Geotechnical Engineering Report

Proposed Material/Equipment Storage Buildings

Fort Logan National Cemetery

4400 West Kenyon Avenue

Denver, Colorado

June 12, 2014

Terracon Project No. 25145055

Prepared for:

FourFront Design, Inc.
Rapid City, South Dakota

Prepared by:

Terracon Consultants, Inc.
Wheat Ridge, Colorado

Terracon

June 12, 2014

FourFront Design, Inc.
517 Seventh Street
Rapid City, South Dakota 57701

Attn: Mr. Garry Black, Federal Program Manager
P: 605.342.9470
E: GBlack@4FRONT.biz

Re: Geotechnical Engineering Report
Proposed Material/Equipment Storage Buildings
Fort Logan National Cemetery
4400 West Kenyon Avenue
Denver, Colorado
Terracon Project Number: 25145055

Mr. Black:

Terracon Consultants, Inc. (Terracon) has completed the geotechnical engineering exploration for the above referenced project. This study was performed in general accordance with our proposal number P25130788 dated November 19, 2013. This report presents the findings of the subsurface exploration and provides geotechnical recommendations concerning earthwork and the design and construction of foundations and slabs-on-grade for the proposed project.

We appreciate the opportunity to be of service to you on this project. If you have any questions concerning this report, or if we may be of further service, please contact us.

Sincerely,
TERRACON CONSULTANTS, INC.

COLORADO LICENSED THOMAS J. NEVIN 39525 6/12/2014 PROFESSIONAL ENGINEER

Thomas J. Nevin, P.E.
Senior Project Engineer

Scott Myers, P.E.
Senior Project Engineer

Enclosures
cc: 3 – Above
1 - File

TABLE OF CONTENTS

TABLE OF CONTENTS (Cont'd)

EXECUTIVE SUMMARY

A geotechnical engineering exploration has been performed for the proposed material/equipment storage buildings at Fort Logan National Cemetery located at 4400 West Kenyon Avenue in Denver, Colorado. Based on the information obtained from our subsurface exploration and the laboratory testing completed, the site appears suitable for the proposed construction; however, the following geotechnical conditions will need to be considered:

- Up to 8 feet of fill was encountered on the subject site. We do not possess any information regarding whether the fill was placed under the observation of a geotechnical engineer. In our opinion, the existing fill is likely acceptable to support foundation systems and interior floor systems, provided the anticipated movement is acceptable. The anticipated movement can be reduced by overexcavation, reprocessing of the existing fill materials. Some removal and replacement may be required if unsuitable or soft materials are exposed.

- Based on the geotechnical engineering analyses, it is our opinion the proposed buildings could be supported by spread footing foundation systems constructed on existing fill, new engineered fill or native soils, provided the owner is willing to accept the associated risk of movement. If movement cannot be tolerated, then the buildings could be supported on deep foundations such as drilled piers.

- Based on the properties of the subsurface materials, conventional slab-on-grade construction will be acceptable, provided movement can be tolerated. The anticipated movement can be reduced by overexcavation, reprocessing of the existing fill materials. If the owner is not willing to accept some risk of movement, the interior floor system should be designed as a structurally supported floor.

- The 2009 International Building Code, Table 1613.5.2 IBC seismic site classification for this site is C.

- It has been our experience that portions of subgrade materials below existing pavements/hardscape will likely be relatively moist to nearly saturated and yielding to unstable. This phenomenon is most likely due to moisture collecting in the subgrade through cracks or seams in the pavements/hardscape and not drying due to the presence of the pavements/hardscape. After removal of pavements/hardscape, the contractor should expect unstable subgrade materials that will need to be stabilized prior to construction of new pavements. We anticipate the subgrade can be stabilized by scarifying the subgrade soils to a depth of about 12 inches, processing the scarified subgrade soils, allowing the soils to dry, and compacting the subgrade materials in-place. If scarifying and drying is performed, several days may be required before the subgrade is stable enough for recompaction and paving, depending on the weather.

However, the contractor should be prepared to perform more aggressive stabilization methods such as removal and replacement or by other means discussed in the report

- Close monitoring of the construction operations discussed herein will be critical in achieving the design subgrade support. We therefore recommend that Terracon be retained to monitor this portion of the work.

This summary should be used in conjunction with the entire report for design purposes. It should be recognized that details were not included or fully developed in this section, and this 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.

GEOTECHNICAL ENGINEERING REPORT
PROPOSED MATERIAL/EQUIPMENT STORAGE BUILDINGS
FORT LOGAN NATIONAL CEMETERY
4400 WEST KENYON AVENUE
DENVER, COLORADO

Terracon Project No. 25145055
June 12, 2014

1.0 INTRODUCTION

A geotechnical engineering report has been completed for the proposed material/equipment storage buildings at Fort Logan National Cemetery located at 4400 West Kenyon Avenue in Denver, Colorado.

As part of our subsurface exploration, three (3) borings were drilled to depths of about 25 to 30 feet each below the existing site grade. The Boring Logs and the Boring Location Plan are included in Appendix A of this report.

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

- Subsurface soil conditions
- Groundwater levels
- Earthwork
- Foundation design and construction
- Floor slab design and construction
- Lateral earth pressure
- Seismic considerations
- Grading and drainage
- Pavement thickness design

2.0 PROJECT INFORMATION

2.1 Project Description

Item	Description
Site layout	See Appendix A, Exhibit A-2, Boring Location Plan
Proposed construction	We understand the proposed development will consist of construction of two, single-story pre-engineered metal storage buildings with approximate plan dimensions of about 35 by 130 and 60 by 130 feet. We anticipate basement construction will not be incorporated in the buildings.
Maximum loads	Columns: 50 to 100 kips (assumed) Walls: 2 to 4 klf (assumed)

Item	Description
	Floor slabs: 125 psf max (assumed)
Excavation depths	We anticipate excavations of up to 3 feet will be required for the proposed construction.
Grading	We assume maximum cuts and fills will be on the order of about 5 feet to bring the site to construction grade.
Infrastructure	Installation of underground utilities within about 5 feet of finished site grades. Access drives and parking areas will also be constructed as part of the development of the subject.

2.2 Site Location and Description

Item	Description
Location	The proposed material/equipment storage buildings will be located within the equipment yard at the Fort Logan National Cemetery at 4400 West Kenyon Avenue in Denver, Colorado.
Current development	The site is currently occupied by a storage and maintenance yard.
Current ground cover	Ground cover on the site is asphalt.
Existing topography	We anticipate the site is relatively flat with an elevation difference across the site of about 3 feet or less.

3.0 SUBSURFACE CONDITIONS

3.1 Typical Profile

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

Material Description	Approximate Depth to Bottom of Stratum Below Existing Site Grade	Relative Density / Consistency
Fill materials consisting of sandy lean clay and clayey sand	About 5-1/2 to 8 feet	Clay: Stiff to very stiff Sand: Loose to dense
Native soils consisting of sandy lean clay	About 8 feet, not present in Boring No. 3	Hard
Bedrock consisting of claystone	About 25 to 30 feet, maximum depth explored	Medium hard to very hard

Stratification boundaries on the boring logs represent the approximate location of changes in soil and material types; in-situ, the transition between materials may be gradual. Further details of the borings can be found on the Boring Logs in Appendix A.

Based on the laboratory testing, the fill materials have non- to low expansion potential. The laboratory testing results indicates the claystone bedrock is low to moderately expansive. The samples tested have the following physical and engineering properties:

Boring No.	Depth (ft.)	Fines Content (%)	Liquid Limit (%)	Plasticity Index (%)	Expansion/ Consolidation (%)*
1	4-1/2				0
2	9	81	59	21	+1.4
3	2	30	38	20	0
3	9				+3.5

* Expansion/consolidation testing was performed under a 500 psf surcharge load

Laboratory testing for water soluble sulfate concentration indicated negligible values of about 1 and 2 mg/l. A summary of the laboratory test results is included in Appendix B.

3.2 Groundwater

The borings were observed while drilling for the presence and level of groundwater. The groundwater levels observed while drilling and after completion are presented on the Boring Logs included in Appendix A, and are summarized below.

Boring No.	Depth to groundwater while drilling (ft.)	Depth to groundwater at least one day after drilling (ft.)
1	21.5	--*
2	15.3	--*
3	21.6	--*

* Due to safety concerns, the borings were backfilled immediately after obtaining the initial groundwater measurements.

These observations represent groundwater conditions at the time of the field exploration, and may not be indicative of other times or at other locations. Groundwater levels can be expected to fluctuate with varying seasonal and weather conditions, and other factors.

Based upon review of USGS maps ([1]Hillier, et al, 1983), regional groundwater beneath the project area is expected to be encountered in unconsolidated alluvial deposits on the site at depths ranging from 10 to 20 feet below present ground surface.

Zones of perched and/or trapped groundwater may occur at times in the subsurface soils overlying bedrock, on top of the bedrock surface or within permeable fractures in the bedrock materials. The location and amount of perched water is 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.

Groundwater level fluctuations occur due to seasonal variations in the amount of rainfall, runoff and other factors not evident at the time the borings were performed. Therefore, groundwater levels during construction or at other times in the life of the structure may be higher or lower than the levels indicated on the boring logs. The possibility of groundwater level fluctuations should be considered when developing the design and construction plans for the project.

4.0 RECOMMENDATIONS FOR DESIGN AND CONSTRUCTION

4.1 Geotechnical Considerations

Based on subsurface conditions encountered in the borings, the site appears suitable for the proposed construction from a geotechnical point of view provided certain precautions and design and construction recommendations outlined in this report are followed. We have identified geotechnical conditions that could impact design and construction of the proposed building and other site improvements.

4.1.1 Existing Fill Materials

Existing fill was encountered to depths of about 5-1/2 to 8 feet in the exploratory borings. We do not possess any information regarding whether the fill was placed under the observation of a geotechnical engineer.

Support of foundations and slabs-on-grade on or above existing fill soils is discussed in this report. However, even with the recommended construction testing services, there is an inherent risk for the owner that compressible fill or unsuitable material within or buried by the fill will not be discovered. This risk cannot be eliminated without completely removing the existing fill, but can be minimized by thorough exploration, testing and remedial earthwork.

Terracon's services did not include delineating the horizontal or vertical extent of the existing fill material. There exists the potential for additional construction debris and/or domestic trash to

[1]Hillier, Donald E.; Schneider, Paul A., Jr.; and Hutchinson, E. Carter, 1983, ***Depth to Water Table (1976-1977) in the Greater Denver Area, Front Range Urban Corridor, Colorado,*** United States Geological Survey, Map I-856-K.

be encountered within the fill at this site. Based on our experience and our subsurface exploration, we believe the potential is considered to be low. This could be verified by additional geotechnical exploration or evaluation at the site. If additional exploration is not performed, the owner should make allowances for such conditions to exist in the preparation of the project budget and/or construction plans.

Based upon the field penetration resistance values, in-situ dry densities and moisture contents it is our opinion the existing fill is likely acceptable to support foundation systems and interior floor systems, provided the anticipated movement is acceptable. The anticipated movement can be reduced by overexcavation, reprocessing of the existing fill materials. We recommend we observed the fill materials during the earthwork and foundation excavation to further evaluate the existing fill materials. Some removal and replacement may be required if unsuitable or soft materials are exposed.

4.1.2 Structural Recommendations

Based on the geotechnical engineering analyses, it is our opinion the proposed buildings could be supported by spread footing foundation systems constructed on existing fill, new engineered fill or native soils, provided the owner is willing to accept the associated risk of movement. The anticipated movement of spread footings constructed on the existing fill can be reduced by overexcavation and reprocessing of the existing fill materials. If movement cannot be tolerated, then the buildings could be supported on deep foundations such as drilled piers.

If the owner is willing to accept some risk of movement, slabs-on-grade may be utilized. The anticipated movement can be reduced by overexcavation and reprocessing of the existing fill materials.

Design and construction recommendations for the foundation system and other earth connected phases of the project are outlined in subsequent sections.

4.2 Earthwork

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 Terracon. The evaluation of earthwork should include overexcavation operations, observation and testing of engineered fills, subgrade preparation, foundation bearing soils and other geotechnical conditions exposed during the construction of the project.

4.2.1 Site Preparation

Strip and remove unsuitable fills and other deleterious materials from proposed building areas. All exposed surfaces should be free of mounds and depressions which could prevent uniform compaction.

Stripped materials consisting of unsuitable fills and organic materials should be wasted from the site or used to revegetate landscaped areas or exposed slopes after completion of grading operations.

Areas to receive fill should be initially graded to create a relatively level surface in order to provide for a relatively uniform thickness of fill beneath the proposed structure. All exposed areas which will receive fill, once properly cleared, should be scarified to a minimum depth of 8 inches, conditioned to near optimum moisture content and compacted.

Although evidence of underground facilities such as grease pits, septic tanks, and cesspools was not observed during the site reconnaissance, such features could be encountered during construction. If unexpected fills or underground facilities are encountered, such features should be removed and the excavation thoroughly cleaned prior to fill placement and/or construction.

It is anticipated that excavations for the proposed construction can be accomplished with conventional earthmoving equipment.

Based on conditions encountered during drilling, we do not anticipate groundwater will be encountered during construction.

It has been our experience that portions of subgrade materials below existing pavements/hardscape will likely be relatively moist to nearly saturated and yielding to unstable. This phenomenon is most likely due to moisture collecting in the subgrade through cracks or seams in the pavements/hardscape and not drying due to the presence of the pavements/hardscape. After removal of pavements/hardscape, the contractor should expect unstable subgrade materials that will need to be stabilized prior to construction of new pavements. Terracon anticipates the subgrade can be stabilized by scarifying the subgrade soils to a depth of about 12 inches, processing the scarified subgrade soils, allowing the soils to dry, and compacting the subgrade materials in-place. If scarifying and drying is performed, several days may be required before the subgrade is stable enough for recompaction and paving, depending on the weather. However, the contractor should be prepared to perform more aggressive stabilization methods such as removal and replacement or by other means discussed in the report.

The stability of subgrade soils may be affected by precipitation and seasonal groundwater conditions, repetitive construction traffic or other factors. If unstable conditions are encountered or develop during construction, workability may be improved by overexcavation of wet zones and mixing these soils with crushed gravel or recycled concrete and recompaction. Use of lime, fly ash, kiln dust, cement or geotextiles could also be considered as a stabilization technique. Laboratory evaluation is recommended to determine the effect of chemical stabilization on subgrade soils prior to construction. Lightweight excavation equipment may be required to reduce subgrade pumping.

The individual contractor(s) is responsible for designing and constructing stable, temporary excavations as required maintaining stability of both the excavation sides and bottoming. 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.

4.2.2 Material Types

Engineered fill should meet the following material property requirements:

Fill Type [1]	USCS Classification	Acceptable Location for Placement
On-Site Sand Soils	SC	Sand soils are considered suitable for use as compacted fill below foundation and slab areas.
On-Site Clay Soils	CL	On-site clay soils are considered suitable for reuse as compacted fill below foundation and slabs.
Imported Soils	Varies	Imported soils meeting the gradation outlined herein can be considered acceptable for use as engineered fill beneath foundations, slabs and pavements.

1. Controlled, compacted fill should consist of approved materials that are free of organic matter and debris. Frozen material should not be used, and fill should not be placed on a frozen subgrade. A sample of each material type should be submitted to the geotechnical engineer for evaluation.
2. Debris, if encountered, should be processed to maximum size of 3 inches and blended with on-site soils prior to reuse.

Imported soils (if required) should meet the following material property requirements:

Gradation	Percent finer by weight (ASTM C136)
3”	100
No. 4 Sieve	50-100
No. 200 Sieve	15-70

- Liquid Limit……………………………………………………30 (max)
- Plastic Limit…………………………………………………..15 (max)
- Maximum Expansive Potential (%)………………………..1.5*

*Measured on a sample compacted to approximately 95 percent of the ASTM D698 maximum dry density at optimum water content. The sample is confined under a 200 psf surcharge and submerged.

Consideration could be given to reusing concrete and asphalt construction debris, if encountered provided the materials are properly processed and blended with on-site materials.

In order to reuse the concrete and asphalt, the materials should be processed to a maximum size of 3-inches and blended with the on-site soils at a ratio of 30 percent asphalt/concrete to 70 percent soil. This blended material can be used in both building and flatwork areas.

4.2.3 Compaction Requirements

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.

Item	Description
Fill Lift Thickness	8-inches or less in loose thickness when heavy, self-propelled compaction equipment is used 4 to 6-inches in loose thickness when hand-guided equipment (i.e. jumping jack, plate compactor) is used
Compaction Requirements	Minimum 95% of the materials standard Proctor maximum dry density (ASTM D698)
Moisture Content Cohesive Soil (clay)	0 to +3 % of the optimum moisture content
Moisture Content Cohesionless Soil (sand)	-3 to +3 % of the optimum moisture content

1. We recommend engineered fill be tested for moisture content and compaction during placement. Should the results of the in-place density tests indicate the specified moisture or compaction limits have not been met, the area represented by the test should be reworked and retested as required until the specified moisture and compaction requirements are achieved.
2. Specifically, moisture levels should be maintained low enough to allow for satisfactory compaction to be achieved without the fill material pumping when proofrolled.
3. Moisture conditioned clay soils should not be allowed to dry out. A loss of moisture within these materials could result in an increase in the materials expansive potential. Subsequent wetting of these materials could result in undesirable movement.
4. Processed asphalt or concrete (if used) should be processed to a maximum size of 3-inches in diameter. Additional testing methods may be required at the time of placement in order to determine acceptable compaction effort.

4.2.4 Excavation and Trench Construction

Excavations into the on-site soils will encounter a variety of conditions. Excavations within the clay fill and native clay soils may remain stable for a short period of time. Caving soils are likely when excavating into sand soils. The individual contractor(s) should be made responsible for designing and constructing stable, temporary excavations as required 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.

Soils penetrated by the proposed excavations may vary significantly across the site. The soil classifications are based solely on the materials encountered in the exploratory borings. The contractor should verify that similar conditions exist throughout the proposed area of excavation. If different subsurface conditions are encountered at the time of construction, the actual conditions should be evaluated to determine any excavation modifications necessary to maintain safe conditions.

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.

4.2.5 Grading and Drainage

All grades must be adjusted to provide positive drainage away from the buildings during construction and maintained throughout the life of the proposed project. Infiltration of water into foundation excavations must be prevented during construction. Landscaped irrigation adjacent to the foundation system should be minimized or eliminated. Water permitted to pond near or adjacent to the perimeter of the structure (either during or post-construction) can result in significantly higher soil movements than those discussed in this report. As a result, any estimations of potential movement described in this report cannot be relied upon if positive drainage is not obtained and maintained, and water is allowed to infiltrate the fill and/or subgrade.

Exposed ground should be sloped at a minimum of 5 percent grade for at least 10 feet beyond the perimeter of the structure, where possible. The use of swales, chases and/or area drains may be required to facilitate drainage in unpaved areas around the perimeter of the structure. Backfill against footings and in utility and sprinkler line trenches should be well compacted and free of all construction debris to reduce the possibility of moisture infiltration. After construction and prior to project completion, we recommend that verification of final grading be performed to document that positive drainage, as described above, has been achieved.

Where paving or flatwork abuts the structure, care should be taken that joints are properly sealed and maintained to prevent the infiltration of surface water. Where landscape or xeriscape areas are within 10 feet of the foundations, the areas shall have positive drainage away from the foundation that is not hindered by landscape edging, grade variations or vegetation. In addition, consideration should be given to snow removal practices that will minimize the stockpiling of snow in planter and landscaped areas adjacent to structural improvements.

Roof drains should discharge on pavements or be extended away from the building a minimum of 10 feet through the use of splash blocks or downspout extensions. A preferred alternative is to have the roof drains discharge to storm sewers by solid pipe or daylighted to a detention pond or other appropriate outfall.

4.2.6 Earthwork Construction Considerations

Although the exposed subgrades are anticipated to be relatively stable upon initial exposure, unstable subgrade conditions could develop during general construction operations, particularly if the soils are wetted and/or subjected to repetitive construction traffic. Should unstable subgrade conditions develop, stabilization measures will need to be employed. Options for subgrade stabilization can include removal of unsuitable material and replacement with approved fill material. An alternative can include the use of TX-140 Tensar geogrid overlain by CDOT Class 5 or 6 aggregate base course. The depth of aggregate base course will depend on the severity of unstable soils.

Upon completion of filling, care should be taken to maintain the subgrade moisture content prior to construction of foundations and floor slabs. Construction traffic over the completed subgrade should be avoided to the extent practical. Excessive traffic could increase compaction and reduce moisture content within the subgrade.

The site should also be graded to prevent ponding of surface water on prepared subgrade or in excavations. Excessive wetting of the on-site soils will reduce the materials ability to support fills and/or structures. If the subgrade becomes significantly wetted, the affected area should be removed, allowed to dry to near optimum moisture content and should be properly compacted at the recommended moisture content. If the subgrade should become frozen, saturated, or disturbed, the affected material should be removed or these materials should be scarified, moisture conditioned, and recompacted prior to foundation and slab-on-grade construction.

Terracon should be retained during the construction phase of the project to observe earthwork and to perform necessary tests and observations during overexcavation operations, subgrade preparation; placement and compaction of controlled compacted fills; backfilling of excavations into the completed subgrade, and just prior to construction of slabs-on-grade.

4.2.7 Soluble Sulfate Test Results

The following table lists the results of laboratory soluble sulfate testing. These values may be used to estimate potential corrosive characteristics of the on-site soils with respect to contact with the various underground materials which will be used for project construction.

Boring No.	Sample Depth(feet)	Soluble Sulfate[1] (mg/l)
2	9	1
3	2	2

1. Results of soluble sulfate testing indicate that samples of the on-site soils tested possess negligible sulfate concentrations when classified in accordance with Table 4.3.1 of the ACI Design Manual. The results of the testing indicate ASTM Type I Portland Cement is suitable for project concrete on and below grade. However, if there is no (or minimal) cost differential, use of ASTM Type II Portland Cement is recommended for additional sulfate resistance of construction concrete. Concrete should be designed in accordance with the provisions of the ACI Design Manual, Section 318, Chapter 4.

4.3 Foundations

Based on the geotechnical engineering analyses, it is our opinion the proposed buildings could be supported by spread footing foundation systems constructed on existing fill, new engineered fill or native soils, provided the owner is willing to accept the associated risk of movement. The anticipated movement associated with spread footings constructed on the existing fill can be reduced by overexcavation and reprocessing of the existing fill materials. If movement cannot be tolerated, then the buildings could be supported on deep foundations such as drilled piers.

4.3.1 Spread Footing Foundation Design Recommendations

Design recommendations for spread footing foundation systems are presented in the following paragraphs.

Description	Option 1	Option 2
Required overexcavation depth	None	All existing fill must be removed and replaced with engineered fill
Material at foundation base	Existing fill	Engineered fill[4]
Maximum net allowable bearing pressure	1,500 psf	2,500 psf
Coefficient of friction at base of footing	0.3	0.3
Estimated total movement	About 1 inch or more	Less than 1 inch
Estimated differential movement[5]	About ½ to ¾ inch	About ½ inch

1. Exterior footings should be placed a minimum of 36 inches below finished grade for frost protection and to provide confinement for the bearing soils.
2. Finished grade is the lowest adjacent grade for perimeter footings and floor level for interior footings.
3. Interior footings in heated areas should bear a minimum of 12 inches below finished grade.
4. Engineered fill may consist of on-site soils free of deleterious material or imported fill that has been properly moisture conditioned and compacted, as recommended in this report.
5. The estimated differential movement is based on a distance of about 40 feet.

Footings should be proportioned on the basis of equal total dead load pressure to reduce differential movement between adjacent footings. Additional foundation movements could occur if water from any source infiltrates the foundation soils; therefore, proper drainage should be provided in the final design and during construction and throughout the life of the structure. Failure to maintain the proper drainage as recommended in the "Grading and Drainage" section of this report will nullify the movement estimates provided above.

4.3.2 Spread Footing Construction Considerations

Spread footing foundation systems may be constructed on existing fill, new engineered fill or native soils, provided the owner is willing to accept the associated risk of movement, as presented in the previous section.

Engineered fill below foundations should be moisture conditioned and compacted as recommended in the "Compaction Requirements" section of this report.

Footings and foundation walls should be reinforced as necessary to reduce the potential for distress caused by differential foundation movement. The use of joints at openings or other discontinuities in masonry walls is recommended.

Unstable soil conditions may be encountered in the base of the excavations for the proposed footings. If unstable conditions are encountered, these will need to be stabilized prior to the placement of structural fill or constructing the footings. The use of angular rock, recycled concrete and/or gravel pushed into the yielding subgrade are generally considered suitable means of stabilizing soft soils below foundations. Alternatively, the use of geogrid materials in conjunction with gravel have also been successfully used to stabilize soft soil conditions below foundations.

If unstable soil conditions are encountered, a representative from our office should observe the conditions to provide site specific recommendations.

4.4 Seismic Considerations

Based on our subsurface exploration and laboratory testing, it is our opinion that the soils have a low risk of liquefaction. The following table presents the seismic site classification based on the 2009 International Building Code:

Code Used	Site Classification
2009 International Building Code (IBC)[1]	C[2]

1. In general accordance with the *2009 International Building Code,* Table 1613.5.2.
2. The 2009 International Building Code (IBC) requires a site soil profile determination extending a depth of 100 feet for seismic site classification. The current scope requested does not include the required 100 foot soil profile determination. The borings for the project extended to a maximum

depth of about 30 feet and this seismic site class definition considers that similar soil conditions exist below the maximum depth of the subsurface exploration. Additional exploration to deeper depths could be performed to confirm the conditions below the current depth of exploration. Alternatively, a geophysical exploration could be utilized in order to confirm the seismic site class.

4.5 Interior Floors

Slabs-on-grade may be utilized for the interior floor systems provided some movement can be tolerated. We estimate potential movement on the order of about 1 inch for slabs-on-grade constructed on the existing fill and native soils. If slabs-on-grade are constructed on new engineered fill, we estimate the potential movement to be on the order of about ½ inch. If the outlined floor slab movement cannot be tolerated, then a structural floor should be used.

4.5.1 Design Recommendations

If the owner is willing to accept a higher risk of movement, slabs-on-grade may be constructed on the existing fill and native soils. If the owner would like to reduce the risk of slab-on-grade movement, existing fill below slabs-on-grade should be overexcavated, moisture treated and compacted back to grade.

Even when bearing on properly prepared fill, movement of the slab-on-grade floor system is possible should the subgrade soils undergo an increase in moisture content. If the owner cannot accept the risk of slab movement, a structural floor should be used.

For structural design of concrete slabs-on-grade, a modulus of subgrade reaction of 100 pounds per cubic inch (pci) may be used for point or limited area loads on floors constructed on existing fill or native soils. A modulus of subgrade reaction of 150 pci may be used for point or limited area loads on floors constructed on new engineered fill.

Additional floor slab design and construction recommendations are as follows:

- Positive separations and/or isolation joints should be provided between slabs and all foundations, columns or utility lines to allow independent movement.

- Control joints should be provided in slabs to control the location and extent of cracking.

- Interior trench backfill placed beneath slabs should be compacted in accordance with recommended specifications outlined below.

- The use of a vapor retarder should be considered beneath concrete slabs on grade that will be covered with wood, tile, carpet or other moisture sensitive or impervious coverings, or when the slab will support equipment sensitive to moisture. When conditions warrant the use of a vapor retarder, the slab designer and slab contractor should refer to ACI 302 for procedures and cautions regarding the use and placement of a vapor retarder.

- Floor slabs should not be constructed on frozen subgrade.

- Other design and construction considerations, as outlined in Section 302.1R of the *ACI Design Manual*, are recommended.

4.5.2 Interior Floor Construction Considerations

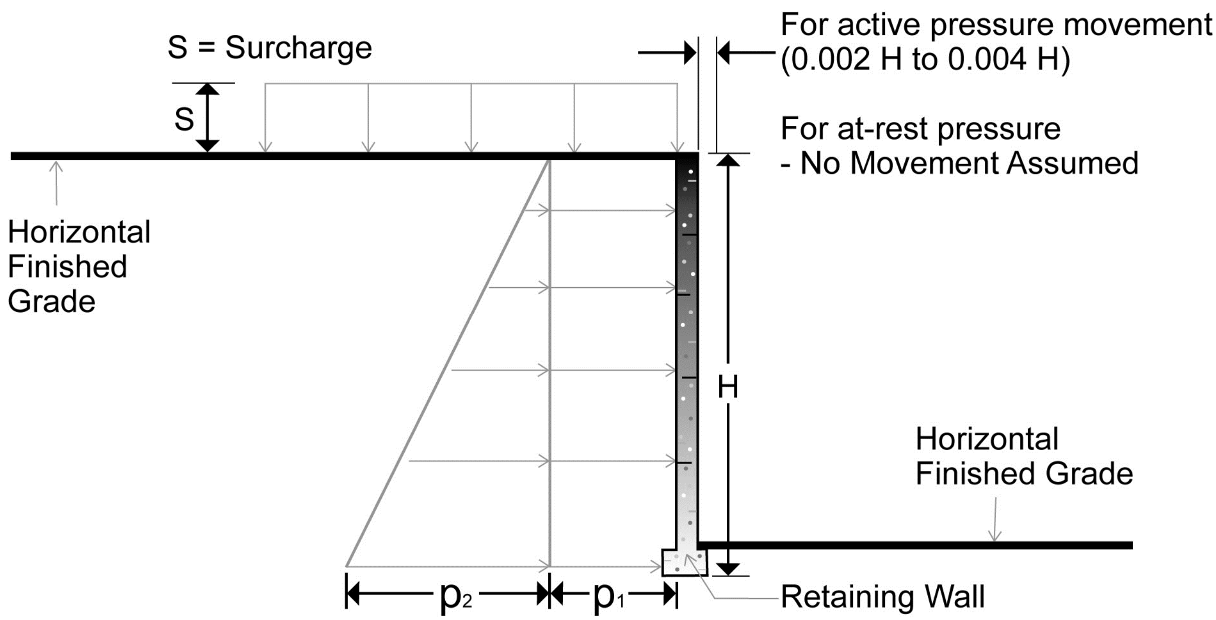
If the owner is willing to accept a higher risk of movement, slabs-on-grade may be constructed on the existing fill and native soils. If the owner would like to reduce the risk of slab-on-grade movement, existing fill below slabs-on-grade should be overexcavated, moisture treated and compacted back to grade.

If conventional slab-on-grade is utilized, at a minimum, we recommend the subgrade soils be scarified 12 inches, moisture treated and compacted. The moisture content and compaction of subgrade soils should be maintained until slabs have been constructed.

Floor slab movement could occur should the floor slab supporting soils be allowed to dry out and subsequently become rewetted, possibly resulting in potential excessive movement causing uneven floor slabs and severe cracking. Future wetting could occur due to over watering of landscaping, poor drainage, improperly functioning drain systems, and/or broken utility lines. Therefore, it is imperative that the recommendations outlined in the “Grading and Drainage” section of this report be followed.

4.6 Lateral Earth Pressures

Although we don’t anticipate walls will be constructed for the buildings that must resist lateral earth pressures, we have provided the following information if plans change. Walls with unbalanced backfill levels on opposite sides should be designed for earth pressures at least equal to those indicated in the following table. Earth pressures will be influenced by structural design of the walls, conditions of wall restraint, methods of construction and/or compaction and the strength of the materials being restrained. Two wall restraint conditions are shown. Active earth pressure is commonly used for design of free-standing cantilever retaining walls and assumes wall movement. The "at-rest" condition assumes no wall movement. The recommended design lateral earth pressures do not include a factor of safety and do not provide for possible hydrostatic pressure on the walls.



EARTH PRESSURE COEFFICIENTS

Earth Pressure Conditions	Coefficient For Backfill Type	Equivalent Fluid Density (pcf)	Surcharge Pressure, p_1 (psf)	Earth Pressure, p_2 (psf)
Active (Ka)	Granular - 0.33	40	(0.33)S	(40)H
	Lean Clay - 0.47	60	(0.47)S	(60)H
At-Rest (Ko)	Granular - 0.50	60	(0.50)S	(60)H
	Lean Clay - 0.64	80	(0.64)S	(80)H
Passive (Kp)	Granular - 3.0	360	---	---
	Lean Clay - 2.1	250	---	---

Applicable conditions to the above include:

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

To control hydrostatic pressure behind below grade walls we recommend that a drain be installed below the foundation of the wall with a collection pipe leading to a reliable discharge. If this is not possible, then combined hydrostatic and lateral earth pressures should be calculated for clay backfill using an equivalent fluid weighing 90 and 100 pcf for active and at-rest conditions, respectively. For granular backfill, an equivalent fluid weighing 85 and 90 pcf should be used for active and at-rest, respectively. These pressures do not include the influence of surcharge, equipment or floor loading, which should be added. Heavy equipment should not operate within a distance closer than the exposed height of below grade walls to prevent lateral pressures more than those provided.

4.7 Pavement Design and Construction

The design of privately maintained pavements for the project has been based on the procedures outlined by the Asphalt Institute (AI) and the American Concrete Institute (ACI). If improvements to public roadways are anticipated, a pavement design report meeting the City and County of Denver will need to be prepared for submittal, subsequent to final grading.

4.7.1 Design Traffic

We assumed the following design parameters for Asphalt Institute flexible pavement thickness design:

- Automobile Parking Areas
  - Parking stalls and parking lots for cars and pick-up trucks, up to 50 stalls
- Main Traffic Corridors
  - Parking lots with a maximum of 5 trucks per day
- Subgrade Soil Characteristics
  - USCS Classification – SC/CL (Poor Subgrade)

We assumed the following design parameters for ACI rigid pavement thickness design based upon the average daily truck traffic (ADTT):

- Automobile Parking Areas
  - ACI Category A-1: Automobile parking with an ADTT of 1 over 20 years
- Main Traffic Corridors
  - ACI Category B: Commercial entrance and service lanes with an ADTT of 25 over 20 years
- Subgrade Soil Characteristics
  - USCS Classification – SC/CL
- Concrete modulus of rupture value of 600 psi

The above automobile traffic areas correspond to an Equivalent (18 kip) Daily Load Applications (EDLA) of about 3 and the main traffic corridors correspond to an EDLA of about 10. We should be contacted to confirm and/or modify the recommendations contained herein if actual traffic volumes differ from the assumed values shown above.

4.7.2 Subgrade Soils

Based on a subgrade soil Unified Soil Classification of CL, AI classifies the subgrade soil as poor. Existing fill materials will most likely be encountered at the pavement construction elevation. Pavements constructed on the existing fill will have a moderate to high risk of movement. If the owner would like to reduce the risk of movement, we recommend 2 feet of the existing fill material be overexcavated, moisture conditioned and recompacted.

4.7.3 Recommended Minimum Pavement Sections and Materials

Recommended alternatives for flexible and rigid pavements are summarized for each traffic area as follows:

Traffic Area	Alternative	Recommended Pavement Thickness (Inches)			
		Asphalt Concrete Surface	Aggregate Base Course	Portland Cement Concrete	Total
Automobile Parking (AI Class I and ACI Category A)	A	5-1/2			5-1/2
	B	4	6		10
	C[1]			5	5
Main Traffic Corridors (AI Class III and ACI Category B)	A	6-1/2			6-1/2
	B	4	11		15
	C[1]			6	6

1. The minimum pavement section thickness per ACI

Each alternative should be investigated with respect to current material availability and economic conditions. A minimum 6-inch thickness of rigid reinforced concrete pavement is recommended at the location of dumpsters where trash trucks park and load, heavy equipment traffic and in areas of tight turning radius.

For analysis of pavement costs, the following specifications should be considered for each pavement component:

Pavement Component	**Colorado Department of Transportation Criteria**
Asphalt Concrete Surface	Grading S or SX
Aggregate Base Course	Class 5 or 6
Portland Cement Concrete	Class P

4.7.4 Construction Considerations

Site grading is generally accomplished early in the construction phase. However, as construction proceeds, the subgrade may be disturbed due to utility excavations, construction traffic, desiccation, or rainfall. As a result, the pavement subgrade may not be suitable for pavement construction and corrective action will be required. The subgrade should be carefully evaluated at the time of pavement construction for signs of disturbance or excessive rutting. If disturbance has occurred, pavement subgrade areas should be reworked, moisture conditioned, and properly compacted to the recommendations in this report immediately prior to paving.

We recommend the pavement areas be rough graded and then thoroughly proof rolled with a loaded tandem axle dump truck prior to final grading and 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 fills. All pavement areas should be moisture conditioned and properly compacted to the recommendations in this report immediately prior to paving.

The placement of a partial pavement thickness for use during construction is not recommended without a detailed pavement analysis incorporating construction traffic. In addition, if the actual traffic varies from the assumptions outlined above, we should be contacted to confirm and/or modify the pavement thickness recommendations outlined above.

4.7.5 Compliance

Recommendations for pavement design and construction presented in this report depend upon compliance with recommended material specifications. To assess compliance, observation and testing should be performed under the observation of the geotechnical engineer.

4.7.6 Pavement Performance

Future performance of pavements constructed on fill materials at this site will be dependent upon several factors, including:

- Maintaining stable moisture content of the subgrade soils both before and after pavement construction.
- Providing for a planned program of preventative maintenance.

Pavements could crack in the future primarily because of movement of the subgrade soils when subjected to an increase in moisture content to the subgrade. The cracking, while not desirable, does not necessarily constitute structural failure of the pavement, provided that timely maintenance, such as crack sealing is performed. Excessive movement and cracking could result if the subgrade soils are allowed to dry out before paving and subsequently become rewetted.

The performance of all pavements can be enhanced by minimizing excess moisture, which can reach the subgrade soils. The following recommendations should be considered at minimum:

- Site grading at a minimum 2 percent grade onto or away from the pavements.
- Water should not be allowed to pond behind curbs.
- Compaction of any utility trenches for landscaped areas to the same criteria as the pavement subgrade.
- Sealing all landscaped areas in or adjacent to pavements to minimize or prevent moisture migration to subgrade soils.
- Placing compacted backfill against the exterior side of curb and gutter.
- Placing curb, gutter and/or sidewalk directly on subgrade soils without the use of base course materials.
- Placing shoulder or edge drains in pavement areas adjacent to water sources.

Preventative maintenance should be planned and provided for an ongoing pavement management program in order to enhance future pavement performance. Preventative maintenance activities are intended to slow the rate of pavement deterioration and to preserve the pavement investment.

Preventative maintenance consists of both localized maintenance (e.g. crack sealing and patching) and global maintenance (e.g. surface sealing). Preventative maintenance is usually the first priority when implementing a planned pavement maintenance program and provides the highest return on investment for pavements.

5.0 ENVIRONMENTAL EVALUATION

During advancement of the soil borings, soil samples were collected at five foot intervals for field evaluation and for potential laboratory analysis. Upon removal of the sampler from the borehole, a portion of each soil sample into labeled, glass jars for potential laboratory analysis and another portion of the sample were placed into sealable plastic bags for field evaluation and screening utilizing the Ambient Temperature Headspace (ATH) method.

The ATH soil screening method involves placing a representative soil sample from select sampling intervals into sealable plastic bags, resealing the bags, and allowing the bag contents to equilibrate to the surrounding ambient conditions. After a stabilization period, the headspace vapors above the bagged soil sample were screened with a Mini-Rae photo-ionization detector (PID) equipped with a 10.6 electron-volt ultraviolet lamp source to detect for the potential presence of volatile organic vapors. The Mini-Rae PID is an instrument capable of measuring volatile vapor concentrations in parts per million (ppm). Terracon calibrated the PID in accordance with the manufacturer's recommendations before the field activities.

Three soil samples were collected for laboratory analysis from the soil borings during the investigation. The soil samples were placed into laboratory provided jars, labeled, stored in an ice-filled cooler, and hand-delivered under chain-of custody procedures to Summit Scientific Laboratory of Golden, Colorado. The samples were analyzed for volatile organic compounds (VOCs) by EPA Method 8260B. The laboratory report is provided in Appendix D.

Field screening detected the presence of volatile vapor concentrations ranging from non-detectable to the highest site reading of 3.0 parts per million (ppm) in the soil sample collected from soil boring B-1 between an approximate depth of 10 and 11.5 feet below ground surface. The field screening results are provided on the soil boring logs in Appendix A. Laboratory analysis did not detect the presence of VOCs above the analytical method detection limits in the soil samples.

A groundwater sample was collected from each of the borings for laboratory analysis. The groundwater samples were collected from the soil boring utilizing a disposable, single-use bailer. After packaging the groundwater sample into laboratory-provided containers, Terracon recorded the sample time on each container label in permanent ink and place the filled containers in an ice-filled cooler and hand-delivered under chain-of custody procedures to Summit Scientific.

Laboratory analysis of the groundwater sample by EPA Method 8260B did not detect the presence of VOCs above the analytical method detection limits. The laboratory report is provided in Appendix D.

The analytical scope of services was intended to assess for potential VOCs and was not intended to identify each chemical compound possibly present on the site.

6.0 GENERAL COMMENTS

Terracon should be retained to review the final design plans and specifications so comments can be made regarding interpretation and implementation of our geotechnical recommendations in the design and specifications. Terracon should also be retained to provide testing and observation during the overexcavation (if performed), grading, foundation and 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 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, either express or implied, are intended or made. Site safety, excavation support, and dewatering requirements are the responsibility of others. In the event that changes 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 Terracon reviews the changes, and either verifies or modifies the conclusions of this report in writing.

APPENDIX A

FIELD EXPLORATION

Field Exploration Description

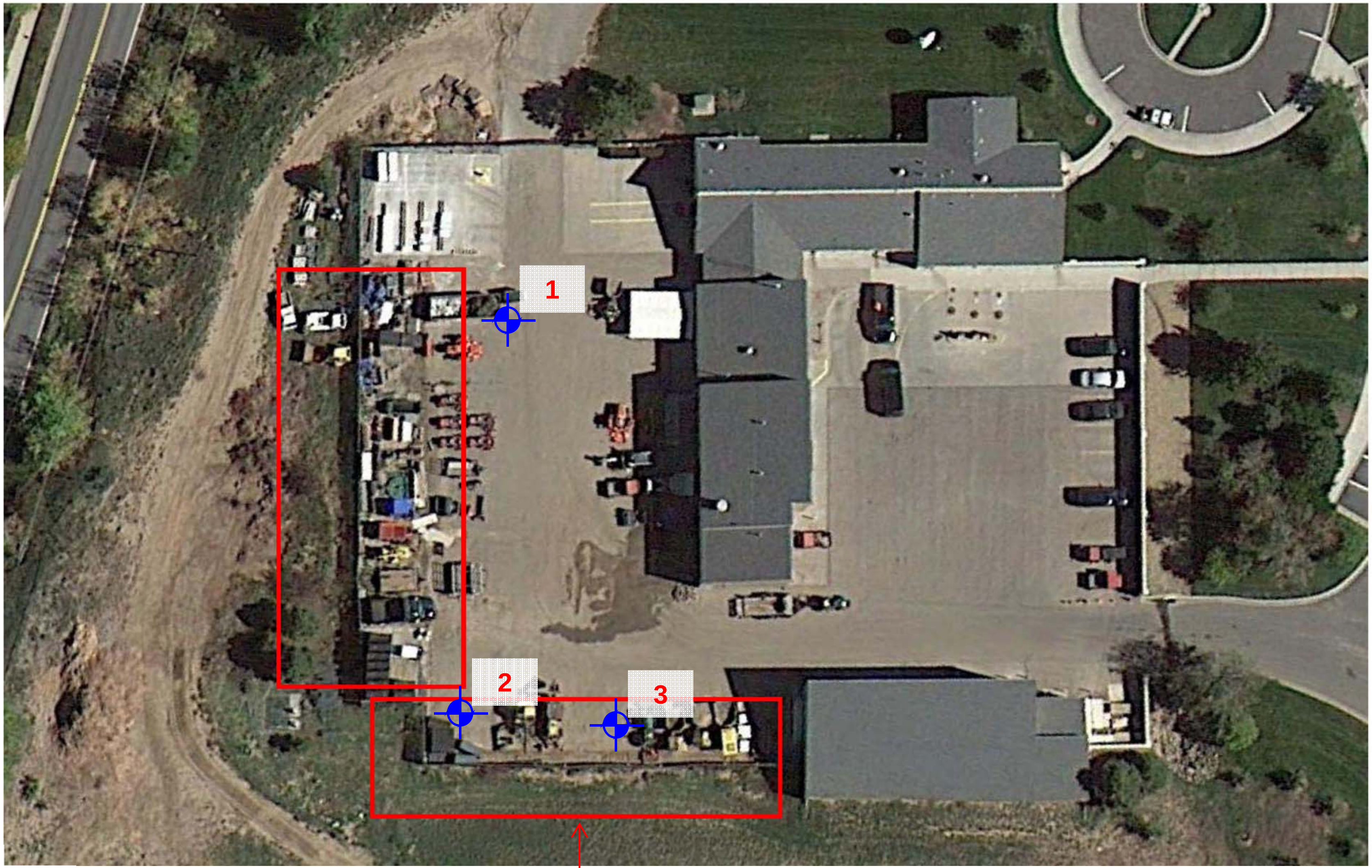
The boring locations are presented in Exhibit A-2. The borings were located in the field by Terracon personnel. A hand-held GPS unit was used to obtain coordinates at boring locations. The accuracy of the coordinates using a hand-held GPS is typically about +/-25 feet, depending upon satellite availability, cloud and canopy coverage, etc. The accuracy of the boring locations should only be assumed to the level implied by the methods used.

The borings were drilled with a CME-45 truck-mounted rotary drill rig with solid-stem augers. During the drilling operations, lithologic boring logs were recorded by the field engineer. Relatively undisturbed samples were obtained at selected intervals utilizing a 3-inch outside diameter ring barrel sampler (RS) and 2.5-inch diameter split-spoon sampler (SS). Penetration resistance values were recorded in a manner similar to the standard penetration test (SPT). This test consists of driving the sampler into the ground with a 140-pound hammer free-falling through a distance of 30 inches. The number of blows required to advance the ring-barrel sampler 12 inches or the interval indicated, is recorded and can be correlated to the standard penetration resistance value (N-value). The blow count values are indicated on the boring logs at the respective sample depths, ring barrel sample blow counts are not considered N-values.

A CME automatic SPT hammer was used to advance the samplers in some of the borings performed on this site. A greater efficiency is typically achieved with the automatic hammer compared to the conventional safety hammer operated with a cathead and rope. Published correlations between the SPT values and soil properties are based on the lower efficiency cathead and rope method. This higher efficiency affects the standard penetration resistance blow count value by increasing the penetration per hammer blow over what would be obtained using the cathead and rope method. The effect of the automatic hammer's efficiency has been considered in the interpretation and analysis of the subsurface information for this report.

The standard penetration test provides a reasonable indication of the in-place density of sandy type materials, but only provides an indication of the relative stiffness of cohesive materials since the blow count in these soils may be affected by the soils moisture content. In addition, considerable care should be exercised in interpreting the N-values in gravelly soils, particularly where the size of the gravel particle exceeds the inside diameter of the sampler.

Groundwater measurements were obtained in the borings at the time of drilling. Due to safety reasons, the borings were backfilled immediately after measuring the initial groundwater level. The borings were backfilled with auger cuttings and asphalt patch. Some settlement of the backfill and/or patches may occur and should be repaired as soon as possible



GRAPHIC SCALE

0' 25' 50'

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

Project Manager: TJN	Project No. 25145055	Terracon Consulting Engineers & Scientists	BORING LOCATION PLAN
Drawn by: TJN	Scale: 1"=50'	10625 W. I-70 Frontage Rd. N. Wheat Ridge, Colorado 80033	PROPOSED MATERIAL/EQUIPMENT STORAGE BUILDINGS
Checked by: SBM	File Name: 25145055/BLP	PH. (303) 423-3300 FAX. (303) 423-3353	FORT LOGAN NATIONAL CEMETERY 4400 WEST KENYON AVENUE DENVER, COLORADO
Approved by: SBM	Date: 6/10/2014		Exhibit A-2

BORING LOG NO. 1

PROJECT: Fort Logan Storage Buildings

CLIENT: FourFront Design, Inc.

SITE: 4400 West Kenyon Avenue
Denver, Colorado

LOCATION See Exhibit A-2

Latitude: 39.6492° Longitude: -105.0425°

DEPTH	Material Description
0.3	**ASPHALT**, (4 inches thick)
5.5	**FILL - SANDY LEAN CLAY (CL)**, with gravel, trace brick fragments, dark gray, stiff to very stiff
8.0	**SANDY LEAN CLAY (CL)**, brown, stiff
18.0	**CLAYSTONE**, brown and gray, medium hard to hard
30.0	**SANDY CLAYSTONE**, blue-gray, hard to very hard
	Boring Terminated at 30 Feet

DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	RECOVERY (In.)	FIELD TEST RESULTS	SWELL (%)	PID (ppm)	WATER CONTENT (%)	DRY UNIT WEIGHT (pcf)	ATTERBERG LIMITS LL-PL-PI	PERCENT FINES
		12	14-16			15	103		
		18	8-5-6		2.9				
5		12	7-9	0 @ 500 psf		21	106		
		9	50/9"			23	103		
10		18	9-15-17		3.0				
		10	50/10"			22	105		
15		18	15-26-32		1.8				
		6	50/6"						
20		12	30-5/6"		2.2				
	▽								
25		5	50/5"						
30		4	50/4"						

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
4-inch outside diameter solid stem flight auger

Abandonment Method:
Backfilled with auger cuttings

See Exhibit A-1 for description of field procedures

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

See Appendix C for explanation of symbols and abbreviations.

Notes:

WATER LEVEL OBSERVATIONS

▽ *Encountered at 21.5 feet while drilling*

Terracon

10625 W I-70 Frontage Road N., Ste. 3
Wheat Ridge, Colorado

Boring Started: 6/2/2014	Boring Completed: 6/2/2014
Drill Rig: CME-45	Driller:
Project No.: 25145055	Exhibit: A-3

BORING LOG NO. 2

PROJECT: Fort Logan Storage Buildings

CLIENT: FourFront Design, Inc.

SITE: 4400 West Kenyon Avenue, Denver, Colorado

LOCATION See Exhibit A-2

Latitude: 39.641° Longitude: -105.0429°

DEPTH	Material Description	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	SWELL (%)	PID (ppm)	WATER CONTENT (%)	DRY UNIT WEIGHT (pcf)	ATTERBERG LIMITS LL-PL-PI	PERCENT FINES
0.5	**ASPHALT**, (5-1/2 inches thick)											
6.0	**FILL - CLAYEY SAND (SC)**, fine to coarse grained, with gravel and clay seams, brown, loose to dense				12	10-16			31	94		
					12	5-7						
		5			18	12-13-24		0.7				
8.0	**SANDY LEAN CLAY (CL)**, brown, hard											
13.0	**CLAYSTONE**, brown and gray, medium hard							0.6				
		10			12	18-27	+1.4 @ 500 psf		24	104	59-27-32	81
25.0	**CLAYSTONE**, blue-gray, hard to very hard				6	50/6"			23	100		
		15	▽		12	23-50/6"		0.7				
					5	50/5"			28	96		
		20			12	33-50/6"		0.5				
		25			3	50/3"			26	102		
	Boring Terminated at 25 Feet											

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
4-inch outside diameter solid stem flight auger

Abandonment Method:
Backfilled with auger cuttings

See Exhibit A-1 for description of field procedures

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

See Appendix C for explanation of symbols and abbreviations.

Notes:

WATER LEVEL OBSERVATIONS

▽ *Encountered at 15.3 feet while drilling*

Terracon

10625 W I-70 Frontage Road N., Ste. 3
Wheat Ridge, Colorado

Boring Started: 6/2/2014	Boring Completed: 6/2/2014
Drill Rig: CME-45	Driller:
Project No.: 25145055	Exhibit: A-4

BORING LOG NO. 3

PROJECT: Fort Logan Storage Buildings

CLIENT: FourFront Design, Inc.

SITE: 4400 West Kenyon Avenue, Denver, Colorado

LOCATION See Exhibit A-2

Latitude: 39.649° Longitude: -105.0428°

DEPTH	Material Description	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	SWELL (%)	PID (ppm)	WATER CONTENT (%)	DRY UNIT WEIGHT (pcf)	ATTERBERG LIMITS LL-PL-PI	PERCENT FINES
0.5	**ASPHALT**, (6 inches thick)											
	FILL - CLAYEY SAND (SC), fine to coarse grained, with gravel and clay seams, brown, loose											
					12	5-7	0 @ 500 psf		12	115	38-18-20	30
					12	4-5			13	115		
		5			18	2-3-4		0.0				
8.0	**CLAYSTONE**, brown and gray, medium hard, ferric staining											
					10	50/10"	+3.5 @ 500 psf		21	108		
		10			18	9-17-18		1.6				
13.0	**CLAYSTONE**, blue-gray, very hard											
					4	50/4"			22	97		
		15			12	24-50/6"		0.0				
					4	50/4"						
		20			12	27-50/6"		0.0				
			▽									
25.0					5	50/5"						
	Boring Terminated at 25 Feet	25										

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
4-inch outside diameter solid stem flight auger

Abandonment Method:
Backfilled with auger cuttings

See Exhibit A-1 for description of field procedures

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

See Appendix C for explanation of symbols and abbreviations.

Notes:

WATER LEVEL OBSERVATIONS

▽ *Encountered at 21.6 feet while drilling*

Terracon
10625 W I-70 Frontage Road N., Ste. 3
Wheat Ridge, Colorado

Boring Started: 6/2/2014	Boring Completed: 6/2/2014
Drill Rig: CME-45	Driller:
Project No.: 25145055	Exhibit: A-5

APPENDIX B

LABORATORY TESTING

Laboratory Testing

Samples retrieved during the field exploration were returned to the laboratory for observation by the project geotechnical engineer, and were classified in general accordance with the Unified Soil Classification System described in Appendix C.

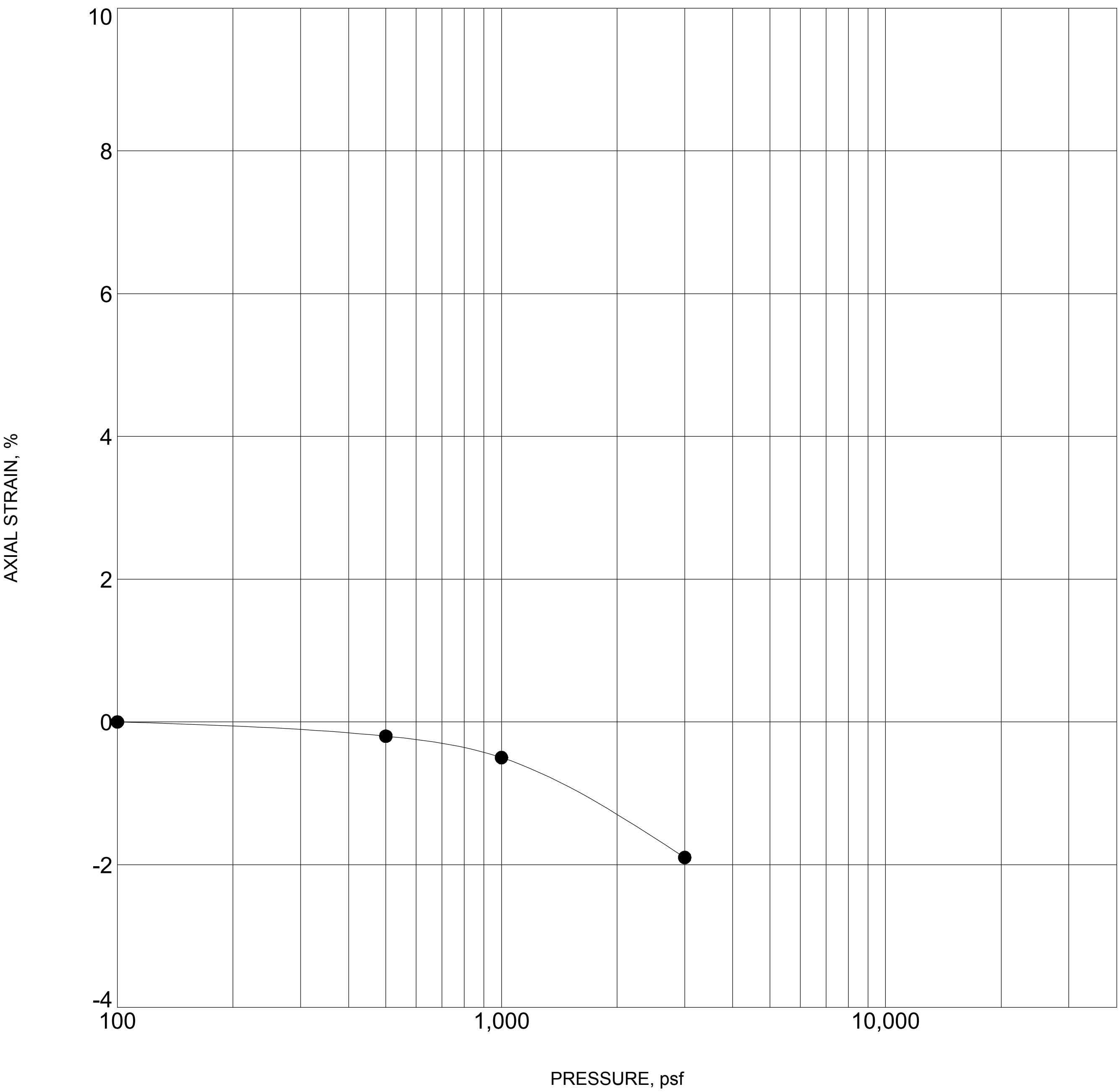
At this time, an applicable laboratory-testing program was formulated to determine engineering properties of the subsurface materials. Following the completion of the laboratory testing, the field descriptions were confirmed or modified as necessary, and the Boring Logs were prepared. The Boring Logs are included in Appendix A.

Laboratory test results are included in Appendix B. These results were used for the geotechnical engineering analyses and the development of foundation and earthwork recommendations. All 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
- Grain size distribution
- Swell/consolidation
- Atterberg limits
- Water soluble sulfate content

SWELL CONSOLIDATION TEST

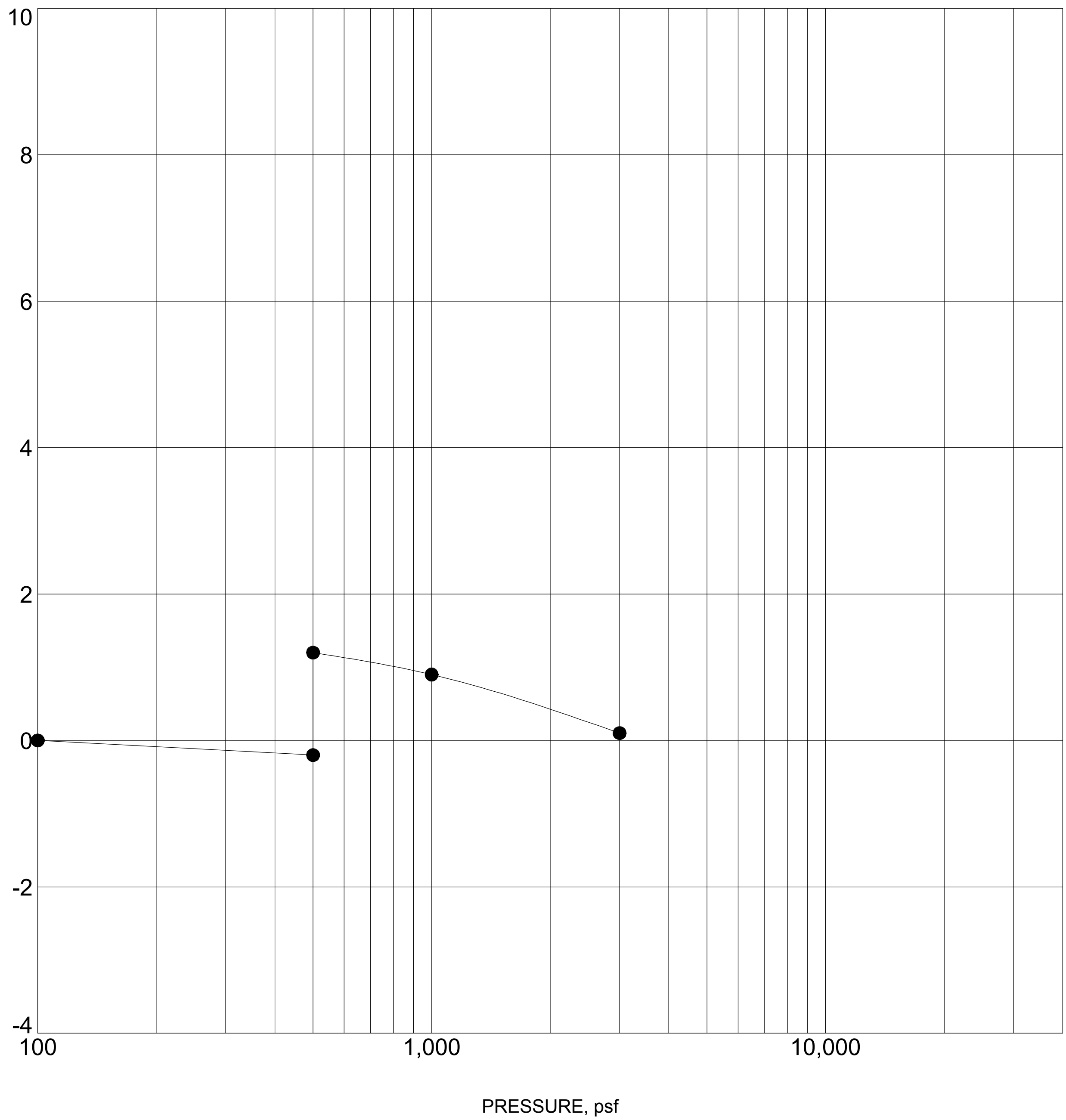


Specimen Identification			Classification	γ_d, pcf	WC, %
●	1	4.5 ft	FILL - SANDY LEAN CLAY	106	21

NOTES:

PROJECT: Fort Logan Storage Buildings	Terracon	PROJECT NUMBER: 25145055
SITE: 4400 West Kenyon Avenue Denver, Colorado	10625 W I-70 Frontage Road N., Ste. 3 Wheat Ridge, Colorado	CLIENT: FourFront Design, Inc.
		EXHIBIT: B-2

SWELL CONSOLIDATION TEST

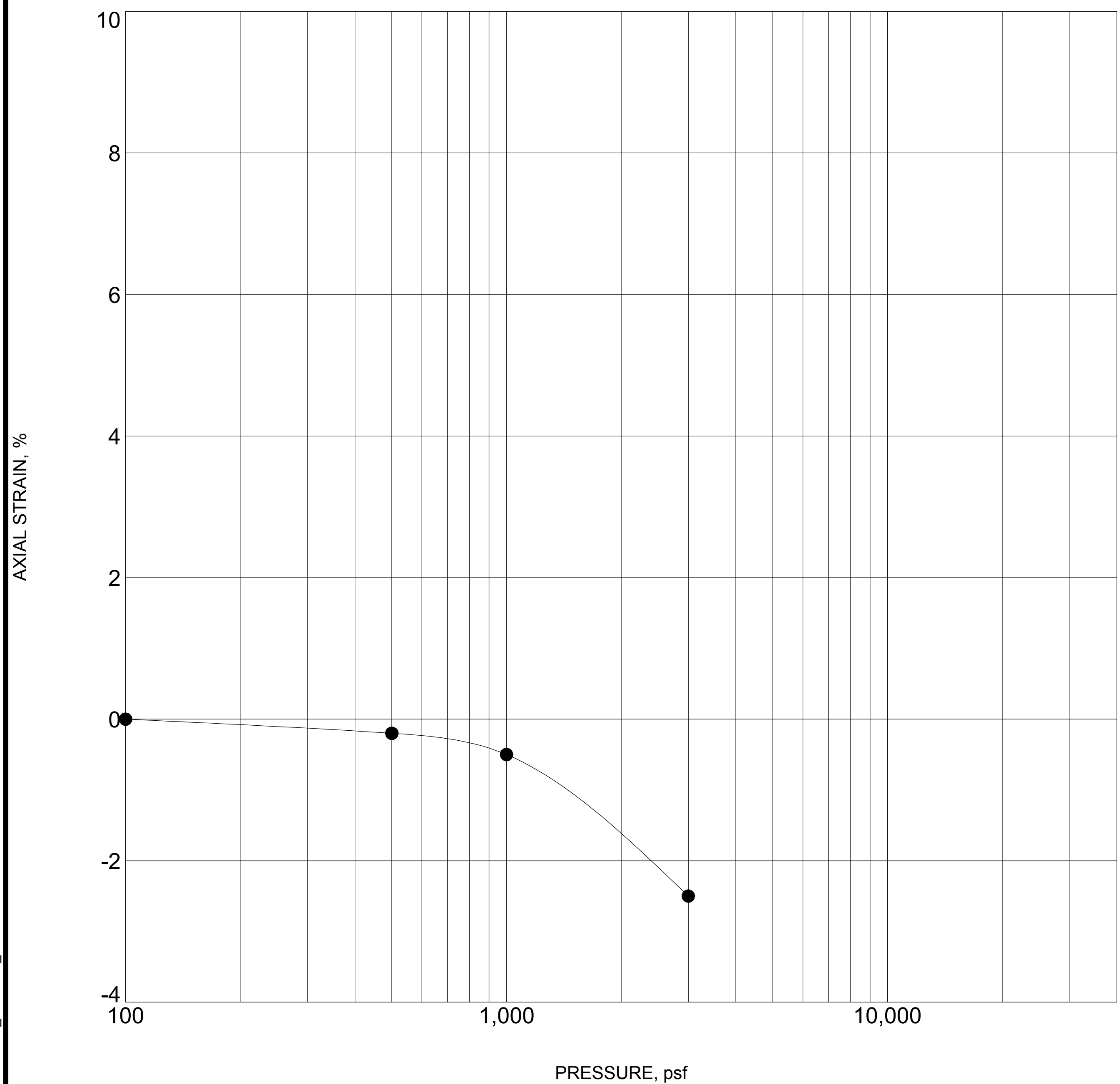


Specimen Identification		Classification	γ_d, pcf	WC, %
●	2 9.0 ft	CLAYSTONE	104	24

NOTES:

PROJECT: Fort Logan Storage Buildings	Terracon 10625 W I-70 Frontage Road N., Ste. 3 Wheat Ridge, Colorado	PROJECT NUMBER: 25145055
SITE: 4400 West Kenyon Avenue Denver, Colorado		CLIENT: FourFront Design, Inc.
		EXHIBIT: B-3

SWELL CONSOLIDATION TEST



Specimen Identification		Classification	γ_d, pcf	WC, %
●	3 2.0 ft	FILL - CLAYEY SAND	115	12

NOTES:

PROJECT: Fort Logan Storage Buildings

SITE: 4400 West Kenyon Avenue Denver, Colorado

Terracon

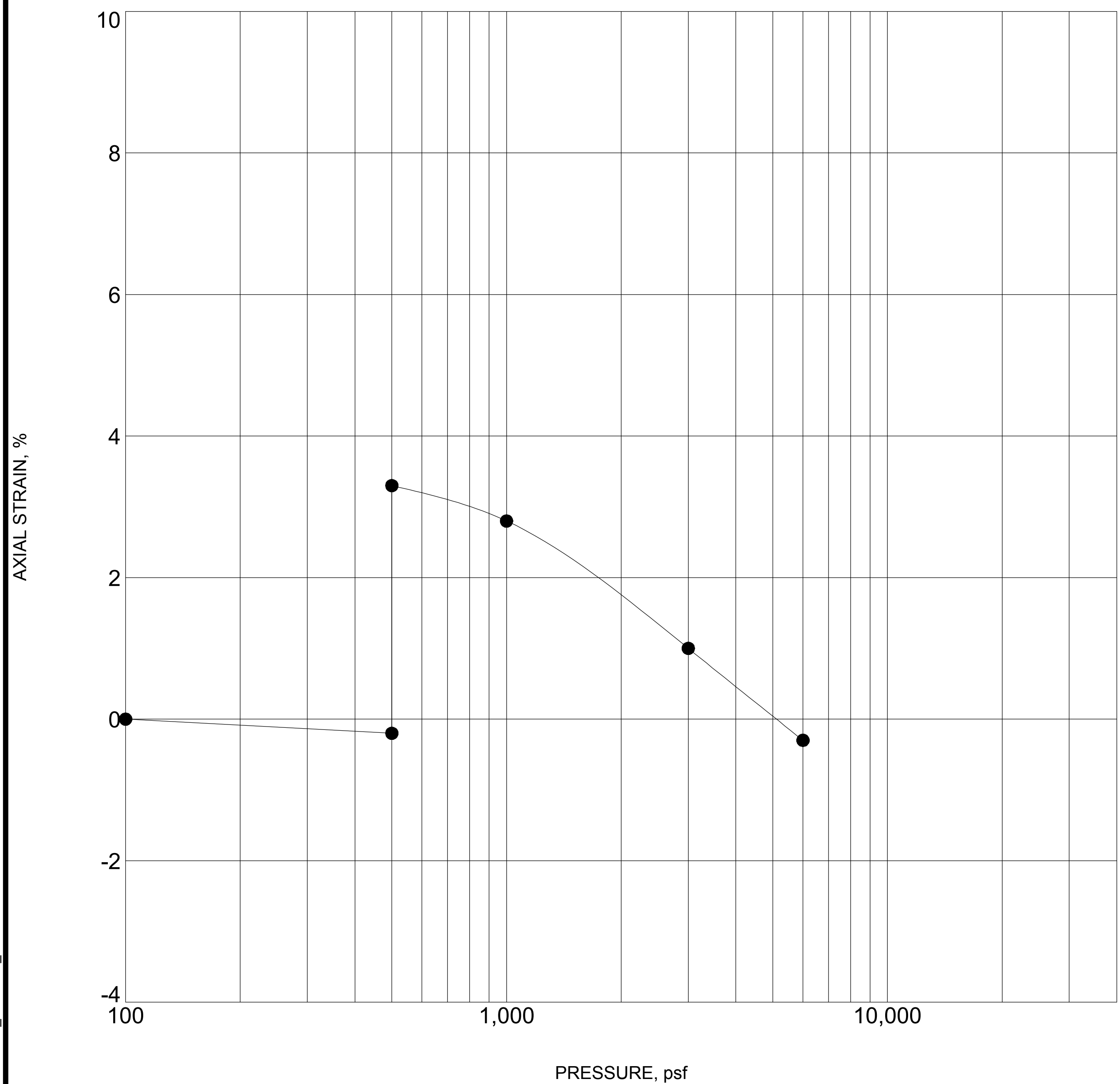
10625 W I-70 Frontage Road N., Ste. 3
Wheat Ridge, Colorado

PROJECT NUMBER: 25145055

CLIENT: FourFront Design, Inc.

EXHIBIT: B-4

SWELL CONSOLIDATION TEST



Specimen Identification			Classification	γ_d, pcf	WC, %
●	3	9.0 ft	CLAYSTONE	108	21

NOTES:

PROJECT: Fort Logan Storage Buildings

SITE: 4400 West Kenyon Avenue Denver, Colorado

Terracon

10625 W I-70 Frontage Road N., Ste. 3
Wheat Ridge, Colorado

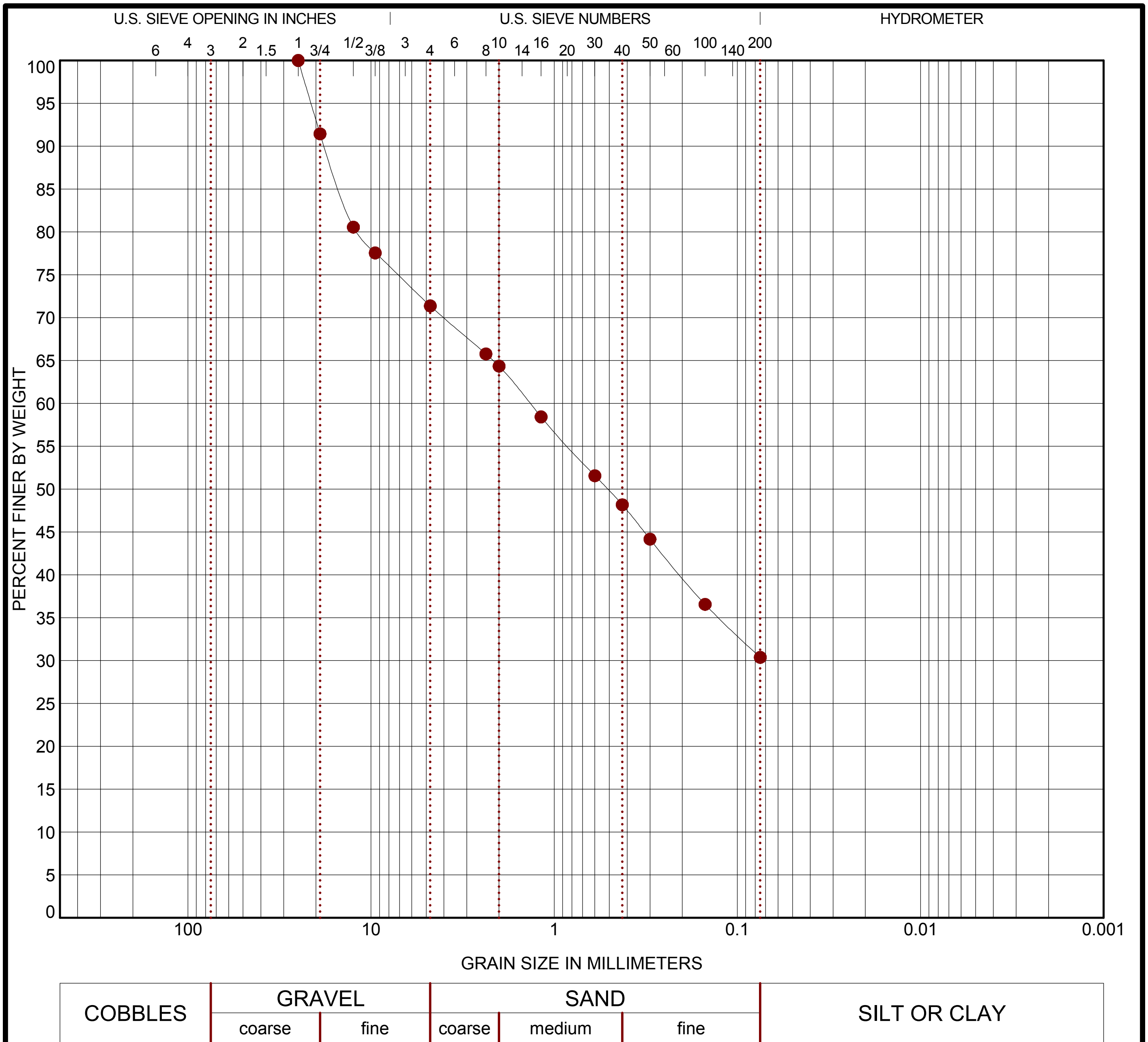
PROJECT NUMBER: 25145055

CLIENT: FourFront Design, Inc.

EXHIBIT: B-5

GRAIN SIZE DISTRIBUTION

ASTM D422



Boring ID	Depth	USCS Classification	LL	PL	PI	Cc	Cu
● 3	2.0	CLAYEY SAND with GRAVEL(SC)	38	18	20		

Boring ID	Depth	D_{100}	D_{60}	D_{30}	D_{10}	%Gravel	%Sand	%Silt	%Clay
● 3	2.0	25	1.358			28.6	41.0	30.4	

PROJECT: Fort Logan Storage Buildings

SITE: 4400 West Kenyon Avenue
Denver, Colorado

Terracon
10625 W I-70 Frontage Road N., Ste. 3
Wheat Ridge, Colorado

PROJECT NUMBER: 25145055

CLIENT: FourFront Design, Inc.

EXHIBIT: B-6

SUMMARY OF LABORATORY TEST RESULTS

Fort Logan Material/Equipment Buildings - Denver, Colorado

Terracon Project No. 25145055

Boring No.	Depth (ft.)	USCS Soil Classification	Initial Dry Density (pcf)	Initial Water Content (%)	Swell/Consolidation		Particle Size Distribution, Percent Passing by Weight					Atterberg Limits		Water Soluble Sulfates (mg/l)	Remarks
					Surcharge (ksf)	Swell (%)	1”	#4	#10	#40	#200	LL	PI		
1	2	CL	103	15											4
1	4.5	CL	106	21	0.5	0									3, 4
1	9		103	23											4
1	14		105	22											4
2	2	SC	94	31											4
2	9		104	24	0.5	+1.4					81	59	21	1	3 ,4, 5
2	14		100	23											4
2	19		96	28											4
2	24		102	26											4
3	2	SC	115	12	0.5	0	100	71	64	48	30	38	20	2	3, 4
3	4	SC	115	13											4
3	9		108	21	0.5	+3.5									3, 4
3	14		97	22											4

Notes:
Initial Dry Density, Initial Water Content, and Swell/Consolidation values obtained from undisturbed samples unless otherwise noted
* = Partially disturbed sample
- = Compression/settlement
NV = no value
NP = non-plastic

REMARKS
1 Remolded Compacted density (approximately 95% of ASTM D698 maximum density near optimum)
2 Remolded Compacted density (approximately 95% of ASTM D1557 maximum density near optimum)
3 Submerged to approximate saturation
4 Dry density and/or moisture content determined from one ring of a multi-ring sample
5 Minus #200 Only

Exhibit B-7

Terracon

APPENDIX C

SUPPORTING DOCUMENTS

GENERAL NOTES

DESCRIPTION OF SYMBOLS AND ABBREVIATIONS

SAMPLING

Auger	Shelby Tube	Split Spoon
Rock Core	Macro Core	Modified California Ring Sampler
Grab Sample	No Recovery	Modified Dames & Moore Ring Sampler

WATER LEVEL

- Water Initially Encountered
- Water Level After a Specified Period of Time
- Water Level After a Specified Period of Time

Water levels indicated on the soil boring logs are the levels measured in the borehole at the times indicated. Groundwater level variations will occur over time. In low permeability soils, accurate determination of groundwater levels is not possible with short term water level observations.

FIELD TESTS

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

DESCRIPTIVE SOIL CLASSIFICATION

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

LOCATION AND ELEVATION NOTES

Unless otherwise noted, Latitude and Longitude are approximately determined using a hand-held GPS device. The accuracy of such devices is variable. Surface elevation data annotated with +/- indicates that no actual topographical survey was conducted to confirm the surface elevation. Instead, the surface elevation was approximately determined from topographic maps of the area.

STRENGTH TERMS

RELATIVE DENSITY OF COARSE-GRAINED SOILS (More than 50% retained on No. 200 sieve.) Density determined by Standard Penetration Resistance Includes gravels, sands and silts.			CONSISTENCY OF FINE-GRAINED SOILS (50% or more passing the No. 200 sieve.) Consistency determined by laboratory shear strength testing, field visual-manual procedures or standard penetration resistance				BEDROCK		
Descriptive Term (Density)	**Standard Penetration or N-Value Blows/Ft.**	**Ring Sampler Blows/Ft.**	**Descriptive Term (Consistency)**	**Unconfined Compressive Strength, Qu, psf**	**Standard Penetration or N-Value Blows/Ft.**	**Ring Sampler Blows/Ft.**	**Ring Sampler Blows/Ft.**	**Standard Penetration or N-Value Blows/Ft.**	**Descriptive Term (Consistency)**
Very Loose	0 - 3	0 - 6	Very Soft	less than 500	0 - 1	< 3	< 30	< 20	Weathered
Loose	4 - 9	7 - 18	Soft	500 to 1,000	2 - 4	3 - 4	30 - 49	20 - 29	Firm
Medium Dense	10 - 29	19 - 58	Medium-Stiff	1,000 to 2,000	5 - 7	5 - 9	50 - 89	30 - 49	Medium Hard
Dense	30 - 50	59 - 98	Stiff	2,000 to 4,000	8 - 14	10 - 18	90 - 119	50 - 79	Hard
Very Dense	> 50	≥ 99	Very Stiff	4,000 to 8,000	15 - 30	19 - 42	> 119	>79	Very Hard
			Hard	> 8,000	> 30	> 42			

RELATIVE PROPORTIONS OF SAND AND GRAVEL

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

GRAIN SIZE TERMINOLOGY

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

RELATIVE PROPORTIONS OF FINES

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

PLASTICITY DESCRIPTION

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

Terracon

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

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

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

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

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

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

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

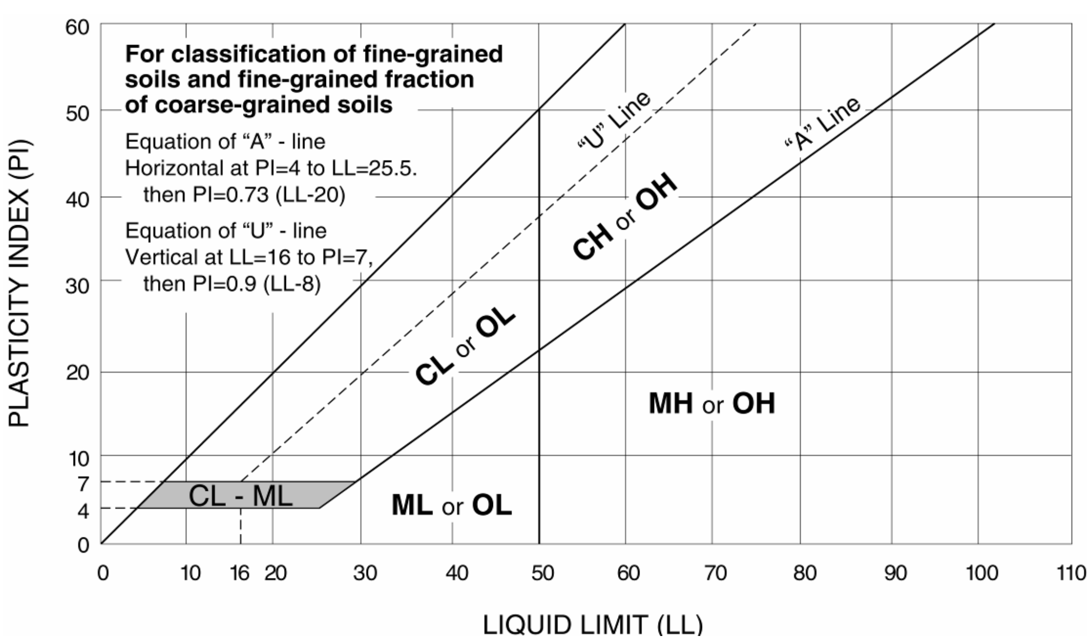
[M] If soil contains $\geq$ 30% plus No. 200, predominantly gravel, add "gravelly" to group name.

[N] $PI \geq 4$ and plots on or above "A" line.

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

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

[Q] PI plots below "A" line.



Terracon

DESCRIPTION OF ROCK PROPERTIES

WEATHERING

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

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

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

Joint, Bedding, and Foliation Spacing in Rock [a]		
Spacing	**Joints**	**Bedding/Foliation**
Less than 2 in.	Very close	Very thin
2 in. – 1 ft.	Close	Thin
1 ft. – 3 ft.	Moderately close	Medium
3 ft. – 10 ft.	Wide	Thick
More than 10 ft.	Very wide	Very thick

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

Rock Quality Designator (RQD) a	
RQD, as a percentage	**Diagnostic description**
Exceeding 90	Excellent
90 – 75	Good
75 – 50	Fair
50 – 25	Poor
Less than 25	Very poor

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

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

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