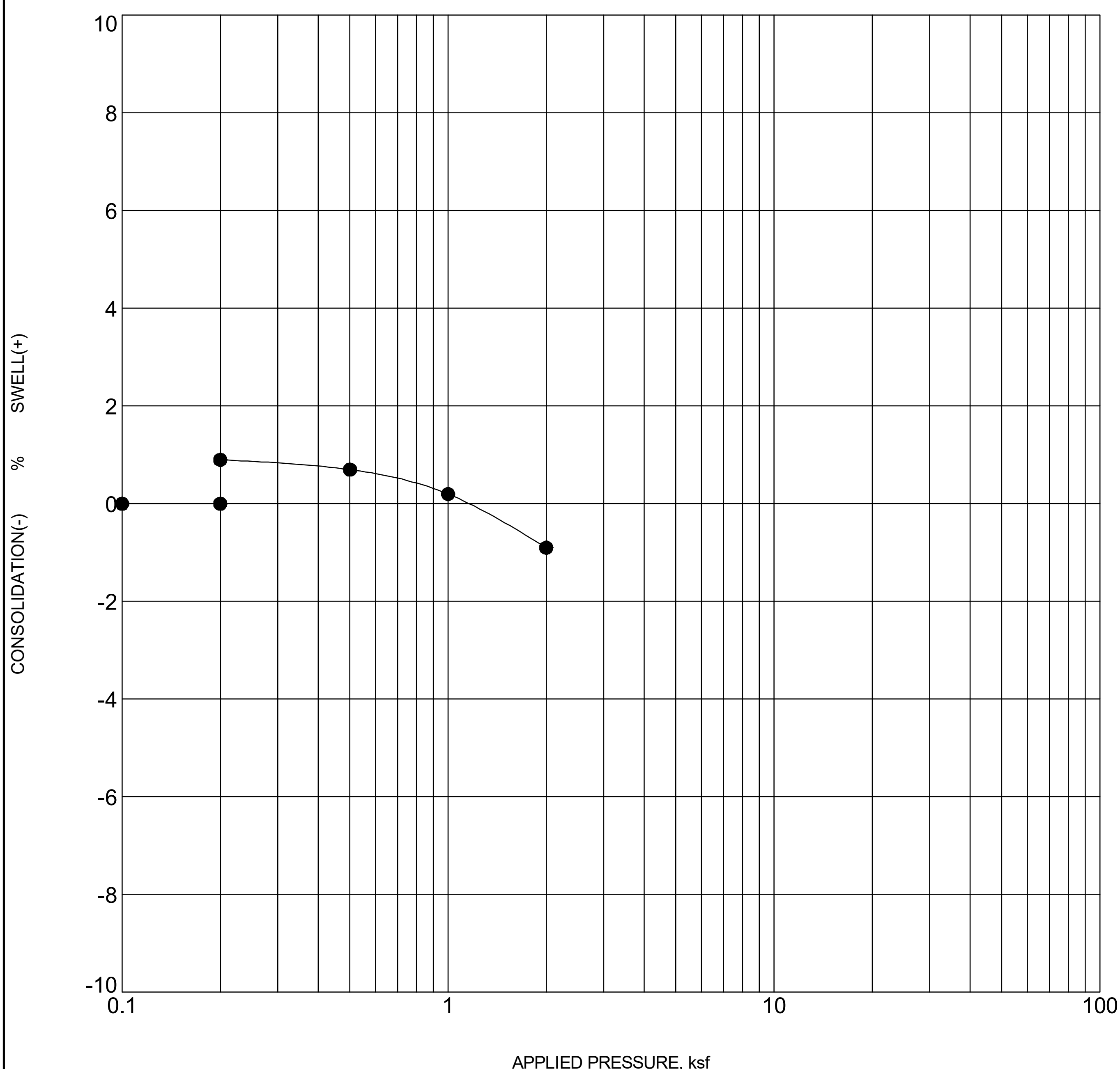
SWELL/CONSOLIDATION TEST

CLIENT Drexel Barrell

PROJECT NAME East 144th Avenue Widening Project

PROJECT NUMBER 18.22.099

PROJECT LOCATION East 144th Avenue between York St. and Colorado Blvd.



BOREHOLE	DEPTH	Classification	γ_d	MC%
● **1**	**2.0**	**FILL - LEAN CLAY with SAND**	**102**	**22**

Note: Water Added to Sample at 200 psf.

Date: 5/23/18

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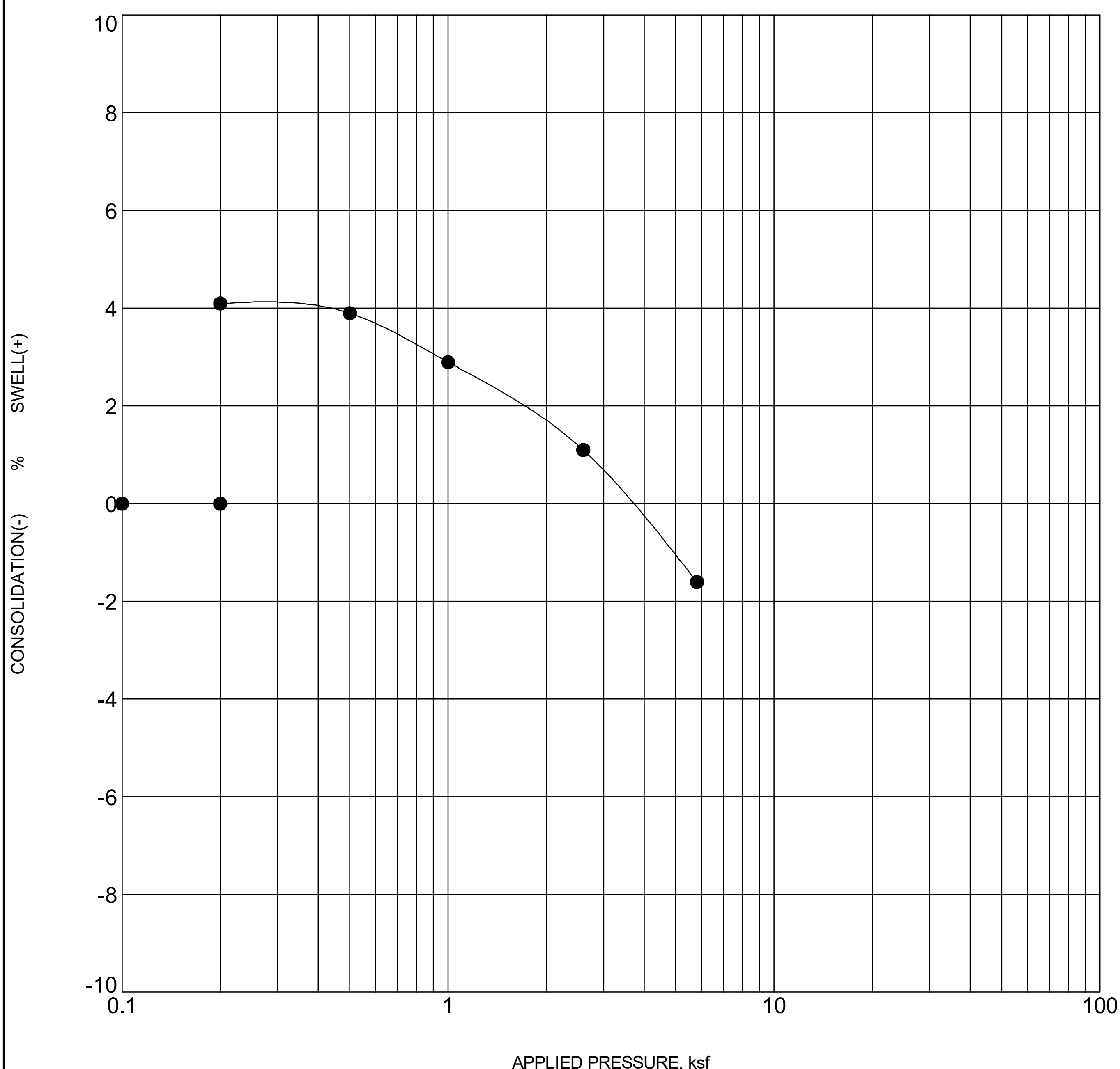
SWELL/CONSOLIDATION TEST

CLIENT Drexel Barrell

PROJECT NAME East 144th Avenue Widening Project

PROJECT NUMBER 18.22.099

PROJECT LOCATION East 144th Avenue between York St. and Colorado Blvd.



BOREHOLE	DEPTH	Classification	γ_d	MC%
● **1**	**4.0**	**FILL - LEAN CLAY with SAND**	**108**	**19**

Note: Water Added to Sample at 200 psf.

Date: 5/23/18

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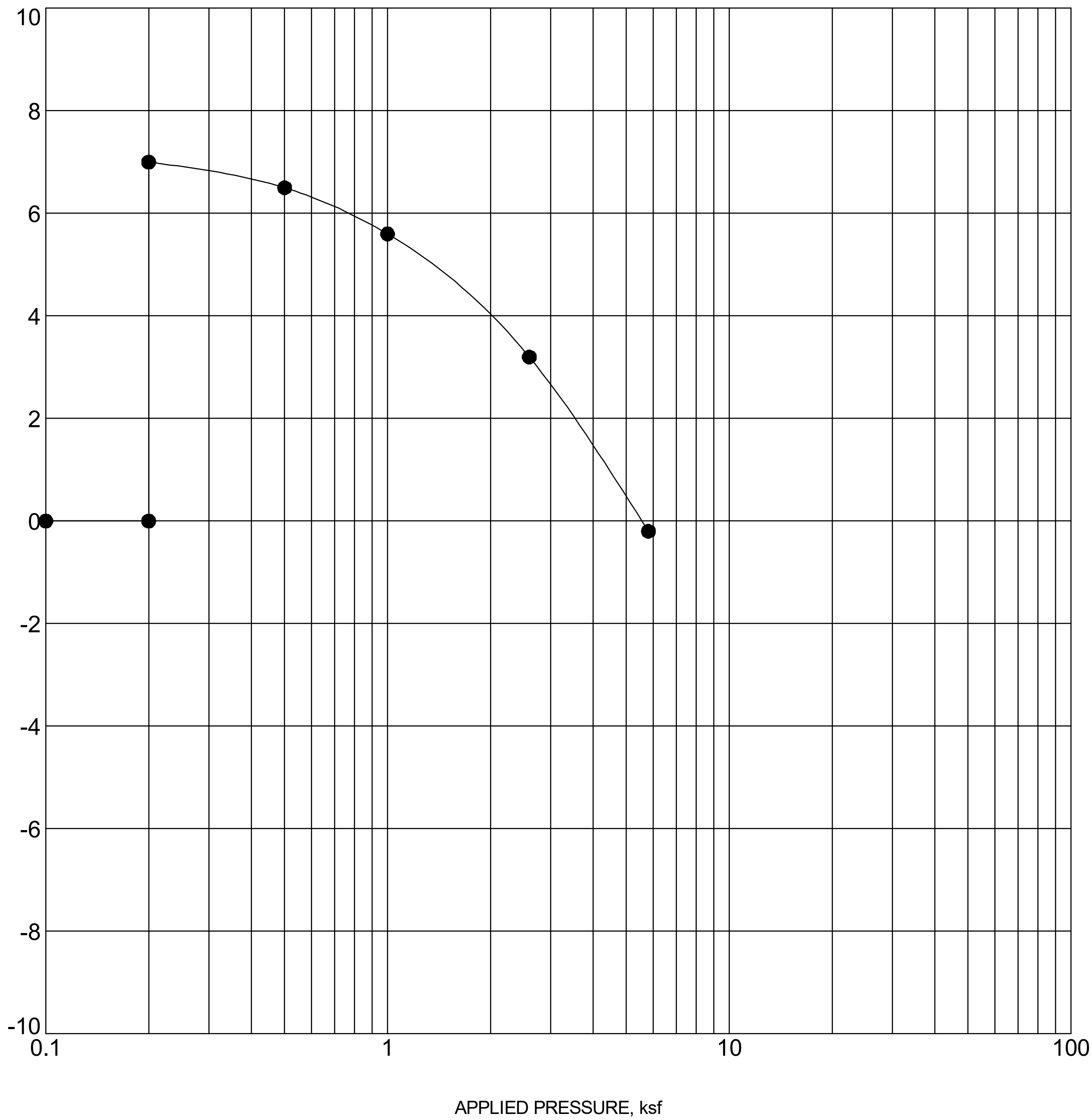
SWELL/CONSOLIDATION TEST

CLIENT Drexel Barrell
PROJECT NAME East 144th Avenue Widening Project
PROJECT NUMBER 18.22.099
PROJECT LOCATION East 144th Avenue between York St. and Colorado Blvd.



BOREHOLE	DEPTH	Classification	γ_d	MC%
● **2**	**2.0**	**SANDY LEAN CLAY**	**122**	**7**

Note: Water Added to Sample at 200 psf.

Date: 5/22/18

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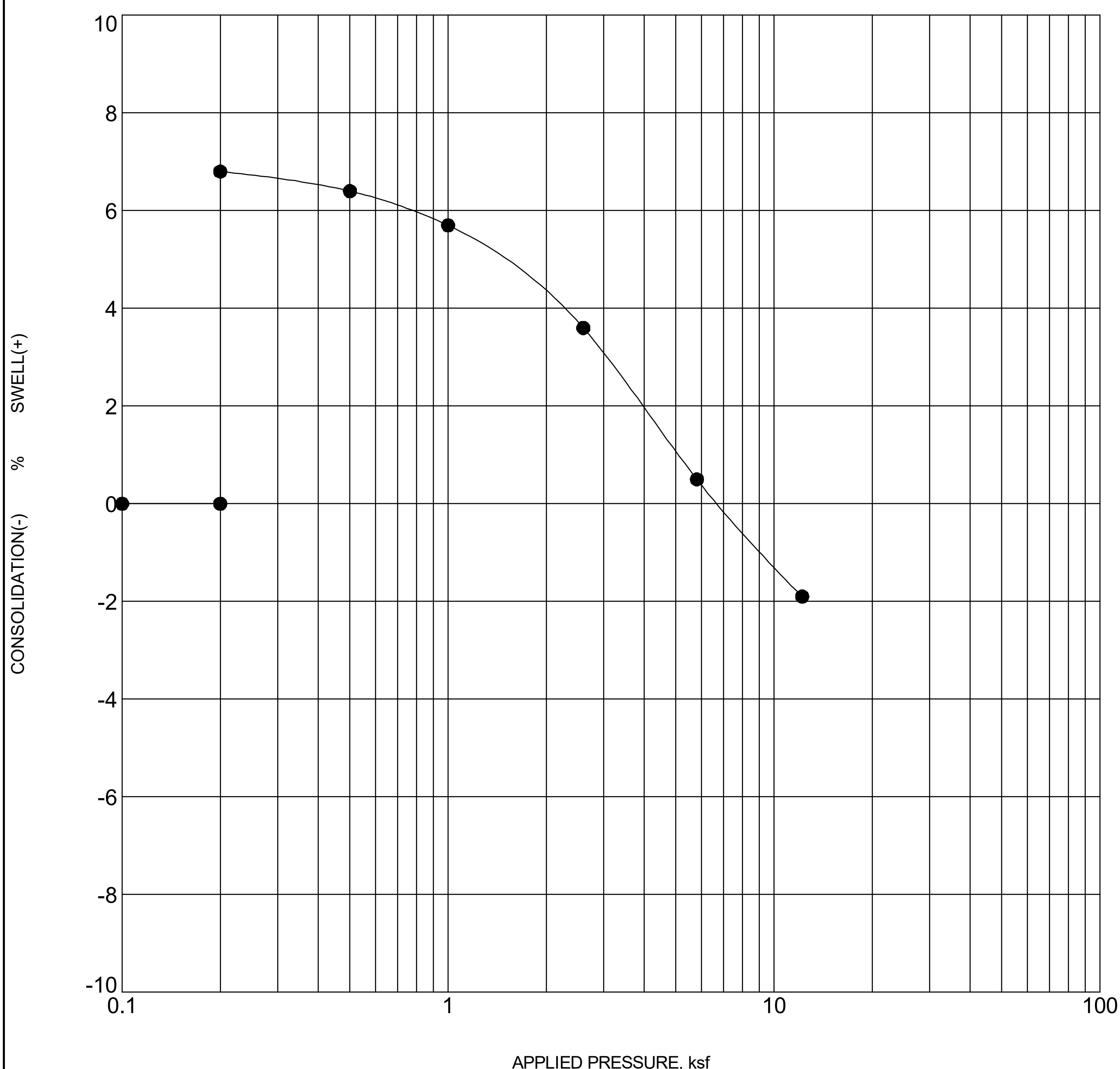
SWELL/CONSOLIDATION TEST

CLIENT Drexel Barrell

PROJECT NAME East 144th Avenue Widening Project

PROJECT NUMBER 18.22.099

PROJECT LOCATION East 144th Avenue between York St. and Colorado Blvd.



BOREHOLE	DEPTH	Classification	γ_d	MC%
● 3	9.0	CLAYSTONE BEDROCK	105	20

Note: Water Added to Sample at 200 psf. **Date: 5/22/18**

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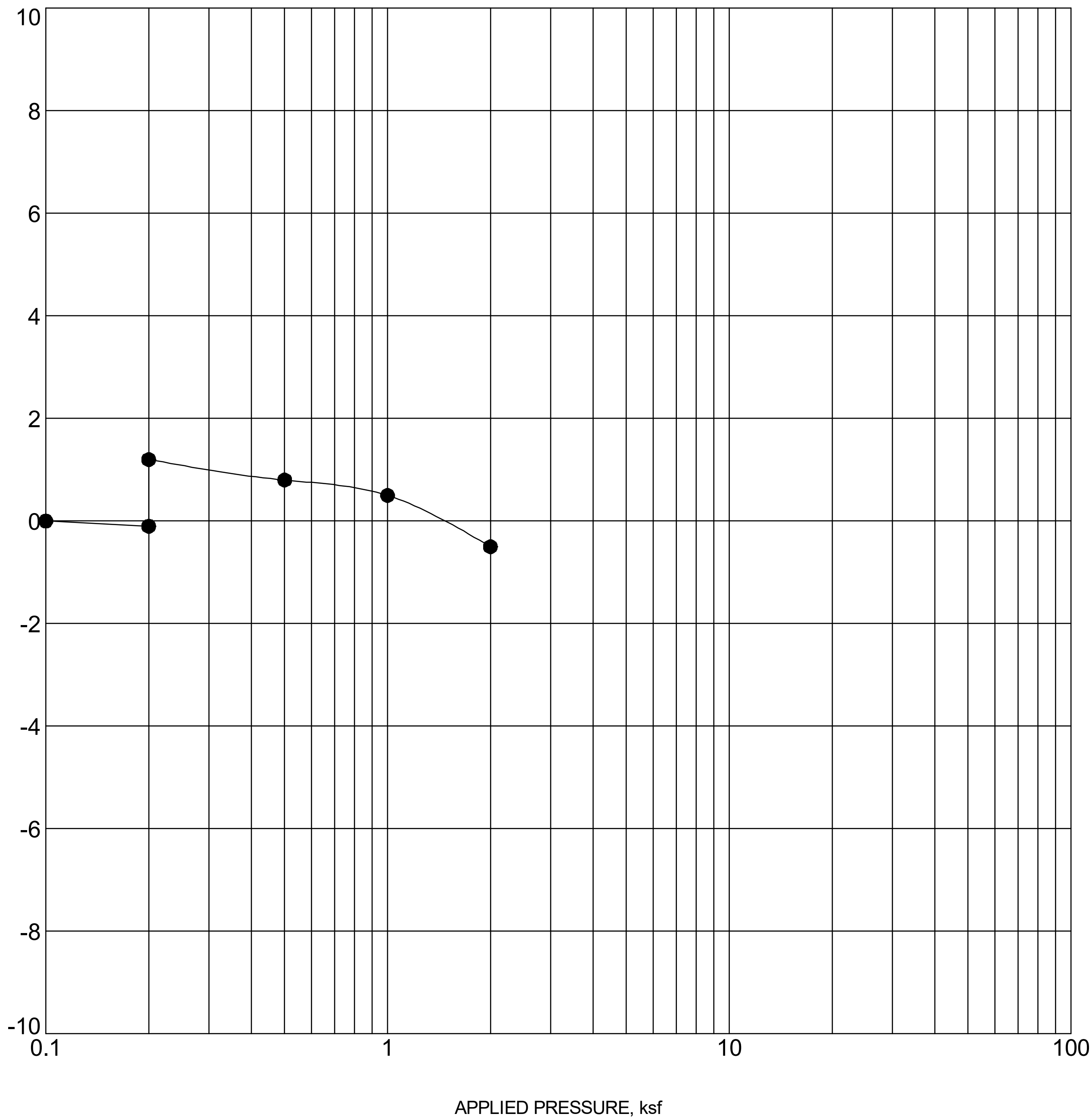
SWELL/CONSOLIDATION TEST

CLIENT Drexel Barrell
PROJECT NAME East 144th Avenue Widening Project
PROJECT NUMBER 18.22.099
PROJECT LOCATION East 144th Avenue between York St. and Colorado Blvd.



BOREHOLE	DEPTH	Classification	γ_d	MC%
● 4	4.0	FILL - CLAYEY SAND to SANDY LEAN CLAY	100	22

Note: Water Added to Sample at 200 psf.

Date: 5/22/18

Cole Garner Geotechnical
1070 W. 124th Avenue, Suite 300
Westminster, CO 80234
Telephone: 303.996.2999

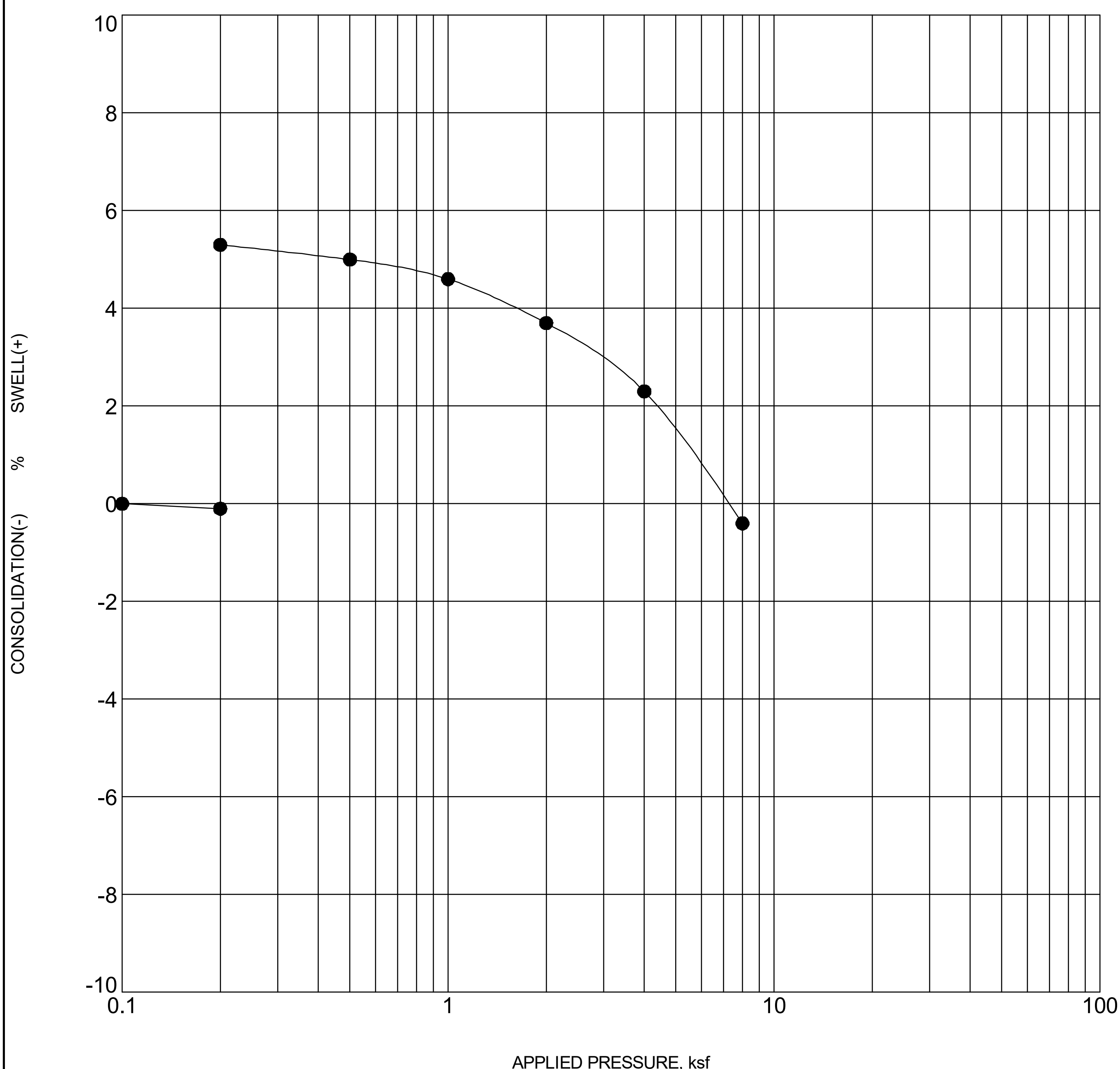
SWELL/CONSOLIDATION TEST

CLIENT Drexel Barrell

PROJECT NAME East 144th Avenue Widening Project

PROJECT NUMBER 18.22.099

PROJECT LOCATION East 144th Avenue between York St. and Colorado Blvd.



BOREHOLE	DEPTH	Classification	γ_d	MC%
● 5	4.0	**FILL - LEAN CLAY with SAND**	102	22

Note: Water Added to Sample at 200 psf.

Date: 5/22/18

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SWELL/CONSOLIDATION TEST

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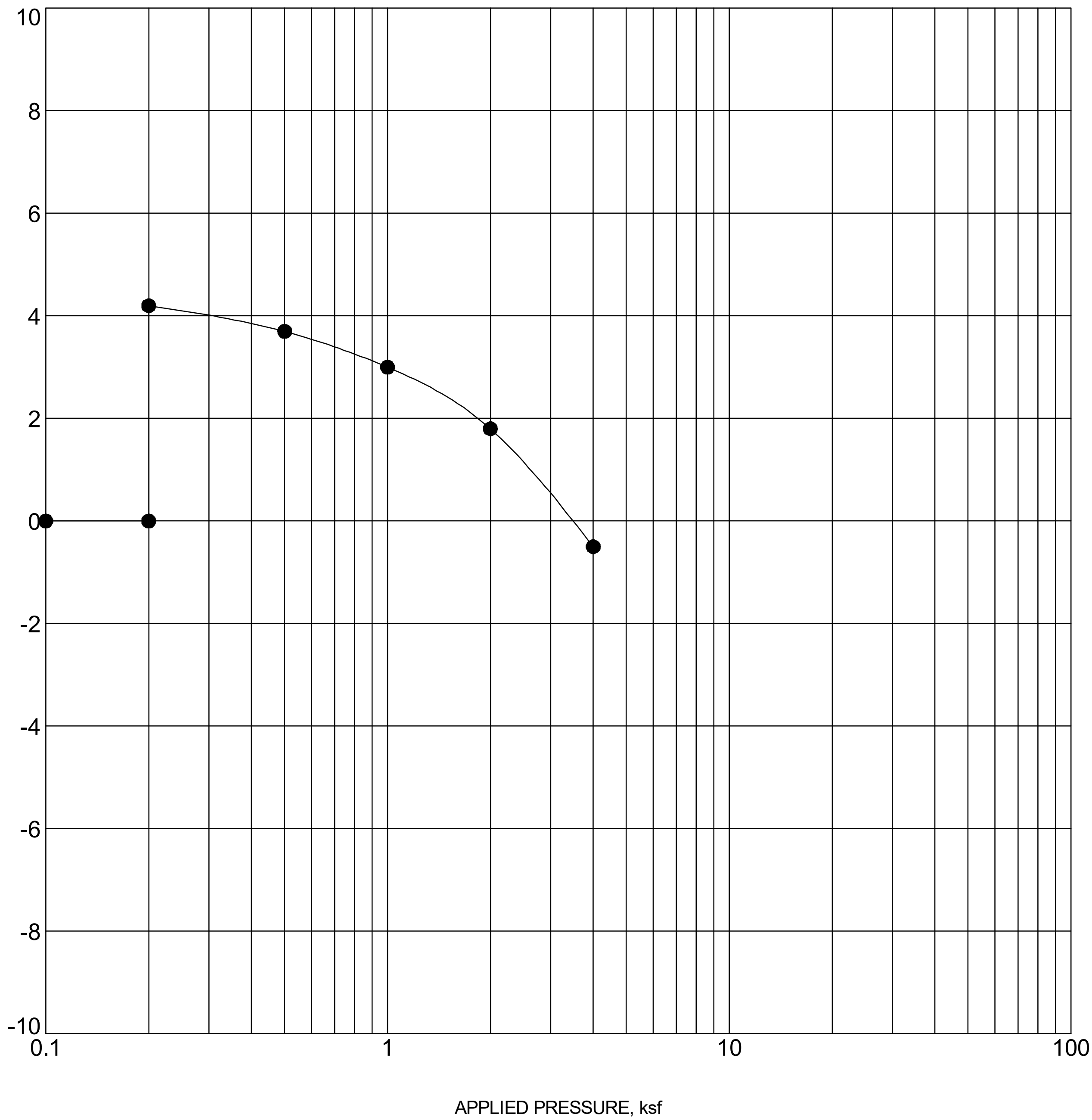

BOREHOLE	DEPTH	Classification	γ_d	MC%
● 6	4.0	**FILL - SANDY LEAN CLAY**	**105**	**19**

Note: Water Added to Sample at 200 psf.

Date: 5/22/18

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SWELL/CONSOLIDATION TEST

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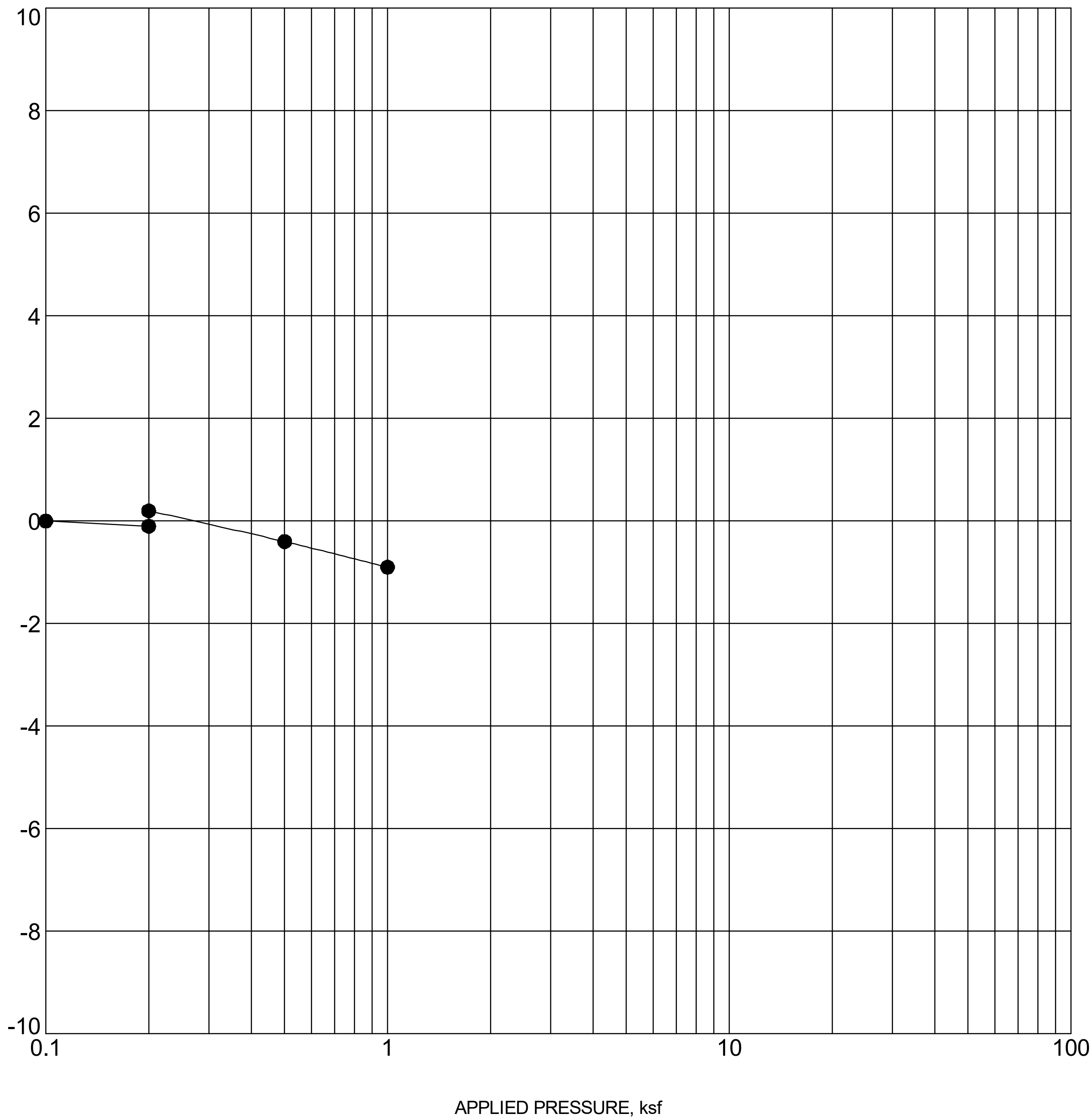

BOREHOLE	DEPTH	Classification	γ_d	MC%
● 7	2.0	FILL - SANDY LEAN CLAY	108	15

Note: Water Added to Sample at 200 psf.

Date: 5/22/18

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SWELL/CONSOLIDATION TEST

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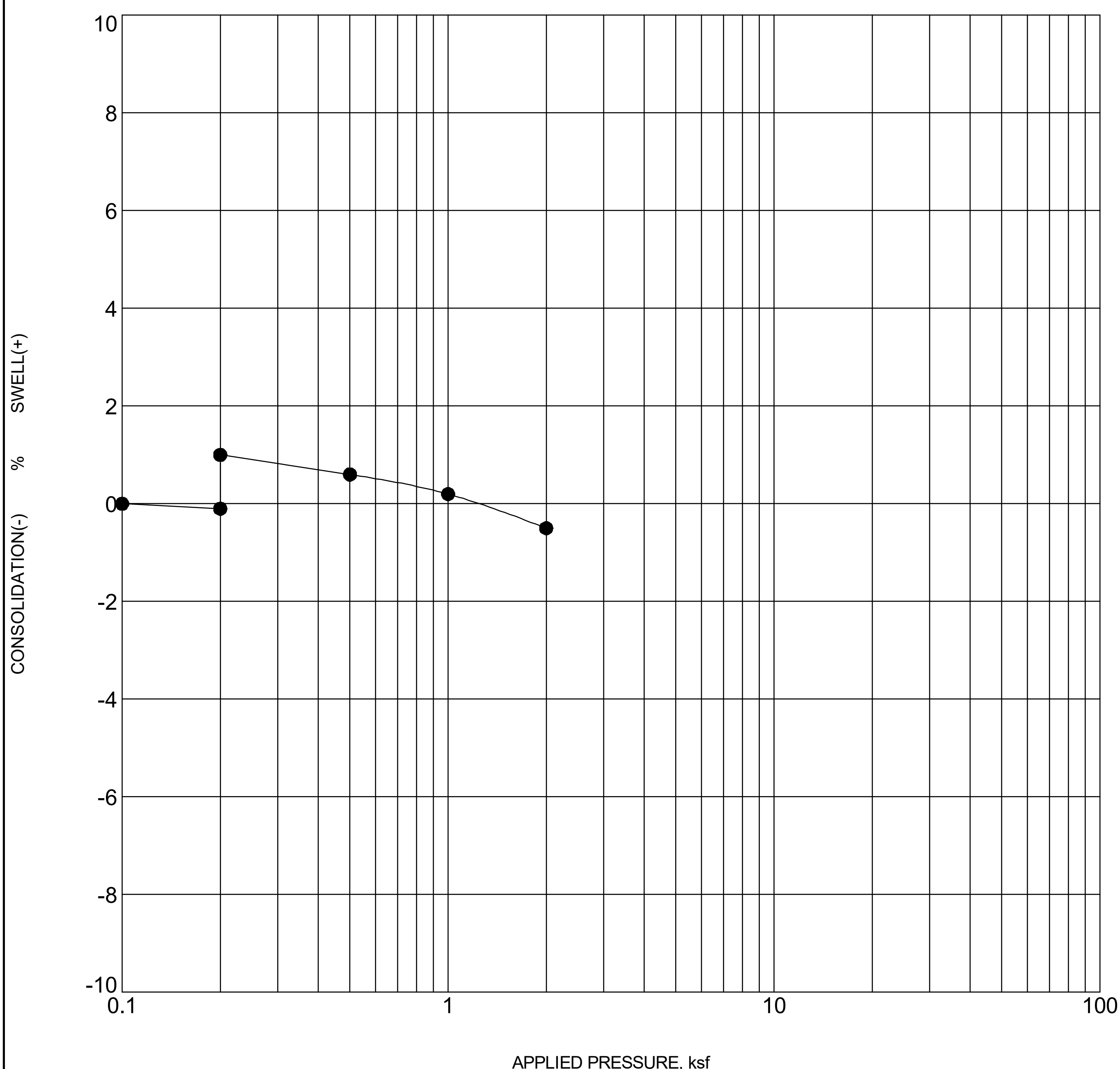

BOREHOLE	DEPTH	Classification	γ_d	MC%
● 8	2.0	SANDY LEAN CLAY	112	15

Note: Water Added to Sample at 200 psf.

Date: 5/22/18

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SWELL/CONSOLIDATION TEST

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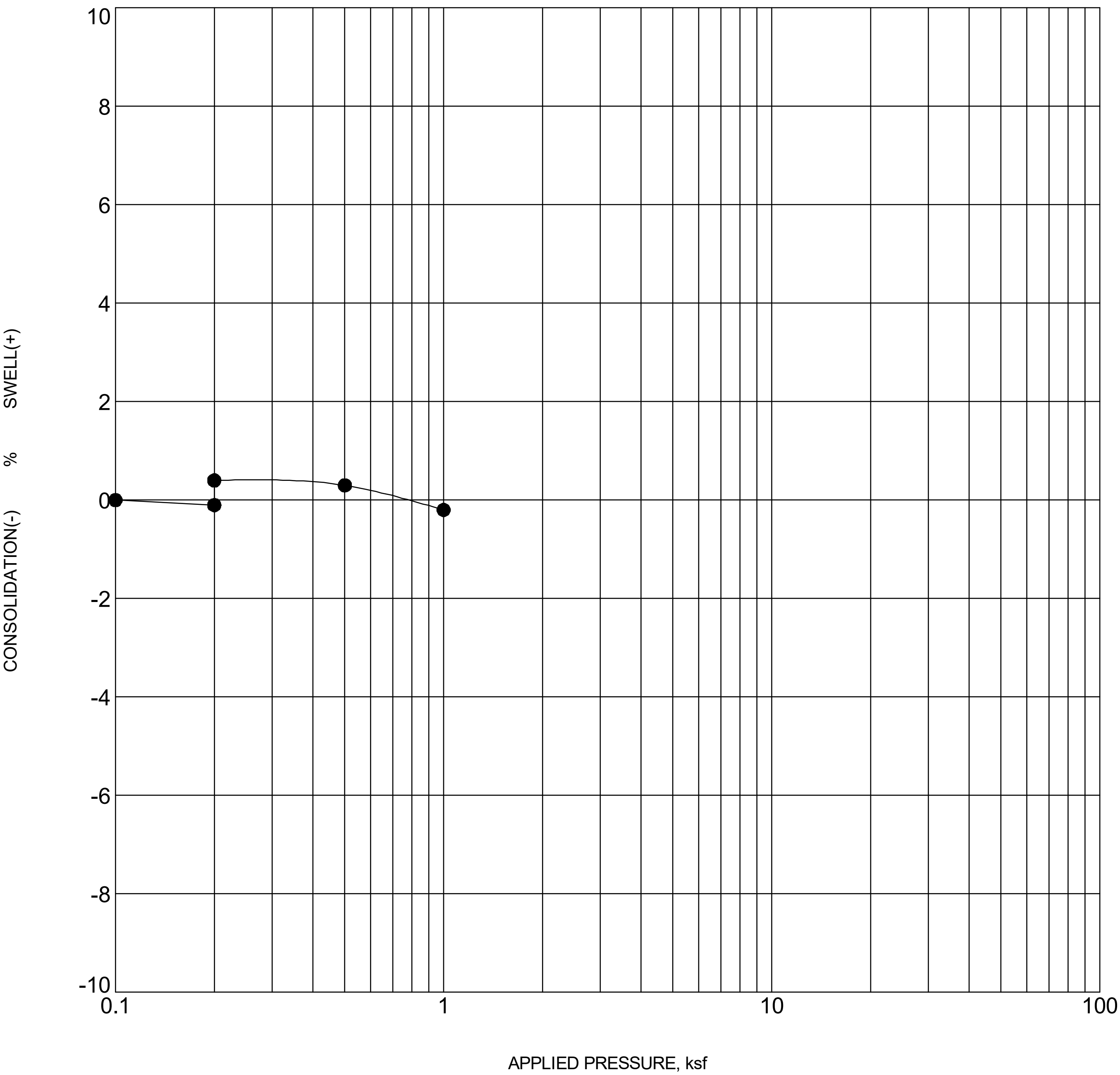

BOREHOLE	DEPTH	Classification	γ_d	MC%
● **9**	**2.0**	**SANDY LEAN CLAY**	**105**	**19**

Note: Water Added to Sample at 200 psf.

Date: 5/23/18

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SWELL/CONSOLIDATION TEST

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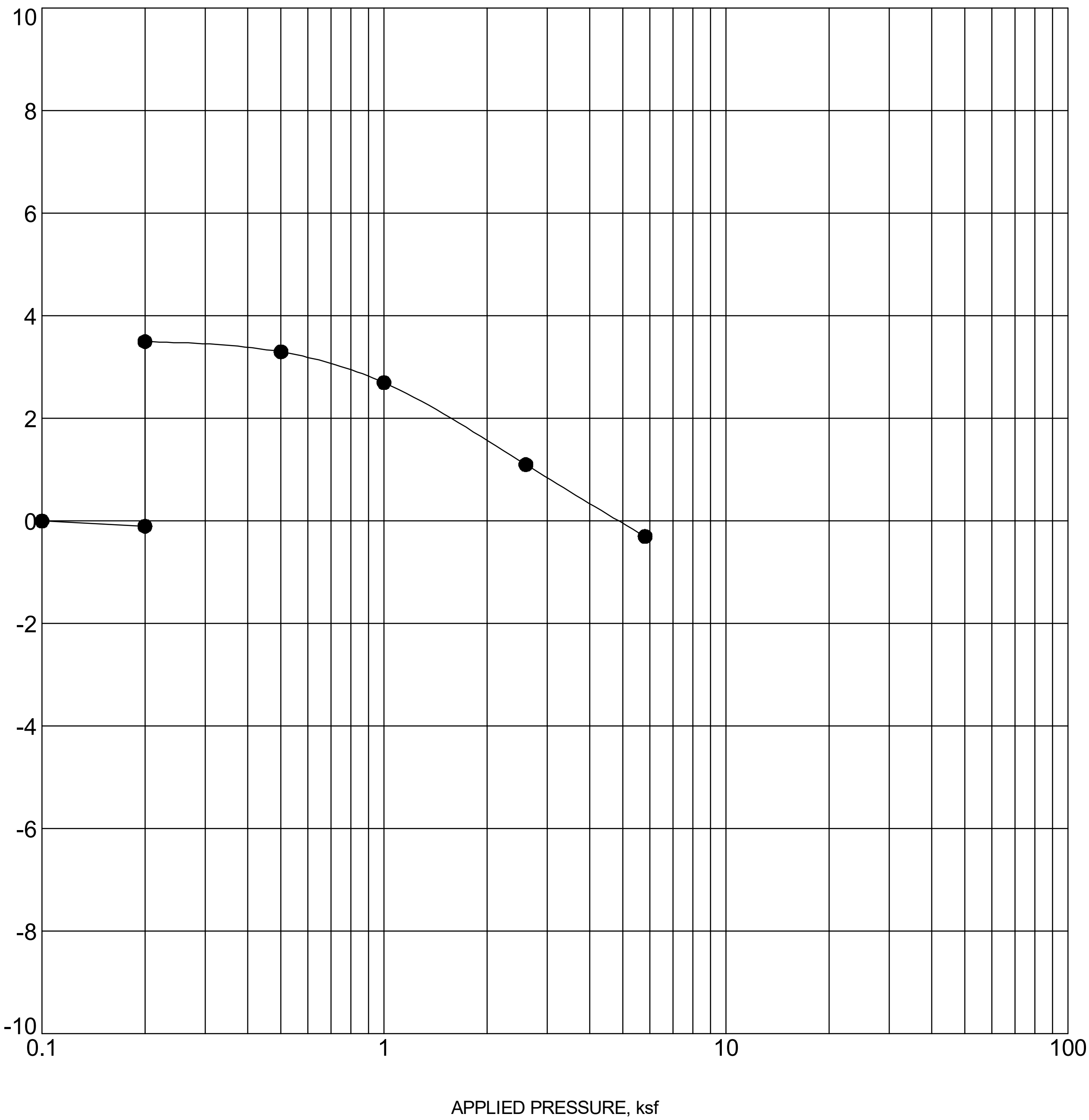


BOREHOLE	DEPTH	Classification	γ_d	MC%
● 11	9.0	**CLAYSTONE BEDROCK**	**102**	**22**

Note: Water Added to Sample at 200 psf.

Date: 5/23/18

intertek psi

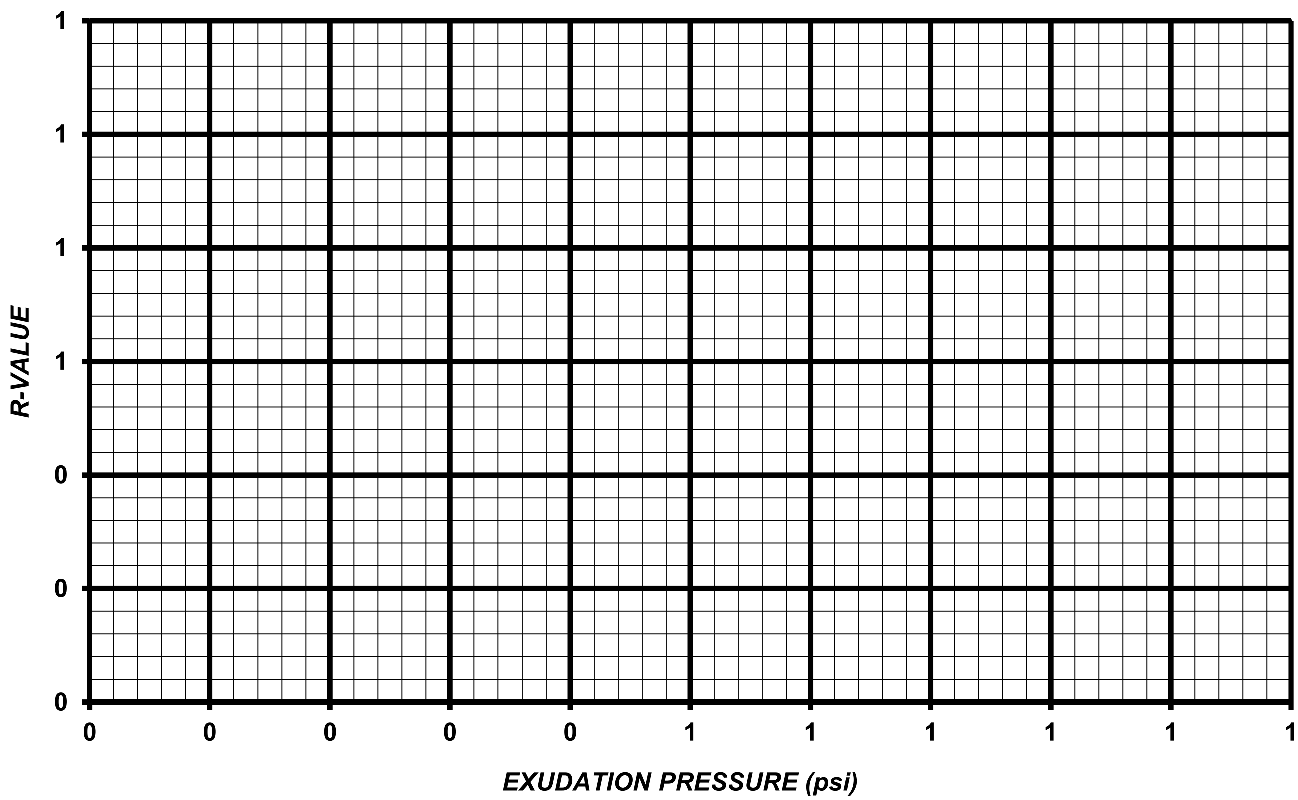
RESISTANCE R-VALUE & EXPANSION PRESSURE OF SOILS ASTM D2844

Tested For:	CG Geotechnical 1070W 124th Ave. Suite 300 Westminster CO 80234	Project Name: Sample Date: Project No.	18.22.099 June 1, 2018 05321313-40

TEST DATA

Sample Description: sandy CLAY

Sample Location: E144 Ave Widening 1@ 0-5'



R-Value @ 300 psi.	< 5

Test Specimen	1	2	3
Moisture Content (%)			
Dry Density (pcf)			
Exudation Pressure (psi)			
R-Value			

Remarks:

ASTM D2844 note 4 states "..material from very plastic clay test specimens will extrude from under the mold… during loading operations. If this occurrs when … fewer than 5 lights are lighted, the soil should be reported as less than 5 R-value."

Respectfully Submitted,
Professional Service Industries, Inc.

Donna Off Project Manager

Cole Garner Geotechnical
1070 W. 124th Avenue, Suite 300
Westminster, CO 80234
Telephone: 303.996.2999

SUMMARY OF LABORATORY RESULTS

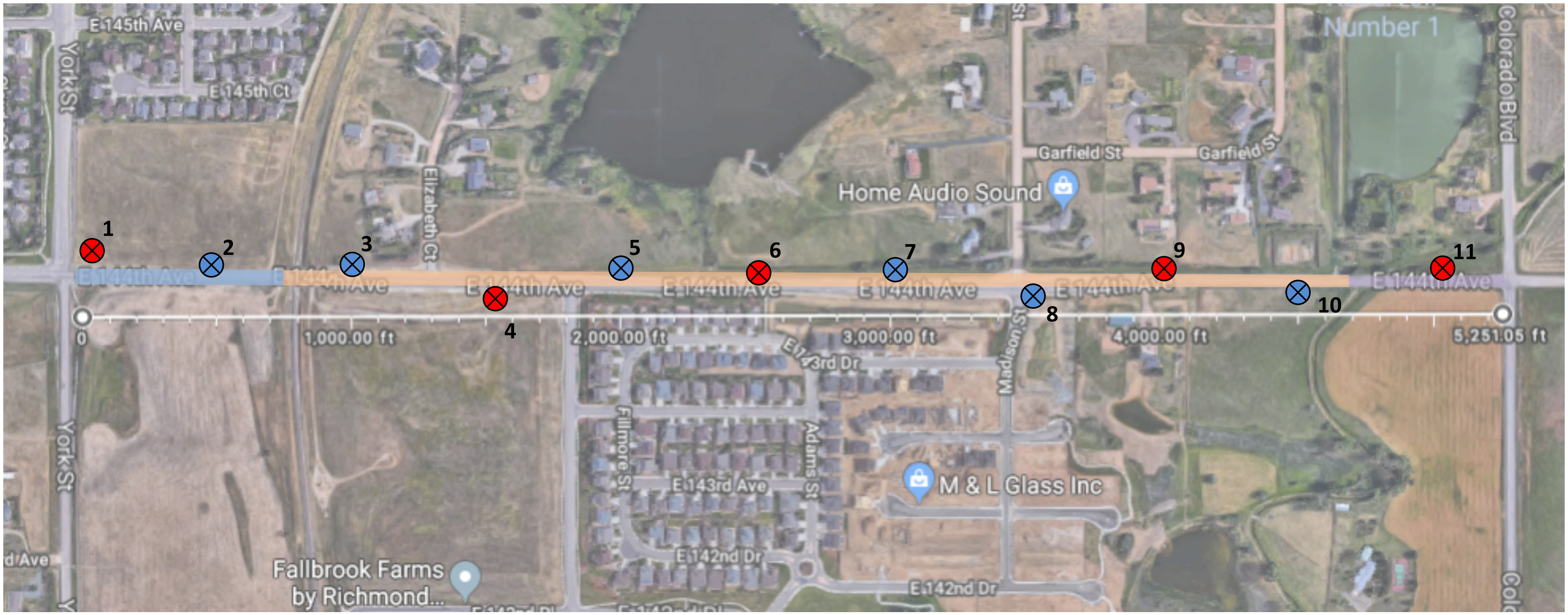
CLIENT Drexel Barrell

PROJECT NUMBER 18.22.099

PROJECT NAME East 144th Avenue Widening Project

PROJECT LOCATION East 144th Avenue between York St. and Colorado Blvd.

Borehole	Depth	Soil Description	Water Content (%)	Dry Density (pcf)	Swell (+) or Consolidation (-)/ Surcharge (%/psf)	Water Soluble Sulfates (ppm)	Passing #200 Sieve (%)	Atterberg Limits		
								Liquid Limit	Plastic Limit	Plasticity Index
1	2	FILL - LEAN CLAY with SAND	17.5	110.3	+0.9/200		84	46	20	26
1	4	FILL - LEAN CLAY with SAND	19.5	107.8	+4.1/200					
1	9	CLAYSTONE BEDROCK	20.7	107.6						
2	2	SANDY LEAN CLAY	6.7	121.8	+7.0/200	600				
2	4	SANDY LEAN CLAY	15.8	111.5			68	42	21	21
3	2	CLAYEY SANDSTONE BEDROCK	27.9	95.0						
3	4	CLAYEY SANDSTONE BEDROCK	28.7	95.0			54	37	21	16
3	9	CLAYSTONE BEDROCK	20.3	104.7	+6.8/200					
4	2	FILL - CLAYEY SAND	20.6	100.0			48	36	21	15
4	4	FILL - CLAYEY SAND to LEAN CLAY	21.6	100.1	+1.3/200					
5	2	FILL - CLAYEY SAND	15.3				42	35	22	13
5	4	FILL - LEAN CLAY with SAND	21.6	102.4	+5.4/200		75	44	20	24
5	9	FILL - LEAN CLAY with SAND	21.4	99.4						
6	2	FILL - SANDY LEAN CLAY	18.5	107.3		400	64	38	21	17
6	4	FILL - SANDY LEAN CLAY	19.5	105.0	+4.2/200					
7	2	FILL - SANDY LEAN CLAY	15.1	107.7	+0.3/200					
7	4	FILL - SANDY LEAN CLAY	20.1	100.8			66	38	21	17
7	9	SANDY LEAN CLAY	21.4	100.1						
8	2	SANDY LEAN CLAY	14.9	111.5	+1.1/200		68	39	21	18
8	4	SANDY LEAN CLAY to CLAYEY SAND	13.3	113.5						
9	2	SANDY LEAN CLAY	18.8	104.6	+0.5/200		57	38	22	16
9	4	SANDY LEAN CLAY	25.2	96.8						
9	9	CLAYEY SANDSTONE BEDROCK	20.0	106.7						
10	4	SANDY LEAN CLAY	24.6	97.3			63	38	21	17
11	2	SILTY SAND	8.5	120.5			20	NP	NP	NP
11	4	CLAYEY SAND to SILTY SAND	15.8	112.8		1200				
11	9	CLAYSTONE BEDROCK	21.7	101.6	+3.6/200					



DESIGN $ESAL_{20}$ = 3,394,500

Blue	A-7-6
Orange	A-6
Purple	A-2-4

PAVEMENT DESIGN INVESTIGATION

- (blue marker) 1 APPROXIMATE BORING LOCATIONS
- (red marker) 1 DENOTES BORING W/ ASPHALT CORE SAMPLE

FIGURE 3 – SOIL TYPES & ESAL DIAGRAM
PAVEMENT THICKNESS DESIGN
144th AVENUE WIDENING
THORNTON, COLORADO
CGG PROJECT NO. 18.22.099

Cole Garner Geotechnical
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APPENDIX C

GENERAL NOTES

GENERAL NOTES

DRILLING & SAMPLING SYMBOLS:

SS:	Split Spoon - 1⅜" I.D., 2" O.D., unless otherwise noted	HS:	Hollow Stem Auger
ST:	Thin-Walled Tube – 2.5" O.D., unless otherwise noted	PA:	Power Auger
RS:	Ring Sampler - 2.42" I.D., 3" O.D., unless otherwise noted	HA:	Hand Auger
CB:	California Barrel - 1.92" I.D., 2.5" O.D., unless otherwise noted	RB:	Rock Bit
BS:	Bulk Sample or Auger Sample	WB:	Wash Boring or Mud Rotary

The number of blows required to advance a standard 2-inch O.D. split-spoon sampler (SS) the last 12 inches of the total 18-inch penetration with a 140-pound hammer falling 30 inches is considered the “Standard Penetration” or “N-value”. For 2.5” O.D. California Barrel samplers (CB) the penetration value is reported as the number of blows required to advance the sampler 12 inches using a 140-pound hammer falling 30 inches, reported as “blows per inch,” and is not considered equivalent to the “Standard Penetration” or “N-value”.

WATER LEVEL MEASUREMENT SYMBOLS:

WL:	Water Level	WS:	While Sampling
WCI:	Wet Cave in	WD:	While Drilling
DCI:	Dry Cave in	BCR:	Before Casing Removal
AB:	After Boring	ACR:	After Casing Removal

Water levels indicated on the boring logs are the levels measured in the borings at the times indicated. Groundwater levels at other times and other locations across the site could vary. In pervious soils, the indicated levels may reflect the location of groundwater. In low permeability soils, the accurate determination of groundwater levels may not be possible with only short-term observations.

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

FINE-GRAINED SOILS			COARSE-GRAINED SOILS			BEDROCK		
(CB) Blows/Ft.	(SS) Blows/Ft.	Consistency	(CB) Blows/Ft.	(SS) Blows/Ft.	Relative Density	(CB) Blows/Ft.	(SS) Blows/Ft.	Consistency
< 3	0-2	Very Soft	0-5	< 3	Very Loose	< 24	< 20	Weathered
3-5	3-4	Soft	6-14	4-9	Loose	24-35	20-29	Firm
6-10	5-8	Medium Stiff	15-46	10-29	Medium Dense	36-60	30-49	Medium Hard
11-18	9-15	Stiff	47-79	30-50	Dense	61-96	50-79	Hard
19-36	16-30	Very Stiff	> 79	> 50	Very Dense	> 96	> 79	Very Hard
> 36	> 30	Hard						

RELATIVE PROPORTIONS OF SAND AND GRAVEL

Descriptive Terms of Other Constituents	Percent of Dry Weight
Trace	< 15
With	15 – 29
Modifier	> 30

GRAIN SIZE TERMINOLOGY

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

RELATIVE PROPORTIONS OF FINES

Descriptive Terms of Other Constituents	Percent of Dry Weight
Trace	< 5
With	5 – 12
Modifiers	> 12

PLASTICITY DESCRIPTION

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

UNIFIED SOIL CLASSIFICATION SYSTEM

Criteria for Assigning Group Symbols and Group Names Using Laboratory Tests[A]				Soil Classification: Group Symbol	Soil Classification: Group Name[B]
Coarse Grained Soils More than 50% retained on No. 200 sieve	Gravels More than 50% of coarse fraction retained on No. 4 sieve	Clean Gravels Less than 5% fines[C]	Cu ≥ 4 and 1 ≤ Cc ≤ 3[E]	GW	Well graded gravel[F]
			Cu < 4 and/or 1 > Cc > 3[E]	GP	Poorly graded gravel[F]
		Gravels with Fines More than 12% fines[C]	Fines classify as ML or MH	GM	Silty gravel[F,G,H]
			Fines classify as CL or CH	GC	Clayey gravel[F,G,H]
	Sands 50% or more of coarse fraction passes No. 4 sieve	Clean Sands Less than 5% fines[D]	Cu ≥ 6 and 1 ≤ Cc ≤ 3[E]	SW	Well graded sand[I]
			Cu < 6 and/or 1 > Cc > 3[E]	SP	Poorly graded sand[I]
		Sands with Fines More than 12% fines[D]	Fines classify as ML or MH	SM	Silty sand[G,H,I]
			Fines classify as CL or CH	SC	Clayey sand[G,H,I]
Fine-Grained Soils 50% or more passes the No. 200 sieve	Silts and Clays Liquid limit less than 50	Inorganic	PI > 7 and plots on or above "A" line[J]	CL	Lean clay[K,L,M]
			PI < 4 or plots below "A" line[J]	ML	Silt[K,L,M]
		Organic	**Liquid limit - oven dried / Liquid limit - not dried** < 0.75	OL	Organic clay[K,L,M,N]
					Organic silt[K,L,M,O]
	Silts and Clays Liquid limit 50 or more	Inorganic	PI plots on or above "A" line	CH	Fat clay[K,L,M]
			PI plots below "A" line	MH	Elastic silt[K,L,M]
		Organic	Liquid limit - oven dried / Liquid limit - not dried < 0.75	OH	Organic clay[K,L,M,P]
					Organic silt[K,L,M,Q]
Highly organic soils		Primarily organic matter, dark in color, and organic odor		PT	Peat

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

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

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

[D] Sands with 5 to 12% fines require dual symbols: SW-SM well graded sand with silt, SW-SC well graded sand with clay, SP-SM poorly graded sand with silt, SP-SC poorly graded sand with clay

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

[F] If soil contains ≥ 15% sand, add "with sand" to group name.

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

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

[I] If soil contains ≥ 15% gravel, add "with gravel" to group name.

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

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

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

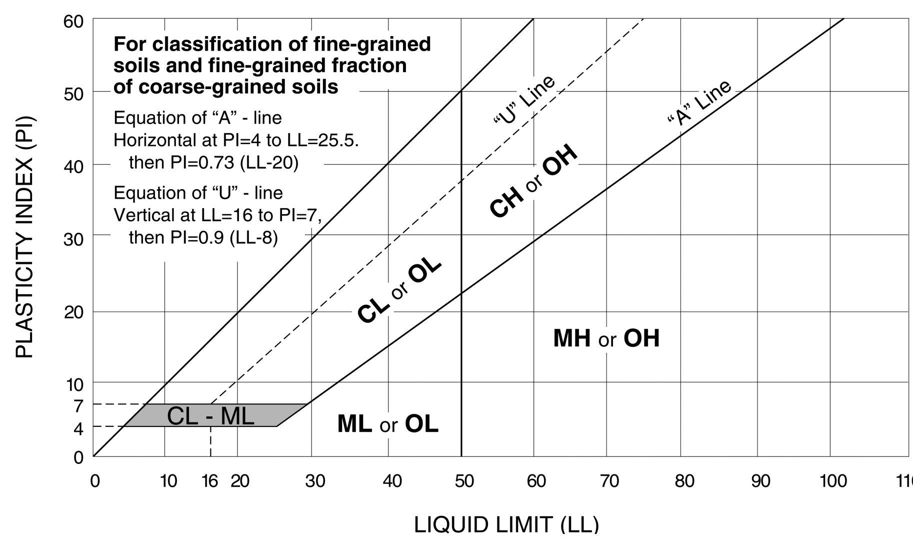
[M] If soil contains ≥ 30% plus No. 200, predominantly gravel, add "gravelly" to group name.

[N] PI ≥ 4 and plots on or above "A" line.

[O] PI < 4 or plots below "A" line.

[P] PI plots on or above "A" line.

[Q] PI plots below "A" line.



ROCK CLASSIFICATION
(Based on ASTM C-294)

Sedimentary Rocks

Sedimentary rocks are stratified materials laid down by water or wind. The sediments may be composed of particles or pre-existing rocks derived by mechanical weathering, evaporation or by chemical or organic origin. The sediments are usually indurated by cementation or compaction.

Chert Very fine-grained siliceous rock composed of micro-crystalline or cyrptocrystalline quartz, chalcedony or opal. Chert is various colored, porous to dense, hard and has a conchoidal to splintery fracture.

Claystone Fine-grained rock composed of or derived by erosion of silts and clays or any rock containing clay. Soft massive and may contain carbonate minerals.

Conglomerate Rock consisting of a considerable amount of rounded gravel, sand and cobbles with or without interstitial or cementing material. The cementing or interstitial material may be quartz, opal, calcite, dolomite, clay, iron oxides or other materials.

Dolomite A fine-grained carbonate rock consisting of the mineral dolomite [$CaMg(CO_3)_2$]. May contain noncarbonate impurities such as quartz, chert, clay minerals, organic matter, gypsum and sulfides. Reacts with hydrochloric acid (HCL).

Limestone A fine-grained carbonate rock consisting of the mineral calcite ($CaCO_3$). May contain noncarbonate impurities such as quartz, chert, clay minerals, organic matter, gypsum and sulfides. Reacts with hydrochloric acid (HCL).

Sandstone Rock consisting of particles of sand with or without interstitial and cementing materials. The cementing or interstitial material may be quartz, opal, calcite, dolomite, clay, iron oxides or other material.

Shale Fine-grained rock composed of or derived by erosion of silts and clays or any rock containing clay. Shale is hard, platy, of fissile may be gray, black, reddish or green and may contain some carbonate minerals (calcareous shale).

Siltstone Fine grained rock composed of or derived by erosion of silts or rock containing silt. Siltstones consist predominantly of silt sized particles (0.0625 to 0.002 mm in diameter) and are intermediate rocks between claystones and sandstones and may contain carbonate minerals.

ROCK CLASSIFICATION
(Based on ASTM C-294)

Metamorphic Rocks

Metamorphic rocks form from igneous, sedimentary, or pre-existing metamorphic rocks in response to changes in chemical and physical conditions occurring within the earth's crust after formation of the original rock. The changes may be textural, structural, or mineralogic and may be accompanied by changes in chemical composition. The rocks are dense and may be massive but are more frequently foliated (laminated or layered) and tend to break into platy particles. The mineral composition is very variable depending in part on the degree of metamorphism and in part on the composition of the original rock.

Marble A recrystallized medium- to coarse-grained carbonate rock composed of calcite or dolomite, or calcite and dolomite. The original impurities are present in the form of new minerals, such as micas, amphiboles, pyroxenes, and graphite.

Metaquartzite A granular rock consisting essentially of recrystallized quartz. Its strength and resistance to weathering derive from the interlocking of the quartz grains.

Slate A fine-grained metamorphic rock that is distinctly laminated and tends to split into thin parallel layers. The mineral composition usually cannot be determined with the unaided eye.

Schist A highly layered rock tending to split into nearly parallel planes (schistose) in which the grain is coarse enough to permit identification of the principal minerals. Schists are subdivided into varieties on the basis of the most prominent mineral present in addition to quartz or to quartz and feldspars; for instance, mica schist. Greenschist is a green schistose rock whose color is due to abundance of one or more of the green minerals, chlorite or amphibole, and is commonly derived from altered volcanic rock.

Gneiss One of the most common metamorphic rocks, usually formed from igneous or sedimentary rocks by a higher degree of metamorphism than the schists. It is characterized by a layered or foliated structure resulting from approximately parallel lenses and bands of platy minerals, usually micas or prisms, usually amphiboles, and of granular minerals, usually quartz and feldspars. All intermediate varieties between gneiss and schist and between gneiss and granite are often found in the same areas in which well-defined gneisses occur.

ROCK CLASSIFICATION
(Based on ASTM C-294)

Igneous Rocks

Igneous rocks are formed by cooling from a molten rock mass (magma). Igneous rocks are divided into two classes (1) plutonic, or intrusive, that have cooled slowly within the earth; and (2) volcanic, or extrusive, that formed from quickly cooled lavas. Plutonic rocks have grain sizes greater than approximately 1 mm, and are classified as coarse- or medium-grained. Volcanic rocks have grain sizes less than approximately 1 mm, and are classified as fine-grained. Volcanic rocks frequently contain glass. Both plutonic and volcanic rocks may consist of porphyries that are characterized by the presence of large mineral grains in a fine-grained or glassy groundmass. This is the result of sharp changes in rate of cooling or other physico-chemical conditions during solidification of the melt.

Granite Granite is a medium- to coarse-grained light-colored rock characterized by the presence of potassium feldspar with lesser amounts of plagioclase feldspars and quartz. The characteristic potassium feldspars are othoclase or microcline, or both; the common plagioclase feldspars are albite and oligoclase. Feldspars are more abundant than quartz. Dark-colored mica (biotite) is usually present, and light-colored mica (muscovite) is frequently present. Other dark-colored ferromagnesian minerals, especially honblende, may be present in amounts less than those of the light-colored constituents.

Quartz-Monzonite and Grano-Diorite Rocks similar to granite but contain more plagioclase feldspar than potassium feldspar.

Basalt Fine-grained extrusive equivalent of gabbro and diabase. When basalt contains natural glass, the glass is generally lower in silica content than that of the lighter-colored extrusive rocks.

LABORATORY TEST
SIGNIFICANCE AND PURPOSE

TEST	SIGNIFICANCE	PURPOSE
California Bearing Ratio	Used to evaluate the potential strength of subgrade soil, subbase, and base course material, including recycled materials for use in road and airfield pavements.	***Pavement Thickness Design***
Consolidation	Used to develop an estimate of both the rate and amount of both differential and total settlement of a structure.	***Foundation Design***
Direct Shear	Used to determine the consolidated drained shear strength of soil or rock.	***Bearing Capacity, Foundation Design, and Slope Stability***
Dry Density	Used to determine the in-place density of natural, inorganic, fine-grained soils.	***Index Property Soil Behavior***
Expansion	Used to measure the expansive potential of fine-grained soil and to provide a basis for swell potential classification.	***Foundation and Slab Design***
Gradation	Used for the quantitative determination of the distribution of particle sizes in soil.	***Soil Classification***
Liquid & Plastic Limit, Plasticity Index	Used as an integral part of engineering classification systems to characterize the fine-grained fraction of soils, and to specify the fine-grained fraction of construction materials.	***Soil Classification***
Permeability	Used to determine the capacity of soil or rock to conduct a liquid or gas.	***Groundwater Flow Analysis***
pH	Used to determine the degree of acidity or alkalinity of a soil.	***Corrosion Potential***
Resistivity	Used to indicate the relative ability of a soil medium to carry electrical currents.	***Corrosion Potential***
R-Value	Used to evaluate the potential strength of subgrade soil, subbase, and base course material, including recycled materials for use in road and airfield pavements.	***Pavement Thickness Design***
Soluble Sulfate	Used to determine the quantitative amount of soluble sulfates within a soil mass.	***Corrosion Potential***
Unconfined Compression	To obtain the approximate compressive strength of soils that possess sufficient cohesion to permit testing in the unconfined state.	***Bearing Capacity Analysis for Foundations***
Water Content	Used to determine the quantitative amount of water in a soil mass.	***Index Property Soil Behavior***

REPORT TERMINOLOGY
(Based on ASTM D653)

Allowable Soil Bearing Capacity	The recommended maximum contact stress developed at the interface of the foundation element and the supporting material.
Alluvium	Soil, the constituents of which have been transported in suspension by flowing water and subsequently deposited by sedimentation.
Aggregate Base Course	A layer of specified material placed on a subgrade or subbase usually beneath slabs or pavements.
Backfill	A specified material placed and compacted in a confined area.
Bedrock	A natural aggregate of mineral grains connected by strong and permanent cohesive forces. Usually requires drilling, wedging, blasting or other methods of extraordinary force for excavation.
Bench	A horizontal surface in a sloped deposit.
Caisson (Drilled Pier or Shaft)	A concrete foundation element cast in a circular excavation which may have an enlarged base. Sometimes referred to as a cast-in-place pier or drilled shaft.
Coefficient of Friction	A constant proportionality factor relating normal stress and the corresponding shear stress at which sliding starts between the two surfaces.
Colluvium	Soil, the constituents of which have been deposited chiefly by gravity such as at the foot of a slope or cliff.
Compaction	The densification of a soil by means of mechanical manipulation
Concrete Slab-on-Grade	A concrete surface layer cast directly upon a base, subbase or subgrade, and typically used as a floor system.
Differential Movement	Unequal settlement or heave between, or within foundation elements of structure.
Earth Pressure	The pressure exerted by soil on any boundary such as a foundation wall.
ESAL	Equivalent Single Axle Load, a criteria used to convert traffic to a uniform standard, (18,000 pound axle loads).
Engineered Fill	Specified material placed and compacted to specified density and/or moisture conditions under observations of a representative of a geotechnical engineer.
Equivalent Fluid	A hypothetical fluid having a unit weight such that it will produce a pressure against a lateral support presumed to be equivalent to that produced by the actual soil. This simplified approach is valid only when deformation conditions are such that the pressure increases linearly with depth and the wall friction is neglected.
Existing Fill (or Man-Made Fill)	Materials deposited throughout the action of man prior to exploration of the site.
Existing Grade	The ground surface at the time of field exploration.

REPORT TERMINOLOGY
(Based on ASTM D653)

Expansive Potential	The potential of a soil to expand (increase in volume) due to absorption of moisture.
Finished Grade	The final grade created as a part of the project.
Footing	A portion of the foundation of a structure that transmits loads directly to the soil.
Foundation	The lower part of a structure that transmits the loads to the soil or bedrock.
Frost Depth	The depth at which the ground becomes frozen during the winter season.
Grade Beam	A foundation element or wall, typically constructed of reinforced concrete, used to span between other foundation elements such as drilled piers.
Groundwater	Subsurface water found in the zone of saturation of soils or within fractures in bedrock.
Heave	Upward movement.
Lithologic	The characteristics which describe the composition and texture of soil and rock by observation.
Native Grade	The naturally occurring ground surface.
Native Soil	Naturally occurring on-site soil, sometimes referred to as natural soil.
Optimum Moisture Content	The water content at which a soil can be compacted to a maximum dry unit weight by a given compactive effort.
Perched Water	Groundwater, usually of limited area maintained above a normal water elevation by the presence of an intervening relatively impervious continuous stratum.
Scarify	To mechanically loosen soil or break down existing soil structure.
Settlement	Downward movement.
Skin Friction (Side Shear)	The frictional resistance developed between soil and an element of the structure such as a drilled pier.
Soil (Earth)	Sediments or other unconsolidated accumulations of solid particles produced by the physical and chemical disintegration of rocks, and which may or may not contain organic matter.
Strain	The change in length per unit of length in a given direction.
Stress	The force per unit area acting within a soil mass.
Strip	To remove from present location.
Subbase	A layer of specified material in a pavement system between the subgrade and base course.
Subgrade	The soil prepared and compacted to support a structure, slab or pavement system.

APPENDIX D

PAVEMENT DESIGN CALCULATIONS

PAVEMENT SECTION ALTERNATIVES DIAGRAM

AASHTO FLEXIBLE PAVEMENT DESIGN

Project: East 144th Avenue Improvements
Location: York Street to Colorado Blvd., Thornton, CO

CGG Project No.: 18.22.099
Scenario: New Travel Lanes, Minor Collector

SN Determination

$ESAL_{20}$ =	3,394,500	*ESALs Applications Over Design Period*	Typ. Range 0.1 to 80 million
R =	90 %	*Reliability*	Typ. Range 80 to 95%
S_o =	0.44	*Standard Deviation*	Typ. Range 0.3 to 0.5
M_r =	3,025 psi	*Subgrade Resilient Modulus*	Typ. Range 3000 to 9000 psi
P_i =	4.5	*Initial Serviceability*	Typ. Range 4.4 to 4.8
P_t =	2.5	*Terminal Serviceability*	Typ. Range 2.0 to 3.0

Design SN 5.43

Composite AC+ABC Alternative on A-7-6 Subgrade

Layer No.	Description	Layer Coefficient, ai	Drainage Coefficient, mi	Layer Thickness, in	SN
1	AC	0.44	1.00	**7.50**	3.30
2	ABC	0.14	1.00	**15.50**	2.17
				Trial SN	5.47

Design SN to Match 5.43
Design is sufficient

Full-Depth AC Alternative on A-7-6 Subgrade

Layer No.	Description	Layer Coefficient, ai	Drainage Coefficient, mi	Layer Thickness, in	SN
1	AC	0.44	1.00	**12.50**	5.50
				Trial SN	5.50

Design SN to Match 5.43
Design is sufficient

AASHTO RIGID PAVEMENT DESIGN

Project: East 144th Avenue Improvements
Location: York Street to Colorado Blvd., Thornton, CO

CGG Project No.: 18.22.099
Scenario: New Travel Lanes, Minor Collector

$ESAL_{20}$ =	3,394,500		*ESALs Applications Over Design Period*	Typ. Range 0.5 to 100 million
PCC MR =	650	psi	*Concrete Modulus of Rupture*	Typ. Range 550 to 750 psi
E =	3,400,000	psi	*Concrete Elastic Modulus*	Typ. Range 3 to 6 million psi
k-value =	100	psi/in	*Modulus of Subgrade Reaction*	Typ. Range 100 to 500 psi/in
R =	90	%	*Reliability*	Typ. Range 80 to 95%
S_o =	0.34		*Standard Deviation*	Typ. Range 0.3 to 0.5
J =	3.6		*Load Transfer Coefficient*	Typ. Range 2.2 to 4.4
C_d =	1.0		*Drainage Coefficient*	Typ. Range 0.9 to 1.1
P_i =	4.5		*Initial Serviceability*	Typ. Range 4.5 to 4.8
P_t =	2.5		*Terminal Serviceability*	Typ. Range 2.0 to 3.0

DESIGN D, inches, = 9.1

AASHTO FLEXIBLE PAVEMENT DESIGN

Project: East 144th Avenue Improvements
Location: York Street to Colorado Blvd., Thornton, CO

CGG Project No.: 18.22.099
Scenario: Rehabilitation - York St. to Madison St.

SN Determination

$ESAL_{20}$ =	3,394,500	*ESALs Applications Over Design Period*	Typ. Range 0.1 to 80 million
R =	90 %	*Reliability*	Typ. Range 80 to 95%
S_o =	0.44	*Standard Deviation*	Typ. Range 0.3 to 0.5
M_r =	3,025 psi	*Subgrade Resilient Modulus*	Typ. Range 3000 to 9000 psi
P_i =	4.5	*Initial Serviceability*	Typ. Range 4.4 to 4.8
P_t =	2.5	*Terminal Serviceability*	Typ. Range 2.0 to 3.0

Design SN 5.43

Overlay Design, Average Existing Pavement = 13 inches, Assume 2" Mill Depth

Layer No.	Description	Layer Coefficient, ai	Drainage Coefficient, mi	Layer Thickness, in	SN
1	AC	0.44	1.00	**5.00**	2.20
2	Existing AC	0.30	1.00	**11.00**	3.30
				Trial SN	5.50

Design SN to Match 5.43

Design is sufficient

AASHTO FLEXIBLE PAVEMENT DESIGN

Project: East 144th Avenue Improvements
Location: York Street to Colorado Blvd., Thornton, CO

CGG Project No.: 18.22.099
Scenario: Rehabilitation - Madison St. to Colorado Blvd.

SN Determination

$ESAL_{20}$ =	3,394,500	*ESALs Applications Over Design Period*	Typ. Range 0.1 to 80 million
R =	90 %	*Reliability*	Typ. Range 80 to 95%
S_o =	0.44	*Standard Deviation*	Typ. Range 0.3 to 0.5
M_r =	3,025 psi	*Subgrade Resilient Modulus*	Typ. Range 3000 to 9000 psi
P_i =	4.5	*Initial Serviceability*	Typ. Range 4.4 to 4.8
P_t =	2.5	*Terminal Serviceability*	Typ. Range 2.0 to 3.0

Design SN 5.43

Overlay Design, Average Existing Pavement = 5.5 inches, Assume 2" Mill Depth

Layer No.	Description	Layer Coefficient, ai	Drainage Coefficient, mi	Layer Thickness, in	SN
1	AC	0.44	1.00	**10.00**	4.40
2	Existing AC	0.30	1.00	**3.50**	1.05
				Trial SN	5.45

Design SN to Match 5.43

Design is sufficient

Traffic Area		Pavement Section Thickness (Inches)			
		Asphalt Concrete Surface	Aggregate Base Course	Portland Cement Concrete	Total
Minor Arterial ***East 144th Avenue*** $ESAL_{20}$=3,394,500	A	7-½	15-½	--	23
	B	12-½	--	--	12-½
	C	--	--	9-½	9-½

PAVEMENT DESIGN INVESTIGATION

1 APPROXIMATE BORING LOCATIONS

1 DENOTES BORING W/ ASPHALT CORE SAMPLE

FIGURE 4 –PAVEMENT ALTERNATIVES DIAGRAM
PAVEMENT THICKNESS DESIGN
144th AVENUE WIDENING
THORNTON, COLORADO
CGG PROJECT NO. 18.22.099

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